User-Oriented Wastewater Treatment Technology in Developing and Newly Industrialising Countries

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Vorwort

Das Thema dieser Schrift ist ungewöhnlich lang. Es projiziert aber immer noch nicht den großen Umfang dieser Abhandlung. Es geht dem Autoren darum, aus den Erfahrungen der Entwicklungshilfe der 60-er und 70-er Jahre lernend, die Notwendigkeit der Einbeziehung des lokalen Nutzers in alle Projekte des Gewässerschutzes (der Abwasserreinigung) darzustellen. Dabei hat die Erfahrung der 80-er und 90-er Jahre gezeigt, dass einfache Ausbildungsansätze nicht genügen. Die ausschließliche Fokussierung auf die Entwicklung einer perfekten technischen Lösung muss dem Konzept einer integralen technischen, ökonomischen und kulturellen Gesamtlösung weichen. Dabei spielt der Begriff „culture“ (nicht direkt als Kultur zu übersetzen sondern vielleicht eher als Zivilisationszustand) eine äußerst wichtige Rolle in Litty´s Arbeit, da für ihn technische Lösungen und der Umgang mit ihnen auch ein Ergebnis der jeweiligen „culture“ sind.

Der Autor hat sich mit ungewöhnlicher Motivation und nach gründlicher und weitgehend autodidaktischer Einarbeitung mit nichttechnischen Aspekten der Wassertechnologie und des Gewässerschutzes, wie z.B. interkulturelle Gesichtspunkte, pädagogische Fragestellungen, hierarchische und Klassen-unterschiede und auch Motivations- und Bewusstseinsfragen um nur einiges zu nennen, befasst. Er untersucht insbesondere die gegenwärtige Situation der Abwasserreinigung in den Ländern China, Deutschland und Indien (alphabetisch aufgeführt) im Hinblick auf ihren gegenwärtigen technischen Stand, ihren Zustand, ihre Leistungsfähigkeit und auch die Anlagenqualität und –instandhaltung. Deutschland wird hierbei weitgehend als Kontrollgröße oder als Bezugseinheit mit erfasst. Soweit so gut im Hinblick auf vordergründig mehr technische Fragestellungen.

Das Ganze unterlegt, begleitet, analysiert und begründet er mit Gesprächen, Interviews und sogar Unterrichtseinheiten mit den damit direkt oder indirekt befassten Entscheidungsfällenden, Managern, leitenden Ingenieuren, in der Forschung und Wissenschaft Tätigen und vor allem auch dem Betriebspersonal. Dieses Personal ist, insbesondere in den Ländern China und Indien unterschiedlichster Herkunft und Qualifikation und damit nicht einfach zu erreichen oder anzusprechen. Es sind gerade diese eigentlich nicht messbaren Gesichtspunkte, die Litty aber versucht hat zu quantifizieren, die die technischen Erkenntnisse zu erläutern und zu extrapolieren versuchen. Und es ist auch das, was die Arbeit Litty´s zu einer besonderen macht, einerseits als eine Quelle von sehr viel bisher kaum oder gar nicht verfügbarer Information und andererseits auch im Hinblick auf die Aussagen.

Diese Schrift ist in fast jeder Hinsicht ungewöhnlich und innovativ für ein ingenieurwissenschaftliches Thema. Sie konzentriert sich nicht auf natur- und ingenieurwissenschaftlichen Untersuchungen, eventuell durchgeführt in einem Labor oder auch mittels einer Pilotanlage. Sondern sie greift das auf, was bisher bei ingenieurwissenschaftlichen Lösungen als entweder unwichtig weggelassen, oder bestenfalls als sog. weiche Kriterien in begleitender oder nur verbal mitgeführter Form am Rande mit berichtet wurde.

Der Autor hat sein sehr umfangreiches Material quantifiziert, objektiviert und durch Vergleiche verdichtet. Er hat Schlüsse daraus abgeleitet, die für Entscheidungsfällende, für Vorgesetzte, für Bildungs- und Ausbildungsverantwortliche von Bedeutung sind. Litty hat gezeigt, daß solche Ansätze notwendig sind, wenn man diese wichtigen Aspekte ernst genommen haben will und wie man sich insgesamt mit solchen Problemen auseinander zu setzen hat.

Der Autor hat mit dieser Arbeit gezeigt, dass er ein bisher sträflich vernachlässigtes Thema, also ein ungelöstes, so angehen und aufbereiten kann, dass es lösbar erscheint. Der Bericht über seine Arbeiten ist immer wieder geprägt von Erfahrung in Entwicklungs- und Schwellenländern. Er ist vor allem aber auch von einer unglaublichen Motivation geprägt die den Jahrzehnte alten Konflikt in der Entwicklungsarbeit („Hilfe zur Selbsthilfe“ gegenüber „Hilfe durch vorwiegend finanzielle und technische Unterstützung“) zu entspannen versucht.

Karlsruhe, im Juli 2008 H.H.Hahn

Abstract

Wastewater treatment in developing and newly industrialising countries follows strikingly different approaches as compared to western nations like Germany. This is reflected by experiences made by the development cooperation as well as in the private sector. Major differences concern both the type of technologies applied and, in particular, the way of technology operation and maintenance by the local staff.

Both India and China are characterised by very high economic growth rates and severe water pollution problems, evoking and a massive demand for wastewater treatment equipment. In a comparative approach focussing on India, China and Germany, the present study identifies severe deficiencies in the availability and application practices of water treatment technology in India and China. Possible reasons and solutions are discussed. Wastewater treatment plants in the three countries were inspected and the type and status of treatment technologies was evaluated. Interviews were carried out with plant managers and the working staff. Based on requirements for knowledge and skill enhancement identified in this way, training modules for staff qualification were designed and carried out on water treatment plants in India. Guided expert interviews were performed to gather information on the evaluation of the wastewater treatment situation by local experts in relevant fields, and to gain insight in the cultural, socio-economical and political context of the current approaches and situation.

In total, more than 60 wastewater treatment plants were inspected and about 50 interviews were carried out on these sites. More than 90 guided expert interviews were performed with representative experts from scientific institutions, administration, the private sector, educational institutions, bilateral development cooperations and NGOs.

The study revealed considerable differences between these two biggest Asian newly industrialising countries regarding targeted water quality standards, treatment efficiencies, technology level, equipment characteristics and aspects of plant operation and maintenance. The comparative analysis of the technology level shows that wastewater treatment technology in China is approximating German standards, which is reflected in a high degree of automation and modern treatment processes. In contrast, wastewater treatment in India is at a significantly lower technological level and is mainly focussing on BOD-removal approaches. Typical characteristics of treatment plant equipment in India include a low degree of automation and relatively low manufacturing quality. In both countries, severe deficits in operation and in maintenance of treatment plant technology were observed.

The results of the staff and expert interviews as well as equipment inspections suggest that low levels of awareness and motivation are predominant reasons for operation and maintenance deficits in both countries. Related knowledge deficits were apparent to varying degrees in both countries. Especially the results of the data collection in China clearly reveal the problems associated with the application of imported western technology. In both India and China, solutions to increase the qualification level of the staff are in urgent need, concerning both engineers and technical personnel. Especially in India, an increase in knowledge and awareness for aspects of practical plant operation among engineers is of major importance. Due to the strictly hierarchical work organization, senior staff is often hesitant to involve in practical work and appreciate related issues and emerging problems. Recommended measures for improving the situation in India should include (a) the implementation of legal guidelines, (b) the development and execution of suitable staff qualification concepts, (c) an improvement of the working conditions, and (d) the application of incentive systems. Importantly, the social image of wastewater treatment needs to be upgraded by appropriate promotional measures and publicity work in communities. A privatisation of the wastewater sector is strongly recommended for India. In China, first promising steps towards qualification of treatment plant staff exist.

Recommended criteria for the design and choice of suitable water treatment technologies to be applied in India and China are high material quality, robustness, as well as simplicity and low automation degree especially in India. In the current scenario, complex automation should be strictly avoided, so that successful long-term plant operation can be assured. The results of the expert interviews reflect a higher degree of quality awareness in China than in India, where the predominant decision criterion when choosing treatment technologies is their price. In urban as opposed to rural regions, a stronger focus on advanced and innovative technical solutions for wastewater treatment was apparent in both countries.

Cultural values that are portrayed in intercultural literature were similarly reflected in the expert interviews carried out in India, China and Germany in this study. From the Asian perspective, reliability and quality awareness are the most appreciated German values, whereas a lack of flexibility is seen critically. In the interviews with western experts, the position that the own perspective is the benchmark for the rest of the world was frequently observed. The overall results of this study suggest that many problems currently compromising the efficient application of wastewater treatment technology in the newly industrialising countries India and China can potentially be avoided by a better integration of socio-economical and cultural aspects in mutual agreements and decision making.

Zusammenfassung

Problemdarstellung und Forschungsfragen

Die vorliegende Forschungsarbeit befasst sich mit einem Thema, das in der Siedlungswasserwirtschaft bisher wenig Beachtung gefunden hat, obwohl das Problemfeld der Nutzung von Abwasseraufbereitungstechnologie in Entwicklungs- und Schwellenländern hinreichend bekannt ist und gerade von deutscher Seite immer wieder beklagt wird.

Ineffizienter Betrieb von Klärwerken, unzureichende Ablaufwerte und Defizite bei Wartung und Instandhaltung von Anlagen zur Abwasserbehandlung stellen in vielen Ländern ein großes Problem dar. Selbst einfache Technologien werden oft mangelhaft betrieben, oder fallen bereits nach kurzer Betriebszeit aus. Die Erfahrungen der vergangen Jahrzehnte haben unter anderem dazu geführt, dass dem sogenannten „Capacity Building“ in der Entwicklungszusammenarbeit eine große Bedeutung beigemessen wird. Außerhalb der Entwicklungszusammenarbeit hingegen scheint das Thema immer noch wenig Beachtung gefunden zu haben, da effektive Lösungsstrategien fehlen. Betrachtet man die Situation der Abwasseraufbereitung in vielen Entwicklungs- und Schwellenländern, muss die kritische Frage gestellt werden, wie effektiv Maßnahmen zur Aus- und Weiterbildung von Klärwerkspersonal sind, wenn sie denn existieren und umgesetzt werden.

In einer vergleichenden Untersuchung des Klärwerksbetriebs in Indien, China und Deutschland wurde das Problemfeld im Detail beleuchtet. Im Kern der Untersuchungen standen folgende Fragen:

- Wie ist der Status von Abwasseraufbereitungstechnologie auf Klärwerken in Indien und China?

- Was sind die Ursachen von Defiziten in Betrieb und Instandhaltung, und wie können Verbesserungen erreicht werden?

- Wie ist die Personal- und Bildungssituation auf Klärwerken in Indien und China, und wie kann eine Anpassung an die Anforderungen moderner Abwasseraufbereitungstechnologie erreicht werden?

- Was sollten die Eigenschaften moderner Abwasseraufbereitungstechnologie sein, so dass ein nachhaltiger Anlagenbetrieb sichergestellt ist?

- Welche Bedeutung haben kulturelle Aspekte für die Umsetzung von Projekten im Abwassersektor?

- Welche grundlegenden Unterschiede bestehen auf Expertenebene in Indien, China und Deutschland, und welche Schlussfolgerungen können für die Anwendung von Abwassertechnologie gezogen werden?

Methoden

Um das Problemfeld zu erschließen, wurden hauptsächlich sozialwissenschaftliche Methoden angewandt.

Zum einen wurden in Indien, China und Deutschland Klärwerke besucht und Interviews mit Klärwerksleitern geführt. Hierbei ging es darum, wesentliche Informationen zu Maschinentechnik, Anlagenbetrieb, Wartung und Instandhaltung, sowie zum Klärwerkspersonal zu gewinnen. Zusätzlich wurden Anlagenkomponenten fotografisch dokumentiert und die Fotoaufnahmen nach definierten Parametern ausgewertet.

Um vertiefende Informationen zu Bildungshintergrund, Arbeitssituation und Einstellungen des Klärwerkspersonals zu gewinnen, wurden Klärwerksmitarbeiter mit Hilfe von Fragebögen befragt. Von besonderem Interesse sind Meinungen und Einstellungen auf Expertenebene. Als Erhebungsmethode wurde das leitfadengestützte Experteninterview gewählt, wobei in Indien und China Experten aus Wissenschaft, Verwaltung und Wirtschaft den Schwerpunkt der Befragungen bildeten. In Deutschland wurden vorwiegend Experten aus Wissenschaft, Entwicklungszusammenarbeit und Wirtschaft interviewt. Insgesamt wurden in Indien, China und Deutschland mehr als 60 Klärwerke besucht, wobei rund 50 Interviews geführt wurden. Mehr als 90 leitfadengestützte Experteninterviews wurden mit Experten aus Wissenschaft, Verwaltung, Wirtschaft, Entwicklungszusammenarbeit, dem Bildungsbereich und NGOs geführt. Zusätzlich zu den oben genannten Methoden wurde ein Pilotversuch zur Ausbildung von Klärwerkspersonal in Indien durchgeführt, um vertiefende Informationen zu den Möglichkeiten der Mitarbeiterqualifikation zu gewinnen. In diesem Zusammenhang wurde ein spezielles modulares Schulungskonzept entwickelt und auf seine Eignung getestet.

Ergebnisse & Schlußfolgerungen

Die Ergebnisse der Datenerhebung zeigen deutliche Unterschiede zwischen Indien und China, sowohl was den Bestand an Verfahren und Technologien zur Abwasseraufbereitung, als auch den Zustand der Anlagenteile angeht. Auf chinesischen Klärwerken eingesetzte Maschinentechnik hat in den letzten Jahren deutlich aufgeholt in Bezug auf Automation und Qualität, und auf vielen Anlagen ist annähernd westlicher Standard erreicht. Die fast ausschließlich eingesetzte indische Maschinentechnik in Indien liegt deutlich hinter China und Deutschland zurück, sowohl in Bezug auf Materialauswahl und Fertigungsqualität, als auch Leistungsfähigkeit. Das Gros der indischen Klärwerke ist lediglich auf BSB-Abbau ausgelegt. Während auch chinesische Maschinentechnik zunehmend in Edelstahl gefertigt wird, wird in Indien in der Regel immer noch Normalstahl als Standardmaterial eingesetzt.

Wartung und Instandhaltung sind sowohl in Indien, als auch in China äußerst problematisch, wie die Ergebnisse der Klärwerksinspektionen zeigen. Dies konnte in der vorliegenden Studie vor allem anhand der untersuchten Parameter Korrosionsfreiheit und Schmutzfreiheit gezeigt werden. Der Vergleich zwischen eingesetzter deutscher Maschinentechnik auf deutschen und chinesischen Klärwerken zeigt sehr deutlich die Defizite in Wartung und Instandhaltung. Häufig werden wichtige Anlagenkomponenten nur unzureichend gereinigt, Reparaturen werden in mangelhafter Qualität ausgeführt und defekte Komponenten werden nicht selten ohne Ersatz entfernt, ungeachtet der Auswirkungen auf den Gesamtprozess.

Die Ergebnisse der Mitarbeiterbefragungen in Indien, China und Deutschland zeigen ein sehr geringes Bildungsniveau vor allem auf indischen Klärwerken, sowohl in den Bereichen Elektrotechnik, Mechanik und Chemie/Biologie, als auch im Bereich Abwasser und Reinigungsverfahren. Aus- oder Weiterbildungsmöglichkeiten für Klärwerkspersonal gibt es in Indien nicht. Charakteristisch ist ein hoher Anteil von ungelernten Hilfskräften auf indischen Klärwerken. In China konnte ein deutlich höheres Bildungsniveau nachgewiesen werden, welches jedoch immer noch hinter der Qualifikation von Klärwerksmitarbeitern in Deutschland zurück liegt. Hierin ist ein Hauptgrund für die unzureichende Wartung und Instandhaltung von deutscher Technologie auf chinesischen Klärwerken zu sehen. In Indien stellt sich dieses Problem in dieser Form bislang nicht, da die fast ausschließlich eingesetzte indische Technologie relativ robust und einfach zu warten ist. Große Schwierigkeiten sind allerdings in naher Zukunft zu erwarten, wenn es nicht gelingt, die Qualifikation des Klärwerkspersonals anzuheben, da zunehmend komplexere Anlagentechnik eingesetzt werden wird. Dies zeigen auch die Experteninterviews in Indien.

Eine besondere Rolle bei der Betrachtung der Arbeitsorganisation spielt die stark hierarchische Struktur der indischen Gesellschaft, die sich auch in der Organisation des Anlagenbetriebs widerspiegelt. Auch der traditionell geringe Wert praktischer Arbeit in Indien wie in China ist von großer Bedeutung. Als wesentlicher Grund für die beschriebene Problematik in Betrieb und Wartung von Abwassertechnologie muss ein Mangel an Bewusstsein, Motivation und Fachwissen für Belange des praktischen Anlagenbetriebs auf der Ingenieurebene gesehen werden. Dies zeigt unter anderem die Tatsache, dass selbst auf vielen großen Klärwerken keine Wartungspläne existieren, oder bestimmte Wartungsarbeiten, wie z.B. Ölwechsel von Getriebemotoren teilweise überhaupt nicht durchgeführt werden. Von großer Bedeutung in China ist die Tatsache, dass das Wartungspersonal in der Regel kein Englisch spricht, die Betriebshandbücher von importiertem Equipment aber üblicherweise in englischer Sprache abgefasst sind – ein Umstand, der von vielen Klärwerksmitarbeitern und Klärwerksleitungen beklagt wird. Sehr kritisch wird vor allem in China der schlechte After-Sale-Service westlicher Anlagenbauer gesehen.

Die Ergebnisse der Experteninterviews sowohl in Indien, als auch in China zeigen eine starke Fixierung auf moderne und innovative Anlagentechnik, vor allem unter Wissenschaftsvertretern und im privatwirtschaftlichen Bereich. Die Wiederverwertung von gereinigtem Abwasser wird vor allem von vielen indischen Experten gefordert. Betriebliche Aspekte, wie einfache Handhabbarkeit spielen vor allem in Indien eine untergeordnete Rolle. Hauptentscheidungskriterium ist der Preis. Ebenfalls charakteristisch ist ein sehr geringes Qualitätsbewusstsein in Indien, sowie eine oftmals geringe Fachkompetenz auf Entscheidungsebene im öffentlichen Bereich. Im Gegensatz dazu zeigen die Ergebnisse der Experteninterviews in China ein zunehmendes Qualitätsbewusstsein, sowie eine stärkere Berücksichtigung von Aspekten des Anlagenbetriebs.

Basierend auf den Ergebnissen der Datenerhebung muss geschlussfolgert werden, dass Abwassertechnologie für Länder wie Indien und China primär charakterisiert sein sollte durch

- Einfachheit
- Robustheit
- Hohe Materialqualität
- Geringe Automation.

Einfachheit, sowohl in Bezug auf Konstruktion und Betrieb, muss höchste Priorität haben. Ein hoher Automationsgrad erleichtert zwar vordergründig den Anlagenbetrieb, führt aber zu massiven Problemen, sobald Betriebsanpassungen oder Reparaturen durch das Betriebspersonal durchgeführt werden müssen. Robustheit und hohe Materialqualität sind ebenfalls zentrale Anforderungen an

Abwassertechnologie, sowohl aufgrund der Umwelteinflüsse, als auch der in dieser Studie nachgewiesenen Defizite bei Wartung und Instandhaltung. Einfachstlösungen, wie z.B. Abwasserteiche oder DEWATS-Technologien, scheiden für urbane Räume aufgrund des hohen Flächenbedarfs und der steigenden Anforderungen an die Ablaufqualität praktisch aus. Statt dessen sind innovative Lösungen erforderlich, die sich vor allem durch Kompaktheit, geringen Energiebedarf, sowie durch die Möglichkeit der Wiederverwertung des gereinigten Abwassers auszeichnen.

Empfehlungen

Lösungsansätze zu einem verbesserten Klärwerksbetrieb in Indien müssen an mehreren Stellen angreifen. Von grundlegender Bedeutung ist die Steigerung von Fachwissen und Bewusstsein für Belange des praktischen Anlagenbetriebs auf Ingenieurebene. Hierzu ist das deutsche Konzept der „Kläranlagennachbarschaften" gut geeignet und dessen Einführung zu empfehlen. Die Einbeziehung des praktischen Betriebspersonals in Kläranlagennachbarschaften erscheint in Indien gegenwärtig unrealistisch. Die Einführung von Anreizsystemen, wie leistungsabhängige Entlohnung von Personal und Leistungsvergleichen von Klärwerken ist unbedingt zu empfehlen. Nicht zuletzt aufgrund der geringen Motivation des Klärwerkspersonals sind Maßnahmen zur Verbesserung der Arbeitsbedingungen auf den indischen Klärwerken, sowie zur Image-Aufwertung der Arbeit auf Kläranlagen als Beitrag zum Umweltschutz dringend zu empfehlen. Generell ist eine langfristige Privatisierung des Klärwerksbetriebs anzustreben, da im öffentlichen Sektor in Indien kaum Veränderungen zu erwarten sind.

Um eine Steigerung des Fachwissens auf Techniker- und Arbeiterebene zu erreichen, erscheint die Durchführung anlagenspezifischer Weiterbildungsmaßnahmen vor Ort sehr erfolgversprechend, was auch der durchgeführte Pilotversuch zur Mitarbeiterschulung zeigte. Obwohl langfristig durchaus sinnvoll, ist die Akzeptanz von formalen Ausbildungsgängen in der gegenwärtigen Situation aufgrund des schlechten Images der Abwasseraufbereitung zweifelhaft, was die Ergebnisse der vorliegenden Studie zeigen. Zudem ist die Bereitschaft von Klärwerksleitungen Personal für Schulungsmaßnahmen freizustellen gering, ganz abgesehen von den Kosten. Die Schaffung und Umsetzung rechtlicher Rahmendingungen für Mindestanforderungen an die Qualifikation von Klärwerkspersonal, sowie die effektive Kontrolle des Anlagenbetriebs, statt nur der Ablaufwerte, ist daher dringend angezeigt.

Im Vergleich dazu ist man in China bereits einen großen Schritt voraus. Hier wurden bereits erste Schulungsmöglichkeiten für Klärwerkspersonal geschaffen, wenngleich diese den Bedarf bei weitem nicht decken. Auf vielen Klärwerken wird die Notwendigkeit gesehen, das Betriebspersonal zu Weiterbildungsmaßnahmen zu entsenden. Ein von der Kreditanstalt für Wiederaufbau (KFW) finanziertes Schulungszentrum in Qingdao wurde sehr positiv aufgenommen, wie Interviews mit Klärwerksleitern zeigten. Im Mai 2007 wurde in Peking ein neues Deutsch-Chinesisches Schulungszentrum für die Ausbildung von Klärwerkspersonal gegründet. Während in Indien die Kontrollinstanzen von der Stadtentwässerung entkoppelt sind, können die Kontrollinstanzen in China ihre Kontrollfunktion momentan nicht effektiv wahrnehmen, da sie auf einer Ebene mit Institutionen der Wasserver- und Abwasserentsorgung in die Verwaltungsstruktur eingebunden sind. Eine Umstrukturierung ist dringend erforderlich – Anzeichen dafür sind bislang jedoch nicht zu erkennen.

Die oben beschriebenen Anforderungen an die Abwassertechnologie sind zu beachten. Um den langfristigen Betrieb höherwertiger, komplexer Anlagentechnik sicherzustellen, ist die Auslagerung bestimmter Wartungs- und Instandhaltungsarbeiten an entsprechende Dienstleistungsunternehmen vor Ort zu empfehlen. Dies gilt insbesondere für Indien. Bedarf und Marktpotential bestehen in China bereits in großem Umfang, was auch nicht zuletzt der Erfolg eines deutschen Unternehmens, das sich unter anderem auf die Beschaffung von Ersatzteilen westlicher Maschinentechnik spezialisiert hat, deutlich macht.

Der Vergleich der Ergebnisse der Experteninterviews in Deutschland, Indien und China zeigt, dass unterschiedliche Einschätzungen und Einstellungen als Ausdruck des jeweiligen kulturellen Hintergrundes nicht unproblematisch sind. Länderspezifische kulturelle Werte aus Untersuchungen zur interkulturellen Kommunikation konnten auch in der vorliegenden Studie festgestellt werden. So werden Verlässlichkeit und Qualitätsdenken auf der deutschen Seite aus asiatischer Perspektive geschätzt und ein Mangel an Flexibilität kritisiert. Auf deutscher Seite konnte in den Experteninterviews sehr häufig die problematische Haltung festgestellt werden, dass die eigenen Werte und Einstellungen als universeller Maßstab auch für andere Nationen gesehen werden. Dies gilt nicht zuletzt auch für den Wert von und damit auch den Umgang mit Technik. Eine Sensibilisierung von Personen, die in siedlungswasserwirtschaftliche Projekte eingebunden sind, durch entsprechende interkulturelle Trainings ist daher zu empfehlen.

Fazit

Ein enormer Bedarf an Abwassertechnologie ist in den nächsten Jahren sowohl in Indien, als auch in China zu erwarten. Schätzungen zufolge werden in Indien bislang nur rund 20% des Abwassers der Städte mit mehr als 50.000Einwohnern gereinigt. In China werden rund 45% des städtischen Abwassers gereinigt, wobei die Schätzungen sehr vage sind. Beide Länder stellen enorme Summen für Investitionen in diesem Bereich bereit. Basierend auf den Ergebnissen sowohl dieser Studie, als auch anderen Einschätzungen zur Marktsituation, ergeben sich sehr gute Marktchancen für deutsche Anlagenbauer und Systemlieferanten. Die vorliegende Studie macht allerdings deutlich, dass große Unterschiede im Abwassersektor in Indien und China bestehen, die berücksichtigt werden müssen.

Bestimmte Unterschiede in der Anwendung von Abwassertechnologie werden auch in Zukunft weiter bestehen – Veränderungen sind vor dem jeweiligen kulturellen Hintergrund nur in gewissen Grenzen und nur langfristig möglich. Unterschiede sollten daher zu einem gewissen Grad weniger als Defizite, sondern vielmehr als Ausdruck der jeweiligen Kultur gesehen werden.

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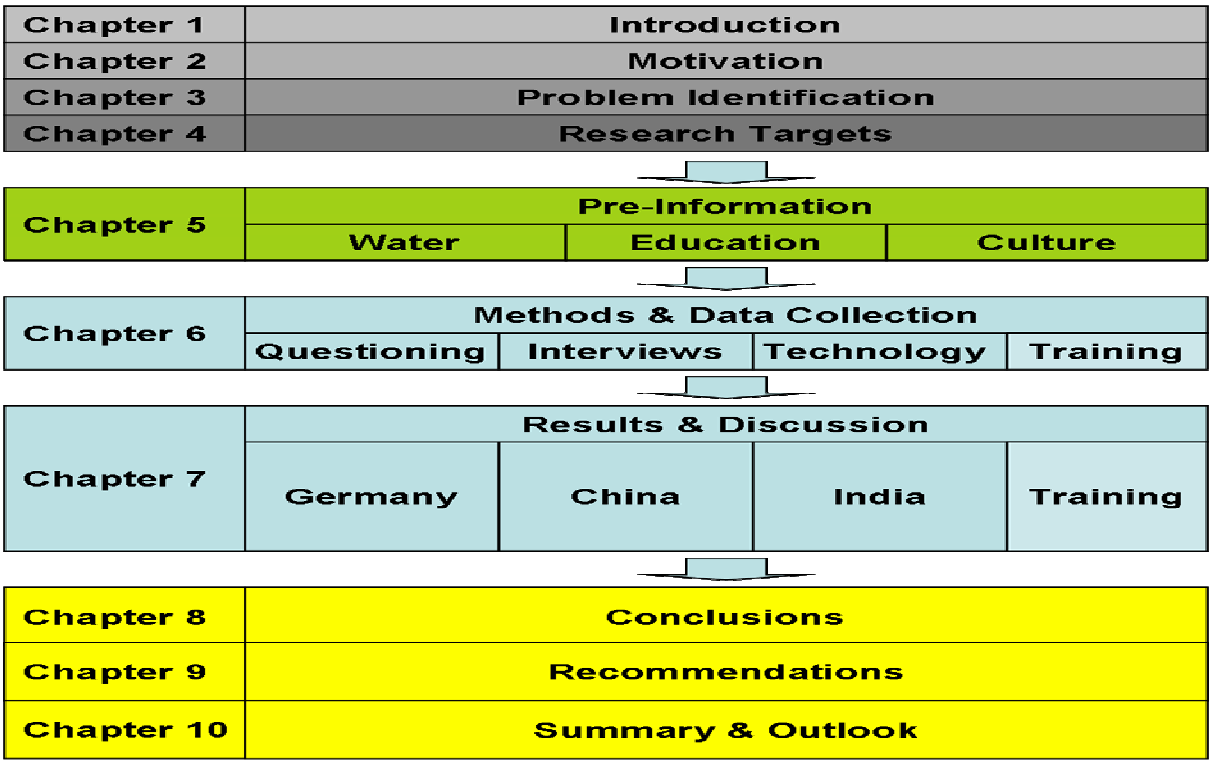
LIST OF CONTENTS

Structure of the Research Work

This research work is structured in 5 major parts. In the introduction, **chapter 1**, a general introduction to the topic of the research work is given. After this, the motivation of this work is presented in **chapter 2** based on some illustrating examples from practice. In **chapter 3**, a detailed problem identification is carried out, wherein different parties, concerned with the research topic are considered. In **chapter 4**, targets and research questions of this study are formulated. In the second part of this work, basic information on the situation in the different countries regarding water & wastewater, as well as education and culture are given in **chapter 5**. As the research work is located between different cultures, also an introduction on intercultural communication, major cultural differences between India, China and Germany, as well as the role of technology in the different countries is presented in chapter 5.3. In **chapter 6** the scientific methods that were chosen, in order to answer the defined research questions, are presented. After this, the implementation of the different methods in India, China and Germany is described. In the following part, the results of the data collections are presented and discussed for the different countries in **chapter 7**. In chapter 7.5, the results of pilot trainings that were carried out in India are presented and discussed. In the final part of this work, major conclusions are drawn in **chapter 8**, from the results, for the concerned parties in wastewater treatment, as well as design and selection of treatment technologies. The conclusions give answers to the research questions. In **chapter 9**, concrete recommendations are given. In **chapter 10**, a summary and an oulook are given.



1 Introduction

The water situation almost all over the world is becoming more and more problematic. Some decades ago, water scarcity was a problem mainly in desert areas in Africa and in certain parts of Asia. In the respective regions the population has adapted to the situation, dry seasons changed with wet season and after periods with enough rain for livestock and agriculture also periods of severe drought had to be overcome. Over centuries, water was available more or less in similar quantities and qualities.

But in the last decades, water has become a valuable good in more and more countries, not only in traditionally arid areas. Reasons and possible solutions how the challenging problems can be solved or at least how worsening of the situation can be prevented are discussed on almost regular basis with increasing intensity on various conferences not only on expert level, but more and more also on political level. The sometimes heard forecast that the wars of the future will be about water, not on oil, appears too extreme, but the message is a dolorous truth: Water is more and more scarce and the quality is decreasing dramatically in many countries. The climate change debate forecasts even worse problems for the water situation in many regions of the world.

Although water has also become a critical topic in western countries too, the countries on the African and Asian continent are confronted with very severe situations and even worse forecasts for the future. Population growth, urbanisation, industrialisation and intensive agriculture are only some reasons for increasing water shortages besides climatic changes. In China, one of the fastest growing economies in the world, about 70% of rivers and lakes are considered as high polluted, less than 20% of the solid waste is treated. Air pollution is also a big problem - 6 of 10 cities with the highest air pollution are in China (Gehring 2006).

Two basic strategies against above mentioned water problems can be identified:

1) Minimisation of the water demand

2) Maximisation of the efficiency of the water usage

Although enormous efforts are made in order to control the water demand, the success is doubtful especially in newly industrialising countries. Countries like India or China are developing extremely fast in recent years and a stabilisation can hardly be seen. Related to this fast industrial growth are phenomena like urbanisation and dramatically increasing water demand especially in urban areas. In the dilemma between economic growth and available water sources, water becomes more and more a limiting factor. In India, the situation has to be seen very critical – the quality of surface water as the major source for drinking water is decreasing after a slight improvement until the year 2005. Similarly, a dramatic rise of pathogens can be stated.

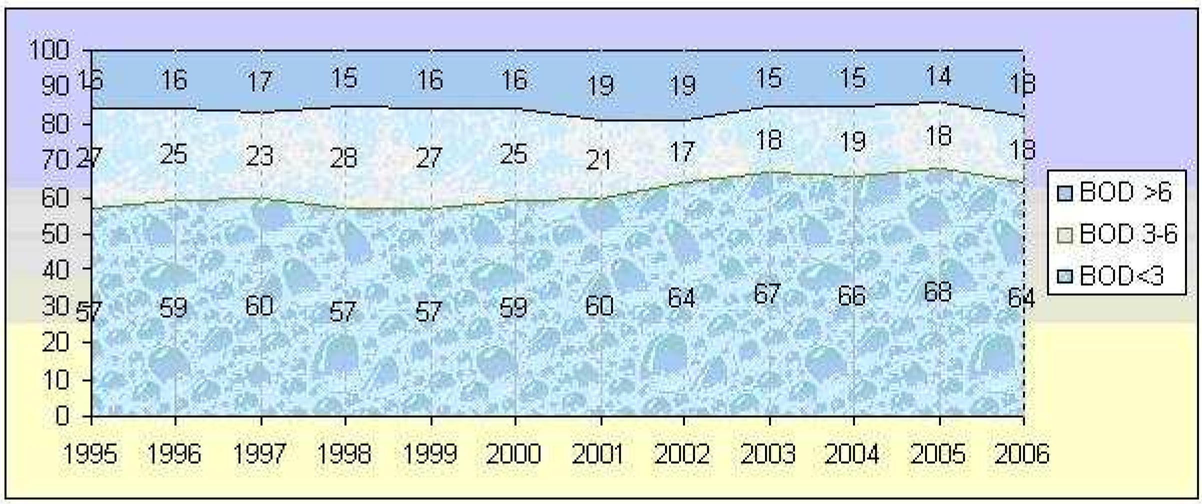


FIGURE 1: SURFACE WATER QUALITY TREND BOD (MG/L) IN INDIA (CPCB 2008A)

Beside minimisation of the water demand, the maximisation of the efficiency of water usage, including reuse of water, becomes the major target of the future. Various technical solutions for the municipal as well as for various industrial sectors in different climatic conditions have been developed and implemented all over the world. Very often legislative guidelines, in the industrial field also cost-benefit calculations, are the driving forces for the realisation of high investments in environmental protection technology. In both cases one major target is cost minimisation, which means that with a minimum of investment and running costs the required results in terms of quality of the treated effluent for discharge or reuse have to be achieved. The discussion which processes or concepts are suitable for which application and which country is very intensive on the expert level. When it comes to the economic level, costs come into the game and many technically ideal solutions are not implemented because they are not cost efficient. When it comes to the user side, interestingly hardly any potential adaptation difficulties are taken into account. After decades of experience in the development aid, it surprises that very often obviously – especially in the private sector - it is assumed almost without any critical thoughts that any technically skilled person in the world will handle a technical process in the same way. What is the right of existence of a technical product, if it cannot be applied properly for the purpose it was created?

How is the right for existence determined, if not by the successful handling of a technology by the staff of a wastewater treatment plant? The experience from the 60ies and 70ies in the international development aid lead to increasing awareness that local users have to be considered and trained accordingly. The experiences in the 80ies and 90ies showed improvements but also that only training is not enough. From the cultural point of view this does not surprise. A technical artefact from a western society is shifted into a completely different society with completely different cultural values – a different language is only one facette of cultural uniqueness of every society.

Looking at the experience from projects in the water and wastewater sector and the efforts in that field from a wider perspective, it can be postulated that the major challenge is to avoid an exclusive focus on the development of a perfect technical solution, but that also means the equal consideration of technical, economical, educational and cultural aspects. “In the consideration of science and technology transfer it has to be considered that modern natural science and technology is neither value neutral nor culture-invariant” (Irrgang 2006).

2 Motivation

Why such a broad title? Wastewater treatment in developing and newly industrialising countries – a huge topic. It is not possible to cover such a vast field in detail in one work. The approach of this study is different. In order to show the motivation for this study, some short stories and personal experiences of the author shall be given first.

Story No.1:

In an effluent treatment plant of a distillery in India, the outlet values for BOD and COD could not be met and the company wanted to find out what could be done to meet the required outlet standards. During a three weeks observation of the plant operation, it was found – amongst others - that the compressors for the diffused aeration of the second activated sludge system was in operation for less than 50% of the time. Asked about the reason the staff mentioned that the compressor would last longer that way.

Story No.2:

The plant manager and chief engineer a small municipal sewage treatment plant in India complains that the outlet values for BOD are too high. A company specialised in wastewater projects was contacted and it was planned to renovate and modify the treatment plant. In a plant visit it was found that the surface aerator of the aeration tank was put in operation only 50% of the time. Discussions with the staff showed the basics of activated sludge process were not known. Continuous aeration might have solved the problem already.

Story No.3:

A German manufacturer exported and installed a screen in India. Several years later, the client was recontacted. The machine was not working any more. Reason: A simple cotter pin on the drive system was broken. The screen was bypassed, no repair was carried out by the client and the high quality screen wasn't used any more.

Story No.4:

On one effluent plant in India, the pipe from a sludge collection pit was blocked. The solution was that a worker went almost naked into the sludge pit and tried with bare hands to remove the blocking.

Story No.5:

An Indian sewage treatment plant purchased a UV disinfection system from a well known German company that counts as a specialist in this field. The system was delivered, but could not be put into operation properly by the local staff. The Indian client tried to contact the supplier to find a solution and put the system into operation, but the client felt left alone – sold and forgotten. On a conference in Mumbai, the disappointed responsible engineer gave a presentation some time later. Title: Learning by mistake. His message: Never buy from this company – the advantages to buy Indian equipment!

Story No.6:

On a plant visit in China on a plant with mainly German equipment, a visitor wondered why several mixers for wastewater lay in one room. They were obviously used, but not very old. It was found that the mixers were all damaged and just removed from the respective ponds. No replacement, no repair.

Above shown examples illustrate very drastically some potential problem fields when cultures collide in the field of wastewater treatment in developing and newly industrialising countries. The typical purely technical position that for every problem a technical solution can be found that automatically works, if the system is well designed, is challenged by the factor man. The field of wastewater treatment is basically a technical discipline. Civil engineers, environmental engineers, process and chemical engineers try to tackle the key problem, which is basically to make dirty water clean. In an extended sense, it includes the whole field of water – use, reuse, nutrients, sludge, energy, etc. Technicians in almost all countries of the world are working on solutions for problems in their own country and other countries, that means for applications outside their cultural environment. Whether it is the municipal wastewater treatment in a medium sized city in Germany or a megacity in India, whether it is the high heavy metal load in a river somewhere in Europe or the effluent of a distillery in India – from the technical perspective, for each problem, a solution can be found that is only limited by financial aspects. Above shown examples indicate that the conclusion that technical problems require technical solutions is not sufficient, as the factor man is not recognised. Although the fact that any technical solution has to be operated and maintained by men sounds almost trivial, that any discussion on this topic seems to be waste of time from the technicians point of view, the reality forces the responsible acting wastewater specialist to focus also on non-technical aspects. Very common is the almost traditional “fight” between the technicians and the merchants. Very often the best technical solution is too costly, the best solution from the financial point of view is technically doubtful.

When the technical and financial questions are solved, only then the men who should handle and benefit from the respective technology normally come into the game. Plans are drawn, operation and maintenance manuals are written, spare parts lists are added and the contact data or a hotline of the supplier is mentioned. For more complex equipment, the client can choose very often, which service items he wants to purchase with the equipment: installation, running in, training, spare part packages etc.

This very typical business scheme in wastewater treatment assigns the user of a technology the lowest priority within the triade “technology, project realisation, man”. Within the own culture, technical equipment and processes are intuitional designed according to basics of the own culture. It can be assumed that the person who is responsible for the repair of a screen has a similar sense for technical relations than the designer or manufacturer of the equipment, due to the same cultural base. A skilled German plant operator has a basic understanding of technology that is common in Germany. A skilled plant operator in India knows very well how an Indian screening system is working - he is embedded in the existing value and work scheme of his culture, like the Chinese operator is in his culture. In that sense it is only logic that adaptation problems occur when technical equipment as an artefact of one culture is transferred into another culture.

Wastewater treatment or the complete field of water and its use in general, is more and more a global issue, with high importance especially in many developing and newly industrialising countries. Population growth, economic growth and in recent years the consequences of the climate change are challenging the water and wastewater specialists all over the world. International conferences show that knowledge exchange over cultural barriers is almost normal nowadays and one should think that a broad understanding among different cultures exists as it is mentioned again and again on conferences almost like a mantra. But the reality is different. The reasons of problems in the implementation of wastewater processes and technologies seem to be easily identifiable. Local staff is not qualified enough, spare parts are too expensive and the delivery takes too much time, misunderstanding etc. But what is behind all this? Is there a chance to reduce the failure risks to a minimum or is there no other chance than to accept the situation as it is? Looking very closely to the different problems that occurred and occur in the private sector, in the public sector and also within the international development cooperation, it has to be considered that always men who are separated by various distances from each other have to work together. The physical distance and also the distance in the language is understood and can be overcome by all involved partners, whereas additional distances – distances that are routed in the respective cultures - seem to exits that are not recognised.

3 Problem Identification

As mentioned in the previous chapter, wastewater treatment in developing and newly industrialising countries is a very complex topic. Besides the pure technical challenge, many additional parameters have to be considered both for design and construction, but also for the operation and maintenance of treatment facilities. In order to illustrate the major problem fields, a differentiated look on the person groups involved in wastewater treatment projects is important.

3.1 Users of Wastewater Technology in Newly Industrialising Countries

Who are the users of wastewater treatment technology? Is it the operating engineer in the control room of a treatment plant or the mechanic who repairs a damaged inlet screen? Or is it the chief engineer of the drainage department, who is in charge for several sewage treatment plants in his city and who is responsible for the discharge standards set by the control authorities? In a wider understanding, all persons and institutions that are concerned with design, construction, operation and maintenance of a treatment facility can be considered as users with very complex relations and very often with very different interests, although it is the overall target to purify wastewater. For more detailed considerations of the respective groups, the increasing process distance with increasing hierarchy level plays an important role.

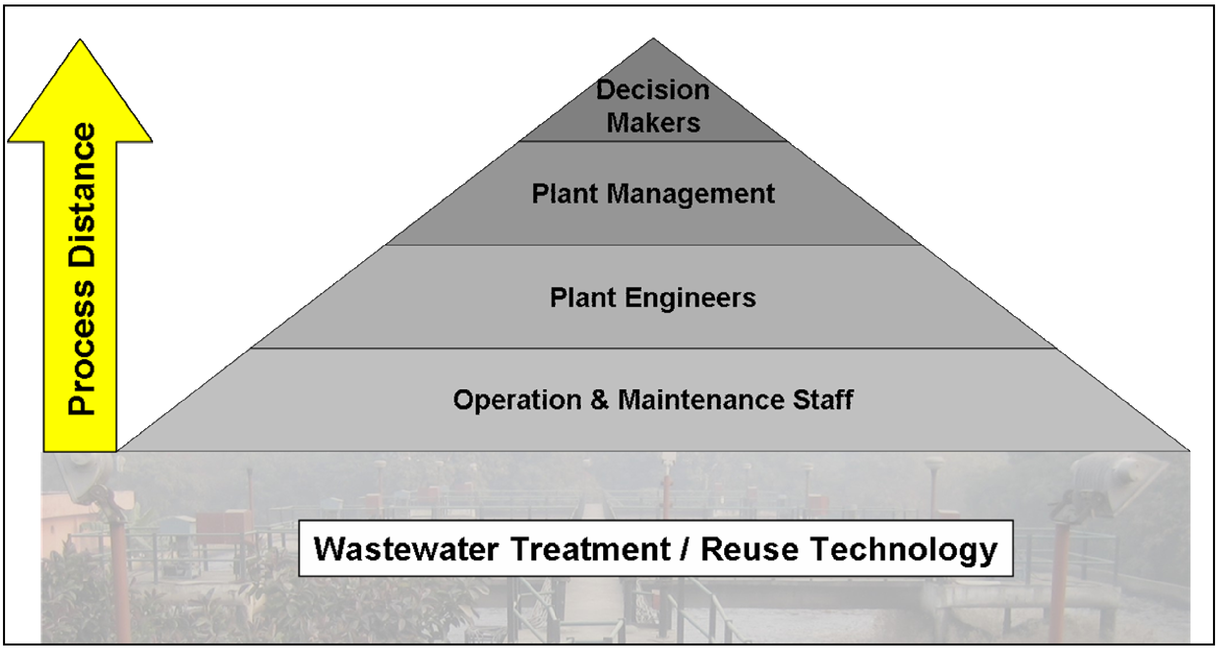


FIGURE 2: USER LEVELS AND PROCESS DISTANCE IN WASTEWATER TREATMENT

Decision Making Level

As decision making level all persons and institutions are considered who take the decisions regarding the investment in technical solutions for wastewater treatment. Depending on project size and finance system, these are institutions on municipal, district or state level in the public sector. In the private sector, it is the owner or the managing board of the respective industrial complex who takes the major decisions. The major motivation on the decision making level are legal guidelines that have to be met by the owner or responsible operator of a treatment facility. Another motivation that becomes more important in some regions in recent years is the reuse aspect, because of water scarcity in many developing and newly industrialising countries. Treated wastewater becomes a product with a value. In the first case, pressure from a control institution, that means from outside, leads to action, in the second case, a potential benefit in terms of usable water as product leads to action. The basic physical model that pressure leads to movement in the direction of the lowest resistance can also be observed in the environmental sector. The lack of legal guidelines and/or implementation forces in many developing and newly industrialising countries has to be seen as one major reason for the dramatic situation in these countries. In the competition of different interests, environmental measures in general are very often of lower priority compared to income generation or profit maximisation, which is also a fertile ground for corruption. Due to the great distance to the real situation of wastewater treatment (see figure 2), the question has to be asked, on which competence base decisions are taken and to what extent operation and maintenance aspects are considered.

Plant Management Level

The plant management level is considered separately, because the interests can differ from the interests of the decision making level. Normally, the plant management level is represented by one person, who has the responsibility for the operation results. Taking a closer look on the plant management, it has to be stated that in many developing and newly industrialising countries, low incentives and weak control instruments for operation exist regarding the compliance with discharge standards. Especially in the public sector, the major task seems to be very often “smoothly” operation under the given financial frame conditions that are fixed by the decision making level. Very often the situation can be observed that equipment exists, the respective aggregates are running, but the efficiency of the treatment process is not controlled and optimised. In many cases, the plant management seems to be confronted with technical installations and processes that it can't handle properly, due to own qualification deficits and qualification deficits among the staff.

Plant Engineers

The group of plant engineers exist mainly on big treatment facilities in densely populated development centres and is considered separately from the workers level. Characteristic for this group is the mainly or exclusively theoretical educational background, very often with absence of any work practical contents due to lack of practical references as essential part of the engineer education. In the organisational structure of a plant it is the duty of the engineers to implement the operational targets set by the plant management, to control the operation and maintenance processes, and to lead the practical staff. Of great importance for the work process is the relation to the operation and maintenance staff that will be analysed in detail in this study.

Operation & Maintenance Staff

The group of operation and maintenance staff comprises all practically working staff on a wastewater treatment plant, that means mainly operators, electricians and mechanics, both on the level of foreman, skilled worker and helper. In opposition to the plant engineers, this group is carrying out practically the required operation and maintenance works and has that way the closest contact to the different technical components on the plant. Therefore, it can be assumed that this staff group plays the most important role for operation and maintenance. However, it can be assumed that the embedding of this group into the work organisation, as well as the relation to superior engineers has an equally strong influence on success or failure of operation and maintenance on wastewater treatment plants.

3.2 Manufacturers and Consultants on the Global Market

For a long period of time, the creation of water and wastewater infrastructure was closely related to the user. In ancient times in Europe, wells and cloaks, later then water and wastewater pipes and sewers were erected locally by local construction specialists. It was the domain of the civil engineer or health engineer. Remarkable key points of this development are the construction of the sewer network in Hamburg in the year 1842 which marqued the starting point for the construction of drainage networks in many other cities in Germany. The first treatment facilities for wastewater were erected in the 1870ies and consisted of sewage fields or screens followed by grit removal tanks and sedimentation tanks. Technologies like Imhoff tank and trickling filter were introduced in many cities beginning of the 20th century. In 1925, the first activated sludge process was introduced in Essen-Recklinghausen in Germany and after the Second World War the activated sludge process became the dominant treatment technology (Seeger 1999). Similarly in other European countries, wastewater treatment became more and more technical, and more and more efficient and complex treatment processes were developed. Parallel to the process development, first purely mechanical, later also more and more electro-mechanical and electrical equipment was required. In todays developing and newly industrialising countries, the major focus was set for a long time only on water supply, which lead to severe problems due to the generated wastewater, especially in urban areas. It is only since about 20-30years that also wastewater treatment has gained in importance - and created business opportunities for western companies. Characteristic for many developing and newly industrialising countries are very limited financial means and a high dependency on external financial sources, especially of the lowest income countries. For that reason the implementation especially of technical measures within the bilateral development cooperation represented an important market field for western export oriented companies. Basically the following business fields can be identified:

- Consulting
- Equipment Supply
- Construction
- Operation & Maintenance

Especially within the financial development cooperation by the German *Kreditanstalt für Wiederaufbau (KFW)* or other financing institutions, the consulting branch could profit. The private market for the consultancy branch is mainly limited to certain regions that bring the financial back-up. Together with the USA, Germany is the leading exporter of water and wastewater technology in the world. In 2006, machinery equipment with a total value of more than 600 million EUR was exported from Germany. This is about three times the volume of Italy or France (VDMA 2007). At least from the German perspective, these figures look positive, considering that in general a further growth of the environmental sector is forecast. From the supplier perspective, turnover, that means sold equipment counts. What is hardly considered is the operation time, especially when the guarantee has expired. A common phenomenon – although very often not justified - is that the user of technical equipment sees the responsibility for technical problems in the operation phase on the supplier side. An awareness that insufficient skills of the operation staff might have led to the problems very often doesn’t exist. Very few German construction companies are directly active in the construction of water and wastewater infrastructure – concrete works are normally carried out by local companies under a local or foreign consultant. An exception is Julius Berger PLC. in Nigeria, a daughter of the German company Bilfinger Berger. Operation and maintenance are also business fields that were mainly covered by local companies. However with the trend for more privatisation of the water and wastewater sector, foreign enterprises with enough capital background enter these fields and cover several business fields. Still leading in field of multi service provision are French companies like Véolia Environment and the Suez group, comprising Degremont and Infilco. In the 1980ies the Suez group started entering in the privatisation of public water supplies and soon after that also entered also in the wastewater treatment field. In the 1990ies, the group started its activities in Eastern Europe, Asia, South America and Asia (Suez 2004) and is today one of the biggest multi service providers in the water and wastewater field. Another player in the international water and wastewater sector is RWE-Thames Water. Beside RWE, German companies played a very minor role until now, mainly due to the small company sizes.

Studies on technology transfer show that German technology, as well as German technical staff obviously does not automatically “fit” into foreign cultures. Figure 3 shows major aspects that are seen critically by German specialists abroad regarding the use of technology by foreign staff.

FIGURE 3: CRITICAL ASPECTS OF TECHNOLOGY USE – GERMAN PERCEPTION (ACCORDING TO HERMEKING, 2001)

Considering the examples given in chapter 2, it can be assumed that different cultural values and perceptions seem to play an important role also for problems in the wastewater sector.

3.3 Bilateral Development Cooperation

Bilateral development cooperation has a long tradition since the start of the "Extended Assistance Program of the United Nations for Economic Development of Underdeveloped Countries and Regions"(today UNDP) after the Second World War. Today, numerous organisations exist under the roof of the United Nations, European Commission, World Bank, International Monetary Fund, World Bank and World Trade Organisation plus regional development banks, numerous multilateral institutions, NGOs and churches. Germany joined the UN-program in 1952 and in 1956, the German parliament resolved upon a 50 millon DM program for bilateral development assistance. One of the first target countries of the German development aid was India (BMZ 2007A). Since that time, the worldwide bilateral development assistance of western nations has changed a lot over the last decades, both regarding the motivation of the donor countries and the programmatic orientation.

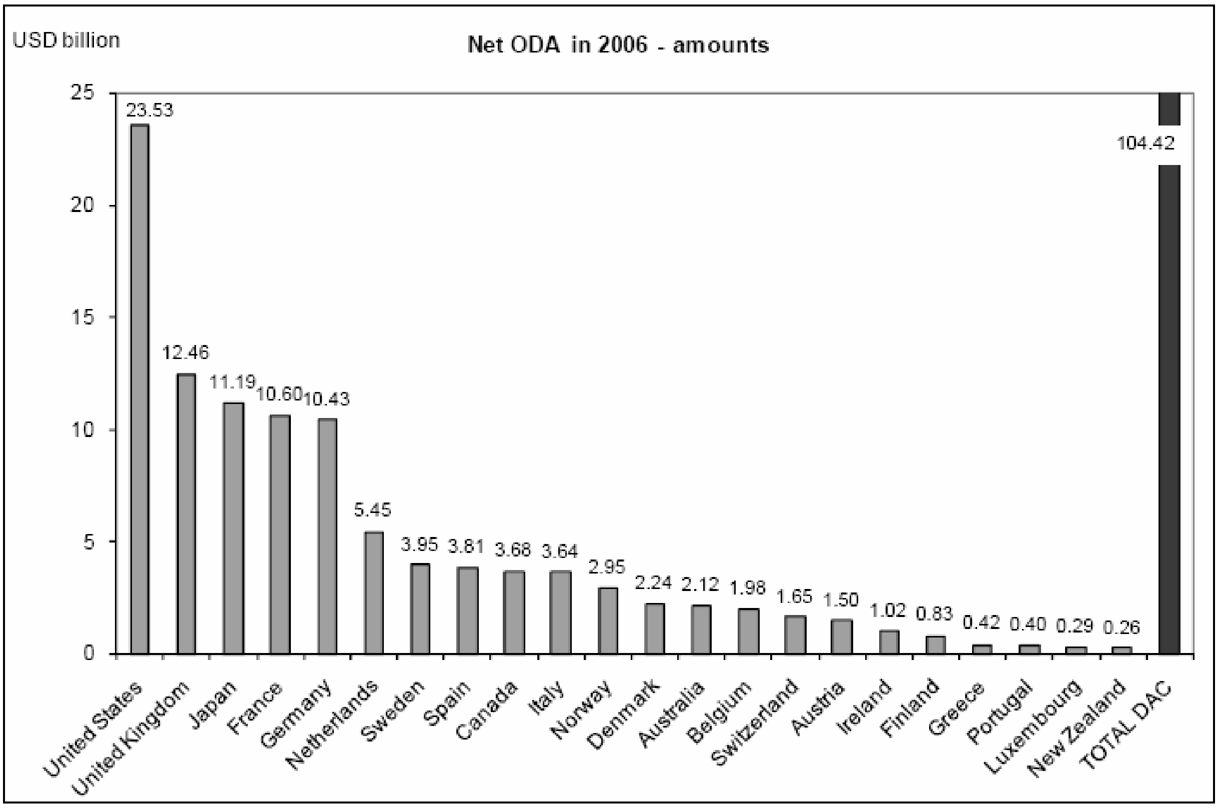


FIGURE 4: DEVELOPMENT ASSISTENCE COMMITTEE (DAC) MEMBERS' NET OFFICIAL DEVELOPMENT ASSISTANCE IN 2006 (OECD 2007)

As visible in figure 4, with a value of 23.53 billion USD the United States are on position one regarding the absolute expenditures for development assistance. The United Kingdom, Japan, France and Germany are following with about half the amount. Looking at the expenditures for development assistance as percentage of General National Income (GNI), the US are on rank 21 with only 0.18% of GNI compared to Sweden on position 1 with 1.02% of GNI and Germany on position 13 with 0.36% of GNI (OECD 2007). Regarding the regional focus of the German development assistance, about 46% of the expenditures were used for projects in Africa and about 30% were used for projects in Asia in 2006 as the two major focus regions (BMZ 2007B). Currently, the engagement of Germany in the water sector is focusing on 23 countries, with an annual total funding of about 350 million EUR per year. Following the information of the German Federal Ministry for Economic Cooperation and Development (BMZ), the German government intends to keep that level also in future. Above mentioned figures show the enormous dimension of investments in the water sector within the bilateral development cooperation.

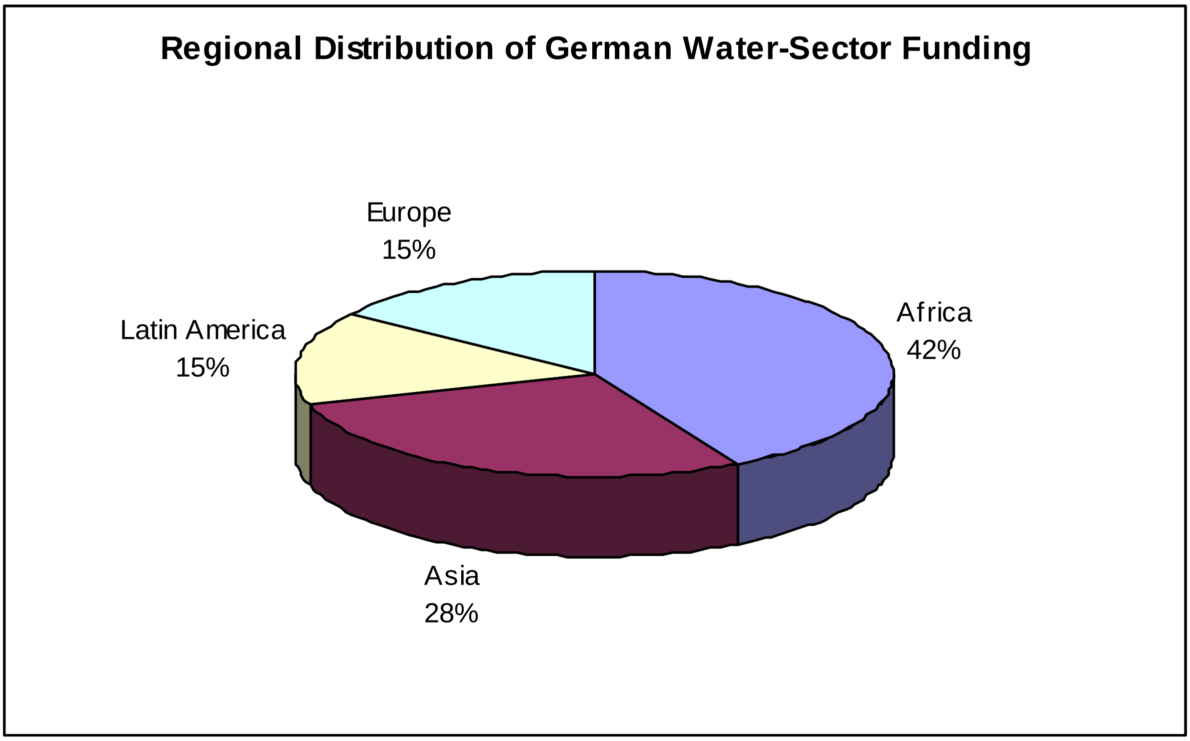


FIGURE 5: REGIONAL DISTRIBUTION OF GERMAN WATER SECTOR-FUNDING (ACCORDING TO BMZ, 2005)

Despite improvements also in the water and wastewater sector in many countries, the development assistance has been and is still under controverse discussion, last but not least because of the development support for extremely fast industrialising countries like China for example. The basic critic points can be summed-up in the two major categories motivation and effectiveness. Regarding the motivation, economic interests behind an engagement in developing countries are a basic critic, also in the discussion about the consequences of globalisation, whereas ideological aspects have almost disappeared after the cold war period.

Regarding the effectiveness of activities and projects a closer look specifically on the water and wastewater sector shows, that regardless the motivation to improve water supply and sanitation, the middle- and long-term results were not always as expected, although sustainable development has become the main guideline for development, expressed by the Brundtland-Commission in 1987. Machinery equipment that can't be operated or not repaired by local staff is a problem also in the German development cooperation, as the experience of KFW bank in China indicates. The German bank *Kreditanstalt für Wiederaufbau (KFW)* is the mainly executing institution for financial support, whereas *Gesellschaft für technische Zusammenarbeit (GTZ)* is in charge for technical support under the roof of the Federal Ministry for Economic Cooperation and Development (BMZ). Figure 6 gives an outlook on the German financial development assistance in the water sector in China.

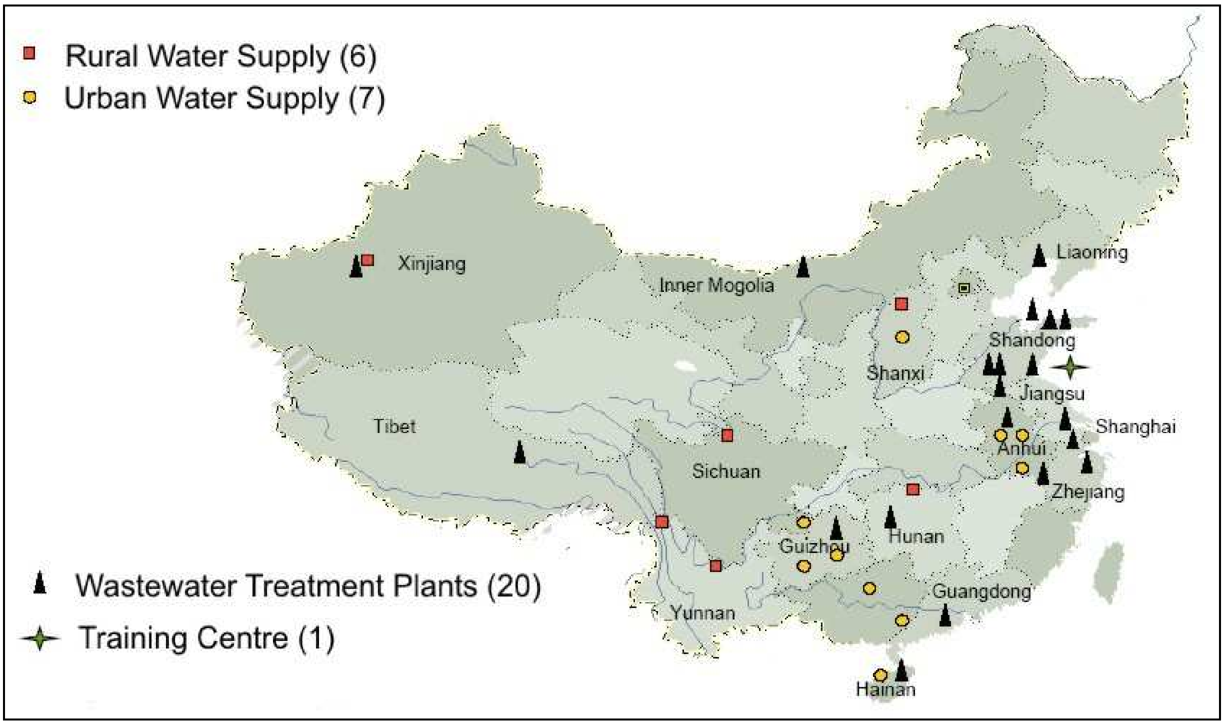


FIGURE 6: GERMAN FINANCIAL DEVELOPMENT ASSISTANCE IN THE WATER SECTOR IN CHINA (KARL 2006, MODIFIED)

The experience of KFW, GTZ and other organisations, like Bremen Overseas Research and Development Association (BORDA) shows that the higher the pre-analysis and the participation of local decision makers and interest groups, the higher the chances for sustainability. Stories about water pumps that were not used by the local population in an African country because the sealings are of leather are classic examples how a good intension can fail its target. The wastewater situation of Chennai shows very drastically the consequences, when water supply is pushed forward without considering the generated wastewater – financed by the world bank. As a consequence, today especially the poorest population groups are suffering from water borne and water related diseases. The fact that even projects of local organisations that are not “separated” by the cultural distance like a foreign organisation, are very often also not successful as planned, shows the extremely high sensitivity for the people and the local culture that is required. A typical example is the construction of compost toilets in the 1990ies by an Indian NGO with the intention to improve the sanitary conditions. In many cases the toilets were used as storage room for agricultural products – the people preferred open defeacation (Wilderer and Paris 2001). Undoubtedly today, the need for intensive participation is widely recognised within the international development assistance. In recent years, also signs for another paradigm shift can be seen in the German development cooperation in the water sector. “When expanding infrastructure in the water sector, precedence should be given to repair work and the rehabilitation of existing water supply and sanitation systems, as well as making efficiency gains, rather than creating new capacities” (BMZ 2005). Although a stronger focus is set on capacity building from the donor side, the critical question has to be asked, whether the need for capacity building – also regarding operation and maintenance - is also recognised by the partner countries to such an extent that leads to long-term action. Doubts are indicated. The current study on the Indian and Chinese wastewater scenario shall help to get a better understanding on this topic.

4 Target of the Research Activities

Based on the key hypothesis that successful and sustainable wastewater treatment is only possible, if aspects of technology, project realisation and education/culture are equally considered by all involved parties and partners, answers to the following research questions are to be given in this study:

- What is the technical status of treatment plant equipment on Indian and Chinese wastewater treatment plants?
- What are the reasons of operation and maintenance deficits, and how can an improvement of plant operation and maintenance be achieved?
- What is the manpower and education situation on Indian and Chinese wastewater treatment plants and how can an adaptation to the requirements of modern wastewater treatment technology be achieved?
- What should be the characteristics of modern wastewater treatment technology, so that sustainable operation and maintenance is assured?
- What relevance have cultural characteristics for the realisation of projects in the wastewater sector?
- What basic position differences exist on expert level in India, China and Germany, and what conclusions can be drawn for the implementation of wastewater treatment technology?

In a comparative study above mentioned questions will be answered on the example of India, China and Germany as an industrialised nation, having strong relations with many developing and newly industrialising countries. Essential component of the approach to the answering of the research questions is the creation of a suitable data base, consisting of the determination of the technology status on wastewater treatment plants, the situation of treatment plant staff and positions of experts in the different countries. Figure 7 gives an outlook on study concept and research targets.

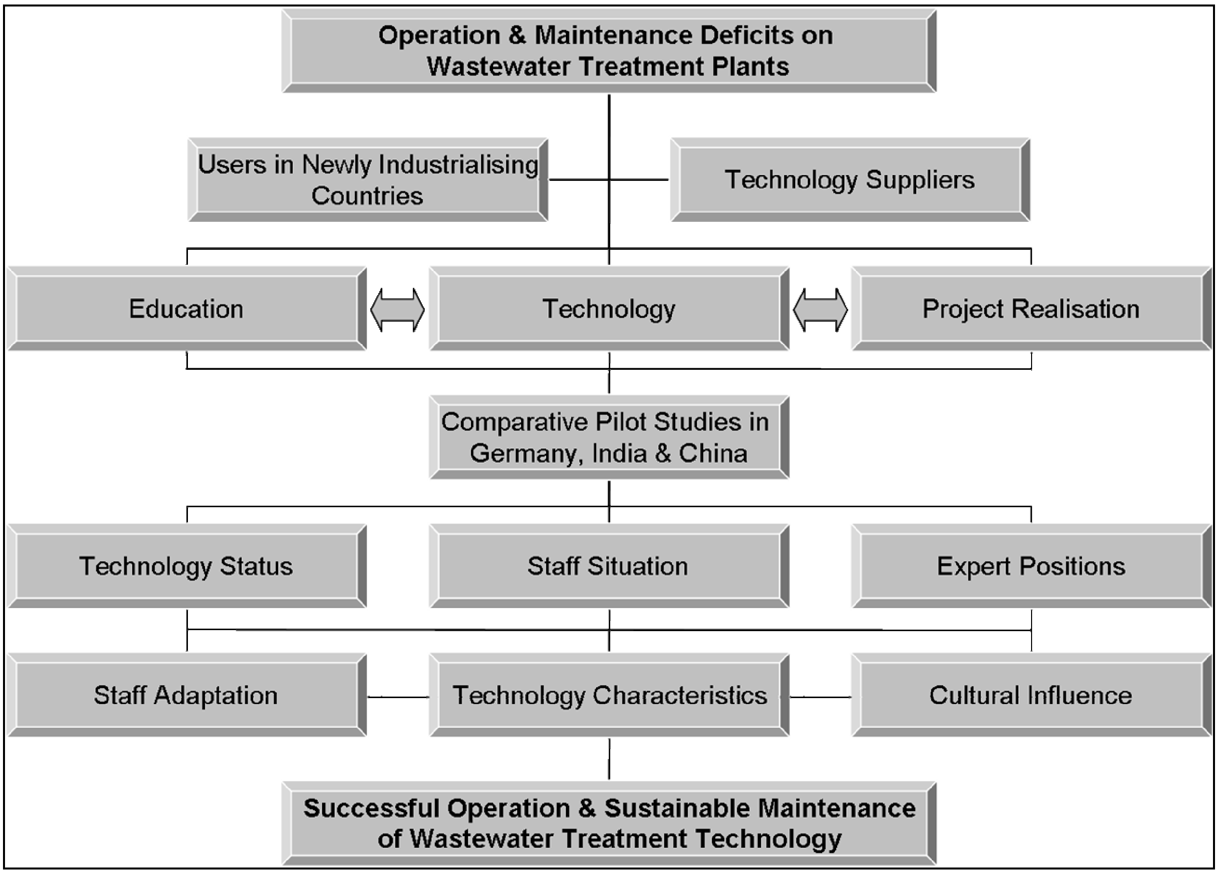


FIGURE 7: OUTLOOK STUDY CONCEPT AND TARGETS

5 Relevant Pre-Information on India, China & Germany

5.1 Water, Wastewater and Legal Framework

In the following, short introductions on the water and wastewater situation, as well as the legislative framework in India, Germany and China will be given.

5.1.1 India

Some summarising key information based on information of the Central Water Commission (2005):

Estimated Annual Precipitation [mm]	1.194		
Geographical Area [million km²]	3.3		
Population [billion]	1.1		
Per Captita Water Availability [m³]	1.704		
Total Estimated Utilisable Water [billion m³]	1.122		
- Surface Water	690		
- Ground Water	432		
Per Capita Utilisable Water [m³]	1.022		
Per Capita Consumption [m³][A]	470		
Projected Water Demand [billion m³]	*2000*	*2025*	*2050*
- Domestic	42	73	102
- Irrigation	541	910	1.072
- Industry	8	23	63
- Energy	2	15	130
- Others	41	72	80

TABLE 1: OUTLOOK WATER RESOURCES INDIA (CENTRAL WATER COMMISSION 2005, MODIFIED); A: ROUL (2006)

Characteristic for the water resources situation in India is a regional and seasonal unequal distribution of precipitation, and that way strong variation of the water availability through the year. From June to September, about 75% of the total yearly rain falls during the south-west monsoon. Regionally, the total precipitations vary in a range between less than 400mm in Rajasthan and about 4.000mm in regions like Uttaranchal, Assam and Arunachal Pradesh (CPCB 2001A). Considering the critical value of 1.700m³/capita (Falkenmark indicator) for water stress (UN-HABITAT 2003), the average water availability in India is on the limit.

Regarding the water quality, many surface water bodies are severely polluted. About 15% of rivers and lakes have a BOD of more than 6mg/l (MoEF 2004). In many regions of the country the ground water is polluted due to infiltration of contaminated surface waters, sewage and leachates from solid waste disposals (CPCB 2003). As visible in table 1, the water demand goes far beyond the utilisable water resources in near future. Pipe losses are high due to leakages in the distribution network. The water price is of highest political brisance in India. Water supply and wastewater treatment are highly subsidised by the state. According to the information of the National Institute for Urban Affairs in 2005, the water price for domestic use is in a range between 2.5Rs/m³ and 5,0Rs/m³ for most cities. Block tariffs are common (Alex 2007). The water price for industrial use is in a range between 6Rs/m³ and 35Rs/m³ (Alex 2007). An extra fee for wastewater treatment doesn’t exist in India. An estimation of the expenses of Indian citizens for water is difficult, considering the lowest population levels. Although for the middle and upper class, the water prices are extremely low, water supply by private tankers due to not existing pipe infrastructure can be a high proportion of the livelihood costs of poor populations groups. However, an increase of the water price appears unavoidable.

Currently, about 30.000m³ of sewage are generated every day from 414 Class I cities (more than 100.000 inhabitants) and 489 Class II cities (between 50.000 and 100.000 inhabitants). In total, only about 21% of the sewage is treated (CPCB 2005).

Introduction Indian Water Legislation

The following table gives an outlook on the different authorities in the water field in India.

	Field of Responsibility				
Authority	Surface Water Quality	Ground Water Quality	Water Supply	Drinking Water Quality	Wastewater Treatment
Central Pollution Control Board	X	X			X
Central Water Board	X				
Central Ground Water Board	X	X			
Ministry of Urban Development		X	X		X
Ministry of Rural Development			X	X	X
Ministry of Environment and Forests	X				X
Municipalities			X	X	X
Metropolitan Development Authority			X	X	X
State Public Health Engineering Depart.				X	

TABLE 2: RESPONSIBILITIES IN THE WATER AND WASTEWATER SECTOR IN INDIA (KRÄMER 2004, MODIFIED)

As visible in above figure, many overlappings exist regarding the responsibilities of the different authorities, which make decision processes very complex.

The regulations regarding use and protection of the water resources in India are very complex. Beside the central legal framework, additional and different regulations exist in the federal states that are in charge for the implementation. As a result, the implementation is on very different levels in the different regions of the country (Alex 2007).

For the water and wastewater sector, basically two acts are relevant that were passed at federal level:

- The Water (Prevention and Control of Pollution) Act (1974)
- The Environment Protection Act (1986)

Most important executing institution under the Ministry of Environment and Forests is the Central Pollution Control Board (CPCB) with its headquarter in Delhi. The CPCB, as well as the creation of other related boards is based on the The Water (Prevention and Control of Pollution) Act. It defines the powers and functions of the boards and the powers for the prevention and control of water pollution. Other important regulations are included regarding funds, budgets, audits, as well as penalties and procedures, if the rules are not matched (CPCB 2001B).

In the Environment Protection Act, India implements the decisions taken on the United Nations Conference on the Human Environment held at Stockholm in June, 1972, in which India participated. The Environment Protection Act goes beyond water and air pollution issues. “Environment" includes water, air and land and the inter-relationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organism and property. “Environmental pollutant" means any solid, liquid or gaseous substance present in such concentration as may be, or tend to be, injurious to environment” (MoEF 1986). Article 5 of the Environmental Protection Act is the legal basis for sanctions against industries in case of non-compliance with pollution standards. “For the avoidance of doubts, it is hereby declared that the power to issue directions under this section includes the power to direct (a) the closure, prohibition or regulation of any industry, operation or process; or (b) stoppage or regulation of the supply of electricity or water or any other service.” (MoEF 1986). Especially for considerations regarding water consumption and water pricing, two major aspects have to be considered:

First of all, the National Water Policy states:

“Water is a prime natural resource, basic human need and a precious national asset. Planning, development and management of water resources need to be governed by national perspectives” (MWR 2002).

Second, the question of ownership and right to use. Based on the Easement Act from 1882, the ground water belongs to the land that someone owns, whereas the surface water belongs to to the respective federal state (Alex 2007). Like in the US and many other countries, ground water comes under private ownership in India. From the legal point of view, groundwater basically comes under the tenancy laws of the states. "In short, water is attached like a chattel to land property" (Azariah and Jacob 2000).

Outlook Indian Discharge Standards for Wastewater

The following table gives an outlook on the major discharge standards for municipal wastewater in India.

Parameter		**Inland surface water**	**Public sewers**	**Land for irrigation**	**Marine/coastal areas**
		(a)	(b)	(c)	(d)
BOD (3days at 27°C)	mg/l	30	350	100	100
COD	mg/l	250	-	-	250
SS	mg/l	100	600	200	(a) For process waste water (b) For cooling water effluent 10 per cent above total suspended matter of influent.
NH_4-N	mg/l	50	50	-	50
NO_3-N	mg/l	10	-	-	20
TKN	mg/l	100	-	-	100
Dissolved phosphates (as P)	mg/l	5.0	-	-	-
pH		5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
Oil and grease	mg/l	10	20	10	20
* Detailed information on all discharge standards is available at CPCB (www.cpcb.nic.in)					

TABLE 3: MAJOR DISCHARGE STANDARDS FOR SEWAGE IN INDIA (CPCB 2008B, MODIFIED)

5.1.2 China

Like in India, the water resources situation is characterised by strong unequal distribution of precipitation. About 80% of the water resources are located south of the Yangtze river, whereas only 30% of the agricultural surface and 50% of the population are located in that area. Severe water scarcity due to extremely low precipitations exists in the north China plain, with precipitation rates between 400mm and 800mm, and water resources of only 710m³ per capita (Abele 2006).

Estimated Annual Precipitation [mm]	601
Geographical Area [million km²][A]	9.6
Population [billion]	1.3
Water Resources [billion m³] - Surface Water * - Ground Water *	2.413 2.323 744
Water resources per capita [m³]	1.856
Water Utilisation [billion m³]	505
Per Capita Consumption [m³]	427
Water Consumption [billion m³] - Domestic [%] - Agriculture [%] - Industry [%]	555 11.7 64.7 22.2
Water Catchment [%] - Surface Water - Ground Water	 81.2 18.5

TABLE 4: OUTLOOK WATER RESOURCES CHINA (ACCORDING TO ABELE 2006); A: JAGGER AND EAST (2004)

The water quality is very critical – about 90% of the water resources of the country are polluted, according to the Ministry of Construction. About 75% of the lakes are polluted in a way that they can't be used for drinking water supply, whereas detailed and consistent statistics of the pollution degree of surface waters don't exist – the significance of official evaluations is doubtful (Abele 2006). Wastewater treatment in China is developing extremely fast since that last 10-15 years. Especially in the western provinces, many new sewage treatment plants were built. Until 2006, about 1.000 plants were built of which 19 were built with co-finance from Germany. Following the information of the statistical yearbook, about 40% of almost 100 million m³/d of wastewater are treated (NBSC 2006). Other sources speak of a treatment rate of 50% (Meierjohann 2007). In newspaper reports, an amount of 200 billion m³ of sewage per year is mentioned, which corresponds to almost 550 million m³/d (Abele 2006). In the industrial sector about 55 million m³/d out of 60 millon m³/d are treated according to the required discharge standards (NBSC 2006). Other than in India, fees for wastewater treatment exist in China. The following table gives an outlook on water and wastewater pricing in China.

Water/Wastewater Fees	**Beijing**	**Shanghai**	**Guangzhou**
Domestic Fees [RMB]			
Drinking Water	2.8	1.03	1.32
Wastewater	0.9	0.9-1.0	0.7
Industry [RMP]			
Drinking Water	4.1	1.3	1.83
Wastewater	1.5	1.2-1.4	0.7

TABLE 5: OUTLOOK WATER AND WASTEWATER PRICING IN CHINA (ACCORDING TO ABELE, 2006)

Similar like in India, the water fees are far too low – water supply and wastewater treatment are highly subsidised. With less than 1% of the living costs in average, the expences for water are significantly low compared to the recommended proportion of 5% by the world bank (Abele 2006).

Introduction Chinese Water Legislation

	Field of Responsibility				
Authority	Surface Water	Ground Water	Water Supply	Drinking Water Quality	Wastewater Treatment
Ministry of Water Resources	X	X	X		
Ministry of Construction			X	X	X
State Environmental Protection Administration	X	X			X

TABLE 6: RESPONSIBILITIES IN THE WATER AND WASTEWATER SECTOR IN CHINA

The Ministry of Water Resources is in charge for water catchment, including dams, power plants and reservoirs. Based on the 7 major protection and catchment areas, sub-commissions exist on provincial level that are separated from the provincial government. The Ministry of Construction is responsible for the water and wastewater infrastructure. Branch offices exist on provincial level that assure the compliance of infrastructure measurements, like sewer constructions (Abele 2006). The State Environmental Protection Administration (SEPA) is the major control institution in the environmental sector. The SEPA evaluates projects like industrial compounds in the planning phase regarding their impact on the water resources and the environment and can deny projects already in the planning phase. The major task of the SEPA is to assure that the legal discharge standards are meet by the industry. Beside the fact that only a small proportion of the huge number of companies are controlled, structural deficits exist (Abele 2006). Pollution related regulations exist already in the Constitution of the People’s Republic of China of 1982, as amended in 1988 and 1993. In article 9 is written that “the State ensures the rational use of natural resources and protects rare animals and plants. The appropriation or damage of natural resources by an organisation or individual by whatever means is prohibited”. Article 26 requires that “the State protects and improves the living environment and the ecological environment. It prevents and remedies pollution and other public hazards” (Shen, Cheng et al. 2002). Other than in India, all water resources are state owned, which creates a very different situation with respect to water pricing and control. For the water and wastewater field, the following laws are relevant:

- Water Resources Law 1988
- Marine Environmental Protection Law 1982
- Flood Control Law 1997
- Water Pollution Prevention and Control Law 1984 (amended 1996)
- Environmental Quality Standard for Surface Water (GB3838-88)
- Combined Wastewater Effluent Standards for Type 1 and Type 2 Pollutants (GB8978-96)
- Quality Standard for Groundwater (GB/T 14848-93)

The Water Law of the People's Republic of China (Order of the President No.74) regulates planning for water resources, utilisation, protection, water areas and waterworks. Also the economical use of water resources and the law-enforcement is regulated in the water law (Zemin 2002). As already mentioned, environmental issues are regulated by the State Environmental Protection Agency (SEPA). The Law of the People's Republic of China on Prevention and Control of Water Pollution of 1984 regulates the establishment of water quality and discharge standards, control, prevention of surface and groundwater pollution, and the sanctions against violations (MEP 1984). Although the central government puts a stronger emphasis on environmental aspects in the actual Five-Year Plan, industrial growth has still higher priority on province level. Severe sanctions or company closures are very rare, although the legal possibilities exist (Abele 2006). Although the environmental protection regulation is considered to be well developed for a newly industrialising country, deficits are seen regarding the implementation. It is estimated that China looses about 8-13% of the national income due to environmental damages (Bringewski 2006). The industrial growth rate in that way is compensated by the costs caused by environmental destruction.

Outlook Chinese Discharge Standards for Wastewater

Parameter	**Unit**	**Standard Class I**		**Standard Class II**	**Standard Class III**	**Into Public Sewers**	
		A	**B**			**with STP**	**no STP**
COD	mg/l	50	60	100	120*)	500	150
BOD_5	mg/l	10	20	30	60*)	300	100
SS	mg/l	10	20	30	50	-	-
Animal-/Plant Oil	mg/l	1	3	5	20	-	-
Petroleum etc.	mg/l	1	3	5	15	-	-
LAS	mg/l	0,5	1	2	5	-	-
Total N	mg/l	15	20	-	-	-	-
NH_4-N	mg/l	5 (8)	8 (15)	25 (30)	-	35	25
Total P (start before 31.12.2005)	mg/l	1	1.5	3	5	8	1
Total P (start after 31.12.2005)	mg/l	0.5	1	3	5	8	1
Coloration	Dilution	30	30	40	50	-	-
pH	-	6-9					
Feacal Coliforms	/l	1.000	10.000	10.000	-	-	-
Temperature	℃	-				35	35
Pb	mg/l	-				1.0	1.0
Hg	mg/l	-				0.05	0.05
*) Minimum required COD removal rate 60% if COD inlet > 350mg/l Minimum required BOD removal rate 50% if BOD inlet > 160mg/l **) Values in brackets for temperatures > 12℃ STP: Sewage Treatment Plant							

TABLE 7: MUNICIPAL WASTEWATER DISCHARGE STANDARDS IN CHINA (GB 18918-2002 AND CJ 3082-1999, MODIFIED)

In China, basically four discharge standards exist for wastewater and it depends on the immission standard (BG 3838-2002) of the respective receiving water body, which discharge standard has to be met: For water of Standard Class I A, no restrictions exist regarding the use as process water or discharge in water bodies for recreation, like lakes and rivers. Also the discharge into water bodies with poor self cleaning characteristics is permitted. Treated wastewater meeting the discharge values of Class I B can be discharged into surface water bodies (immission standard III) and into the sea (immission standard II). Class II water is permitted for discharge into surface water bodies (immission standard IV and V) and into the sea (immission standard IV). Class III water is for the discharge into water bodies of minor relevance (Cornel and Wagner 2005).

5.1.3 Germany

The following table gives an outlook on the water resources situation in Germany.

Estimated Annual Precipitation [mm]	789
Geographical Area [tkm²]	357
Population [million]	82.5
Water Resources [billion m³]	188
Water resources per capita [m³]	2.278
Water Utilisation [billion m³][A]	43.9
Per Capita Consumption [m³]	431
Water Consumption [billion m³]	36
- Domestic [%]	15
- Agriculture [%]	< 1
- Industry [%]	22
- Energy [%]	63
Water Catchment [%]	
- Surface Water	78.4
- Ground Water	21.6

TABLE 8: OUTLOOK WATER RESOURCES IN GERMANY (ACCORDING TO BMU, 2006); A: FEDERAL STATISTICAL OFFICE OF GERMANY (2004)

Climatically, German lies in the moderately humid climate zone. Other than in India for example, frequent weather changes all over the year are characteristic. However, also regional differences in the precipitation exist, with maximum values of almost 2.500mm near the Alps (Allgäu) and minimum values of less than 450mm in some parts of Eastern Germany. The water demand for irrigation is less than 1% of the total water demand. Drinking water supply is mainly assured by ground water extraction – about 74% of the drinking water supply is assured by groundwater extraction (BMU 2006). Due to special geological conditions, like karst areas in southern Germany, water is supplied over hundreds of kilometres to densely populated centres in some regions. Pipe losses are less than 10%.

Fees exist both for water supply and wastewater treatment. The fees are based on the real costs for catchment, treatment and infrastructure of the respective service provider. According to information of the Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU), the average water price in 2004 was about 1.77EUR/m³. Considering the daily water consumption in Germany, that means costs for water of about 84EUR per year. Wastewater fees are about 2.14EUR/m³ in average, based on the fresh water consumption and 2.79EUR/m³, if the calculation is based on the separate consideration of sewage and storm water (BMU 2006).

Based on a biological classification on 30.000km of total river length, about 35% are considered to be at least critically polluted (BMU 2006). Pollution control measures focuses on the concentrations of nutrients and heavy metals, whereas high BOD loads like in many Indian rivers hardly pose a problem in German rivers. Water pollution is of a much lower dimension in Germany than in India and China.

Wastewater treatment has a very long tradition in Germany. Especially plants in the larger development centres exist since several decades and were renovated and extended several times in some cases. Characteristic is the addition of a nutrients removal stage, consisting of nitrification/denitrification process and phosphorous removal in many plants in the 90ies. About 93% of the population is connected to the sewer system with regional differences. In the western part of Germany, about 96%, in the eastern part of Germany only about 76% of the population is connected to the sewer system. About two thirds of the sewer system is mixed system (storm water and wastewater in one pipe) and one third is separate sewer system. The sewer system has an estimated total length of about 500.000km. Other than in countries like India or China, the plant capacity is given in Population Equivalents (PE), not in flow. The municipal wastewater is treated in about 10.000 treatment plants with a treatment capacity of about 148 million PE. Sewage treatment plants (STPs) are operated by municipal utilities, public-law institutions and various other operation organisations. About 10% of the plants are operated by private-law organisations (BMU 2006). About 90% of the wastewater is treated in plants with a capacity of more than 10.000PE (BMU 2002).

Excess sludge is used in very different ways, depending on the respective region. In average, about 32% of the sludge is used in agriculture, 27% is incinerated, 21% is deposited or used for landscaping.

Figure 8 shows the increase of the treatment efficiency of German STPs.

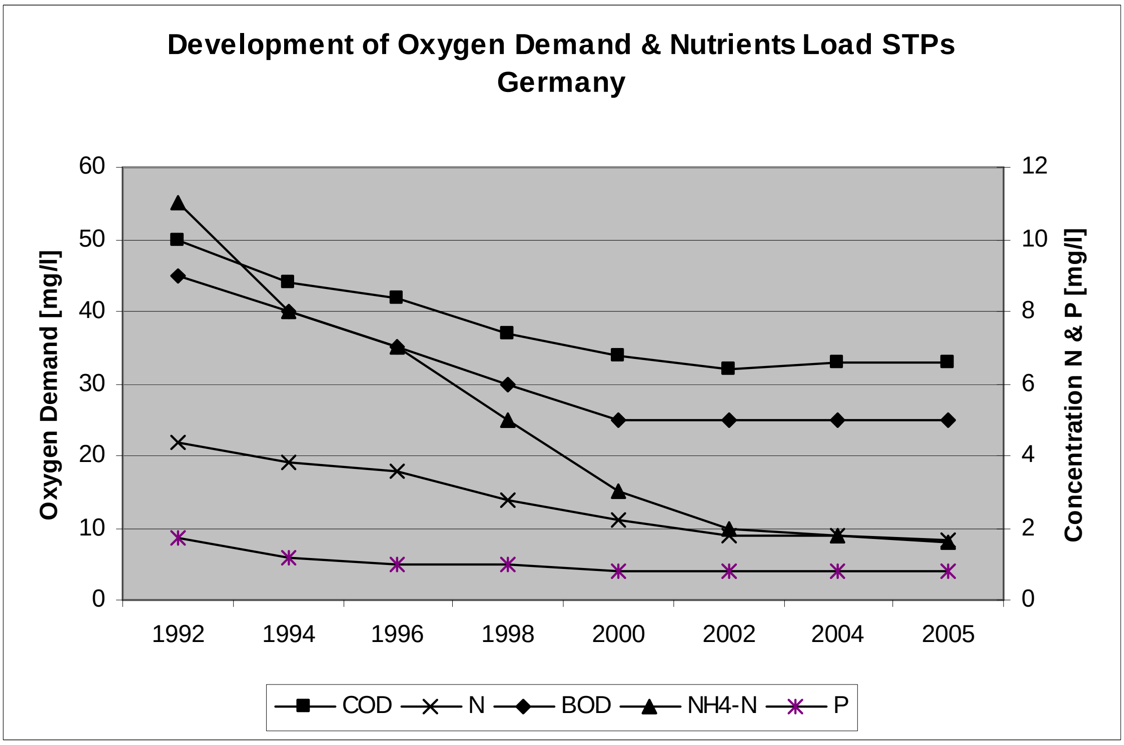


FIGURE 8: INCREASING TREATMENT EFFICIENCY OF GERMAN STPS (ACCORDING TO UBA, 2007)

Introduction German Water Legislation

The following table gives an outlook on responsibility fields of different ministries on water and wastewater issues. Characteristic is a relatively clear regulation of competences and responsibilities between the different institutions.

	Field of Responsibility				
Authority	Surface Water	Ground Water	Water Supply	Drinking Water Quality	Wastewater Treatment
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	X	X	X	X	X
Federal Ministry of Food, Agriculture and Consumer Protection	X	X	X	X	
Federal Ministry of Health			X	X	
Federal Ministry of Education and Research	X	X	X	X	X
Federal Ministry of Economics and Technology			X		X
Federal States & Municipalities			X		X

TABLE 9: RESPONSIBILITIES IN THE WATER AND WASTEWATER SECTOR IN GERMANY

From various regulations that exist regarding water and wastewater, the following major statuary mechanisms are of major relevance for the wastewater sector:

- The EC Water Framework Directive (2000)
- The EC Urban Wastewater Directive (1991)
- The EC Drinking Water Directive (1998)
- The Federal Water Act (2002)

- The Wastewater Ordinance (AbwV)
- The Wastewater Levy Act (2005)

Characteristic for the German water and environmental legislation is the embedding the European legislation. “Germany is both involved in drafting EC legislation (directives and regulations) and bound by such legislation.” (BMU 2006). The EC Water Framework Directive can be considered as the most important legal basis for the water resources on European level. It contains basic regulations regarding the managing of water bodies across national borders. The focus is on rivers basin management. Article 1 states: “Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.” (Eu-WFD 2000). The directive requires from the EU states plans and programs, how the major target of a good status of the water resources in the respective river basins will be achieved until the end of 2015, which puts pressure on the member countries to act (BMU 2006). On European level, the EC Urban Wastewater Directive regulates collection, treatment and discharge, both of municipal and industrial wastewater. The EC Drinking Water Directive concerns the drinking water quality in the European Union.

The Federal Water Act constitutes basic guidelines for the management of water resources in terms of quantity and quality in Germany. The act constitutes that all water bodies are under the control of the government, which means that basically any kind of water use requires official permission. Although exceptions exist, this is a very important principle – other than in India for example, no private ownership exists for groundwater. The Wastewater Ordinance (AbwaV) is the main basis for the erection and control of sewage treatment facilities, both for municipal and industrial wastewater treatment in Germany. The heart of the ordinance is the constitution of the required standards for the discharge of wastewater. The Wastewater Levy Act regulates the fees for the discharge of treated wastewater in receiving water bodies.

Outlook German Discharge Standards for Wastewater

The following table gives an outlook on the German major discharge standards for municipal wastewater. Other than in India or China, the required discharge standards depend on the plant size – the higher the plant capacity in terms of BOD-load, the stricter the respective maximum values.

Parameter Unit	COD mg/l	BOD_5 mg/l	NH_4-N mg/l	Total N mg/l	Total P mg/l
Size Class 1 **< 60kgBOD/d**	150	40	-	-	-
Size Class 2 **60-300kgBOD/d**	110	25	-	-	-
Size Class 3 **300-600kgBOD/d**	90	20	10	-	-
Size Class 4 **600-6.000kgBOD/d**	90	20	10	18	2
Size Class 5 **> 6.000kgBOD/d**	75	15	10	13	1

TABLE 10: GERMAN DISCHARGE STANDARDS FOR MUNICIPAL WASTEWATER (ABWV 2002, MODIFIED)

5.2 Education Tradition & Vocational Training

As education aspects play an important role in the considerations on treatment plant staff, short introductions on the education systems in Indian, China and Germany will be given in the following chapters.

5.2.1 India

Although officially abolished in 1947, the cast system is still very present in Indian culture and has also still a strong influence on the work structure and the education system. Originally, casts are closed groups of religious nature into which somebody is born, but they are also profession groups that are characterised by very strong hierarchies (Irrgang 2006). Practical work has a very low image and is denied by the upper population level, whereas academic and theoretical qualification has a high value. The reason for the negative image of physical work is seen in the Hindu mind/intellect ideal (purusa) and the shame of matter (prakrti) (Rolly 1986). Characteristic is a strong tendency to accept authorities, although the modern personal ideal is based on purpose rationality, flexibility and innovation (Rolly 1986). However, teachers are accepted as authorities that should not be disturbed with questions or even criticised. Course situations are dominated by frontal presentations of a teacher or an instructor. In India, nearly 1 million schools exist for close to 200 million students (Plomp, Anderson et al. 2003).

Looking at the Indian education system from the technical job market side, five major categories of absolvents can be identified: workers without specific skills, craftsmen, technicians, engineers and scientists. Almost all children visit elementary school, although many break up in order to generate income for the family. About 49% of the respective age groups visit secondary level schools. After this, about 10% of the respective age groups are in higher academic education (Jagger and East 2004). The following figure gives an outlook on the Indian education system:

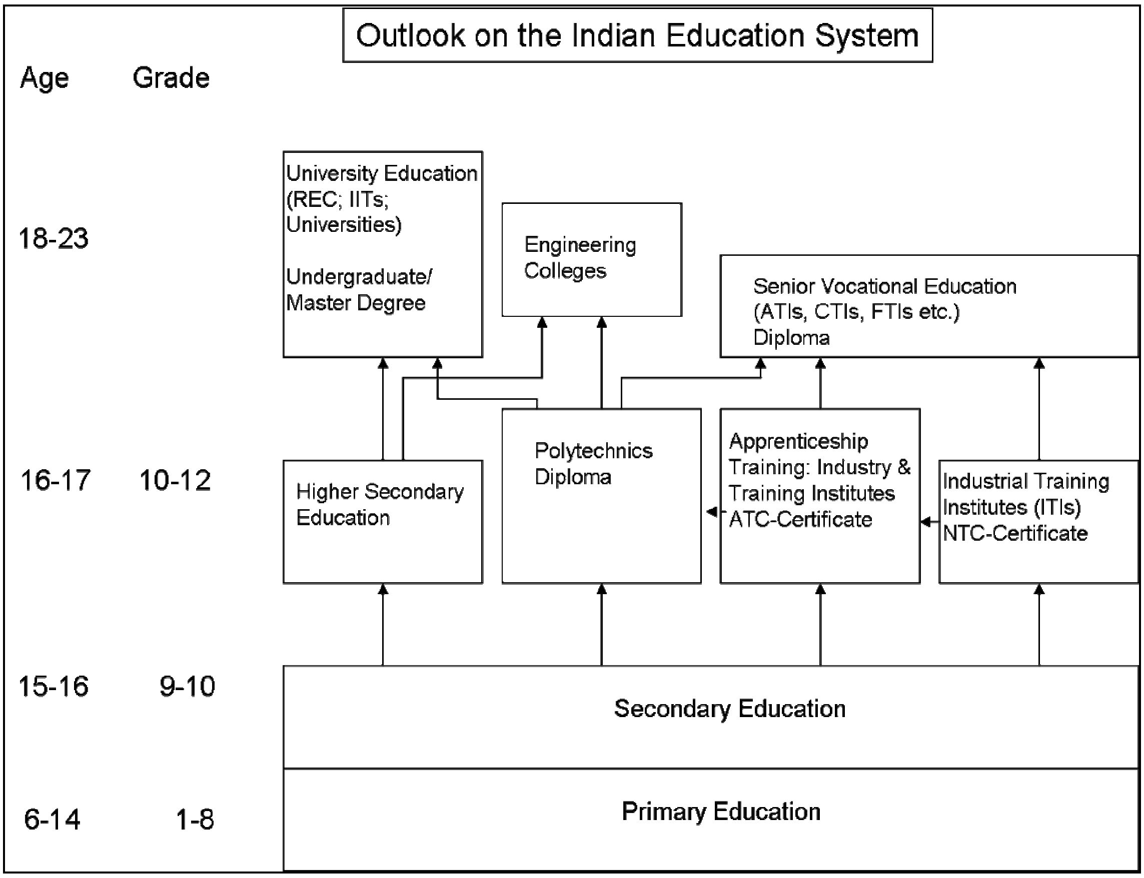


FIGURE 9: OUTLOOK EDUCATION AND TRAINING SYSTEM IN INDIA (DAR, WU ET. AL. 2006, MODIFIED)

Regarding the sector of vocational education, the picture is relatively poor compared to other countries as visible in figure 10. Less than 10% of the labour force is vocationally trained compared to more than 70% in countries like Korea, Japan, Germany or Canada.

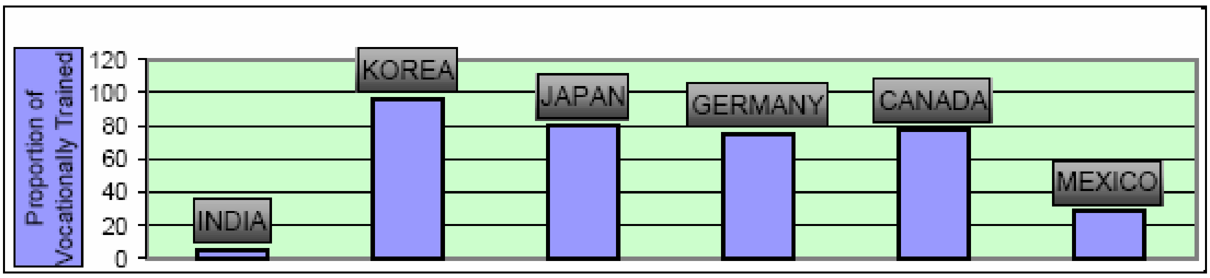


FIGURE 10: PROPORTION OF VOCATIONALLY TRAINED LABOUR FORCE – OUTLOOK (GASSKOV, AGGARWAL ET AL. 2003)

About 44% of the labour force is illiterate, 23% finish elementary school and 33% finish secondary school successfully.

The so called "Craftsmen Training Scheme" started in 1950. It was introduced by the government with the major focus to "ensure a steady flow of skilled workers…" (DGE&T 2005). Vocational education in India is mainly carried out on Industrial Training Institutes (ITI) and Polytechnics, whereas ITIs are the major column for the development of practical skilled staff. Today, they are under control of the respective state governments or union territories. In the time period 2002/2003, about 373.000 seats were sanctioned on public ITIs and about 305.000 seat were sanctioned at private ITIs (Gasskov, Aggarwal et al. 2003).

In ITIs, practical and theoretical components are taught under scholar conditions for a period of 1-3 years. After that, a separate apprentice period of 3-4 years in the job follows. Vocational education in Polytechnics is more focussed on theoretical education for a period of about 2.5 years, followed by a 6 months project work in a company.

Critical voices regarding the current vocational education system exist in the private sector, as the results of a survey among 55 enterprises in India show.

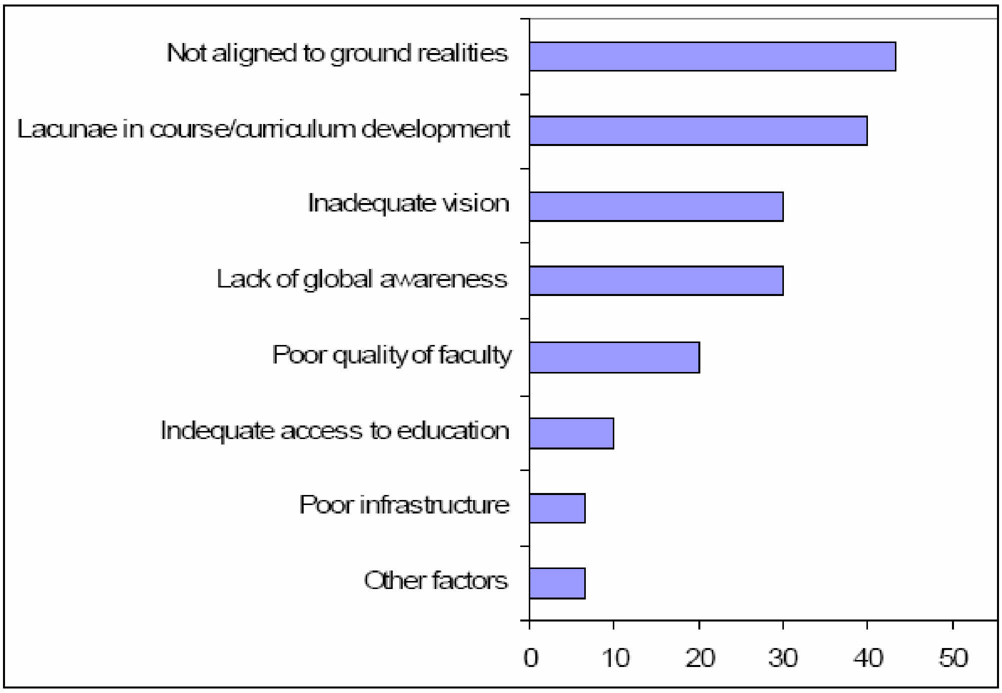


FIGURE 11: EMPLOYERS CONCERNS WITH VOCATIONAL EDUCATION AND TRAINING SYSTEM [%] (DAR, WU ET AL. 2006)

In the same study, 87% of the enterprises are convinced that training institutions should be closer to industry practices and stress the need of a collaborative education between scholar education and industry. Almost 60% of the enterprises state that institutions “are not geared up to meet the challenges of the global economy” (Dar, Wu et al. 2006).

The following table regarding the funding priorities shows that institutions of vocational education, like ITIs and vocational schools have lowest priority, which shows the low recognition of practical education. The table shows also, the graduates from IITs, which have the highest funding priority, mainly go abroad.

Institution Group	**Entry Level**	**Duration**	**Priority for Funding**	**Utility in Local Industry**
IITs	10th plus 2	4 years	1	4 - mainly abroad
RECs	10th plus 2	4 years	2	3 - mainly R&D
Engg. Colleges	10th plus 2	4 years	2	3 - mainly local industry
Polytechnics	10th Class	3 years	3	2 - mainly local industry
ITIs	10th Class	2 years	4	2 - mainly local industry
Voc. Schools	8th Class	1 year	5	1 - mainly local industry

TABLE 11: EDUCATION INSTITUTIONS, FUNDING PRIORITY AND LOCAL AVAILABILITY (NATARAJAN AND THANGAMANI 1996, MODIFIED)

For wastewater treatment, no courses exist in the Indian vocational education system. In certain polytechnics special courses exist on “Public Health and Environmental Engineering” with a duration of 3years. In Hyderabad (Andhra Pradesh) a post diploma course in environmental engineering exists. These courses focus very strong on theoretical education, whereas work practical contents for treatment plant operation are hardly included. An expert interview with teaching staff in this study showed that the number of applicants for the post-diploma course has dramatically decreased as the student would expect better job opportunities in other disciplines in industry.

5.2.2 China

The following figure gives an outlook on the Chinese education system.

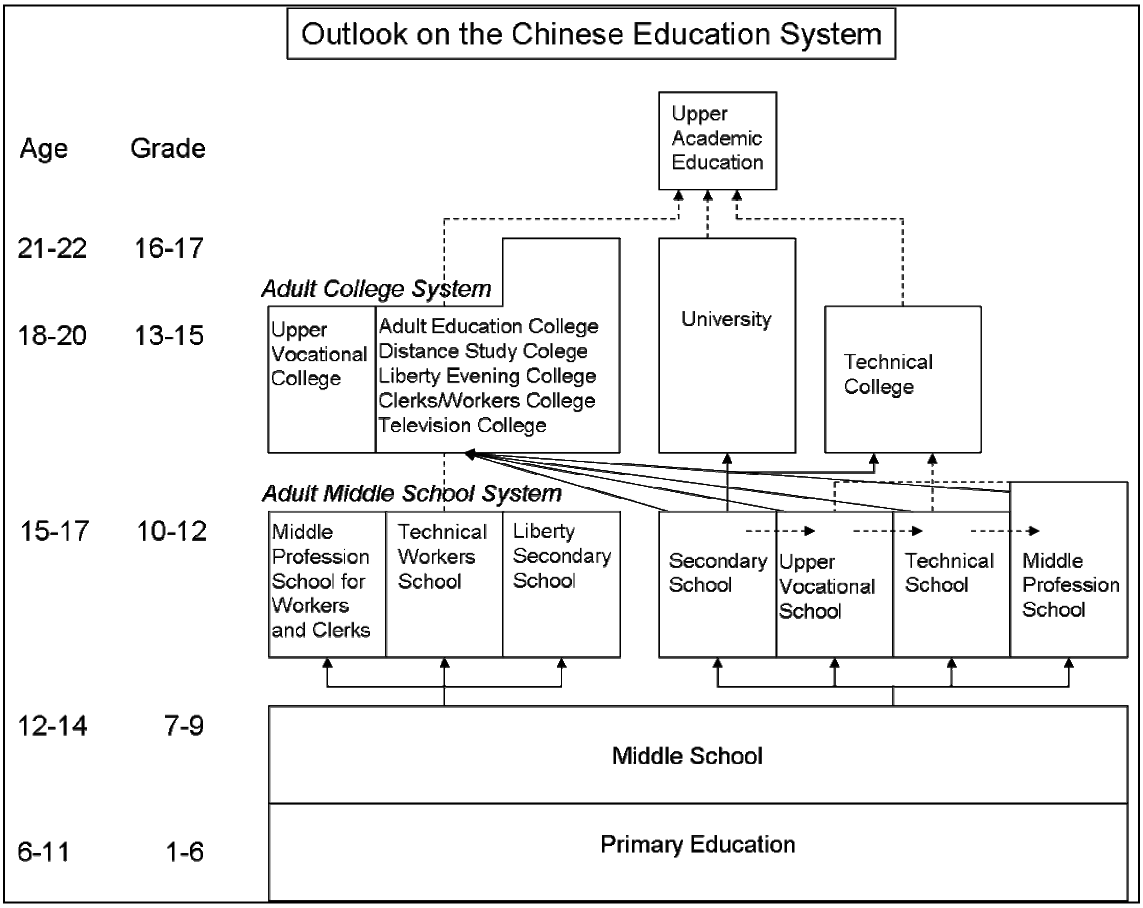


FIGURE 12: OUTLOOK EDUCATION SYSTEM IN CHINA (GTZ 1994, MODIFIED)

Traditionally, the Chinese society is characterised by strong hierarchies following the Confucian tradition. Like in India, also the Chinese education system is very hierarchical. Obedience and acceptance of authorities are promoted. Scholars are trained to learn knowledge contents without reflection (Hirn 2006). Collective and integrative values are very important, whereas individuality has a low value (Reuter and Zhang 1998). End of the 90ies, the government recognised the deficits of the education system and started reforms. The education system should develop more creativity (Hirn 2006). Similarly like in India, theoretical knowledge has a high value, whereas practical work is denied. In the resolution of the communist party in 1985 that was repeated several times in the following years, “the disrespect of the professional and technical education” among the population is deplored and was the driving force for reforms especially on the education of skilled workers (GTZ 1994). The existing imbalance between demand of skilled practical manpower and the huge number of bachelor students who graduate in recent years from universities all over

China shows that still today practical skilled work is obviously not appreciated, at least not attractive.

Regarding organisation structure and sponsorship, vocational schools can be classified in two categories: One type are vocational schools that are directly organised by certain enterprises. These schools profit from financial support by the respective enterprise. Another type are schools that are organised by the respective professional institution – independent from enterprises. Characteristic for both school categories is that the complete training – theoretical and practical – is carried out in the school. The complete training period is spent in the training school. Only in the final year, excursions or short practical trainings outside in real work situations are carried out. About 55% of the education is theoretical education (Trowe 1995). Training courses in the field of wastewater treatment don't exist in the vocational education system.

5.2.3 Germany

The following figure gives an outlook on the German education system.

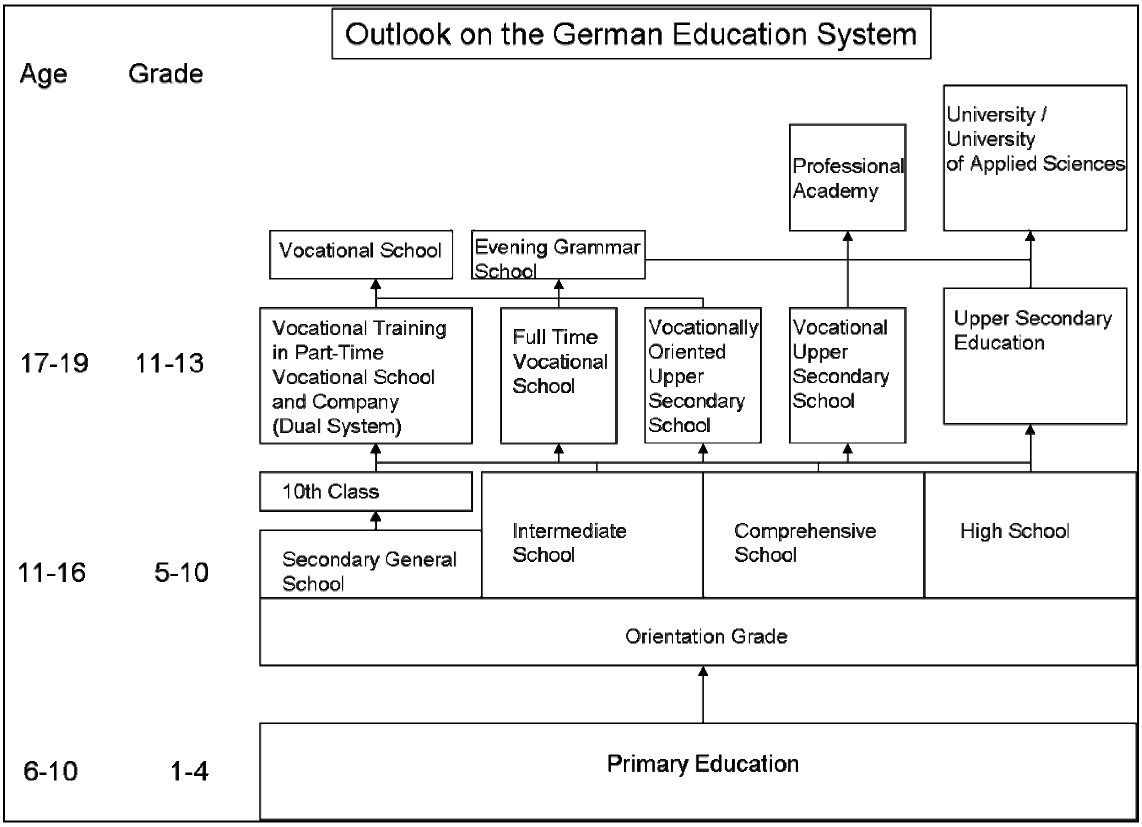


FIGURE 13: OUTLOOK EDUCATION SYSTEM IN GERMANY (ACCORDING TO KMK, 2008)

Characteristic for the German education system is the separation of the secondary education level in three major school types - “Hauptschule” (Secondary General School), “Realschule” (Intermediate School) and “Gymnasium” (High School) - that doesn’t exist in that form in other countries (see figure 13). The “Gesamtschule” (Comprehensive School) includes the three other school types. Other than in India or China, Germany society is characterised by very flat hierarchies and high transparency between the different population levels, which is also characteristic for the education system. Creativity and problem solving competence are high values.

Vocational education in German is based on the dual education parallel in school and in practice. Basically, skilled practical work – especially on master level – has a high recognition in German culture. Most teaching professions take 2-3 years, depending on the pre-qualification of the apprentices. During that time the apprentices are 1-2 days per week in school and the remaining time in the practical work situation in order to learn practical skills. The targets of vocational education are defined in the syllabus and go far beyond the transmission of technical competence. Vocational schools should lead to profession ability, whereas competence includes the respective technical competence, as well as human and social competence. Beside preparation for professional flexibility and motivation for further qualification, the ability to “act responsible in public” is a major task of vocational schools. A similar important target of vocational schools is the development of decision-making and responsibility competence, which is understood “as the readiness and ability of the individual, to behave thoughtful, individual and socially responsible in social, professional and private situations” (KMK 2002).

The Conference of Ministers of Education (*Kultusministerkonferenz*) precises the targets of vocational education as follows:

“Decision-making develops from the three dimensions of professional competence, personal competence and social competence. *Professional competence* means the readiness and the ability to solve assignments and problems target oriented, proper, method-directed and independent based on professional knowledge and abilities. *Personal competence* means the readiness and ability to clarify, consider and evaluate requirements and limitations in family, profession and public, to develop own talents, as well as to develop life plans. It includes particularly personal habits, like independence, ability to give and receive criticism, self-criticism, self-confidence, reliability, sense of responsibility and conscientiousness. It includes also the development of thoughtful values and self-determined binding to values. *Social competence* means the readiness and ability to live and create social relations, to realise and to understand devotion and tensions, as well as to deal and communicate

with others in a rational and responsible way. It includes particularly the development of social responsibility and solidarity. Methods and learning competence develop from a balanced development of these three dimensions" (KMK 2002).

Other than in India and China, a teaching profession for the work on STPs exists in Germany since 1994. Before, the common practice was to train technicians on wastewater treatment in short-term courses. In Austria, the first teaching profession for wastewater treatment was developed in 1998. Like in other learning professions, the apprentice learns theoretical skills in a vocational school, whereas work practical skills and competences are learned in the work process on a wastewater treatment plant. Theoretical and practical skills are transmitted parallel for a period of 3years, whereas about 80% of the training time is foreseen for practical education. About 1-2 days per week, the apprentices are in school - the rest of the time they learn practical skills on the plant. Alternatively, block courses are offered, depending on the regional availability of training institutions. In 2003, due to higher qualification demands, four specialised vocational training courses were formed from initially one. The following figure gives an outlook on the subjects that are taught in the training course "Specialist for Wastewater Technology".

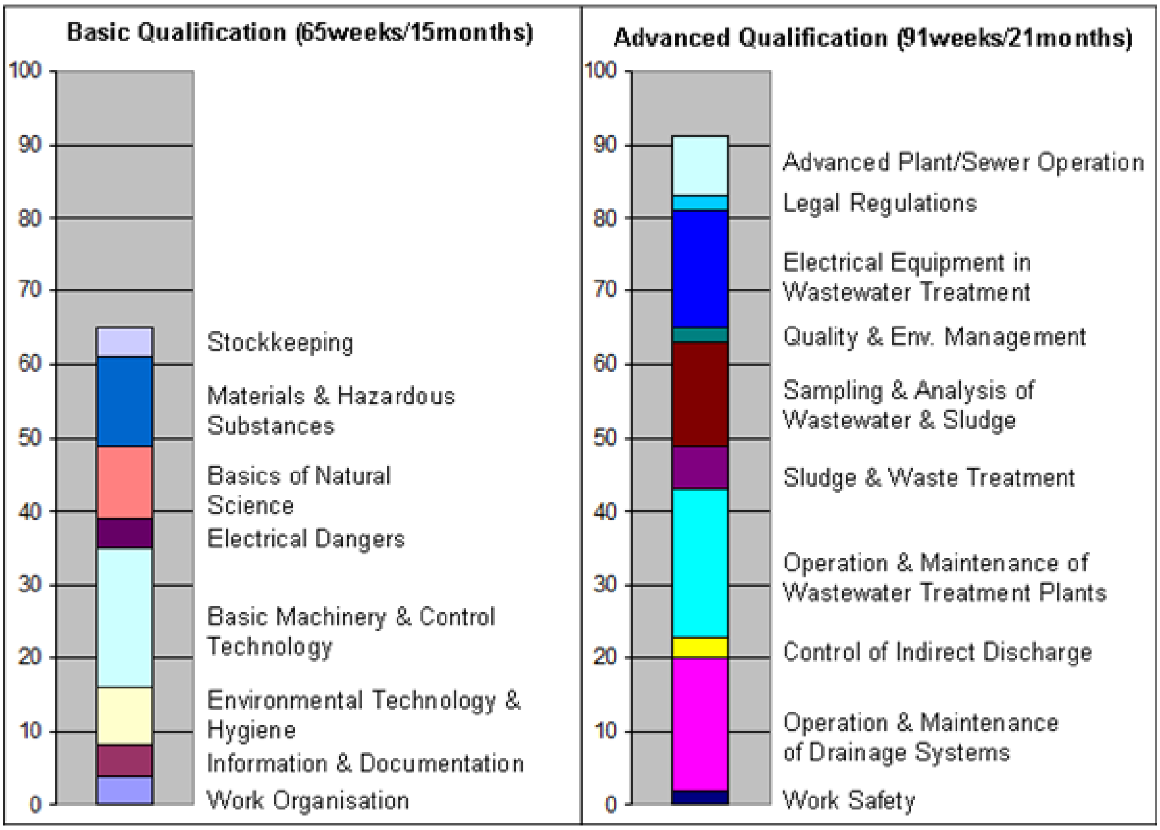


FIGURE 14: OUTLOOK EDUCATION SUBJECTS "SPECIALIST FOR WASTEWATER TECHNOLOGY" (ACCORDING TO KMK, 2002)

Other courses that were developed in the field of water, wastewater and waste are

- Specialist for Pipe, Sewer and Industry Service
- Specialist for Recycling and Waste Management
- Specialist for Water Supply Technology

A very important role for education in the wastewater sector in Germany play so called “Wastewater Treatment Plant Neighbourhoods”. The concept is presented in the following passage.

Self-help Assistance – The German STP-Neighbourhood Concept

STP-neighbourhoods are unions of about 15-20 STPs in a region with the major target of knowledge sharing. The first STP-neighbourhoods were developed in 1968. Today, about 500 neighbourhoods exist in Germany and about 60 exist in Austria and Switzerland. In Poland, one neighbourhood is in the trial phase (DWA 2007). Between two and four times per year, the neighbourhood meetings take place, guided by an experienced treatment plant specialist, who is an engineer, scientist or an experienced master in the field. The major focus of the meetings is on practical operation aspects. As most of the plant staff should be able to take part in the meetings, the organisation is that way, that important works on the plant can be carried out prior and after the meetings. The neighbourhoods are organised by the German Association for Water, Wastewater and Waste (DWA) – the finance is assured by a yearly contribution towards expenses. Since the development of the STP-neighbourhoods, the following positive results could be stated, according to information of the German Association for Water, Wastewater and Waste (DWA):

- Sustainable increase of the plant efficiencies
- Reduction of operation costs
- Knowledge share and knowledge gain for optimisations
- Actual information on the implementation of legal issues
- Uniform work documentation material and work instructions
- Efficiency comparison

The basic principle of the STP-neighbourhoods is the informal reciprocal support in operation and maintenance in the normal work – like good neighbours.

5.3 Introduction to Intercultural Communication

As in this study the relevance of cultural and communication aspects for the field of wastewater treatment on the example of India and China will be determined, a short introduction on intercultural communication will be given in the following passages.

The discussion on intercultural competence has a long tradition and started already in the social-psychological science in the US in the 1960ies. Until the beginning of the 1980ies, the focus of the studies was on the identification of habits of intellectual persons that are successful in an intercultural contact. However, this early discussion was relatively undifferentiated – characteristics of intercultural competence could neither be defined, nor were they verified in reality. Today, a change has occurred from a global “intercultural competence” to concrete “intercultural communication competence” (Bolten 1999). In the centre of the discussion is the identification of intercultural communication skills that can be classified in three major groups according to Bolten (1999):

1. Capability to handle psychological stress (depressions, frustration, fear, loneliness in the interaction, as well as ambiguity tolerance)

2. Capability to create interpersonal relations (empathy, interpersonal skills, capability to create personal relations, impartiality)

3. Practical communication skills (capability for open communication)

Very essential for all actors at the cultural interface of wastewater treatment in developing countries is the question: What are the main differences between the related cultures? Important answers to this question were provided by the works of Hofstede. Starting in the late 60ies he conducted studies on the impact of cultural differences on management level for more than three decades. In his initial study, opinion surveys were carried out among 116.000IBM employees in 40 countries (Schneider and Barsoux 2003). His results have to be regarded as milestones in this field of research. As a central result, five basic value dimensions were identified by Hofstede, by which countries (national cultures) can be characterised.

- Individualism/Collectivism (degree to which persons are self-oriented or family-oriented)

- Masculinity/Feminity (tendency towards masculine values like materialism, competitiveness or assertiveness, or feminine values like the importance of relationships, caring for others or quality of life)

- Uncertainty Avoidance (degree of discomfort with uncertainty or preference of stability and predictability)

- Power Distance (degree to which unequal power distribution in organisations and institutions is accepted by the society)

- Long-Term Orientation vs. Short -Term Orientation

The relevance of these different values depends on the respective country. It has been revealed that for Asian countries, “Long-Term Orientation” is very strong, whereas “Uncertainty Avoidance” is less relevant (Schneider and Barsoux 2003). The following figure gives an outlook on the expression of the five referred values for India, China and Germany.

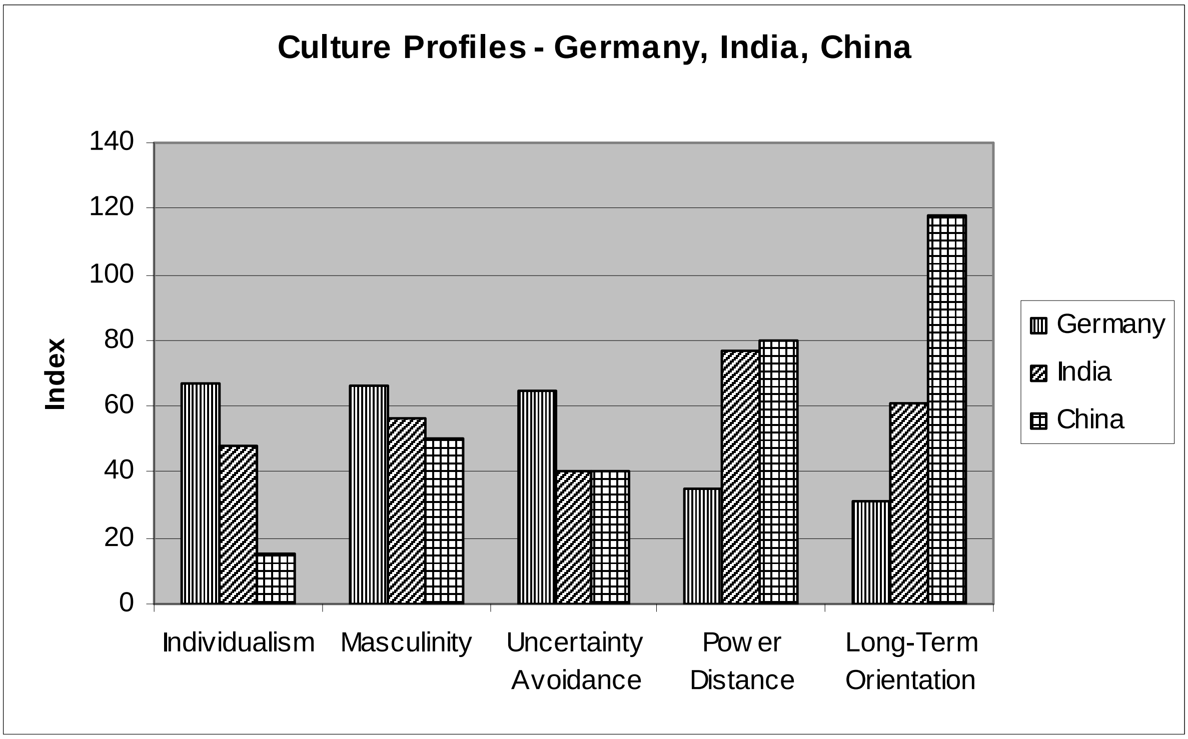


FIGURE 15: CULTURE PROFILES OF GERMANY, INDIA AND CHINA (ACCORDING TO HOFSTEDE, 1991 AND 2001)

As visible in figure 15, India and China are very similar regarding masculinity, uncertainty avoidance and power distance. Big differences exist with respect to individualism and long term orientation. Germany is very different from these two Asian countries in almost all values, except for masculinity.

Other basic cultural characteristics are the temporal orientation and the relevance of the context of communication in different cultures. Characteristic of *monochronic time orientation* are a strong emphasis on schedules and promptness. Events are scheduled sequentially, whereas priorities are set. Characteristic of *polychronic time orientation* is the strong consideration of involved people, rather than schedules. In practice, this means a low planning degree of meetings and events. Few things are fixed – changes of plans are always possible (Seng and Lim 2004). India and China are characterised by polychronic time orientation, whereas Germany is an example for a culture with monochronic time orientation.

Regarding the communication pattern, cultures can be divided in *low-context* and *high-context* cultures. In low-context cultures, information is transmitted explicitly – important is what is said but not how it is said. Compared to this, in high-context cultures communication is characterised by the incorporation of non-verbal information transmission and indirect communication styles (Seng and Lim 2004). Asian cultures like India and China are high-context cultures, whereas Germany is an example for a low-context culture.

Various studies and guidebooks exist on the importance of intercultural aspects in business relations especially. Understanding the business partner's cultural background is considered as a highly important factor in all project stages. For business relations, contacts on the institutional level, as well as for any other contact on the academic/expert level across cultures, structure has to be considered as a very important aspect, comprising power distance and uncertainty avoidance. Based on the results of Hofstede's studies, four major types of business culture can be classified that are shown in figure 16. Unlike the Anglo/Nordic culture or the Latin culture, the Asian culture is on the opposite edge compared to Germany. Strong differences exist both in terms of uncertainty avoidance and power distance. Loyalty and strict hierarchies are characteristics of many Asian countries. The social role and personal relations are of highest importance, especially in China. Low uncertainty avoidance can be seen in the high flexibility in time planning in many regions in India, whereas regional exceptions exist. Looking at the "well oiled machine" Germany, very strong uncertainty avoidance exists. Strong organisation and control are fundamental characteristics in German culture and can be found in all business processes. Another characteristic is a low power distance, which is a very significant difference, compared to Asian countries, but also Latin-American countries.

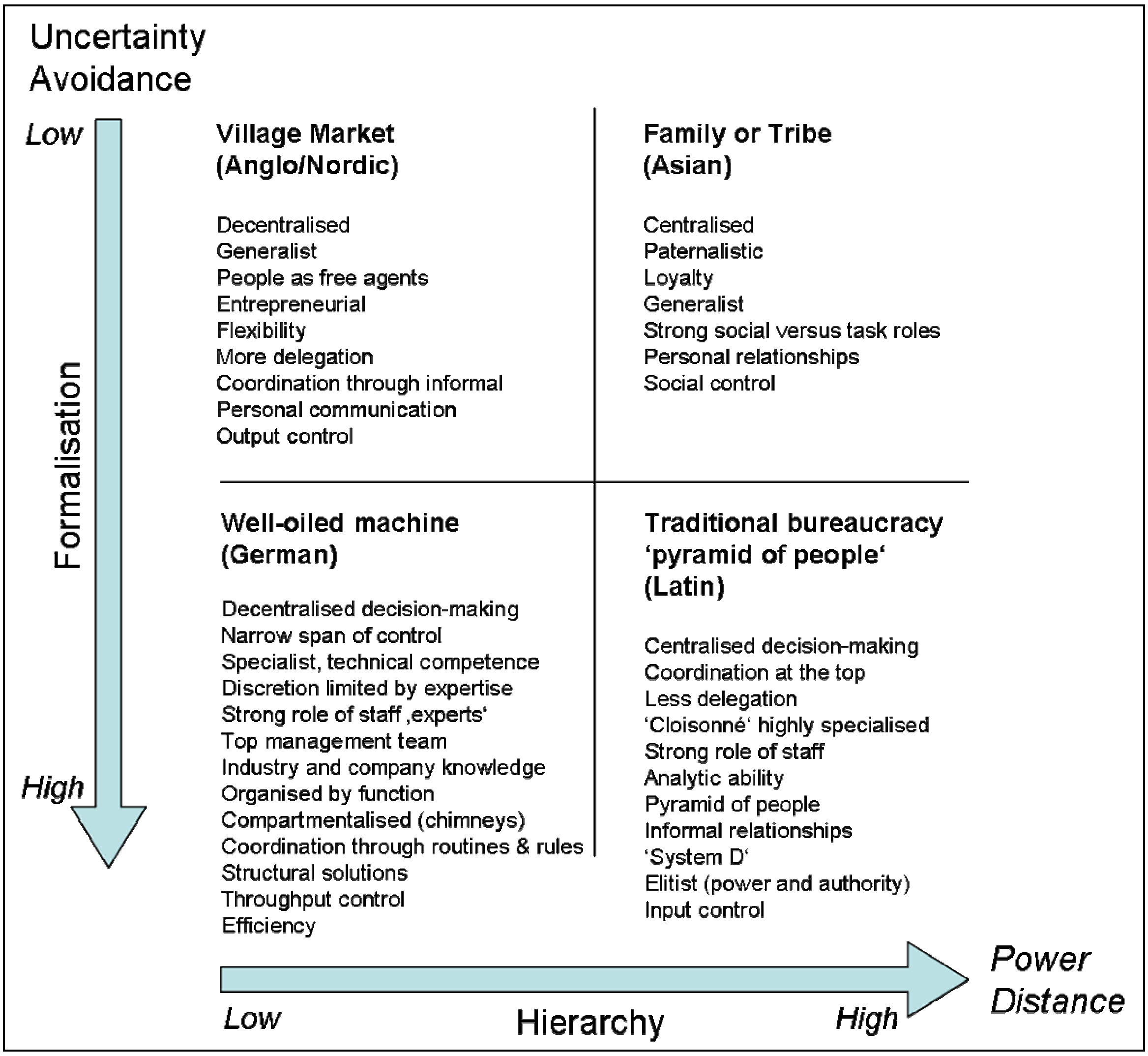


FIGURE 16: CULTURAL PROFILES & ORGANISATION (MODIFIED ACCORDING TO SCHNEIDER & BARSOUX, 2003)

As meetings are basic situations in all intercultural contacts, the characteristics of meetings are considered more in detail. The following figure shows the typical sequence of negotiations in northern Europe.

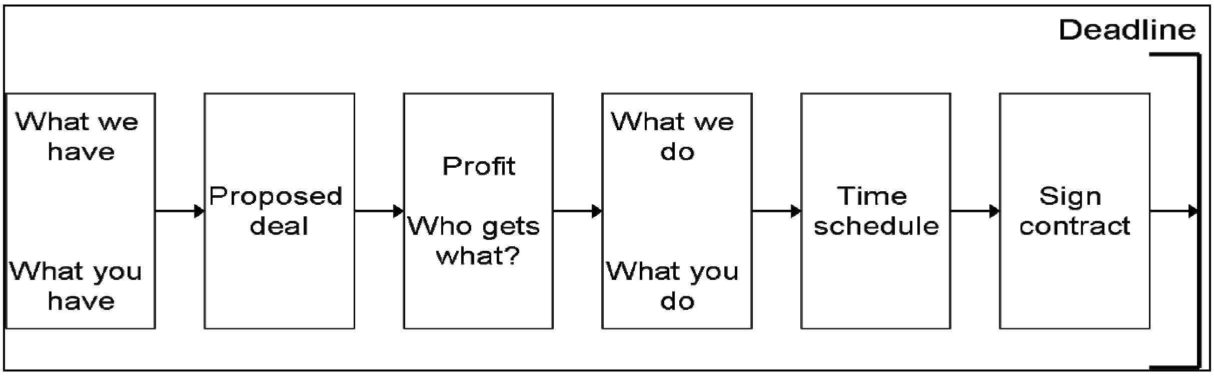


FIGURE 17: WESTERN ONE-STAGE SCHEME IN MEETINGS (MODIFIED ACCORDING TO LEWIS, 1996)

Meetings in Asian countries can be divided basically into two stages. In the first stage, the main focus is on the identification of who and what is best, that means the determination of the meeting situation, comprising physical appearance, body language, indirect discussion, courtesy and face saving (especially in China). At the end of this phase, either the planning stage or another meeting scheduled for the planning phase follows. In this phase, the aim is to find an overall solution regarding the profit of the involved parties. Characteristic is the focus on a long-term perspective – both regarding viability and relations.

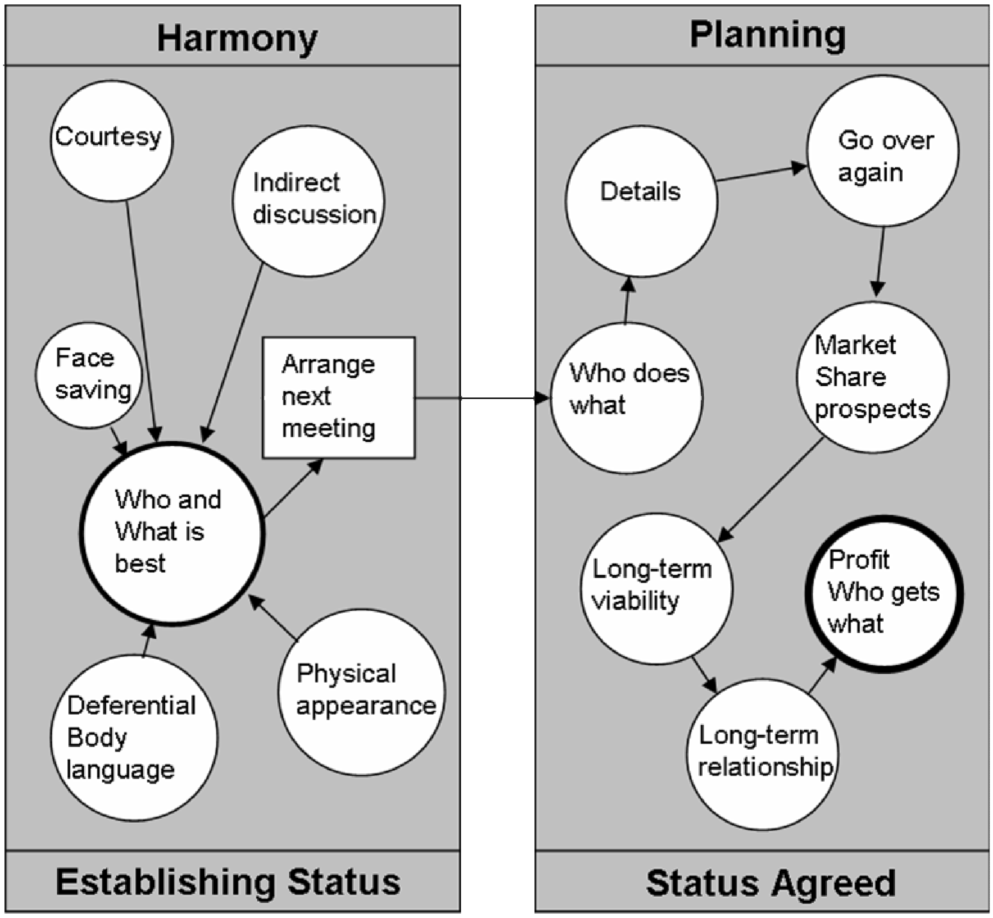


FIGURE 18: ASIAN MEETING SCHEME (MODIFIED ACCORDING TO LEWIS, 1996)

Another important aspect that has to be considered for technology transfer is the value of technology in different cultures. In his study on technology transfer into the Arabic, Russian and Latin-American region, Hermeking summarises that in Germany *technology is coequal with humans*, whereas in the other cultures analysed, *humans have priority over technology* (Hermeking 2001). This basic value difference regarding technology has to be considered in the comparative study between India, China and Germany.

6 Materials & Methods

6.1 Choice of Data Collection Methods

6.1.1 General Considerations & Sociological Methods

A very essential point of the study is the generation of a suitable database that gives information on the present state. The target of the research project is the description of a problem field that was practically never handled before in a scientific approach. For that reason, an explorative approach was chosen. For the following reasons, India and China were chosen:

1) Severe and increasing problems regarding water quantity and water quality
2) Rapid urbanisation and industrialisation
3) High growth rate in the wastewater sector
4) Important market for the German export industry in the wastewater sector
5) Important partner of the German development cooperation
6) Good existing relations on the scientific level

Due to the explorative nature of the project and the limited financial means for data collection, a combination of qualitative and quantitative methods was chosen. The following table gives an outlook on the major characteristics of qualitative case study and quantitative research design.

Qualitative Case Study	**Quantitative Research Design**
Few Samples	Many Samples
Much Information	Much Information
Specific Information	Broad Information
Several Methods	One Method
Holistic View	Particular View

TABLE 12: COMPARISON QUALITATIVE CASES STUDY AND QUANTITATIVE RESEARCH DESIGN (LAMNEK 1993)

Via the combination of quantitative and qualitative methods, also named as triangulation, the advantages of both methods can be used. In the social sciences, triangulation means approaches that use different methods to analyse one and the same subject of interest (Bos and Koller 2002).

The following table gives an outlook on information fields and data collection methods:

Type of Information	Technology State	Manpower Situation	Facts & Positions on Expert Level	Training Possibilities & Motivation
Information Source	Plant Visits	Treatment Plant Workers	Experts & Decision Makers	Treatment Plant Workers
Main Critical Aspects	▪ Permission ▪ Location ▪ Sampling ▪ Staff Mistrust	▪ Status Problem ▪ Language ▪ Superior Permission	▪ Partly Reservation ▪ Interruption ▪ Planning ▪ Reachability	▪ Planning ▪ Language ▪ Superiors ▪ Material Choice
Type of Data Generation Method	Quantitative/ Qualitative Method	Mainly Quantitative Method	Qualitative Method	Qualitative Method
Chosen Method	Guided Expert Interview & Photographs	Questionnaire Based Questioning	Guided Expert Interview	Pilot Trainings

TABLE 13: INFORMATION FIELDS AND DATA COLLECTION METHODS

For the conceptualisation of the data collection and the methods choice, target group specific criteria, like education level, knowledge field and time capacity had to be considered. In addition, cultural aspects had to be considered, as previous experience with treatment plant staff and experts in India indicated. Organisational questions, like required permissions, had to be clarified in advance as far as possible. Detailed information on the different data collection methods is given in the following chapters.

6.1.2 Questionnaire Based Staff Interview

One of the main targets of the study is the comparison of information on work knowledge and motivation of treatment plant workers in India, China and Germany. In order to gain suitable and actual data, a qualitative approach was chosen. Following the definition of Laatz, “Qualitative studies are such, where data is normally gained by measuring or counting and is analysed with mathematical-statistical methods” (Laatz 1993). The measurement frame is normally defined and standardised to a relatively high grade, so that the data collection itself, as well as the data analysis can be carried out with much lower effort than qualitative research methods. Due to the plausible differing time availability for the interviews of the workers, a modular questionnaire design was chosen. Due to relatively long questioning times and concentration losses, only two stages of the original three stage design concept were applied. Part A contains a series of questions that represent the absolute minimum for the questioning. Part B is a wishful extension, if both enough time is available and the test person is still concentrated and motivated. The following figure shows the basic concept of the applied two-stage questionnaire.

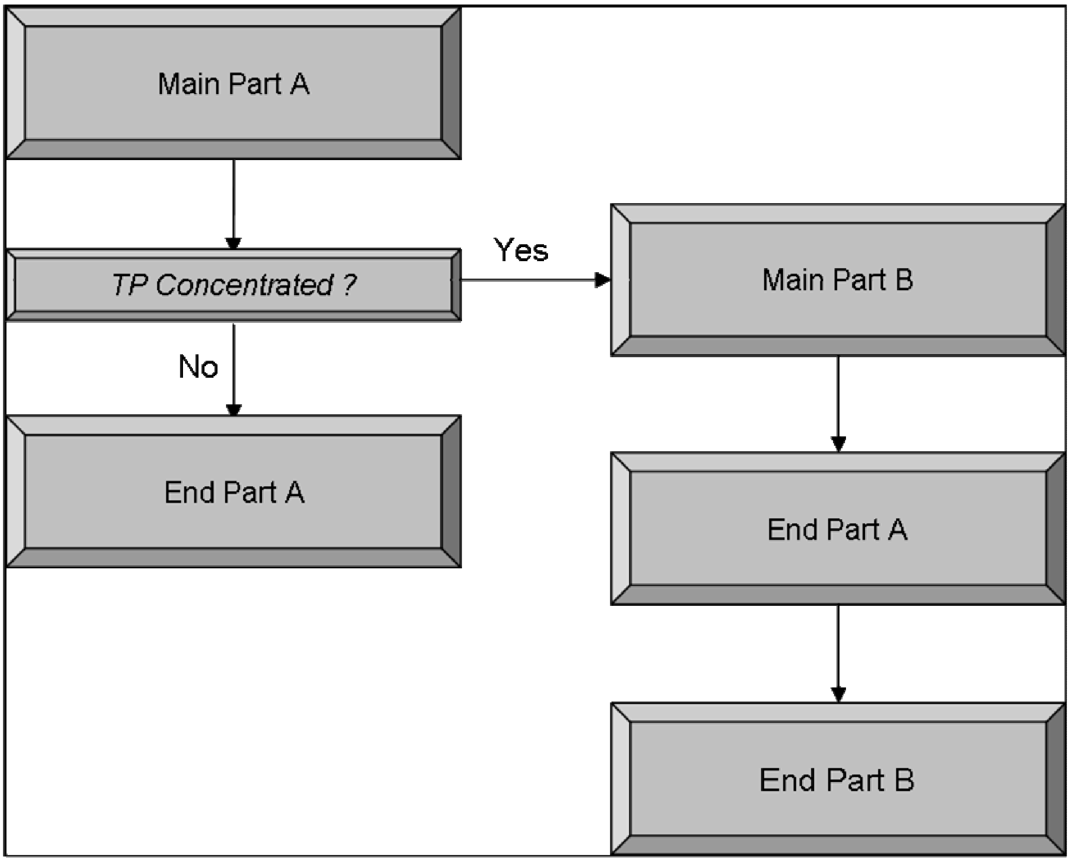


FIGURE 19: MODULAR QUESTIONNAIRE DESIGN PRINCIPLE PLANT STAFF

The following table shows the question fields that were covered by the questionnaire.

Education	▪ Scholar Education ▪ Professional Education ▪ General Knowledge ▪ Work Specific Knowledge
Professional Situation	▪ Professional Position ▪ Income Situation ▪ Work Satisfaction ▪ Work Motivation
Personal Situation	▪ Drinking Water Supply ▪ Sanitation ▪ Social Status ▪ Demographic Data
Position	▪ Environmental Pollution ▪ Water & Wastewater ▪ Education & Training
Facts	▪ Plant Operation

TABLE 14: QUESTION FIELDS OF QUESTIONNAIRE DESIGN

The basic disadvantage of standardisation in a quantitative approach is that interesting information fields that were not foreseen prior to the data collection are not measured. In order to equalise this potential disadvantage to a certain extent, the questionnaire consisted of both open-end and closed questions, although the majority are of closed type. However, by the inclusion of several open questions, unpredictable statements of the test persons needed to be registered.

Figure 20 gives an outlook on the question type distribution of the questionnaire. In total, the questionnaire consists of 40 questions, comprising also socio-demographic questions. Thirty questions are closed questions, ten are open questions of which six are used, to get information on the persons position. In Appendix C the complete questionnaire can be found.

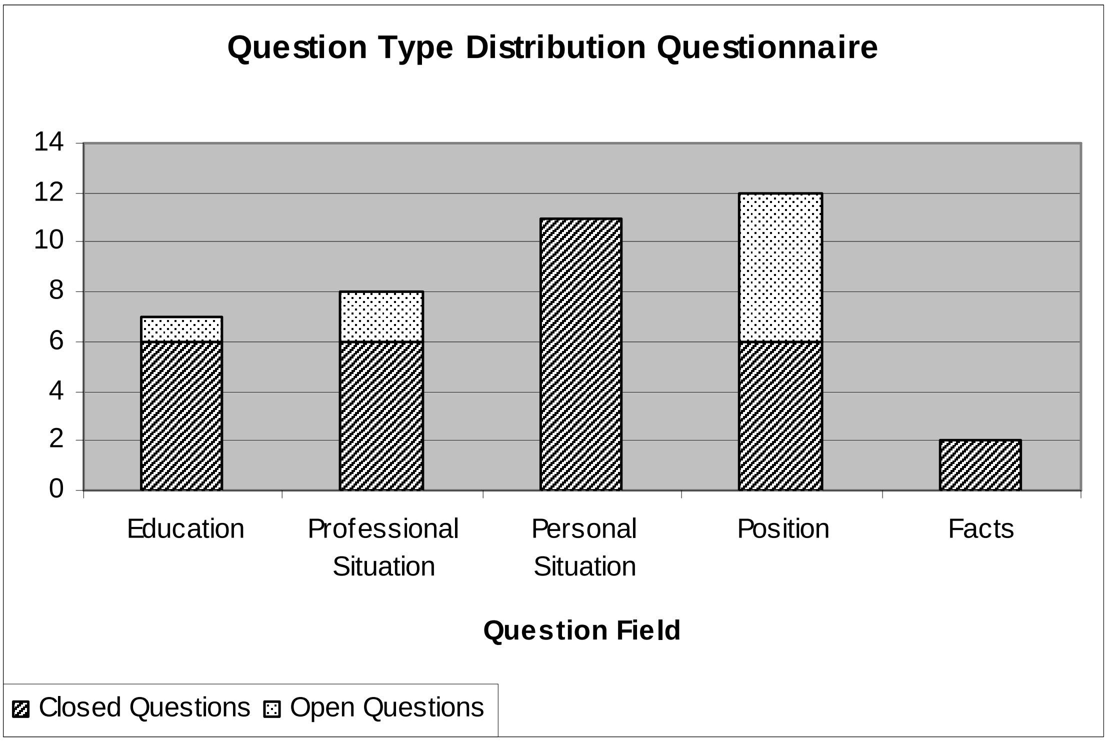


FIGURE 20: QUESTION TYPE DISTRIBUTION OF WORKERS QUESTIONNAIRE

For the questionnaire development, cultural characteristics had to be considered in addition to general principles of questionnaire design, especially concerning the distribution of direct and indirect questions. Indirect questions were used especially to get information on positions regarding the work situation.

In order to allow a direct comparison, the same questionnaire was used in India, China and Germany. Adaptations of answer categories were only carried out in very culture specific questions, like questions regarding the political system or the income situation.

Trial interviews were carried out in Germany with Indian test persons in order to discover eventual misunderstandings and to get pre-information on aspects like time demand, development of concentration and motivation of the test person etc. The first trials showed a relatively fast decrease of the test persons concentration and motivation because of the relatively long questioning period of 30 to 90 minutes, depending on test person and questionnaire sections. For that reason, a set of questioning tools was developed.

Questioning tools were designed to

- Keep attention and concentration of the test person on a high level
- Achieve holistic interaction rather than pure language based questioning

- Simplify comparisons of answer sets
- Simplify decision processes
- Assure understanding of complex question architectures
- Minimise the risk of misunderstandings due to language barriers

The questioning tools basically consist of coloured paperboard cards and arrows of various shapes in combination with sorting boxes.

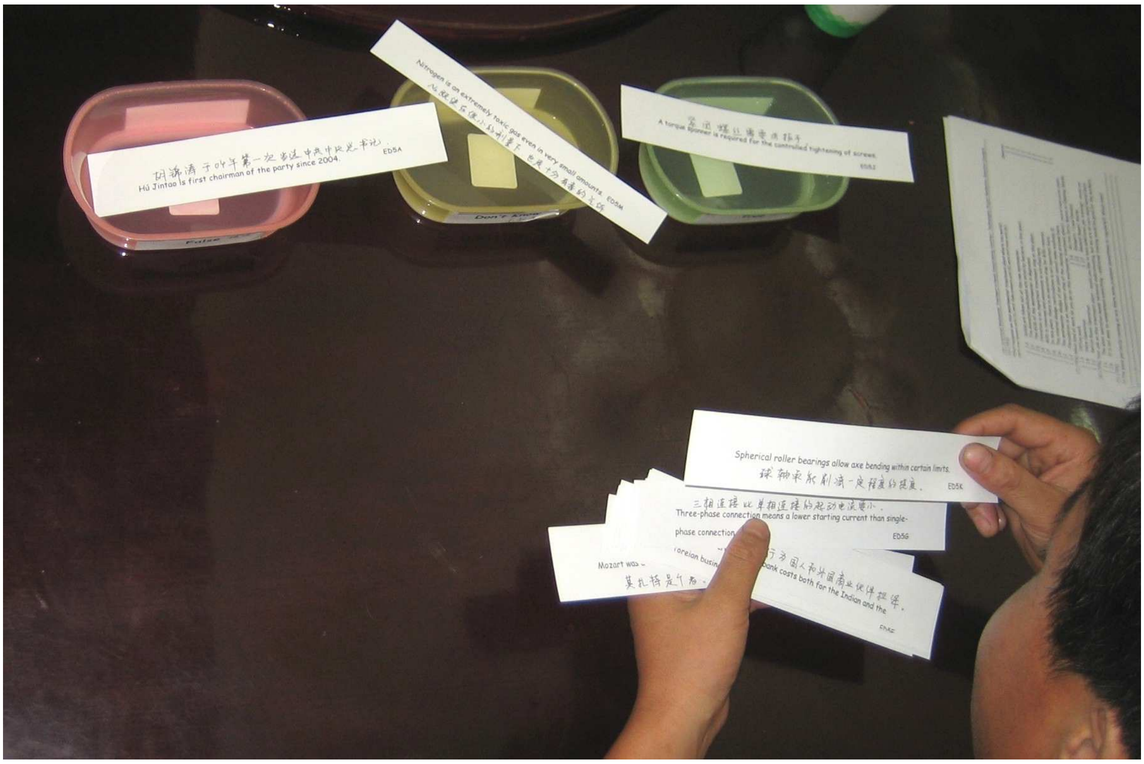


FIGURE 21: QUESTIONING TOOLS APPLICATION IN CHINA

Regarding the question design, the questions can be divided into 9 major groups that are characterised according to aspects like grade of complexity, number of subtopics and answer categories, and use of supporting tools. In the following, the different major question types are described:

1) Questions with three answer categories for a large number of subtopics

For this question type, one sorting box for each answer category and one paperboard for each subtopic was created. In the questioning situation, the question is explained to the test person and the paperboard cards are handed over with the instruction to sort them into the boxes according to the answer category, after being read to the test person.

2) Questions with three answer categories for a large number of subtopics and additional registration of the true answer scenario

Material and questionning procedure of this question type are the same like under point 1. In addition, the interviewer checks the real situation to fix the evaluation schedule for each answer category, which means the test persons answer is compared to the interviewer's observation on site.

3) Questions with a large and complex text content of two answer categories referring to a special scenario

The text passages of both answer categories are written on one big paperboard, which is handed over to the test person after the question is read to the test person. Then all answer categories are read. Seeing the potential answers that can also be explained more in detail in case of misunderstandings, the test person makes his or her choice.

4) Priorising questions

At this type of question, the test person ranks a certain number of subtopics of a question field. All subtopics are written on an arrow shaped paperboard, which are handed over and read to the test person. He or she is instructed to place the cards in a row between two additional border cards that represent “Highest Priority” and “Lowest Priority”.

5) Questions with several answer categories that should be compared and ranked

All answer categories are written on small paper cards. The ranking table is a big paperboard with blank spaces for the test person's choice. As this question type is relatively complex, extensive explanation of the question scenario by the interviewer is required. Then both ranking table and answer categories are handed over to the test person with instruction to choose a certain number of categories and to rank them. All answer categories are read to the test person and explained if required.

6) Questions with several answer categories for simple choice

All answer categories are written on one big paperboard card. The question is read to the test person, the paperboard card is handed over to the test person and all answer categories are read to the test person. Then the test person makes his or her choice.

7) Simple fact questions

The questions are directly read to the test person without any supporting tools. Additional explanation is given by the interviewer, if required.

8) Simple choice between up to three possible answer categories

The questions are directly read to the test person without any supporting tools. Additional explanation is given by the interviewer if required.

9) Open questions

Open questions are asked directly without the use of supporting tools. In case of understanding problems, additional explanations are given to the test person. Answers and comments are noted as detailed as possible by the interviewer.

Sampling Planning

Due to experience with treatment plant management and plant staff in India prior to this study, it was known that several factors like location of plants, permissions, cooperation and time availability on site, etc. would have to be considered in the planning phase of the sampling. Especially in the private sector, that means industrial wastewater treatment, problems of access were expected. The test with an Indian test person in Germany showed already a relatively high time demand for the questioning. As the questioning of the treatment plant workers is embedded in a treatment plant visit where also the technical equipment should be documented and an expert talk with the plant management should be carried out, it would not have been possible to question all the staff, although this would have been ideal for the data collection. The first questionings in India showed that the questioning of more than two employees is hardly possible. It was therefore decided to question two employees in each wastewater treatment plant. Rather than to analyse a very limited number of plants in detail, the focus was set on an explorative outlook on the situation in the different countries.

The main focus of the questioning is set on the technicians/skilled workers that are operators or that are working in the mechanical or electrical field and helpers who are assisting the technicians, as this group is directly confronted with operation and maintenance of the technical equipment. Table 15 shows the criteria for the test persons group.

Works Field Specific Criteria	▪ Mechanic/Fitter ▪ Electrician ▪ Operator ▪ Helper
Hierarchy Criteria	▪ Foreman ▪ Technician/Skilled Worker ▪ Helper Level

TABLE 15: TEST PERSONS CRITERIA - WORKERS QUESTIONING

Regarding the distribution of test persons from the different work fields, relatively equal proportions of the different work fields were envisaged. Because of the fact that the questionings had to be carried out parallel to the work processes, it was expected that the test person choice depends to a great extent on the availability and the plant management. As per total number of wastewater treatment plants, at least 20 test persons should be questioned in each country.

6.1.3 Visually Based Methods

Visual methods have a supportive function in this comparative study between three different cultures and mean a special kind of observation. Although questioning is the most used data collection method in social sciences – and the most important in this study - , observation is the base method. Observation means the collection of experience in a non-communicative process by the use of all sensing possibilities (Laatz 1993). Comparing the information content of visual information with text content as the “typical” way of information transportation, it has to be stated that with an image, a sense unity can be reached that that goes beyond text by concentration. Visual information is characterised by a meaning surplus compared to text information (Jung and Müller-Doohm 1993).

In order to support the information gained by expert interviews with the management of wastewater treatment plants regarding technology status and aspects of operation and maintenance, photographs of technical equipment taken on treatment plants are analysed. Considering the explorative approach of this study, the analysis of photographs represents an additional and uncomplicated information source, especially regarding the data collection phase. The main advantages:

- Actuality
- Uncomplicated Data Collection
- Low Organisation Effort
- Image of Reality
- Possibility of Qualitative & Quantitative Analysis

Although the subjects of observation are technical products, due to the conditions – widely unknown research field with very different cultural and structural background – the analysis of – photographic - observations was chosen as a methodological approach normally used in sociology. The general potential points of critics of observation given by (Grümer 1974) are:

- Reliability and Validity
- Selection of Observation Units
- Recording of Observation Data
- Possibilities of Analysis
- Inference Problem

In order to use the observation method for the description of the technology state, above aspects were checked. Reliability and validity is assured by the fact that the data is collected and achieved photographically and that the photos are analysed based on a relative scale for defined criteria after pre-analysis and determination of the range of the relative scale. That way, the personal and situational influence of the observer is minimised. A high grade of validity can be assumed as the observation in the study is based on photographs. Observation units, that means suitable photographs, were selected from the population of all photographs that could be taken on STPs and ETPs (industrial effluent treatment plants). In order to develop also quantitative conclusions and to show tendencies beside qualitative comparison, the quantitative analysis is based on the existing database – taken photographs - after the data collection. For the analysis, the population is not the real existing overall equipment of all visited plants, but the photographically documented equipment in all three countries. Recording and analysis of the visual information is realised by digital photographs that allow the determination of even small equipment and surface details. Inference problems are excluded by the fact that only visible characteristics or characteristics that are confirmed during the site visits through the personal experience of the observer. The practical realisation is embedded into the plant inspection visits and the expert interviews with the plant management.

The photographic documentation and analysis is applied as a supporting method because of the high qualitative information content of the visual medium photo. The results should show trends, give a first impression of the technology state and should serve as a first information basis for more detailed quantitative and qualitative studies. As already mentioned above, the observer's perception influence is minimised by pre-analysis test and relative comparison. As the observer is from the field of wastewater treatment technology with practical experience in Europe and India, it is assumed that both qualitative description and relative grading of the photographed equipment is carried out with sufficient expert knowledge.

According to the research questions, the analysis of treatment plant equipment is targeting on the following aspects:

General Equipment Characteristics	▪ Type of Equipment ▪ Origin of Equipment ▪ Age of Equipment
Equipment Status & Efficiency	▪ Structural Equipment ▪ Machinery Equipment ▪ Control Equipment
Maintenance	▪ Effectiveness

TABLE 16: TARGET INFORMATION PHOTOGRAPHIC ANALYSIS

Data Analysis

As the methodological discussion in sociological literature on visual understanding shows, no clear strategy exists for the analysis of photographs or images in general. Different authors suggest very different approaches depending on type and content of the visual material. In the field of arts, the method of iconology is approved, which consists of 3 phases. In the first phase, the pre-iconographic description, an item is described according to its formal habits. The facts and normative contents of an image are analysed and expressed. In the second phase, thematic relations of motives are analysed. The target of the third phase is the decoding of the meaning content (Jung and Müller-Doohm 1993). For the analysis of the photographs of treatment plant equipment, only the first step of this method is applied. Figure 22 gives an outlook on the data analysis procedure applied.

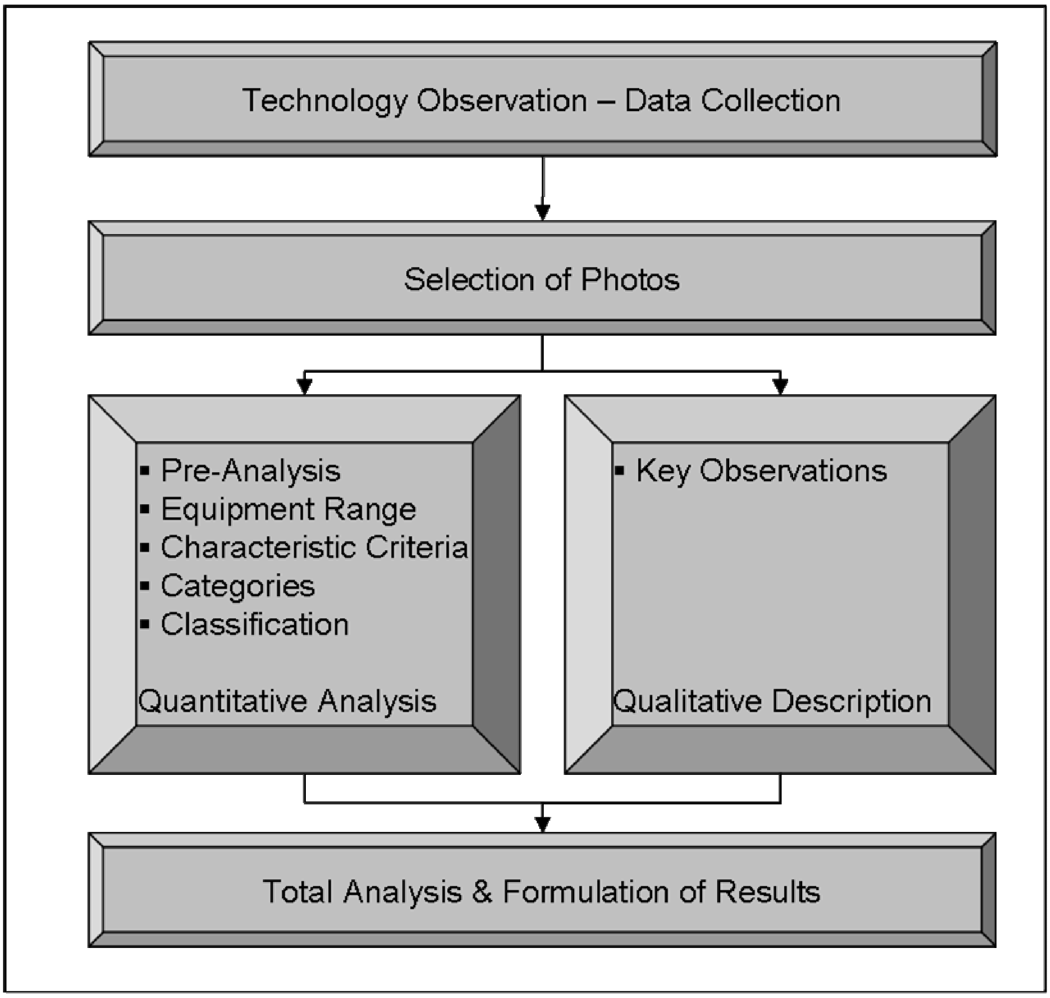


FIGURE 22: ANALYSIS CONCEPT EQUIPMENT PHOTOGRAPHS

For the data analysis a combined process consisting of quantitative and qualitative parts is chosen. First of all, the gathered photos of plant equipment are pre-selected, the total data base for the analysis is defined and the photos are grouped both according to the equipment that is shown and the plant the equipment belongs to. For the quantitative approach, a pre-analysis is carried out and the total range of equipment types is determined, based on which the analysis is carried out later. Then, characteristic criteria, that means the range of criteria that can be described, are determined and categories are defined for each criterion. The quantitative analysis is carried out software based with the software SPSS. For the analysis of the photographs, 7 parameters were defined. Each parameter consists of different criteria that are determined for each analysable plant component in a category range between -2 (very negative) and +2 (very positive). The criteria are weighed and the respective parameter is determined as index value (see table17).

Parameter	Criteria	Weight
Efficiency	▪ Specific Construction Demand ▪ Specific Space Demand ▪ Specific Material Costs ▪ Specific Energy Demand ▪ Technology Level	▪ 16,7% ▪ 16,7% ▪ 16,7%* ▪ 16,7%* ▪ 33%
Manufacturing Quality	▪ Dimension Accuracy ▪ Surface Accuracy	▪ 50% ▪ 50%
Material Choice	▪ Potential Corrosion/UV Resistance ▪ Coating Quality	▪ 50%** ▪ 50%**
Stability	▪ Static Design ▪ Material Thickness	▪ 50% ▪ 50%
Corrosion Freeness	▪ Rust/Weathering ▪ Fissures/Flaking	▪ 50% ▪ 50%
Cleanliness	▪ Surface Cleanliness ▪ Technical/Detail Cleanliness	▪ 50% ▪ 50%
Function Ability	▪ Mechanical/Physical Intactness ▪ Durability	▪ 50% ▪ 50%

*: The parameter "Specific Energy Demand" was not determined for covers, handrails, piping, valves, housings, mountings, cabling, control panels, sensors and weirs. For these equipments, the parameter "Specific Material Costs" has a weight of 33%.

**: For equipment without coating, the parameter "Potential Corrosion/UV Resistance" has a weight of 100%).

TABLE 17: PARAMETERS AND WEIGHED CRITERIA OF PHOTO ANALYSIS

In addition to the quantitative analysis, qualitative aspects of the technical equipment are considered. Key observations and specific phenomena are identified and described for the different equipment types. Summarising results are formulated.

6.1.4 Guided Expert Interview

The field of wastewater technology and its operation should not only be approached on grass root level on wastewater treatment plants on site, but also from the academic and management level. The guided expert interview was chosen as suitable method for the data generation. That way the collection of very specific insider information from persons with a very different individual background even in their own culture is possible. The following table shows the interest fields that should be covered:

Environmental Situation & Possible Reasons	▪ Problem Awareness ▪ Problem Relevance ▪ Fact Knowledge
Effects of Environmental Pollution	▪ Awareness & Position on Effects ▪ Environment – People – Economy
Awareness & Knowledge of Different Population Levels	▪ Hygiene – Environment ▪ Rural Areas – Urban Areas
Professional Qualification & Education in Water & Wastewater Sector	▪ Existing Manpower on Plants ▪ Education of Engineers & Workers
Facts and Positions on Wastewater Technologies	▪ Concepts & Processes in General ▪ Technology Supply ▪ International Relations ▪ Operation & Maintenance ▪ Excess Sludge Problem (China)
Product Piracy (China)	▪ Quality & Cost Aspects ▪ Protection & Strategies ▪ Perspectives
General Perspectives	▪ Environmental Situation ▪ Technology ▪ Economy & Business Relations

TABLE 18: INTERVIEW GUIDELINES GUIDED EXPERT INTERVIEWS

As the targeted information fields represented a widely unknown area, first information should be gained in an explorative approach. Especially due to its relative openness, the expert interview is suitable to avoid too strong conceptual fixations so that the generation of theories by the test persons remains possible (Kühl and Strodtholz 2002). Unlike free interview methods, the guided expert interview is carried out based on interview guidelines, means a set of topics or questions. The focus of the expert interview is on the individual knowledge of the experts – the experts are interesting as carriers of information and not as persons (Kühl and Strodtholz 2002).

Expert Selection

In the sociological literature the definition of “the expert” is widely discussed. According to Kühl and Strodtholz (2002), experts are function elites within an organisational and institutional context. Experts are also persons who have privileged access to information regarding person groups and decision processes (Kühl and Strodtholz 2002). The following table shows the criteria of choice for the group of experts and the priorisation.

Sector	**Work Field**
1. Wastewater Sector **2. Water Sector** **3. Environment Sector**	▪ University & College Professors/Phds. ▪ Technology Suppliers & Consultants ▪ Politics, Administration & Pollution Control ▪ NGOs, Development Assistance
Education & Social Sciences	▪ *Professional Education* ▪ *General Education* ▪ *Sociology & International Relations*
Media	▪ *Water, Wastewater & Environment*

TABLE 19: CRITERIA OF EXPERT CHOICE FOR GUIDED EXPERT INTERVIEWS

Of primary importance are experts of the wastewater sector, followed by experts from the water and the general environmental sector. Experts from education & social sciences, as well as from the media represent additional specialists in order to get indicative information also on these unknown fields. In the data analysis, especially in the quantitive part, these experts play a minor role.

For the choice of potential experts in the different countries, a priorisation was carried out. Of highest priority are experts from the wastewater field, followed by experts from the general water field and the general environmental sector. Experts with a strong relation to the wastewater sector were of highest interest for the interviews, comprising test persons from science, private sector, administration, control authorities, NGOs and development assistance.

The prioritisation and inclusion also of the other two sectors was carried out for two major reasons: First of all, all three fields are very much interlinked and many experts have special knowledge in several fields. An example: An expert with a broad environmental knowledge that includes also knowledge on wastewater is considered to be from the environmental sector as it is assumed that his or her wastewater specific knowledge is not as profound as of someone who his exclusively working in the wastewater field. The second reason for the priorisation is the practical access to suitable experts in the different countries within a certain time frame during the data collection. For a foreign citizen from a western research institution who is carrying out the data collection in India and China, both selection of interview partners and organisation of the interviews is not an easy task.

Data Analysis

For the data analysis, a combination of quantitative and qualitative analysis is used. In order to get first information and an outlook on the distribution of major statements according to predefined research questions and sub questions, the interviews are analysed in a quantitative way. Questions, sub questions and answer categories are set after the first sighting of the interview transcripts. As visible in figure 22, the first step of the data analysis is the transcription of the interviews that are recorded with a voice recorder. Although work intensive, the transcription is an important step for the data analysis. Figure 23 gives an outlook of the combined analysis approach. For the quantitative analysis, the interviews are screened for defined questions and subquestions. The answers are coded and entered in SPSS software for detailed analysis. Answers are classified according to categories in a range from -2 (very low / very negative) to +2 (very high / very positive). Important key statements are chosen or the total analysis. That way, the results of the quantitative analysis are supplemented and illustrated by key statements of a qualitative consideration.

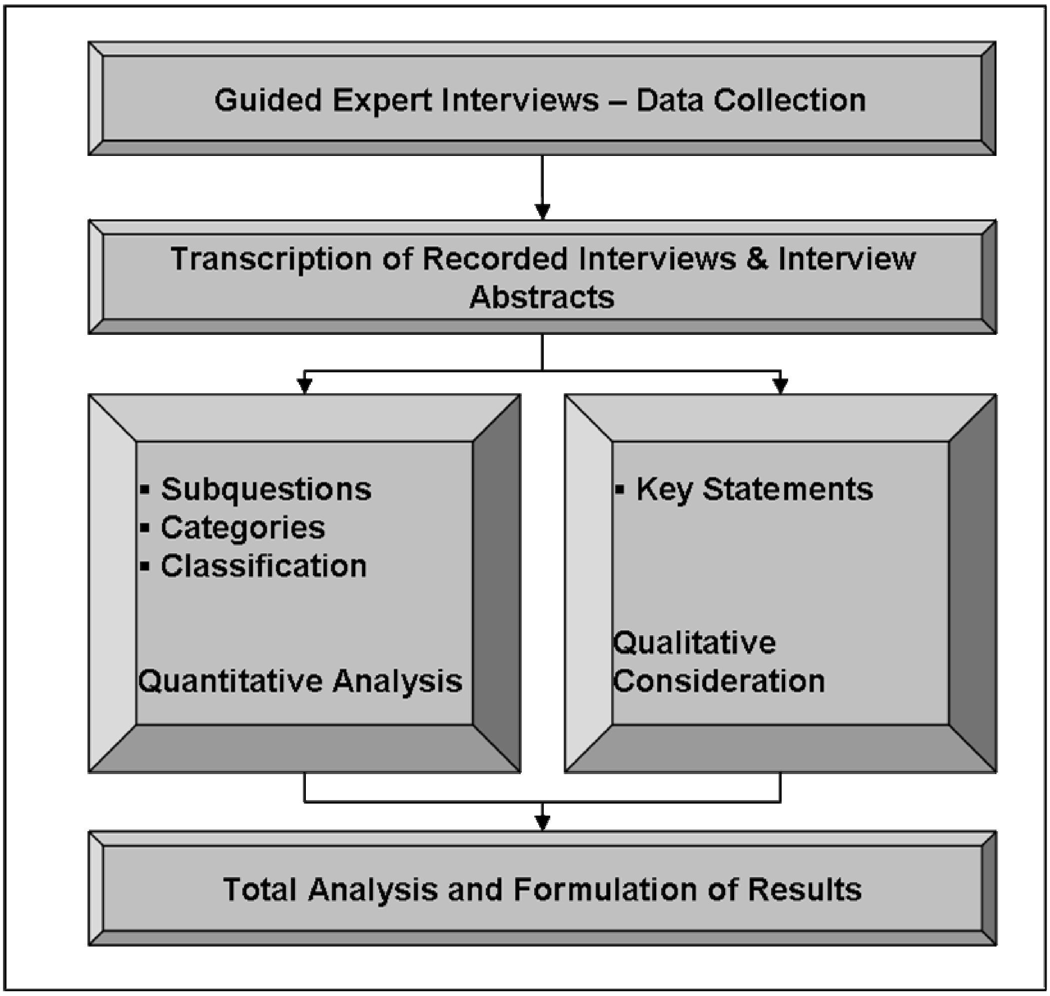


FIGURE 23: ANALYSIS CONCEPT GUIDED EXPERT INTERVIEWS

6.1.5 Pilot Training

General Approach & Target Information

As the considerations in chapter 5.2.1 showed, Indian society and the Indian education system are characterised by very strong hierarchies. As already mentioned training courses for practical treatment plant staff don't exist. Qualification deficits of the staff were assumed, but hardly any information exists on the qualification status, suitable training concepts and possible implementation. It can be assumed that the implementation of training measures will strongly depend on the frame conditions and the social situation on wastewater treatment plants. Therefore, analysis and description of the frame conditions for workers training are important targets of this study. In order to get first information about the behaviour of practical treatment plant staff in a training situation, learning progress and suitability of possible training concepts, pilot trainings were carried out on two STPs and one ETP in India. First answers should be found on basic questions how under the existing frame conditions on site an improvement of technical knowledge and motivation can be achieved.

For the pilot training, a special training concept was developed that should be tested regarding its suitability. The concept is targeting on mixed worker groups – that means a mix of different disciplines and experience grades. Table 20 gives an outlook on the target information of the pilot trainings.

Existing Work Situation	▪ Type of Work ▪ Motivation & Perspective
Possible Training Contents	▪ Interest Fields ▪ Existing Knowledge ▪ Training Topics ▪ Detail Grade
Organisation	▪ Position of Management ▪ Location ▪ Media
Suitability of Poster Based Training	▪ Learning Progress ▪ Acceptance ▪ Method-specific information regarding - Training Time - Breaks - Theoretical Contents - Examples - Discussions - Information Density - Structure

TABLE 20: TARGET INFORMATION OF THE PILOT TRAININGS

Pilot Training Concept

In the pilot trainings, a strong focus was set on intensive communication and participation of the training participants. The practical staff should actively take part in discussions, whereas the training contents orientated on the knowledge requirements of the respective treatment plants. Beside the creation of a basic knowledge base, also motivation increase and the development of a more positive work image were targeted. A major intension was the development of an understanding for the relations between plant stages.

In order to achieve above targets, a modular poster based concept was developed, so that an individual adaptation to the processes and technologies of the respective plant is possible. For each plant stage, one poster was developed – in total 15 posters. Extra posters were developed for image & motivation, monitoring and work safety. In the poster design, a strong emphasis was set on visual information transfer by real photographs and cartoon illustrations (see example “Final Clarifier”, figure 24). According to the existing plants stages on the plants, where the pilot trainings were carried out, the respective posters were chosen, a poster wall was created and material flows between the plant stages were displayed by coloured tape and arrows.

The following table gives an outlook on the aspects that were considered in the concept realisation:

Basic Concept	▪ Plant Specific ▪ Modular Structure ▪ Permanent Proximity & Memento
Appearance	▪ Bright & Positive Colours ▪ Mix of Real Images and Comic Figures
Structure	▪ Basic Theoretical Background Information ▪ Main Practical Relevant Aspects ▪ Key Phenomena - Wrong Behaviour & Consequences - Correct Action & Consequences

TABLE 21: DESIGN PRINCIPLES OF POSTER BASED TRAINING MATERIAL

For each poster – that means for each plant stage - the following main questions should be covered in the training situation:

1. What is the function of the treatment stage or the process within the plant?
2. What is the technical function principle?
3. What typical phenomena or problems can occur?
4. What can be severe consequences, if the problems are not solved?
5. What measures are indicated at certain phenomena or problems?
6. What are the positive consequences of correct actions?

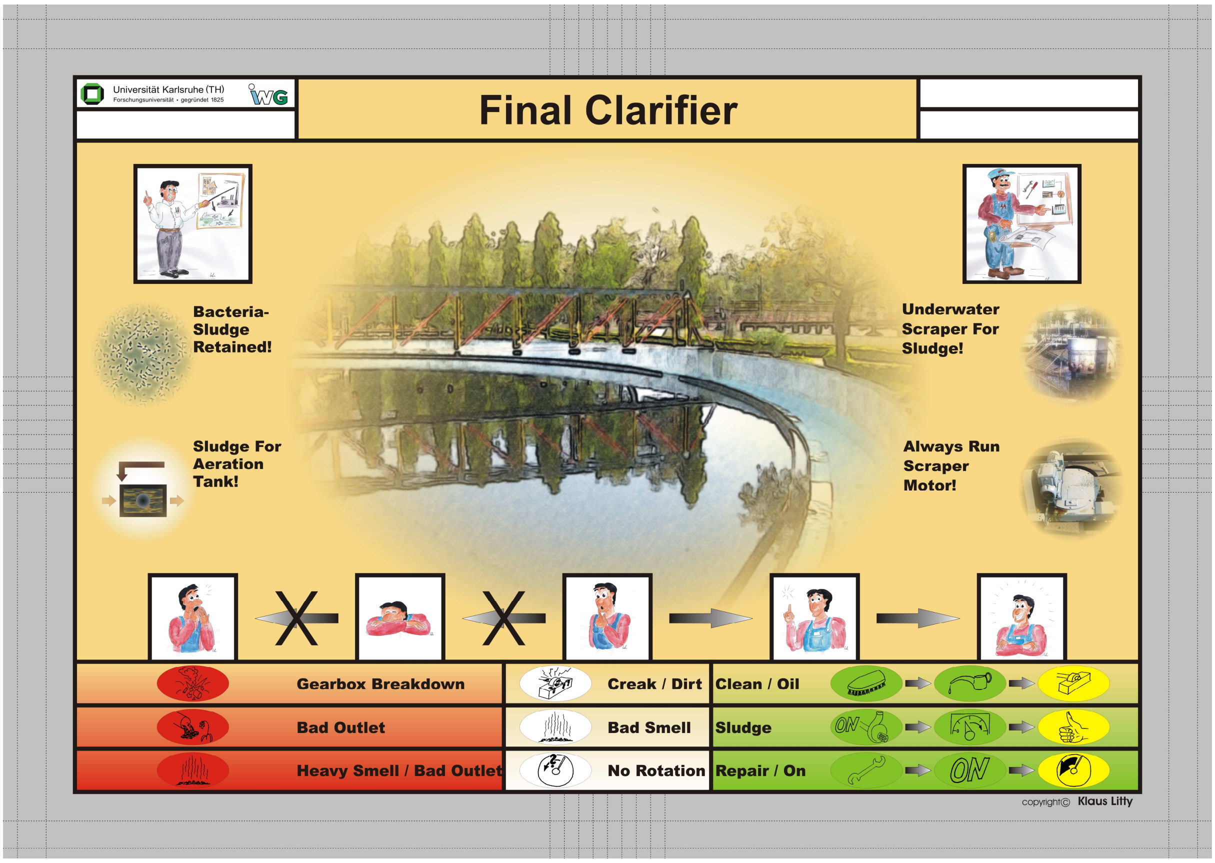


FIGURE 24: TRAINING POSTER MODULE "FINAL CLARIFIER"

6.2 Data Collection

The different data mentioned in chapter 6.1 were collected during several research journeys in India, China and Germany. The following table gives an outlook.

November 2005 – April 2006	▪ Plant Inspections India ▪ Staff Questionings India ▪ Expert Interviews India
September 2006 – November 2006	▪ Plant Inspections Germany ▪ Staff Questionings Germany ▪ Expert Interviews Germany
January 2007 – March 2007	▪ Pilot Trainings India ▪ Plant Inspections India
Mai 2007 – June 2007	▪ Plant Inspections China ▪ Staff Questionings China ▪ Expert Interviews China

TABLE 22: OUTLOOK DATA COLLECTION PERIODS

Between the different data collection phases, the research journeys were prepared and pre-analyses of already collected data were carried out. In the following, the practical implementation of the data collection is described.

6.2.1 Wastewater Treatment Plant Inspections

General Aspects

Location and access of existing wastewater treatment plants in India, China and Germany were very important aspects of this study in order to get up-to-date information. In order to carry out above mentioned steps, important aspects regarding organisation and procedure had to be considered in the different countries that are summarised in the following table.

Location	▪ Information on Existing Plants
Access	▪ Contacts ▪ Permissions
Plant Inspection	▪ Organisation - Appointment - Translator ▪ Availability of Staff for Questioning ▪ Management Permission - Plant Information - Staff Questioning - Photographic Documentation

TABLE 23: FRAME CONDITIONS OF TREATMENT PLANT VISITS

Location

The main focus of the treatment plant inspections in India and China was on urban areas, as on the countryside or even in smaller towns, hardly any technical wastewater treatment facilities exist. In order to avoid regional distortions, plants in the major development centres of the respective country were inspected. In Germany, also small and medium sized technical plants outside urban areas were inspected.

Access

The access to existing plants, that means the creation of contacts and the grant of required permissions, represented the most critical part of the data collection. For most of the visited plants in India and China, official request letters and/or confirmation documents were required after a first contact to the management or the respective administration authority was created.

Plant Inspection

The following table gives an outlook on the different steps of the plant inspections:

Expert Interview Plant Management	▪ Technical Aspects ▪ Manpower ▪ Organisation
Equipment Inspection	▪ Technical Status ▪ Documentation & Crosscheck
Staff Questioning	▪ Workers ▪ Technicians ▪ Foremen

TABLE 24: PLANT INSPECTION STEPS

Prior to the plant inspections, basically organisational issues had to be cleared. In most cases a short pre-visit was arranged, in order to give the respective plant management an outlook on the intended schedule for the plant inspections and to assure a confidential atmosphere for the staff questionings. A critical aspect in most plants was the persuasion of the management why technicians and workers should be questioned and why they should be questioned confidentially. Unfortunately, potential mistrust could not always be cleared, so that in some plants, no permission for the questioning of the workers was granted. In some cases, no permission to take photographs was granted, even though official confirmation documents were presented. If possible, organisational questions, like time demand etc., were discussed in advance with a high ranking member of the plant management. As it was known that especially the simple workers on STPs and ETPs speak only the respective local language and no English, a translator had to be organised. Whenever possible, a person that has no direct work relation to the test person was chosen for the translation. The relation between test person and translator should be as neutral as possible in order to avoid any distortion due to a translator influence. In many cases university students acted as translator. In questionings that were carried out with translating persons that are working in a higher position on the treatment plant, a negative influence on the questioning situation was detected.

Meeting & Expert Interview with Plant Management

The first step of the treatment plant inspections was in almost all cases a meeting with the plant manager or a high ranking engineer. With a few words the research project and its targets were explained and the intended data collection steps on the plant, like equipment inspection and staff questioning, were mentioned and its purpose explained. As already mentioned, the confidential questioning of workers was the most critical part – some plant managers did not agree. In some cases, the presentation of the empty questionnaire together with confirmation documents from the research partners helped to create confidence, but in some cases a "no" had to be respected and accepted. After the clearing of the formal and organisational questions, an expert interview was carried out in most cases. The plant operation in general was discussed based on pre-defined interview guidelines (see figure 25). In this expert talk, starting from frame data like plant capacity, the existing technology, operation related topics, maintenance aspects and the manpower situation were discussed and noted for further data analysis.

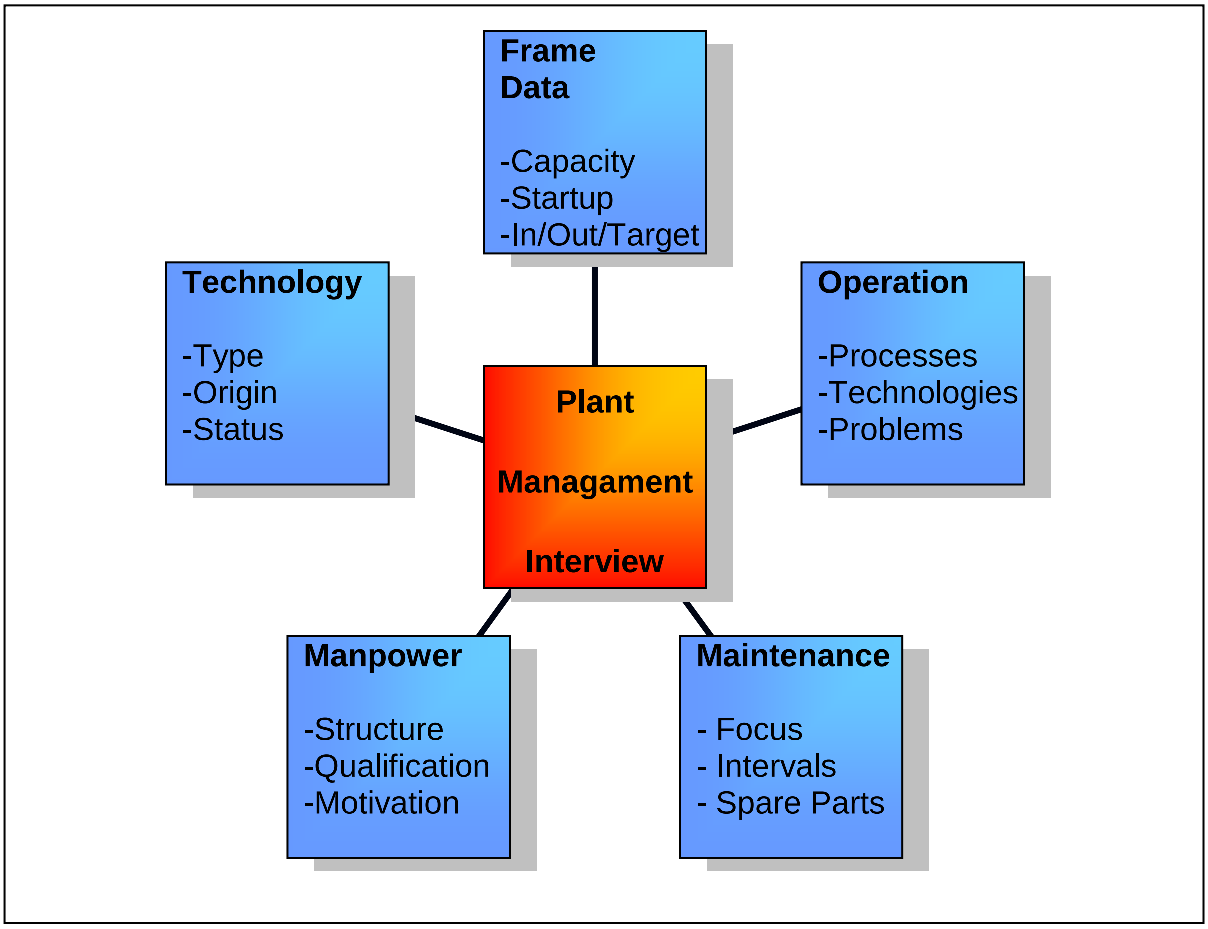


FIGURE 25: QUESTION FIELDS INTERVIEW TREATMENT PLANT MANAGEMENT

The time demand for the interviews with the plant management was between 30 minutes and 60 minutes in most plants, depending on time availability and questioning atmosphere.

Equipment Inspection

After the interview with the plant management, the different plant steps and the technical equipment were inspected. In addition to the plant information given by the interviewed plant managers and engineers, photographs were taken. Additional information, like extreme noise or vibration or reasons of damages, was noted. Unfortunately the management of some plants – especially industrial effluent treatment plants in India – did not allow a photographic documentation. Obviously, negative consequences from control authorities were feared. The time demand for the equipment inspection was between 30minutes and 60minutes in most inspected plants.

Staff Questioning

For the staff questioning, a U-shape sitting situation was arranged: the test person in the middle, on one side the questioning leader and on the other side the translator. This arrangement proved to be very suitable for several reasons: First of all, the interview leader sits close to the test person and can observe any reactions or discomfort. Due to the close contact during the questioning, which included also slight touches on arms and shoulders, vivid and trustful interaction could be created in most cases. By the U-shape arrangement, also the interaction between translator and test person could be well observed. This was very essential especially for the questioning of the Indian test persons. In some cases, a strong influence of the translator on the test person was observed. The translator obviously did not consider the respective technician or helper as a test person, but as a person of much lower social status. No confidence could be created and translators tried to give the answer in their opinion in some cases. If any such tendencies were observed, the interview leader could intervene, discuss the case with the translator or organise another translator. The permanent avoidance of above mentioned problem and the creation of a positive and confidential atmosphere were of major importance for the staff questionings especially in India due to the very strong hierarchical structure.

The time demand for the workers questionings ranged between 60 minutes and 90 minutes in most cases and depended on the following factors:

- Time availability & work organisation
- Translator
- Understanding & concentration ability of test person
- Empathy of test person

Basically, interview tools were used in India, China and Germany. In Germany, the tools had to be avoided for some questions to avoid obvious boredom of the test persons. Interview tools were used in English language for India and translated additionally in Chinese for the use in China. For the questionings in Germany, interview tools in German language were used.

FIGURE 26: WORKERS QUESTIONING ON AN INDIAN SEWAGE TREATMENT PLANT

Plant Visits in India

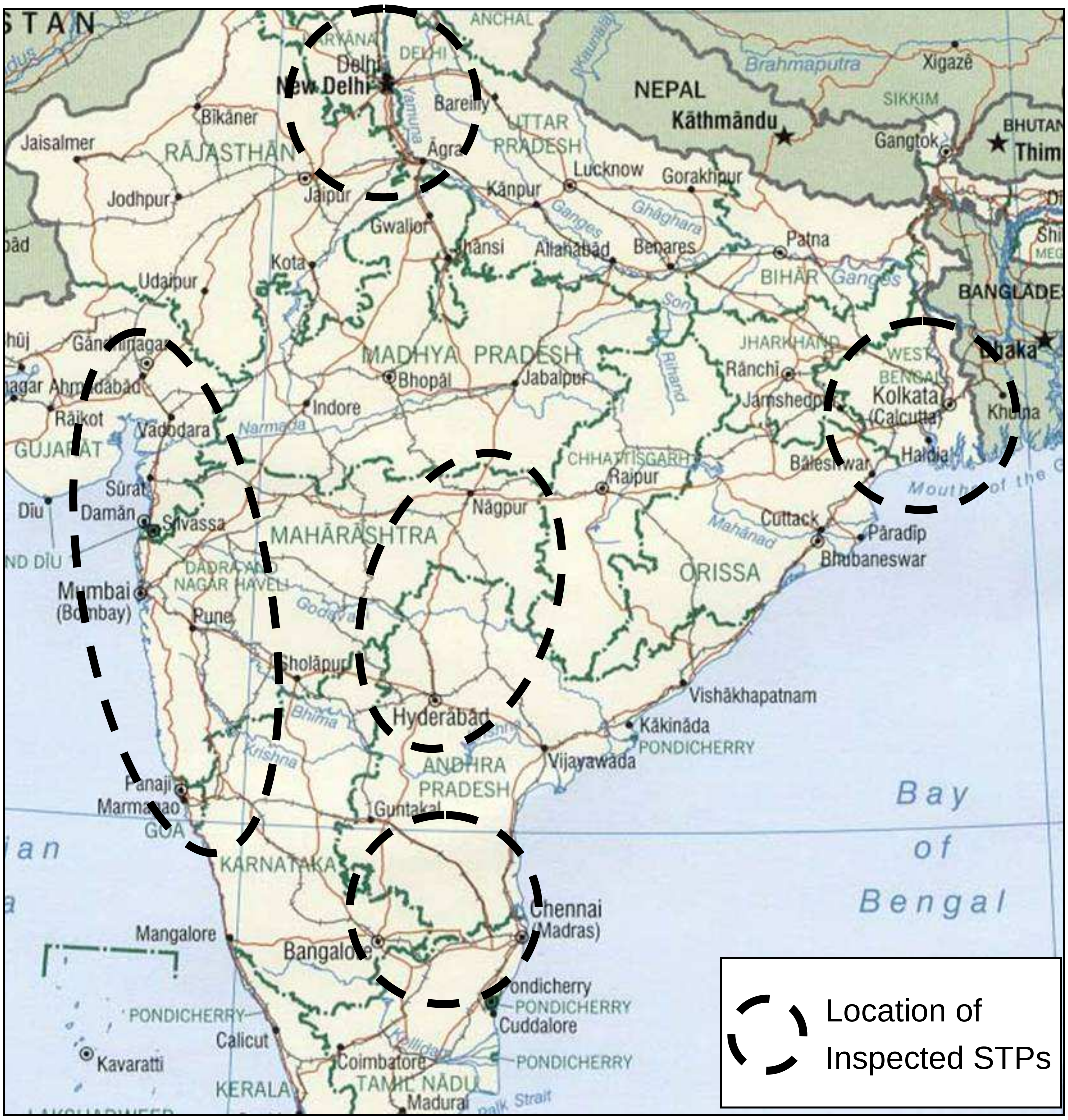


FIGURE 27: OUTLOOK LOCATION OF INSPECTED STPS IN INDIA

Figure 27 shows the location of the inspected sewage treatment plants in India. 28 plants were inspected during a research journey from November 2005 until April 2006 – 6 plants plants were inspected within a second research journey from January to March 2007. For data safety reasons more detailed information regarding the location of inspected STPs and ETPs plants can't be given.

Plant Number	Plant Type	Design Capacity [m³/d]
I-M1	Municipal Sewage	1.000
I-M2	Municipal Sewage	1.500
I-M3	Municipal Sewage	10.000
I-M4	Municipal Sewage	18.160
I-M5	Municipal Sewage	20.000
I-M6	Municipal Sewage	23.690
I-M7	Municipal Sewage	30.000
I-M8	Municipal Sewage	45.000
I-M9	Municipal Sewage	45.500
I-M10	Municipal Sewage	45.500
I-M11	Municipal Sewage	47.500
I-M12	Municipal Sewage	50.000
I-M13	Municipal Sewage	82.500
I-M14	Municipal Sewage	100.000
I-M15	Municipal Sewage	115.000
I-M16	Municipal Sewage	182.000
I-M17	Municipal Sewage	182.000
I-M18	Municipal Sewage	327.600
I-M19	Municipal Sewage	482.300
I-M20	Municipal Sewage	637.000
I-M21	Municipal Sewage	500
I-M22	Municipal Sewage	12.000
I-I1	Industrial (Pharma)	25
I-I2	Industrial (Paints)	200
I-I3	Industrial (Textile)	320

I-I4	Industrial (Distillery)	670
I-I5	Industrial (Textile)	3.000
I-I6	Industrial (Pharma)	3.750
I-I7	Industrial (Leather)	4.000
I-I8	Industrial (Textile)	16.000
I-I9	Industrial (Hotel)	220
I-I10	Industrial (Hotel)	100
I-I11	Industrial (Hotel)	120
I-I12	Industrial (Hotel)	175

TABLE 25: INSPECTED PLANTS IN INDIA

In total, 34 wastewater treatment plants were inspected in India – 22 muncipal plants and 12 industrial plants. For different reasons – like insufficient cooperation of the plant management, or organisational constraints, not all information types could be collected in all visited plants. An outlook on collected data and inspected plants:

- Photo documentation technical equipment: 28 plants
- Expert interview with plant management: 28 plants
- Questioning of practical staff: 23 plants

Important Aspects Regarding Data Collection in India

As already mentioned, the data collection in India included the major development centres. As in New Delhi, the capital of the country, wastewater treatment is very advanced compared to other regions, several plants were inspected in the greater Delhi area. Other plants were inspected in Uttar Pradesh, Gujarat, Maharastra, Goa, Karnataka, Tamil Nadu and West Bengal. Of the inspected industrial wastewater treatment plants, one plant is of a distillery, one of chemical factory, two are of the pharmaceutical industry, three plants of the textile industry, 1 plant of the leather industry and 3. As Gujarat is characterised by a high grade of industrialisation, especially textile industry, several plants of this sector were inspected. In Maharashtra and Karnataka, mainly municipal plants were inspected. In Goa, both municipal plants and several plants of the hotel sector were inspected. Other industrial plants that were inspected are plants of the leather and pharma industry. Beside above mentioned states, plants in Tamil Nadu, Andhra Pradesh and West Bengal were inspected.

For the localisation of existing sewage treatment plants (STPs), the local municipal authorities in the respective cities were contacted directly in most cases. In many cases, local research institutions helped in the localisation of plants and contact creation to the plant management.

In order to get also information on the situation in the private sector, also industrial effluent treatment plants (ETPs) were visited. Main information sources on existing ETPs were control authorities and research institutions that are working with industries in the respective regions. The time demand from first contact, presentation of the research project until the permission and finally plant inspection ranged between two days and two weeks in most cases. As the treatment plant inspections were embedded in a research journey together with expert interviews and other data collection methods that were carried out parallel, time efficient planning of plant visits including application of permissions, according to the intended travel route was a critical factor. Except in one case, almost all municipal authorities in India were very cooperative once the targets and the Indo-German research cooperation with IIT-Delhi as well known research institution was presented. Very helpful were local contacts that helped to reduce existing mistrust especially in industrial plants. Especially big industries are severely under pressure from control authorities and fear potential negative consequences from a research study from which no direct advantage is visible for the company. Due to this fact, several enterprises that were contacted, strictly refused to take part in the data collection.

As already mentioned, the questioning of the practically working staff, was the most critical part of the plant inspection. In many cases the academic plant management had a relatively low understanding, why workers can be part of a research project. Most of the plant engineers associated with research purely technical aspects and claimed that a worker will not be able to give adequate information. In some cases it was not allowed to question the staff confidentially, in some cases staff questionings were not allowed at all. Beside a lack of understanding for the research targets, mistrust and fear due to uncomfortable information that might have been given by the staff can be assumed out as main reasons.

In total, 41 employees were questioned. The following figure gives an outlook on the quantitative distribution of the questioned test persons on wastewater treatment plants in India.

FIGURE 28: PROFESSIONAL POSITION OF QUESTIONED STAFF IN INDIA

Plant Inspections in China

Figure 29 shows the location of the inspected sewage treatment plants in China. All plants were visited during a research journey in May and June 2007. For data safety reasons, the location of one industrial plant is not indicated.

FIGURE 29: OUTLOOK LOCATION OF INSPECTED STPS IN CHINA

The following table gives an outlook on the inspected plants.

Plant Number	**Plant Type**	**Design Capacity [m³/d]**
C-M1	Municipal Sewage	30.000
C-M2	Municipal Sewage	40.000
C-M3	Municipal Sewage	40.000
C-M4	Municipal Sewage	80.000
C-M5	Municipal Sewage	100.000
C-M6	Municipal Sewage	100.000
C-M7	Municipal Sewage	120.000
C-M8	Municipal Sewage	180.000
C-M9	Municipal Sewage	200.000
C-M10	Municipal Sewage	250.000
C-M11	Municipal Sewage	300.000
C-M12	Municipal Sewage	330.000
C-M13	Municipal Sewage	400.000
C-M14	Municipal Sewage	1.000.000
C-M15	Municipal Sewage	80.000
C-I1	Industrial (Food)	unknown

TABLE 26: INSPECTED PLANTS IN CHINA

In total, 16 wastewater treatment plants were inspected – 15 sewage treatment plants and 1 industrial wastewater treatment plant. Seven of the inspected plants were financed by the German bank *Kreditanstalt für Wiederaufbau (KFW)*. An outlook on information type and inspected treatment plants:

- Photo documentation technical equipment: 16 plants

- Expert interview with plant management: 13 plants

- Questioning of practical staff: 13 plants

Important Aspects Regarding Data Collection in China

The inspected plants in China can be collated according the following categories:

- Sewage Treatment Plants
  - State Operated
    - Financed & constructed in cooperation with KFW (7 plants)
    - Financed & constructed by the state or other financing institutions (5 plants)
  - Operated as Public Private Partnership (3 plants)
- Industrial Effluent Treatment Plants (1 plant)

Like in India, plants in the major development centres were chosen for the data collection. In order to locate existing plants, the support of the KFW was very helpful. Prior to the planning of the data collection in China, both location and possible access to plants financed by KFW were discussed with KFW-experts in Germany and in the Beijing office of KFW. Other state owned plants, as well as privately operated plants were identified via university contacts and internet search. The location of industrial plants was very difficult, mainly because of language problems and mistrust of enterprises. Via a research institution one industrial effluent treatment plant could be inspected.

The plant inspections started in Beijing and the province of Liaoning with the visit of two sewage treatment plants and one treatment plant of a food industry. Due to the traditionally strong Sino-German cooperation in the province of Shandong, several municipal plants that were financed by KFW were visited in this province. Except one plant, all plants are municipal wastewater treatment plants. Three inspected plants are operated in Public Private Partnership (PPP) on the basis of BOT (Build Operate Transfer) or TOT (Transfer Operate Transfer).

Access to state owned plants that were co-financed by KFW-bank was assured by summarising pre-information and intended data collection steps that were transferred to the respective municipal plant management by the KFW office in Beijing in advance. Other state owned plants were contacted via local research institutions in the environmental field, whereas also summarising project information was given. In almost all cases, the plant management was basically very open for the presented research targets.

In most cases, the plant management was contacted one or two days prior to the intended inspection date. Very essential for the arrangement of an appointment was a well formulated information document in Chinese language that should help both to create confidence and assure all intended data collection steps – especially the questioning of workers – are possible during the plant inspection. As English is hardly spoken of Chinese wastewater treatment plants, a translator was arranged for each plant visit. In most cases, the English department of the local university was contacted and students could be found who acted as interpreter. Lack of time was a problem in some of the visited plants, especially regarding the workers questioning so that persuasiveness was required in some cases to convince both workers and plant management of the importance of the study in order to complete the data collection.

Like in India, the plant inspections started with the presentation of the research targets, whereas careful explanation of the intended steps and creation of confidence were of high importance. In several cases the plant manager insisted to invite the interviewer for lunch, what can also be interpreted as intension to create a more personal and confidential relation. In the interviews with the plant management, information was given openly and detailed in most cases – critical was only information regarding staff organisation and salary structure in some plants.

Other than in India, the permission to take photographs of plant equipment was granted in all inspected plants. Equipment that was obviously in a very bad state because of no cleaning or no maintenance at all was photographed in such a way that feelings of embarrassment of the plant staff are avoided. Although basically, great friendliness was expressed by the plant staff, a very sensitive approach was required. In almost all plants, an engineer accompanied the inspection tour over the plant, so that special aspects of the equipment could be discussed.

Permissions for the staff questioning were granted in all municipal plants, except in one case, although in the previous contact via a local research institution an okay for the data collection was given. The atmosphere in the interview situation was relaxed and confidential in almost all cases. Very essential was a sensitive and respectful approach both of translator and interview leader towards the work reality and problems of the test person. Other than in India, no negative influence of eventual social status aspects between translator and test person on the interview situation could be observed. Once a certain base of confidence was created, most test persons spoke openly also about personal question fields. Similarly like in India, the choice of the test persons depended to a great extent on staff availability and the superiors. The following figure gives an outlook on the test person distribution. In total, 26 test persons were questioned in China.

FIGURE 30: PROFESSIONAL POSITION OF QUESTIONED STAFF IN CHINA

Other than in India, the proportion of unskilled workers, that means persons without technical education background, is relatively low. For that reason, most questioned test persons are from the groups of skilled workers and foremen.

Plant Inspections in Germany

FIGURE 31: OUTLOOK LOCATION OF INSPECTED STPS IN GERMANY

Figure 31 shows the location of inspected sewage treatment treatment plants in Germany. Almost all plants were visited in September and October 2006. For data safety reasons, the location of the inspected industrial plants is not indicated.

In total, 13 wastewater treatment plants were inspected – 10 sewage treatment plants and 3 industrial effluent treatment plants. In one case, the plant consists of two sections – one section is treating industrial effluent, the other section is treating the municipal wastewater of the nearby municipality. All sewage treatment plants are owned by the respective municipality or administration union, except two plants. In Berlin, wastewater treatment is partially privatised with a 49.9% share of private companies.

The following table gives an outlook on type and capacities of inspected plants.

Plant Number	**Plant Type**	**Design Capacity [m³/d]**
G-M1	Municipal Sewage	38
G-M2	Municipal Sewage	1.900
G-M3	Municipal Sewage	2.300
G-M4	Municipal Sewage	15.500
G-M5	Municipal Sewage	26.500
G-M6	Municipal Sewage	33.800
G-M7	Municipal Sewage	100.000
G-M8	Municipal Sewage	240.000
G-M9	Municipal Sewage	390.000
G-M10	Municipal Sewage	432.000
G-I1	Industrial (Machin.) / Municipal Sewage	1.000 4.200
G-I2	Industrial (Refinery)	7.200
G-I3	Industrial (Paper)	22.200

TABLE 27: INSPECTED PLANTS IN GERMANY

An outlook on information types and inspected treatment plants:

- Photo documentation of technical equipment: 10 plants

- Expert interview with plant management: 13 plants

- Questioning of practical staff: 13 plants

Important Aspects Regarding Data Collection in Germany

Similarly like in India and China, plants in different regions of the country where chosen for the comparative data collection. Location and access of existing treatment plants was unproblematic. As technical facilities for wastewater treatment exist also outside major development centres and the living conditions are very similar all over the country, it was not required to concentrate only on urban areas for the data collection. As visible in figure 31, plants both in urban areas like Berlin, Munich or Karlsruhe and also more rural areas like between Heilbronn and Nuremberg or between Nuremberg and Munich in southern Germany were inspected.

Prior to the plant visits, all plants were contacted in written form and by telephone. Information and confirmation documents were transferred. Formal permissions from municipal administrations were not required in any of the plants. Except one big industry, all contacted treatment plants agreed to take part in the study. Appointments for the plant inspections had to be organised at least several days in advance. Neither for plant information and staff questioning nor for photographic documentation, any basic restrictions existed in the visited municipal sewage treatment plants. The expert interview with the plant management was unproblematic in all visited plants – no objections were observed regarding any information field. The equipment inspections and staff questionings were also unproblematic. No mistrust neither from the management side, nor from the test persons was detected. Like in India and China, a sensitive approach, respect and understanding for the work reality of the test person were important for the questioning situation.

FIGURE 32: PROFESSIONAL POSITION OF QUESTIONED STAFF IN GERMANY

6.2.2 Guided Expert Interviews

General Aspects

Table 28 shows basic practical aspects that had to be considered for the implementation of the guided expert interviews.

Organisation	▪ Time Availability ▪ Avoidance of Interruptions ▪ Explanation Voice Recording ▪ Guide Questions
Interview Situation	▪ Competence Field ▪ Competence Level ▪ Interest ▪ Understanding ▪ Confidence ▪ Relevance

TABLE 28: PRACTICAL ASPECTS OF INTERVIEW IMPLEMENTATION

Regarding the organisation of the expert interviews, sufficient time availability proved to be important, as otherwise it could be assumed that the test person would say anything to get rid of the time stealing interviewer. Interruptions by telephone calls or staff members could not be avoided completely, especially if a test person was involved in important and urgent processes. In most cases, the interview was considered as an interesting change in the stressful work flow of the test persons. The requirement that the interviews were recorded with a voice recorder for detailed data analysis had to be transmitted in a very careful way, especially in India and China. Although confidence and anonymity were guaranteed and confirmation documents were presented, some test persons, especially from administration, did not allow voice recording.

In the interview situation, most experts appreciated the possibility to express their opinion in the expert talks. Based on the interview guidelines, the different information fields were touched and widened according to the expected competence and interest fields of the test person. The creation of confidence and a comfortable atmosphere could be supported by explanations and questions regarding personal experience and observations of the interviewer.

Regarding the quality of the given information, the professional role of the test person had the greatest influence. Especially administration staff was choosing the words very carefully so that politically correct statements where given in some extreme cases. The majority of interviewed test persons were very open in the interview situation and even market strategic information was given from manufacturers and consultants to certain extend. The following recommendations given by Kuniavski (2002) proved to be very useful and important in the interview situations:

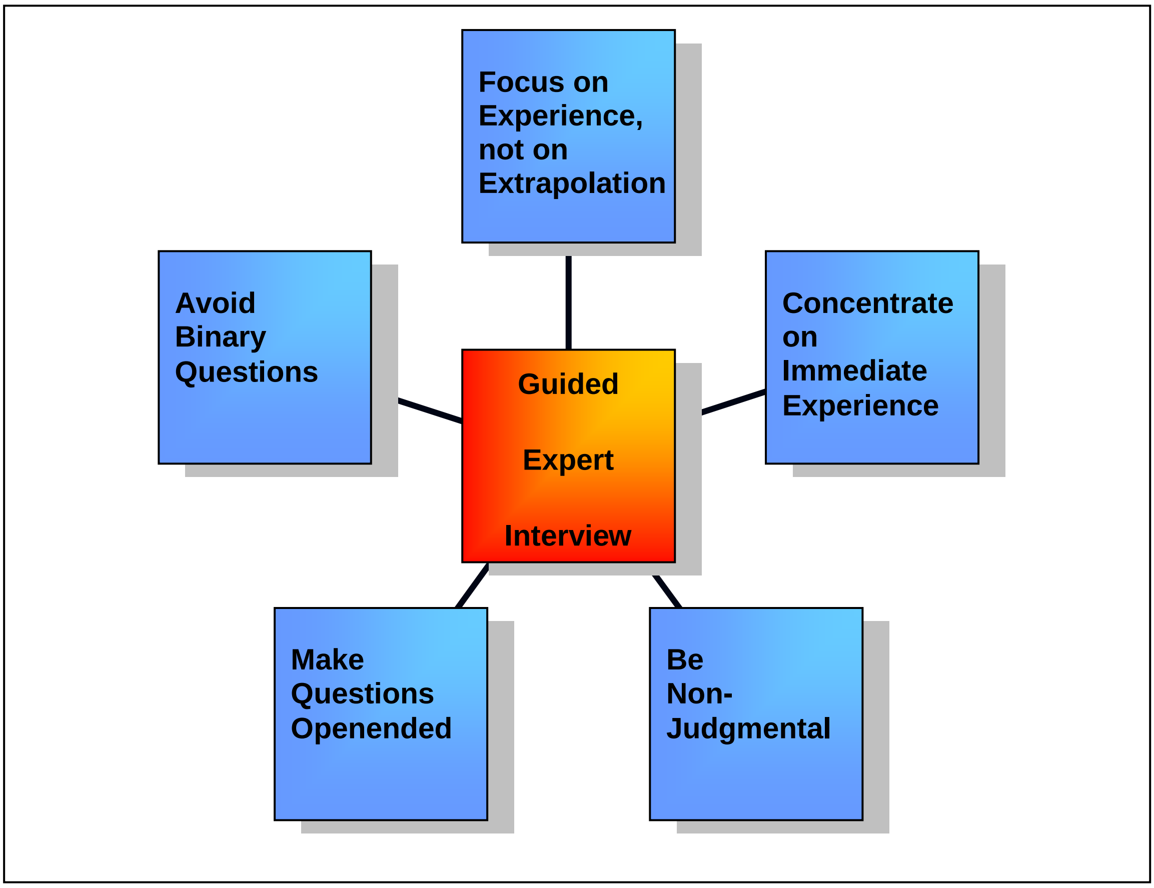


FIGURE 33: PRINCIPLES FOR EXPERT INTERVIEW IMPLEMENTATION (ACCORDING TO KUNIAVSKI, 2002)

All interviews started with a very broad question concerning the environmental situation and possible reasons for the current state, in order to get information on the basic position towards environmental issues and the awareness regarding possible problem fields (see also table 18). In the start-up phase of the interview, the test person was confronted with an overall – even pathetic – topic, from which more detailed research questions could be approached. The test person was motivated to speak from his/her own experience, whenever possible ("From your experience, how do you see…?"). Also, examples from the media were mentioned in order to create a discussion base for certain questions. In certain cases, own impressions or assumptions about certain topics were mentioned, in order to initiate a comment. For very quiet and careful interview partners, the positioning of the interviewer as an observer of obviously incompatible facts, who is seeking for an explanation from the test person as "expert", proved to be useful. Progress and relative openness of the interviews required a high grade of sensitivity and concentration in order to realise changes in the test person's mood.

Figure 34 gives an outlook on the regional distribution of all interviewed experts:

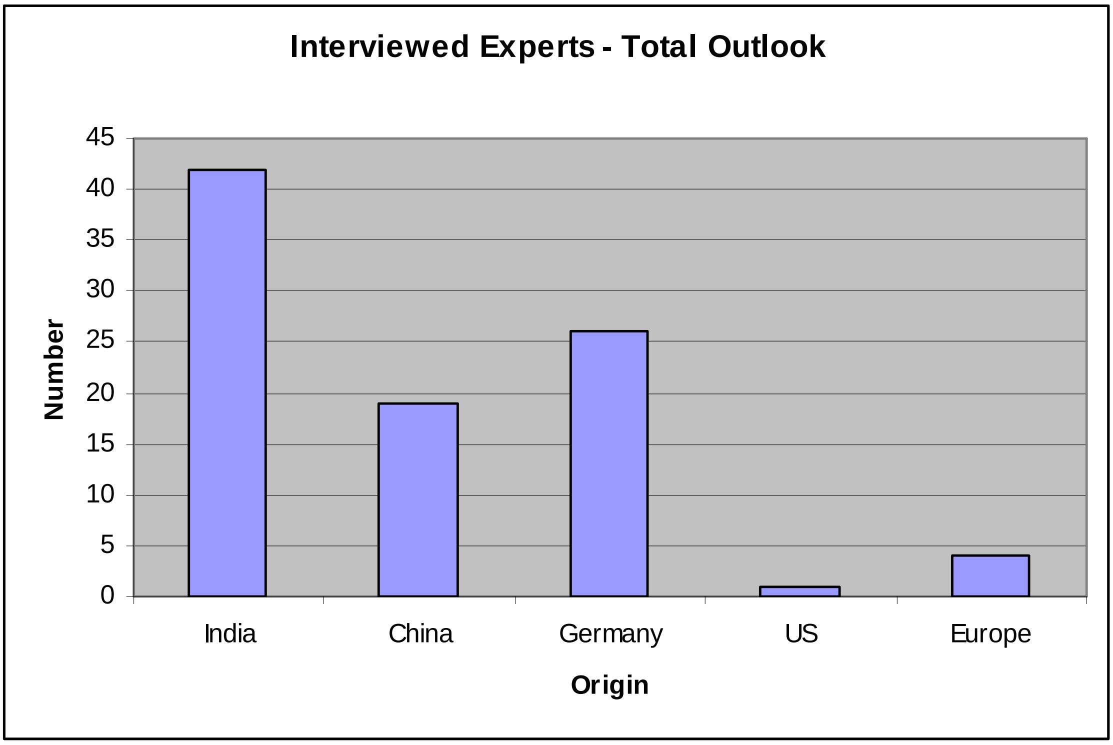


FIGURE 34: INTERVIEWED EXPERTS – TOTAL OUTLOOK

In total, 92 guided expert interviews were carried out and analysed in this study. Western experts in India and China who are working for western institutions or companies were classified according to their origin. The main criterion for the classification is the cultural background of the test person, not the location of the actual work place. For further considerations, three groups were formed: the group of Indian experts, the group of Chinese experts and the group of Western experts, that includes – beside German test persons – one US expert for educational aspects in China, three French experts and one Danish expert.

The realisation of the expert interviews in the different countries is presented in the following paragraphs.

Expert Interviews in India

The organisation of the expert interviews in India was short-term in most cases - appointments were fixed only one or two days in advance in most cases according to the time availability of the test persons. Potential interview partners were identified partly prior to the data collection, whereas the majority of the test persons were selected during the research journey, according to the criteria, presented in table 19.

Interruptions by telephone calls or staff were unavoidable in some interviews. The fact that the interview was recorded by a voice recorder was a very critical point. Although anonymity and confidence were guaranteed, several test persons from administration did not allow voice recording so that notes were taken and a report was written after the interview. Some experts allowed an interview only after having seen a list of the intended questions prior to the interview.

Cultural aspects like appreciation of the social status and respect were fundamental for the interview situation in India. Essential for the interview situation was the avoidance of any impression of test situation or criticism. The test persons were confronted with neutral observations that put the respective test person in a specialist position. A strong focus on technical and purely academic topics could be detected at many test persons. In general, all questions were answered, according to the test person’s competence background. In most cases, the test persons answered very openly and a positive interview atmosphere could be created. Some test persons regarded the interview also as a certain knowledge exchange, depending on the respective social and professional position.

Figure 35 shows the quantitative distribution of the interviewed Indian experts. In total, 42 experts were interviewed in India. Ten experts from water and wastewater departments of municipalities and seven experts from control authorities were interviewed. From the private sector, six consultants and one manufacturer were interviewed. An enterprise with manufacturing and consulting competences was classified as a manufacturer. The group of NGOs includes organisations from the educational field, environmental protection and also technical support in cooperation with agencies of the German development cooperation. From the education field, the director of an Industrial Training Institute (ITI), the director of a municipal environmental training centre and a teacher of a Polytechnique were interviewed. In order to get also information from the media point of view, the editor of a well known magazine on environment technology and pollution control was interviewed.

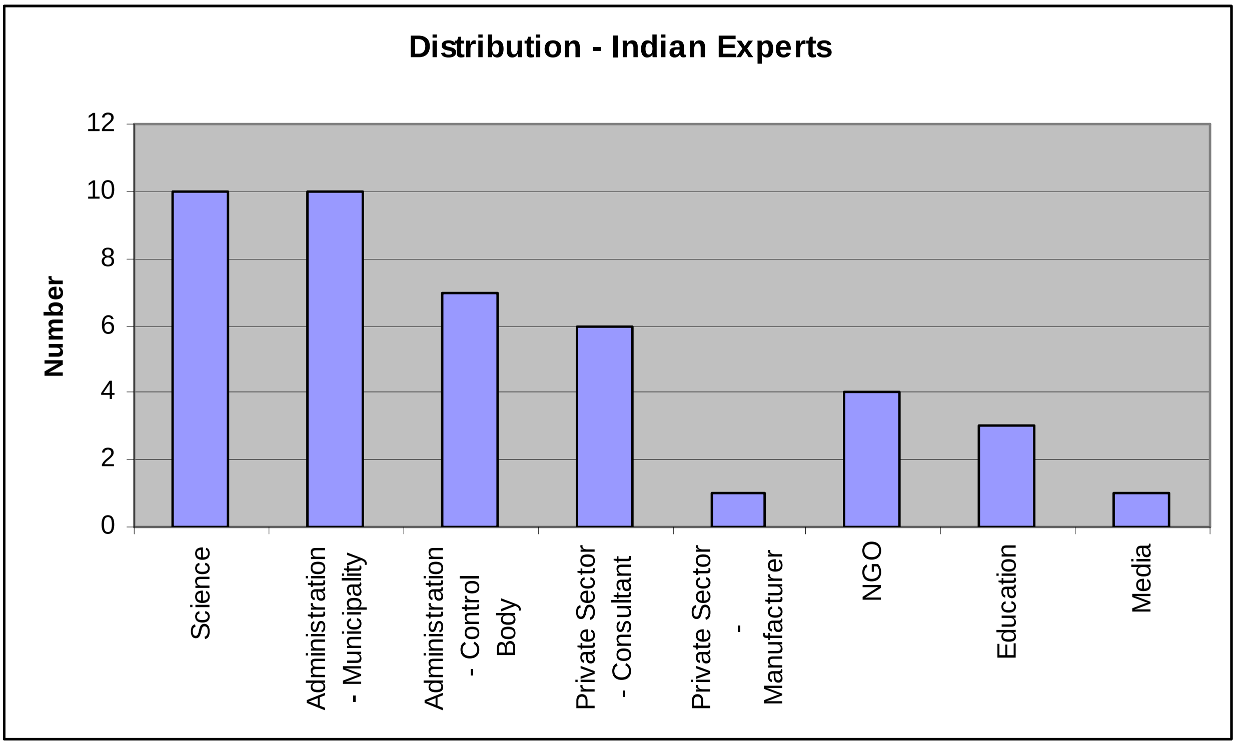


FIGURE 35: DISTRIBUTION OF INDIAN EXPERTS

Expert Interviews in China

Like in India, interviews with Chinese experts were organised short term. After an initial contact via email and/or via telephone, appointments were fixed one or two days in advance. In several cases, language problems occurred, so that the interview required high concentration from both sides and focus on key aspects. In many cases questions had to be repeated several times. Except in two cases, all interviews were carried out without interpreter, due the inevitable information and confidence loss that is caused by the communication via a third person. Interruptions during the interviews were rare – in some cases, the test person preferred the interview to be carried out in a private atmosphere, like in combination with a lunch or dinner. Voice recording was only a critical issue in interviews with experts from administration – in two interviews, notes were taken and interview reports were written. Almost all question fields could be discussed very openly with the test persons. The topic product piracy was a sensitive topic. Many test persons obviously faltered between their own opinion and the potentially social expected opinion.

For the interview situation, confidence was very important, not only for specialists from administration. In many cases criticism in general was only expressed, if absolute confidence was assured and the test person felt safe and comfortable. Almost all experts emphasised a positive role of the government. Most experts – especially from science – were very much focused on technical and academic aspects. Figure 36 gives an outlook on the interviewed experts in China:

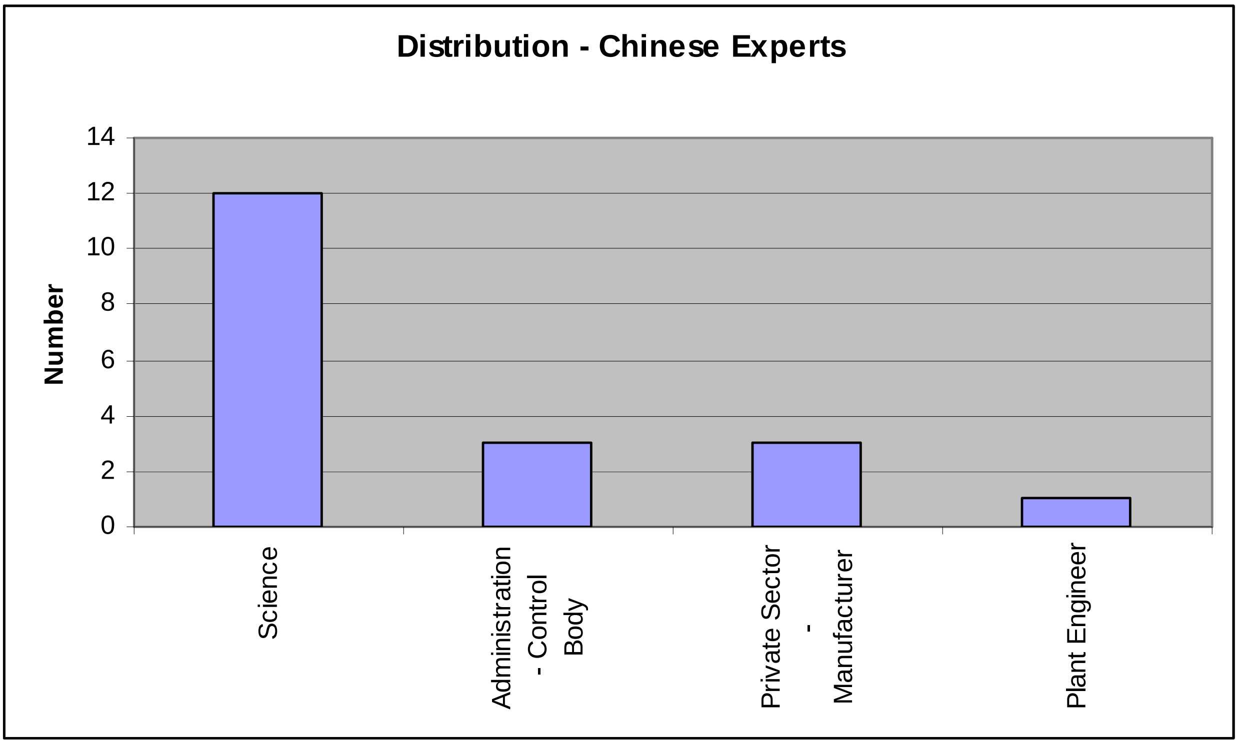


FIGURE 36: DISTRIBUTION OF CHINESE EXPERTS

In total, 19 guided expert interviews were carried out in China. Due to contact and language difficulties under the given data collection scenario, a stronger focus was set on the group of scientists. One interview was carried out with a plant engineer who has long term experience in the technical cooperation within the German development assistance and who could give interesting information from the Chinese perspective.

Expert Interviews in Germany

The interview organisation in Germany required much more pre-planning than in India and China. Not only high ranking specialists have a tight work schedule so that most interviews had to be planned several weeks in advance in most cases. Like in India and China, whenever possible, the interviews were integrated into the data collection journey, during which also the treatment plant visits were carried out parallel. Voice recording wasn't a problem for any of the interviewed experts – all touched question fields could be discussed very openly with all experts.

Compared to the expert interviews carried out with Indian and Chinese experts, the interviews with western experts were very much subject oriented. Situative or status aspects played a much minor role. Compared to interviewed Indian and Chinese experts, questions were answered very directly in most cases and words were chosen less carefully by the test persons from Germany, other European countries or the US. Understanding problems were not observed due to the similar cultural background of test person and interviewer. Although confidence and anonymity were assured to each test person, these aspects were not important for most experts. The following figure shows the quantitative distribution of the interviewed western experts.

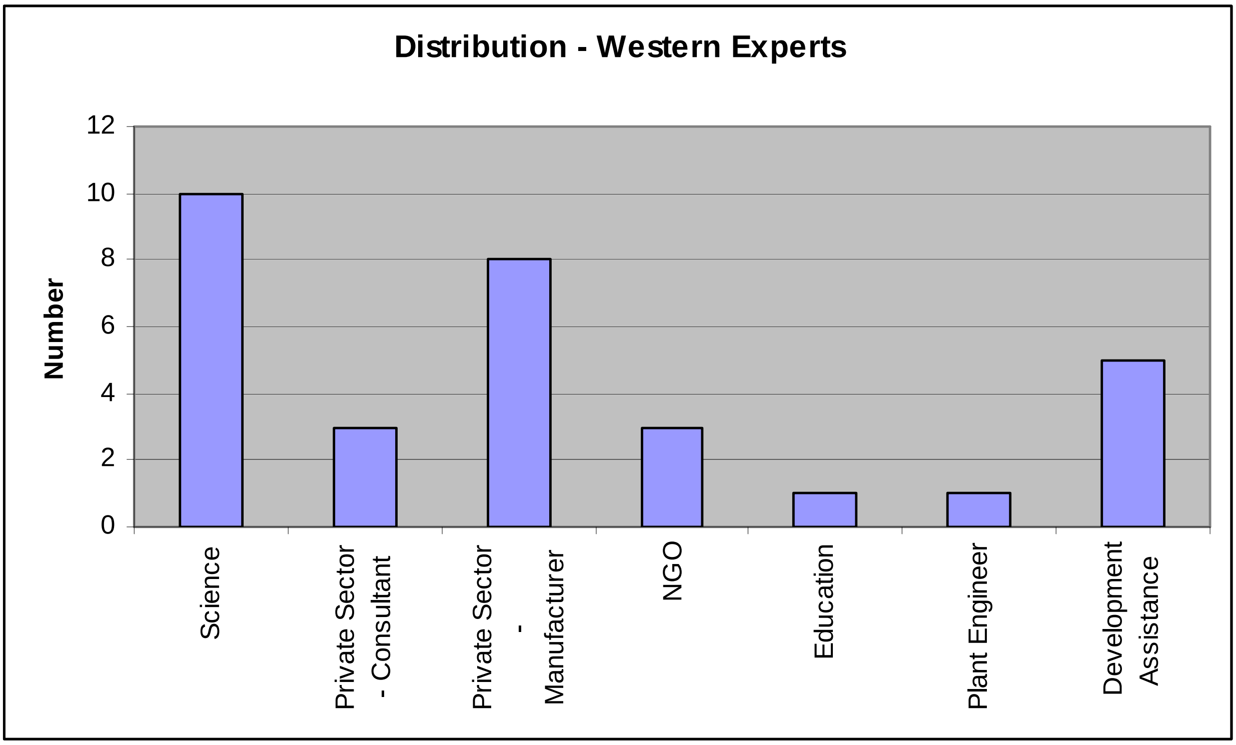


FIGURE 37: DISTRIBUTION OF WESTERN EXPERTS

In total, 31 western experts were interviewed. Other than experts from India and China, who were questioned with focus on their own country, the western experts were questioned with regard to developing and newly industrialising countries. As the major criterion for the choice of western interview partners was that they have experience with developing or newly industrialising countries, no western administration staff from municipalities or control institutions was interviewed. Instead, several experts from the German development cooperation with experience with developing and newly industrialising countries were interviewed. This group includes specialists both from governmental and non-governmental institutions. The group of NGOs consists of German technical and trade associations in Germany, India and China. In order to get also information from a European perspective, two interviews with experienced experts from leading French enterprises and one Danish enterprise in the field of environmental services and equipment manufacturing were interviewed. One expert interview was carried out with a German engineer with long–term experience in the Chinese wastewater sector.

6.2.3 Implementation Pilot Training

Implementation Steps & Plants

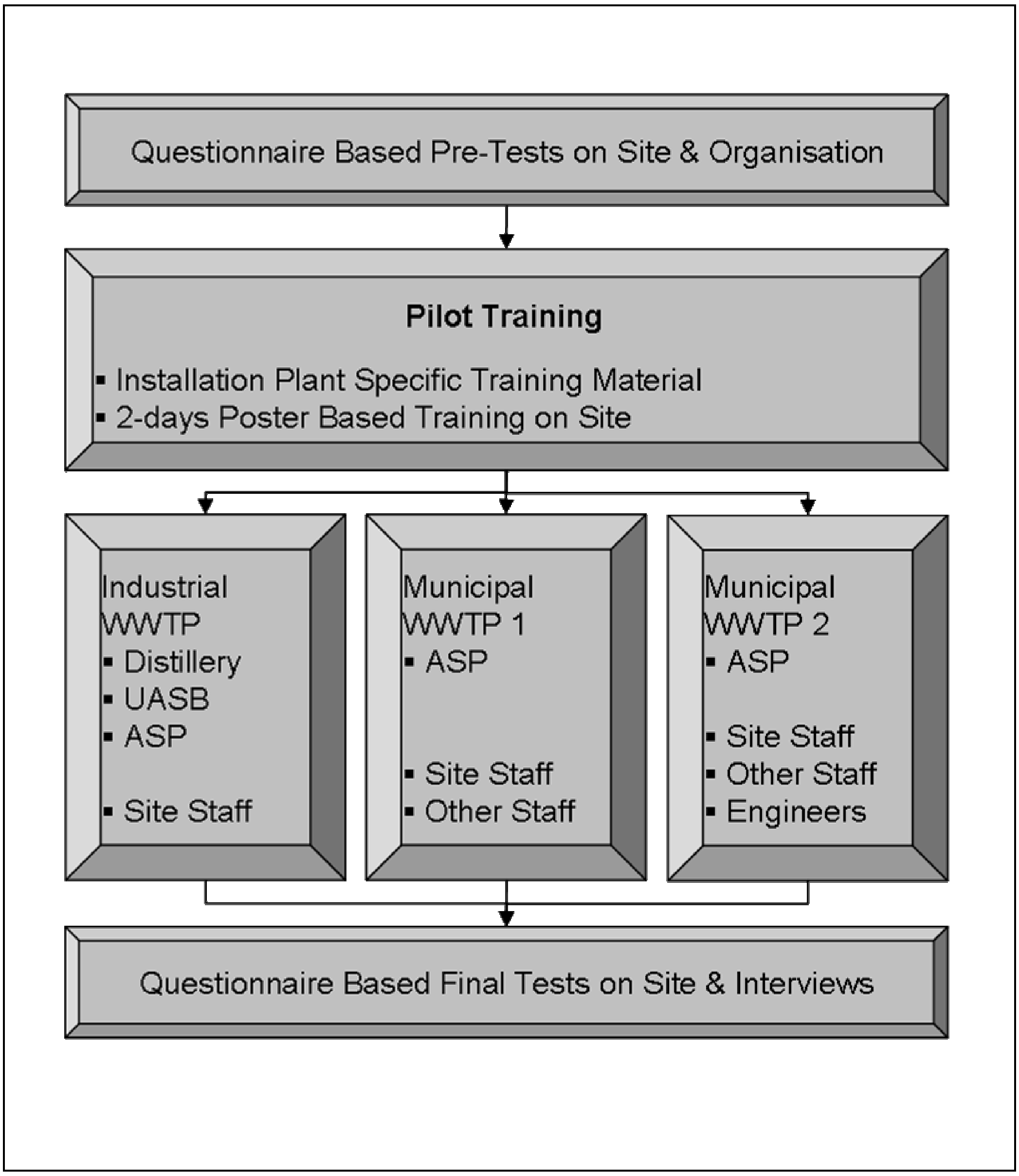


FIGURE 38: IMPLEMENTATION OF PILOT TRAINING

Figure 38 gives an outlook on the implementation steps of the pilot trainings. In total, three trainings were carried out. In order to gain the information, especially regarding existing work situation, possible training contents and suitability of the developed poster based training concept, a part of the training participants was questioned prior and after the trainings. Due to the time demand of the questioning and organisational constraints, questioning of all participants would not have been possible. The questionnaires are attached in appendix D. Of special importance are the observations of the training leader during the trainings.

Media

As main medium a poster set showing the main treatment steps and the streams between the steps of the plant was installed. That way it was assured that the participants of the seminar have always a clear view on the overall plant concept. For the seminar leader the poster wall was a suitable basis for the given explanations. In order to allow detailed visualisations in a flexible way depending on the progress of the seminar and the questions of the workers, an A1-size chart block was used for technical sketches and basic formulas. In addition, printouts and a Laptop were used in some plants for illustrations.

Subjects & Training Progress on the Different Plants

As from pre-investigations a relatively low knowledge background could be assumed, the focus was set on a basic understanding and the relations of the main plant processes. All trainings started with a general introduction on wastewater. Basic questions like the following were covered:

- Why is wastewater a pollutant?
- What are the characteristics of wastewater?
- What are the main parameters of wastewater?

That way, a basic awareness for the relation between wastewater, environmental pollution and hygiene should be initiated. After these very basic considerations, the different plant stages of the respective plant were discussed. The following schedule was followed:

1) Theoretical Basics

2) Main Parameters

3) Structure & Design Aspects

4) Operation & Maintenance Aspects

In the following paragraphs, the pilot training course in the different plants is presented.

Pilot Training on Plant A

The plant is in operation since 1988 and is treating the wastewater of a molasses based distillery and a brewery in an industrial complex in northern India. The design capacity of the plant is 670m³/d. The wastewater is treated in a three-stage process, consisting of a UASB reactor and two activated sludge processes in line. Seventeen persons are working on the plant, including foremen and chemist – one plant manager, four chemists, one electrician, two fitters, one welder, four operators and four helpers. In a previous study on the plant efficiency in 2001, a good social climate between the plant manager and the working staff was stated. For that reason, the plant manager was used as co-seminar leader and interpreter in the pilot training. In total, 7 practical staff members participated in the pilot training. On the first day, 4 training participants were questioned based on a questionnaire. Staff questioning, as well as the training, were carried out in the plant manager's office. After this the first part of the training was carried out for about 2.5hrs starting at 1pm. On the second day, the training started at 10am and was finished at 3pm, followed again by short questionnaire based interviews with the same workers that were already questioned before the training.

On the first training day, yeast tank, pumping system and anaerobic digestion/UASB was discussed. On the second training day, activated sludge process, consisting of aeration tank and clarifier was discussed in detail, comprising oxygen supply, Mixed Liquor Suspended Solids (MLSS) and calculation of the sludge recycling rate. Beside the discussion of the sludge handling and sludge drying bed design, general considerations on plant monitoring and work safety were covered. Finally, an inspection-walk over the plant was carried out with the workers in order to create awareness for potential work safety risks. The training ended with the presentation of photos of treatment plants in Europe.

Pilot Training on Plant B

The plant is in operation since 1998 and is treating municipal wastewater in an extended aeration process. The design capacity of the plant, which is located in Andhra Pradesh, is 20.000m^3/d. Twenty-two persons are working on the plant – four engineers, nine technicians/operators of different disciplines and nine workers.

In total, 4 staff members participated in the pilot training on this plant. The training participants consisted of workers from plant B and another plant in the same city, which is treating wastewater only mechanically. As some of the participants had a long way to reach the STP and arrived very late, also in this plant full day trainings could not be carried out. On the first day, all 4 participants were interviewed with questionnaires. Staff questionings and following pilot training were carried out in the office of the plant manager, whereas the plant manager was almost never present during the trainings. On the first day the training was carried out for about 3 hrs starting at 1pm. On the second training day, the training started at 1:30pm and was finished at 5:15pm, followed again by questionings of the participants.

On the first training day, pump system, screening system and grit separation were covered. In addition, a first introduction on the principles of activated sludge process and extended aeration was given. On the second day, the activated sludge/extended aeration process was discussed in detail based on a real example. That way the importance of the meaning of parameters like Mixed Liquor Suspended Solids (MLSS), Sludge Volume Index (SVI), Sludge Retention Time (SRT), etc. could be demonstrated. Also the procedures of the most important analyses for the control of activated sludge process/extended aeration were discussed. Basic formulas like the determination of the sludge recycle rate were presented. The function principle of decanter centrifuge was shown in detail. The importance of proper maintenance was highlighted. The basic metabolism and important operation parameters of anaerobic digestion were discussed, as the primary sludge of the other plant of the city, which is sewage only mechanically, is fed into anaerobic digesters. Awareness for the sensitivity of the anaerobic processes should be created. After the discussion of the major treatment steps, aspects of work image/motivation, plant monitoring and work safety were covered. In order to raise awareness especially for work safety, an inspection tour over the plant was carried out and possible dangers were pointed out.

Pilot Training on Plant C

Plant C is in operation since about ten years and is treating municipal wastewater plus a relatively high quantity of effluent from small scale industries in an extended aeration process. The plant is located in Goa and has a design capacity of 500m³/d. In total, 22 persons participated in the training. The training group consisted of workers from plant C and another STP in the same city, which is based on cyclic activated sludge process. Other than in the pilot trainings carried out in plant A and B, two participants were superior engineers. Five workers were interviewed prior and after the training. Training and most of the staff questionings were carried out in a separate room in the STP. On the first day, the training was carried out from 10:30am until 16:15pm, interrupted by the lunch break. On the second day, the training started at 10:30am and was finished at 14:30pm, followed by final tests after the lunch break.

On the first training day, the principles of activated sludge process and extended aeration were covered, after the discussion of pump system, screening system and grit separation. Like in the pilot training in plant B, basic formulas like the determination of the sludge recycle rate were presented. A more detailed discussion was carried out on the second training day. The basic procedures for the control of activated sludge/extended aeration process, as well as general aspects of plant monitoring, sampling and documentation were covered. For the staff, work safety was obviously an interesting field, what could be observed in the trainings. The importance of protection clothes, helmets, rescue and fire fighting equipment was highlighted. Potential possibilities to increase the work image were pointed out. An inspection tour over the plant was carried out and possible danger points were explained to the workers. The function principles of decanter centrifuge and anaerobic digester were covered at the end of the training, as these technologies are used on the cyclic activated sludge plant. The following photo shows the training situation on plant C. The results are presented and discussed in chapter 7.5.

FIGURE 39: TRAINING SITUATION ON MUNICIPAL WASTEWATER TREATMENT PLANT

7 Results & Discussion

7.1 Wastewater Technology Status & Trends in India

7.1.1 Efficiency, Technologies & Treatment Plant Operation

Most of the inspected plants were built or upgraded in the last 10-15 years. Activated sludge process is the most common treatment process that is used in 29 plants, out of which 2 are industrial plants, where it is used in combination with anaerobic technology. Regarding anaerobic treatment, UASB-technology is the most spread technology and is used on 3 of the inspected plants, followed by an activated sludge stage or a facultative aerobic step. The first realised large scale membrane bioreactor plant for sewage treatment was also inspected and included in the data analysis. One plant is based on trickling filter technology, another one on rotating immersion disks. One purely mechanical treatment plant is currently upgraded by a UASB reactor step.

Efficiency

In order to describe the purification efficiency of the inspected treatment plants, average inlet and outlet values, as well as required target values were determined based on the information given by the plant management. Figure 40 shows the purification efficiency for BOD of 20 inspected STPs – for data protection reasons anonymised. The inlet values of most plants are in a range between 150mg/l and 300mg/l. Plant I-M8 is an exception – in this plant diluted wastewater from open drains is treated. Looking at the values for BOD, the purification efficiency of most plants is between 80% and 95%, with BOD outlet values between 5mg/l and 30mg/l. One plant is designed for nitrification/denitrification process and achieves a BOD removal efficiency of 99%. One plant that is based on membrane bioreactor technology is designed for nitrification and achieves almost 100% BOD removal efficiency. Also plant IM-5 is designed for nitrification. Plant I-M15 is the only plant that has only a mechanical treatment step with a purification efficiency of 51% in terms of BOD. Almost all plants discharge into surface water bodies. The outlet of the membrane plant is used for park irrigation - the filtered and disinfected effluent of another plant is sold to industry. Three plants don’t achieve the required discharge limit of 30mg/l BOD for most plants. Exceptions like 100mg/l BOD or 20mg/l BOD or even lower values exist for some plants. The discharge standards for India are listed in chapter 5.1.1.

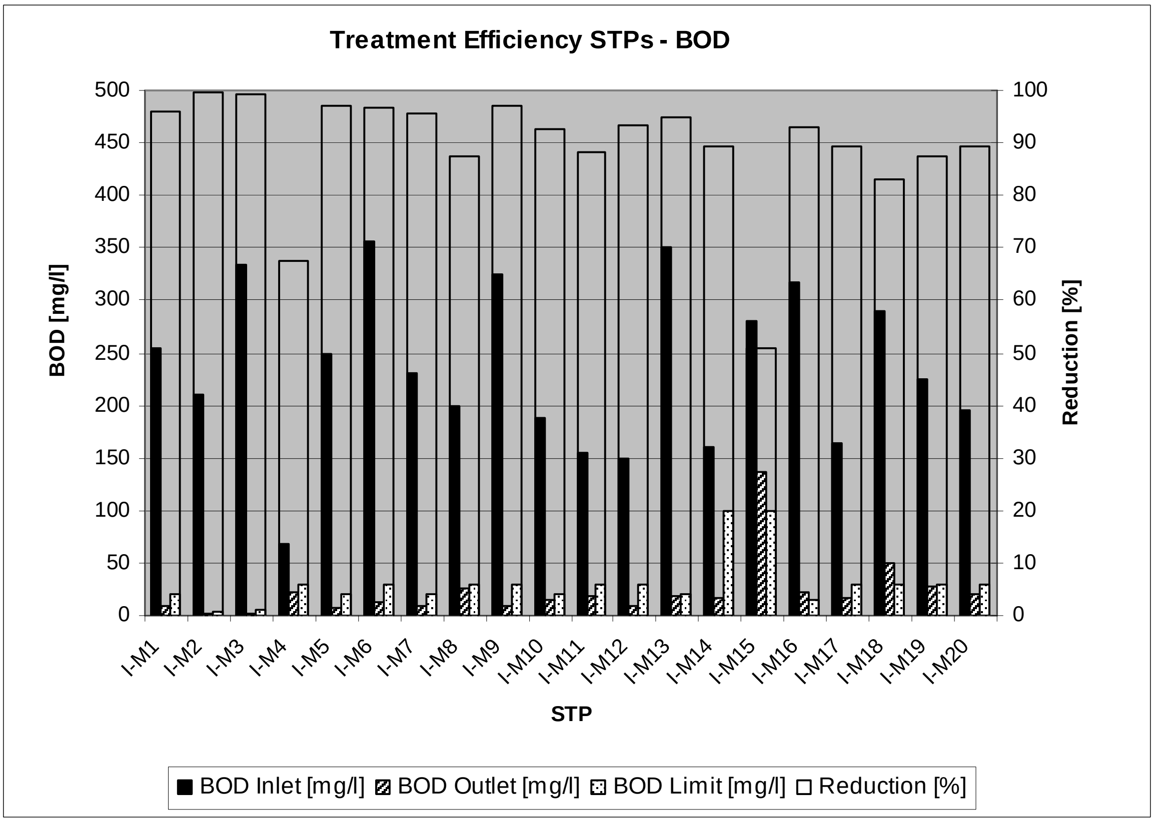


FIGURE 40: TREATMENT EFFICIENCY STPS INDIA - BOD

In municipal plants, the inlet values for COD of most plants are between 300mg/l and 700mg/l and correlate in a ratio of about 2:1 with the values for BOD. The COD elimination rate is between 80% and 95% for most plants. Limit exceedings of COD could not be found for the inspected STPs. Regarding suspended solids, the inlet values are between 250mg/l and 500mg/l. Elimination rates of suspended solids are between 70% and 90%. The limit of 100mg/l SS for discharge into water course was exceeded in one plant (see also chapter 5.1.1.). Specifically for the inspected STPs in Delhi (plants IM-6, IM-9, IM-10, IM-16, IM-17, IM-18, IM-20), an average BOD removal efficiency of about 92% could be determined, whereas the values are in a range between 83% and 97% (see figure 40). Regarding COD, the removal efficiencies for the inspected plants in Delhi could be determined to be in a range between 79% and 95%, with an average value of 89%. For SS, the removal efficiencies are around 90% for most inspected plants in Delhi.

In the industrial field, strong differences exist regarding the different wastewater parameters, depending on the respective industry branch.

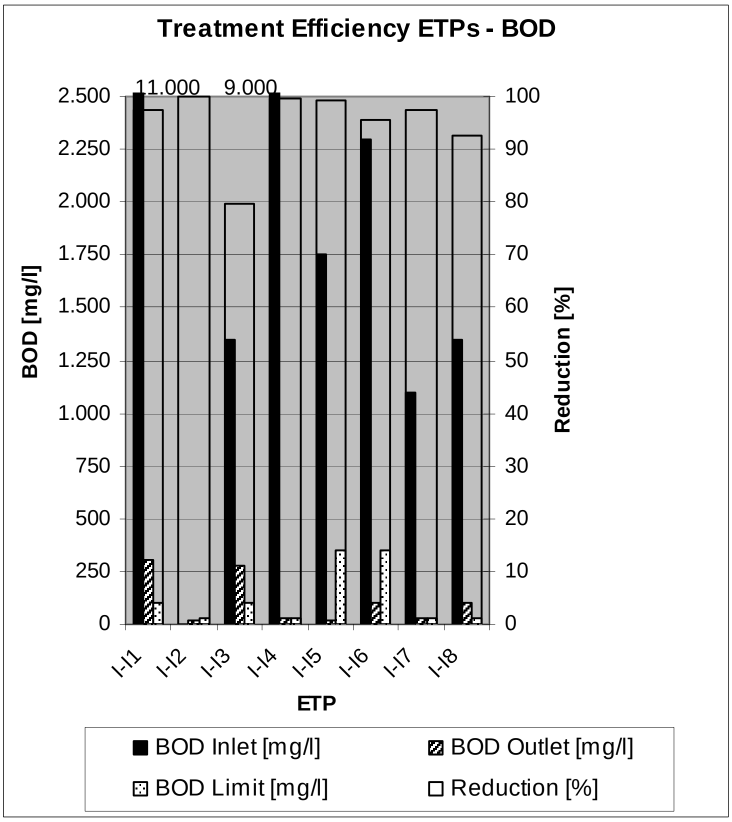


FIGURE 41: TREATMENT EFFICIENCY ETPS INDIA – BOD

As visible in figure 41, the inlet values for BOD are in a range between 11.000mg/l BOD for a pharmaceutical industry and 1.100mg/l BOD for an inspected leather industry. The purification efficiency of the inspected industrial plants is higher than 80%, but in 3 plants the outlet value for BOD is above the required outlet standard. Very problematic is the treatment of dye wastewater (plant I-I3 and plant I-I8), mainly due to the extremely high values for total dissolved solids (TDS) and other substances that are difficult to biodegrade. The treatment of wastewater from pharmaceutical industries (plant I-I1 and plant I-I6) is also problematic, as visible on the limit exceeding of plant I-I1.

Extremely high COD inlet values exist in one pharmaceutical industry and one distillery, with COD values of about 17.000mg/l, respectively 17.500mg/l. Also the concentration of suspended solids is strongly depending on the industry branch and is between 600mg/l SS and 2.250mg/l SS at the inspected effluent treatment plants. Four out of eight inspected plants exceed the required discharge limits in terms of COD, whereas all plants meet the discharge standards for suspended solids. Very problematic are high concentrations of Total Dissolved Solids (TDS) that reach values of 12.500mg/l in a leather industry and 30.000mg/l in an industry for dye and dye intermediates. Currently no effective technical solutions for TDS removal exist on the inspected ETPs so that in the case of the leather industry, the discharge concentration is equal to the inlet concentration. In case of one of the pharmaceutical industries, a reduction of about 16% is achieved. For the distillery, an outlet value of 1.626mg/l TDS was determined (analysis value from 2001). The discharge standard for TDS is 2.100mg/l.

Technologies

For the data analysis, structural, machinery and control equipment are analysed separately. Figure 42 shows the distribution of the inspected equipment on which the photographic analysis of the technology in India is based.

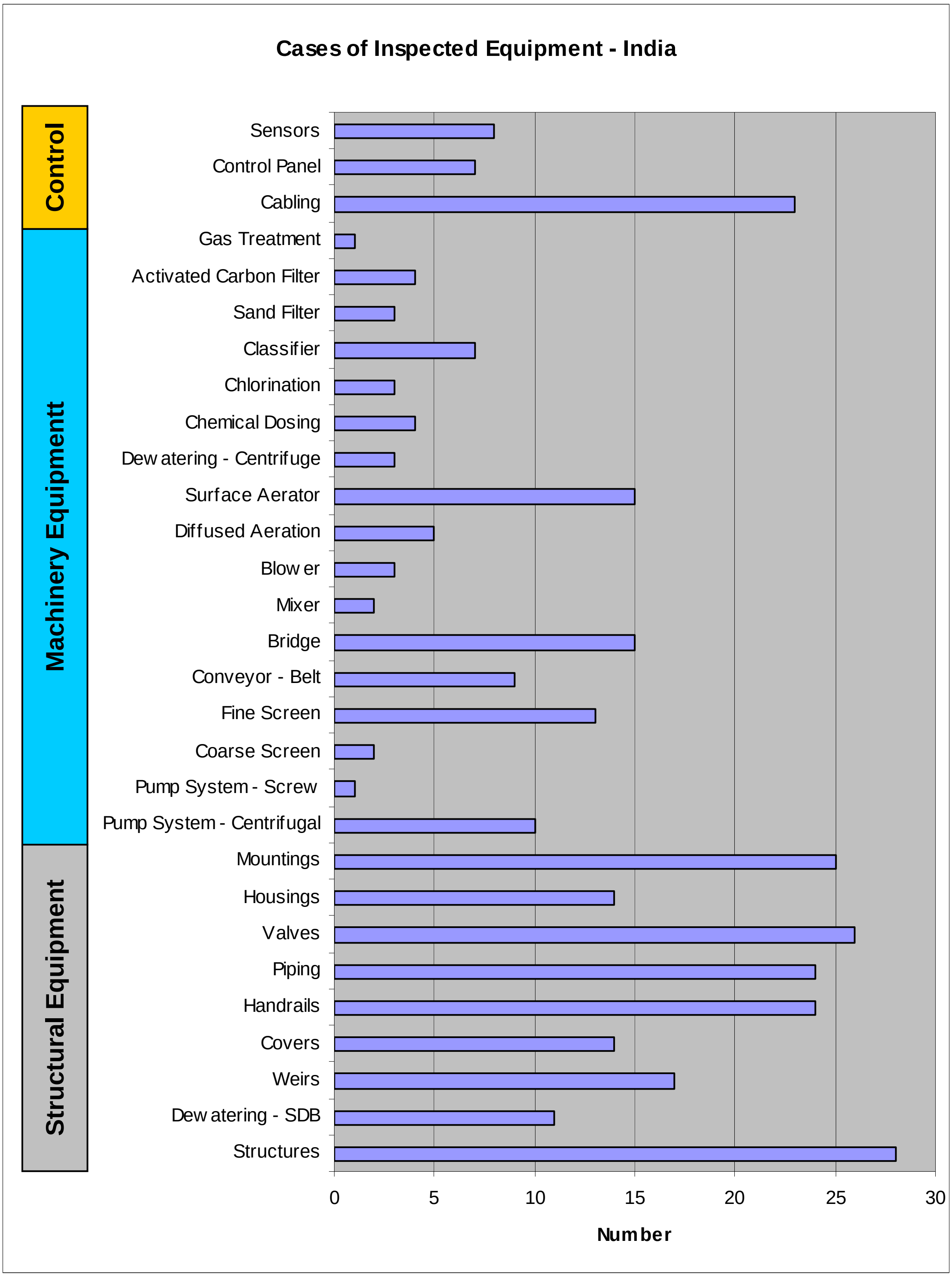


FIGURE 42: CASES OF INSPECTED EQUIPMENT IN INDIA

In the following paragraphs, the results of the analysis based on the criteria shown in chapter 6.1.3 are presented.

Structural Equipment

Age of Structural Equipment

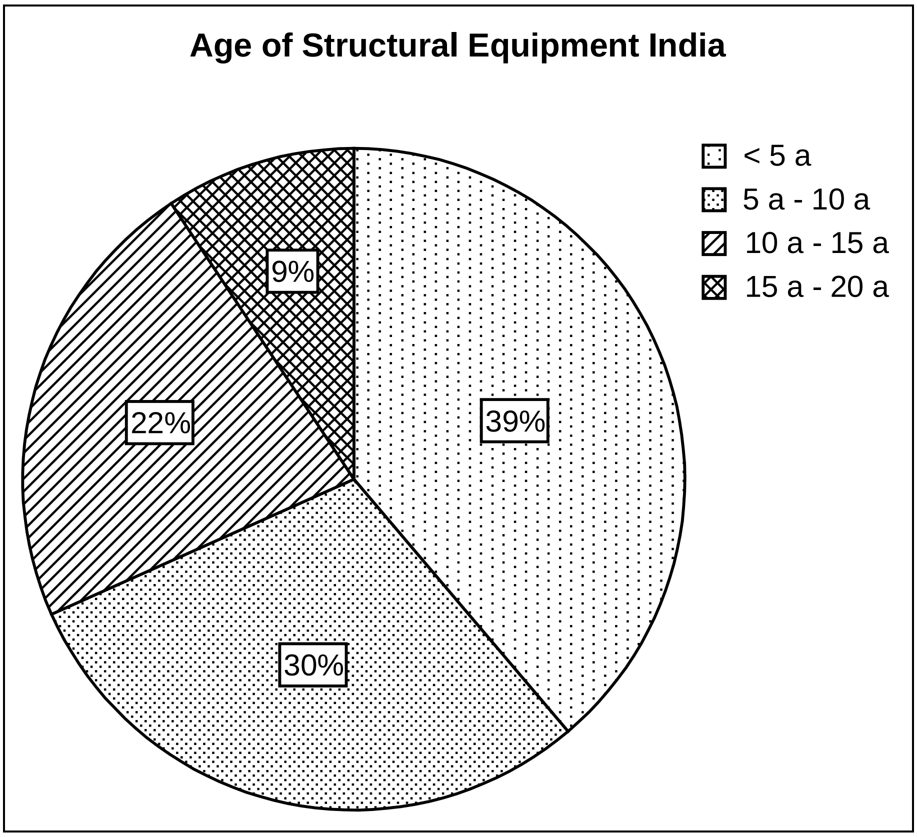


FIGURE 43: AGE OF STRUCTURAL EQUIPMENT IN INDIA

As visible in figure 43, about 39% of the structural equipment is less than 5 years old, about 69% is less than 10 years old, that means the treatment plants are relatively young. This is an important factor that has to be considered in the detailed equipment considerations. The average age of the inspected structural equipment is about 8 years.

Figure 44 gives an outlook on the determined index values for the parameters that were defined in chapter 6.1.3.

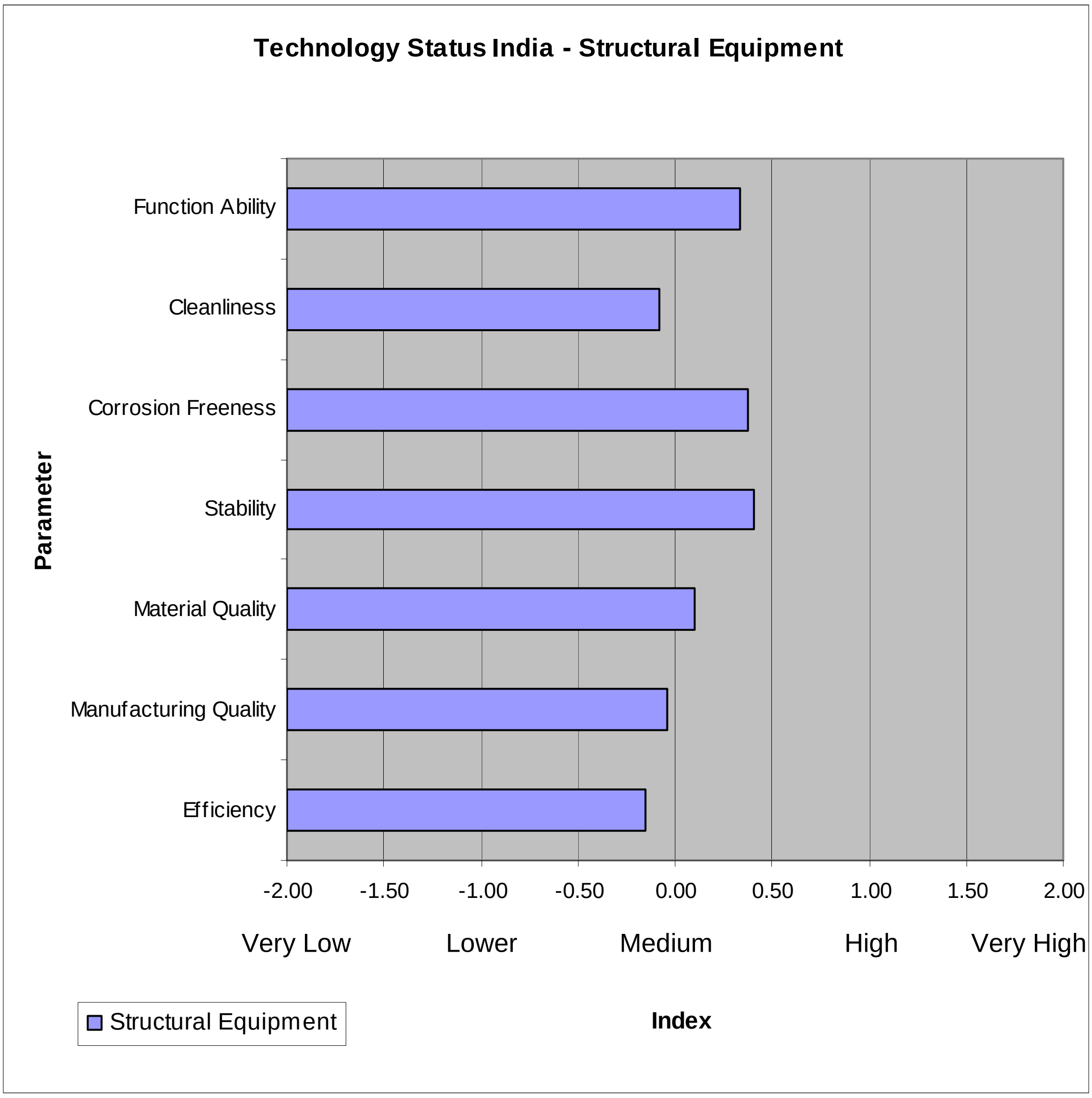


FIGURE 44: TECHNOLOGY STATUS INDIA – STRUCTURAL EQUIPMENT

The consideration of the function ability based on the criteria mechanical/physical intactness and durability leads to an index value of 0.33 and is in the upper medium range. Characteristic are moderate durabilities of the equipment, whereas severe physical damages were hardly detected.

Cleanliness as one main indicator for maintenance awareness is relatively low on the inspected plants. Concrete surfaces and covers are often very dirty, mountings and support structures are very dusty and dirty (see figure 45 and 46). Especially the detail/technical cleanliness is relatively low so that an index value of -0.08 was determined. Weirs are often very dirty and are obviously not cleaned (see figure 45). Automatic cleaning brushes installed on scrapers or bridges hardly exist.

FIGURE 45: FLAKING AND DIRT ON CONCRETE WEIR EDGES ON STPS IN INDIA

FIGURE 46: CORRODED HANDRAILS AND MOUNTINGS ON STPS IN INDIA

For the parameter corrosion freeness, an index value of 0.38 could be determined. Very often, surface corrosion can be detected at covers and mountings, because they are out of metal, which is not sufficiently coated. Housings of outdoor control panels, protection covers for surface aerators etc. are very often severely corroded. In many cases, obviously corroded metal surfaces are overpainted and not treated properly before coating. The quality of protection coatings of normal steel equipment is differing from plant to plant, whereas high quality coated surfaces were hardly found. The fact that severe flaking could be detected in some cases, although obviously coatings are applied, indicates maintenance deficits and a lack of awareness for important details. At handrails the connection to the concrete walk is a critical point regarding corrosion (see figure 46). The upper part of handrails is much less corroded and in many cases almost corrosion free. Critical are fissures and flaking of concrete structures and plastering. Visible and corroded reinforcement steel was detected only in very few and old plants.

The stability of structural equipment could be determined with an index value of 0.41. Concrete structures are characterised by a moderate, in some cases also slightly overdimensioned material thickness. The stability of piping is a critical aspect in many plants. Pipes are very often installed unorganised from one point to the other without any or with very primitive mountings (see figure 47).

FIGURE 47: UNORGANISED AND UNSTABLE PIPING IN INDIA

The material quality of structural equipment could be determined with an index value of 0.10 and is in the medium range. For mountings, covers, housings, piping etc. normal steel is used as standard material, which has basically a relatively low resistance against corrosion. Few galvanised components could be found. Stainless steel is used for piping in very few recently built plants. At weir edges out of concrete, flaking of plastering was observed in several cases, leading to short cut streams, reduced retention time and that way to function deficits of the sedimentation process (see figure 45).

The manufacturing quality of structural equipment is below medium range with an index value of -0.04. Both dimension accuracy and surface quality, especially of concrete structures, are relatively low. Dimensional variations are in a range of several centimetres, surfaces are relatively rough in many cases. Problematic in this regard are weirs of grit chambers and primary/secondary clarifiers out of concrete. As already mentioned, the accuracy of piping is doubtful in many cases (see figure 47).

The overall efficiency of structural equipment, considering specific construction demand, specific space demand, specific material costs, energy demand and technology level shows an index value of -0.14 and is that way in the lower medium range.

In the following paragraph, space demand of structures, as well as level of technology and energy efficiency of the overall process are considered more in detail.

Level of Technology

As shown at the beginning of this chapter, the focus of wastewater treatment in India is currently mainly on BOD removal. Compared to western standard treatment, this treatment target is classified as medium level technology in this study. More than 80% of the plants are targeting BOD removal (see figure 48). More advanced processes like nitrification/denitrification processes, hardly exist. In total, an average value of 0.11 could be determined, which is in the medium range.

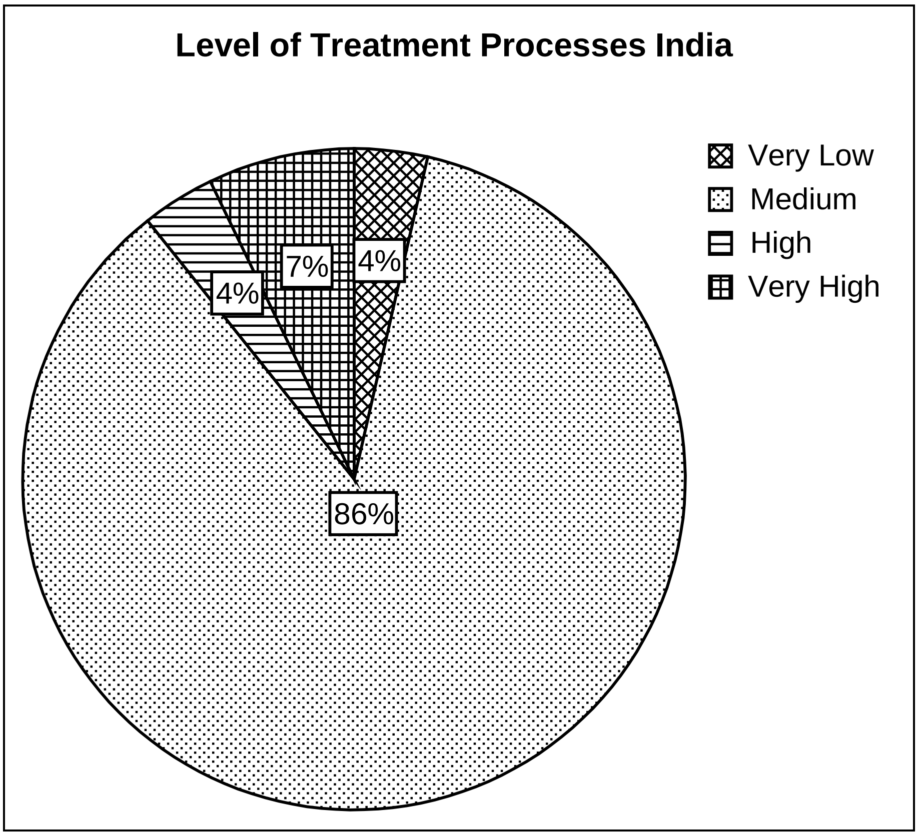


FIGURE 48: LEVEL OF TREATMENT PROCESSES IN INDIA

Specific Space Demand & Energy Efficiency

As visible in figure 49, about 25% of the inspected plants are characterised by a very high space demand. These are mainly activated sludge plants with primary clarifier and sludge drying beds. About 32% of the inspected plants are characterised by high space demand, which are mainly activated sludge plants without sludge drying beds. The structures of about 21% of the inspected plants have a medium space demand – mainly extended aeration plants or plants that are characterised by short distance tank arrangement. About 21% of the plants have a low or a very low space demand. These are medium sized extended aeration plants without sludge drying beds, small plants based on extended aeration process that are integrated in a compact have in hotel building complexes and one membrane bioreactor plant that reaches a maximum of compactness. In total, an average value of -0.57 could be determined for space demand, which means a relatively high space demand.

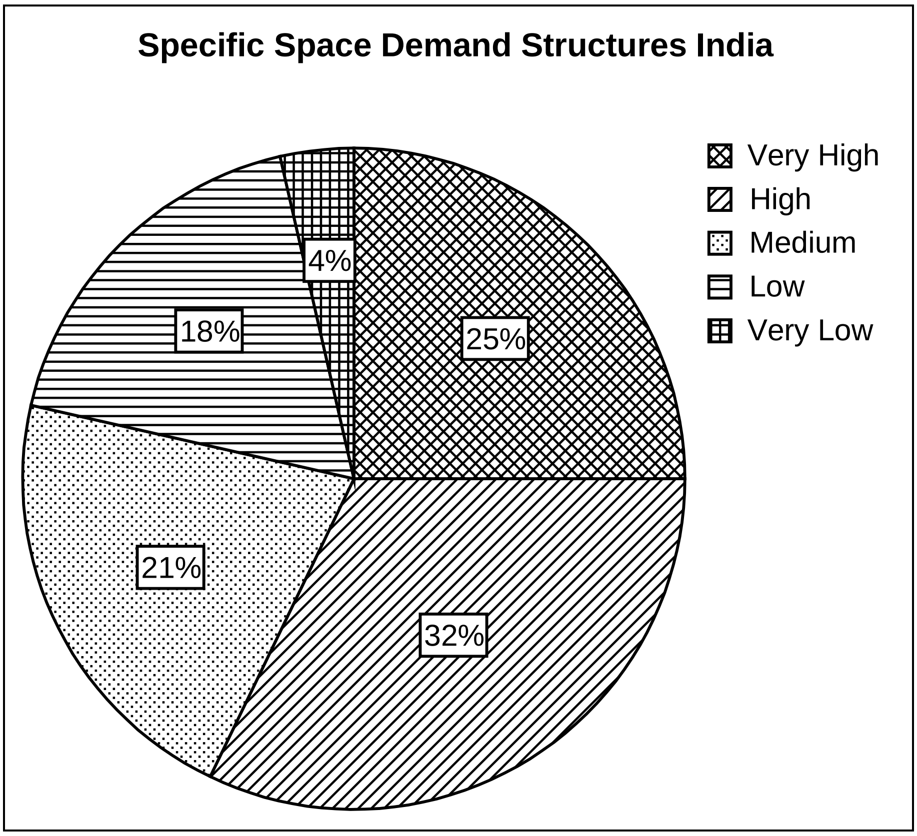


FIGURE 49: SPECIFIC SPACE DEMAND OF STRUCTURES IN INDIA

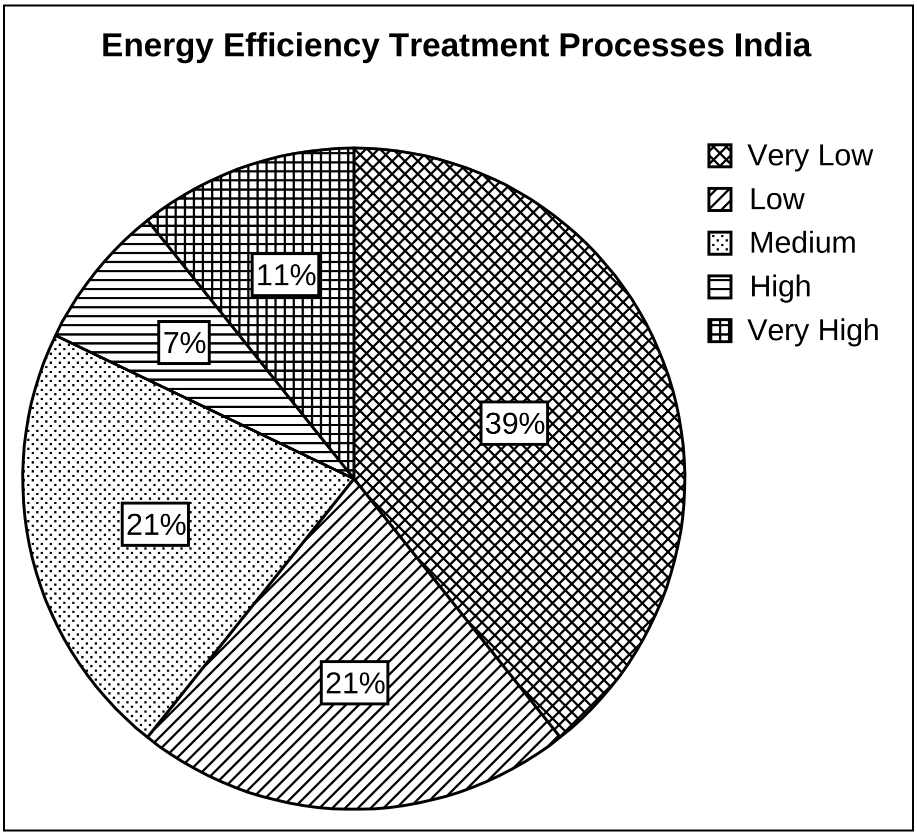


FIGURE 50: ENERGY EFFICIENCY OF TREATMENT PROCESSES IN INDIA

As visible in figure 50, the energy efficiency of the overall treatment processes is relatively low – about 39% of the processes are characterised by very low energy efficiency. These are extended aeration plants without primary clarifier and without energy recovery by anaerobic sludge digestion. The processes of 21% of the inspected plants, which are mainly activated sludge plants without sludge digestion or extended aeration plants with sludge digestion, are characterised by low energy efficiency. In the medium range are 21% - mainly activated sludge plants with primary clarifier and sludge digestion. High energy efficiency was determined for about 7% of the plants, which is trickling filter technology plus sludge digestion and a biodisk plant (rotating immersion disks). About 11% of the plants are based on anaerobic processes for the wastewater treatment and are characterised by very high energy efficiency. In total, an average value of -0.71 could be determined for energy efficiency, which is relatively low.

Machinery Equipment

Origin of Machinery Equipment

About 98% of the inspected machinery equipment where the origin could be determined is sourced in India. Only very few equipment is from European countries. No machinery equipment from the US was found on any of the inspected plants. That means that the following detailed considerations give an outlook mainly on the characteristics of Indian machinery equipment.

Age of Machinery Equipment

As visible in figure 52, about 47% of the inspected machinery equipment is less than 5 years old. About 28% of the equipment is between 5 and 10 years old, only 25% of the machinery equipment is more than 10 years old. The average age of the inspected equipment is about 7 years.

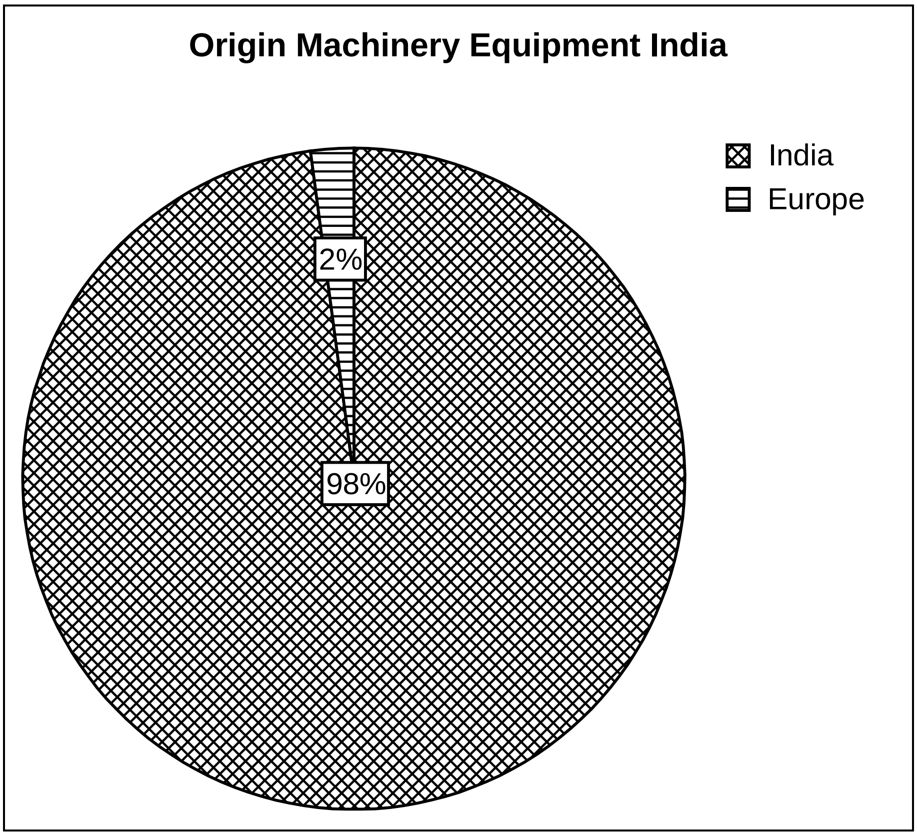


FIGURE 51: ORIGIN OF MACHINERY EQUIPMENT IN INDIA

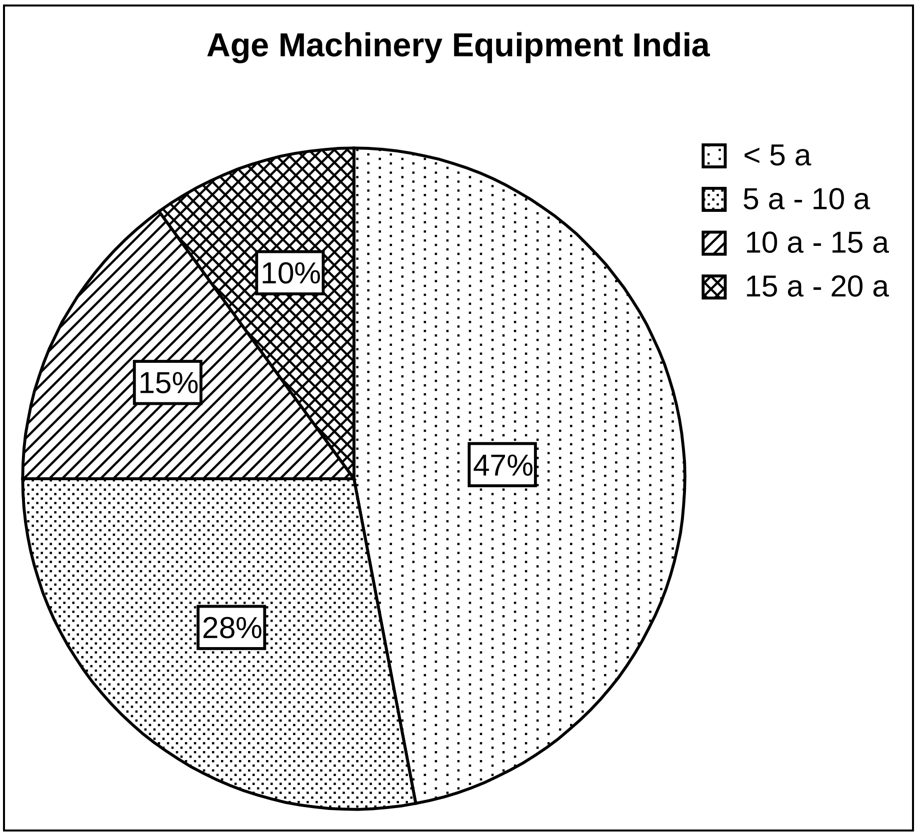


FIGURE 52: AGE OF MACHINERY EQUIPMENT IN INDIA

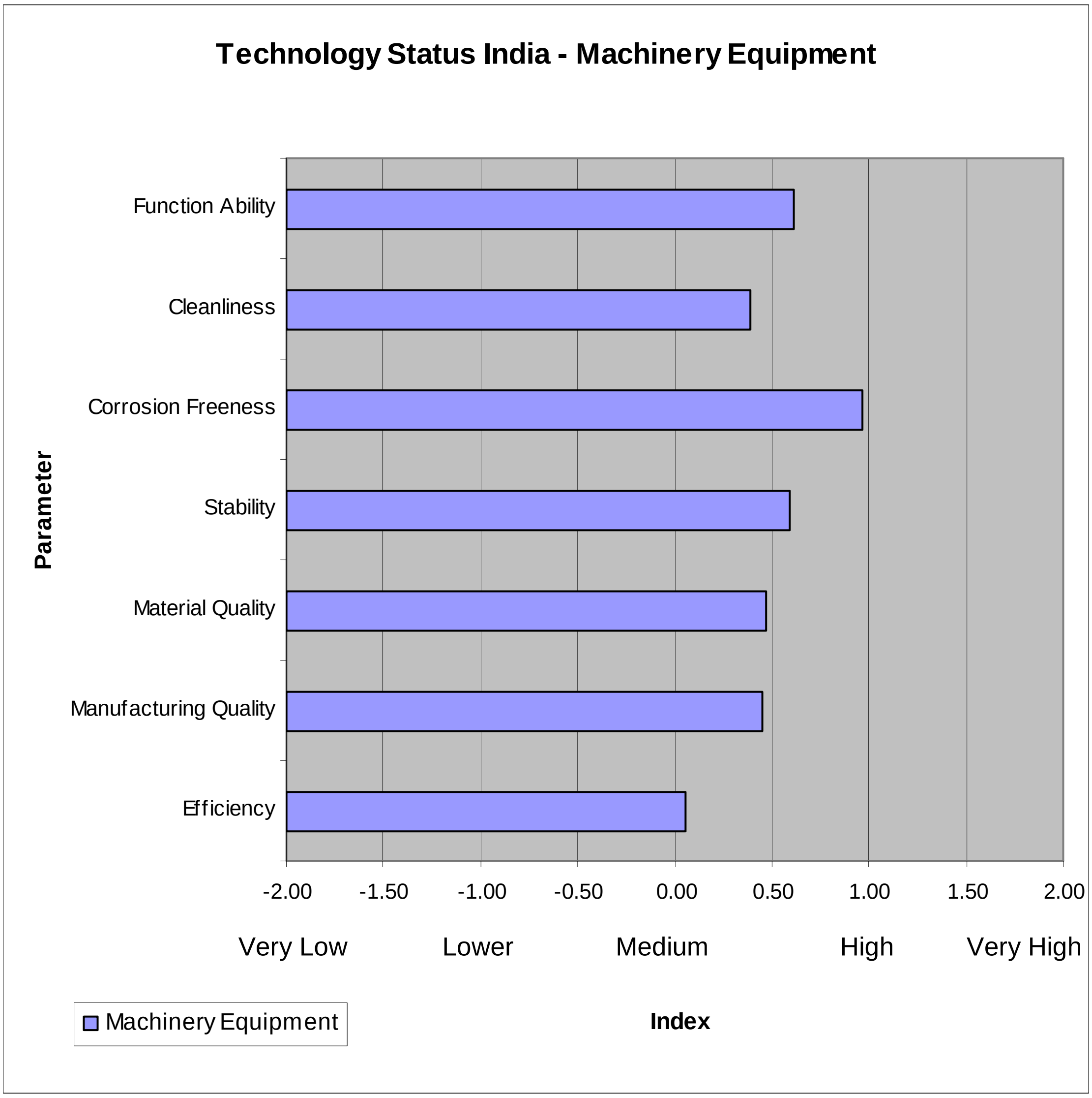


FIGURE 53: TECHNOLOGY STATUS INDIA - MACHINERY EQUIPMENT

For the function ability of machinery equipment an index value of 0.62 could be determined. Severe deficits regarding mechanical/physical intactness could be detected only in very few cases. In several cases, the hydraulic cylinders of relatively new step screens gave very strange sounds and vibrations, which indicated a damage of the cylinders of the hydraulic drive. Generally problematic is the relatively low durability mainly due to the use of coated normal steel.

Cleanliness is in the upper medium range with an index value of 0.39. Both surface cleanliness and detail/technical cleanliness are not very high. Problematic is the observation that in many cases technically relevant moving parts are obviously not cleaned on a regular basis, which indicates deficits regarding maintenance.

FIGURE 54: DIRT COVERED AND SEVERELY CORRODED SCRAPER BRIDGE AND WEIR EDGE IN INDIA

FIGURE 55: SEVERELY CORRODED FINE SCREEN IN INDIA

For corrosion freeness as another indicator for maintenance, an index value of 0.97 could be determined. First of all, this gives a positive picture. Taking a closer look, especially equipment that is in the contact zone water-air is very often severely corroded, like connection elements between scraper bridges and scraper shields (see figure 54). For the stability of machinery equipment in India an index value of 0.59 was determined, which is in the range of high. Characteristic is a relatively high material thickness of many machinery components, like grit removal systems of classifiers or surface aerators. Static design is characterised by simple, clear constructions with good accessibility in most cases. Regarding the material quality of machinery equipment, the use of coated normal steel dominates. In very few cases the use of galvanised steel could be observed - stainless steel is used only very recently for modern automatic screening systems. Characteristic is flaking especially in corners and at connection points. But also at larger surfaces flaking and corrosion could be stated. In total, an index value of 0.47 could be determined for the parameter “material quality”. Plastic is not common as material for machinery components. The following figure shows the distribution of the coating quality of coated equipment. An average value of 0.67 could be determined.

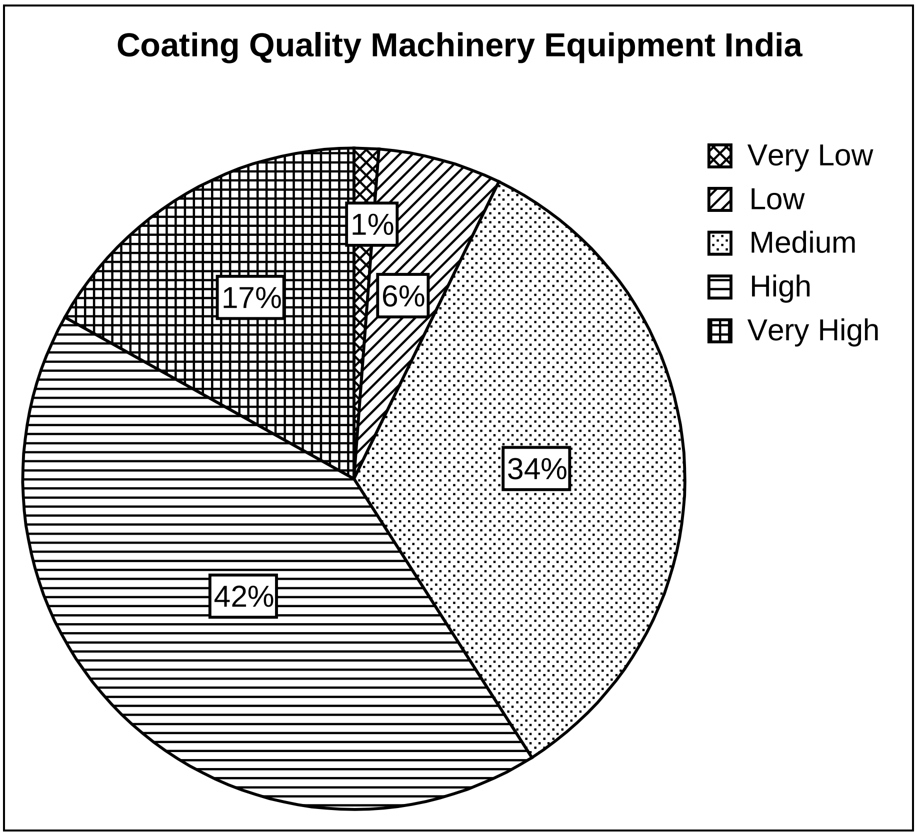


FIGURE 56: COATING QUALITY OF MACHINERY EQUIPMENT IN INDIA

FIGURE 57: WELL COATED GRIT REMOVAL SYSTEM IN INDIA

FIGURE 58: AUTOMATIC BAR SCREEN IN INDIA

For the parameter “manufacturing quality” an index value of 0.45 was determined, which is on the upper end of the medium range. Relatively high dimension tolerances could be stated for many equipment components, like automatic or manual bar screens. The consideration of the surface quality also shows relatively high tolerances in details. Welding connections are of moderate surface quality. For the efficiency of machinery equipment an index value of 0.06 was determined, which is in the medium range.

Level of Technology, Specific Material Costs & Energy Efficiency

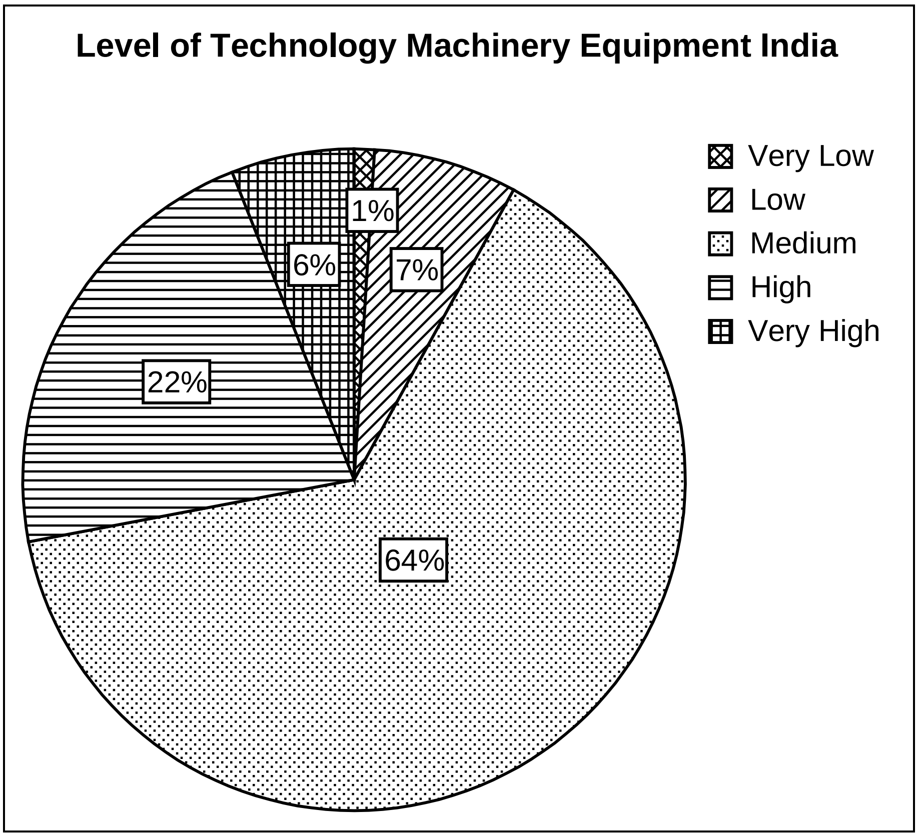


FIGURE 59: LEVEL OF TECHNOLOGY OF MACHINERY EQUIPMENT IN INDIA

Figure 59 gives an outlook on the technology level of the machinery equipment. With 64%, the majority of the inspected machinery equipment is classified on a medium technology level – moderate process efficiency and moderate adaptation/handling possibilities. Pumping systems, belt conveyors, bridges/scraping systems, surface aeration systems, air blowers, dosing systems and classifiers are mainly on a medium technology level. About 8% of the inspected equipment is of lower categories. These are technologies, like manual bar screen or very simple dosing systems. About 22% of the equipment is on a high and very high technology level – mainly diffused aeration systems, disinfection systems, filtration systems (sand, activated carbon). On top end – about 6% - several efficient screening systems, decanter centrifuges and one modern dosing system can be found. For screening systems, a large variety regarding the technology level could be stated, ranging from very basic manual screens through automatically cleaned rakes up to highly efficient stainless steel step screens with very small and accurate spacings. New machines following modern western construction principles indicate a technology change in the next years. An average value of 0.25 could be determined, which is in the upper medium range. For about 92% of the inspected machinery equipment, moderate material costs are characteristic. As already mentioned, coated normal steel is used as standard material. Galvanised components and combinations of normal steel for support structures and galvanised or stainless steel for parts that are in direct contact with wastewater are very rare – about 2% fall into this category. 6% of the equipment consists of high quality material – stainless steel. In the inspections of machinery equipment, stainless steel could only be found at 3 modern screening systems. An average value of -0.14 could be determined, which is in the lower medium range.

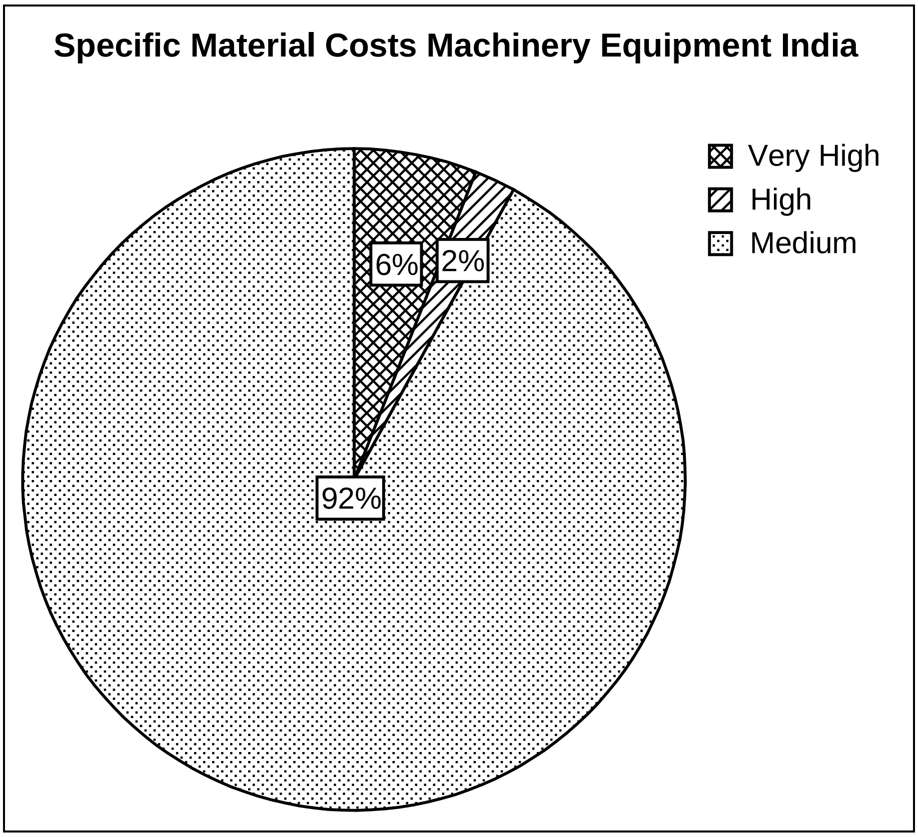


FIGURE 60: SPECIFIC MATERIAL COSTS OF MACHINERY EQUIPMENT IN INDIA

The energy efficiency of the Indian machinery equipment is in a medium range for the vast majority of inspected equipment. Sludge dewatering by decanter centrifuges as a process with a very high energy demand forms the equipment with very low energy efficiency. Only for 6% of the inspected equipment, higher energy efficiency can be stated. An average value of 0 could be determined.

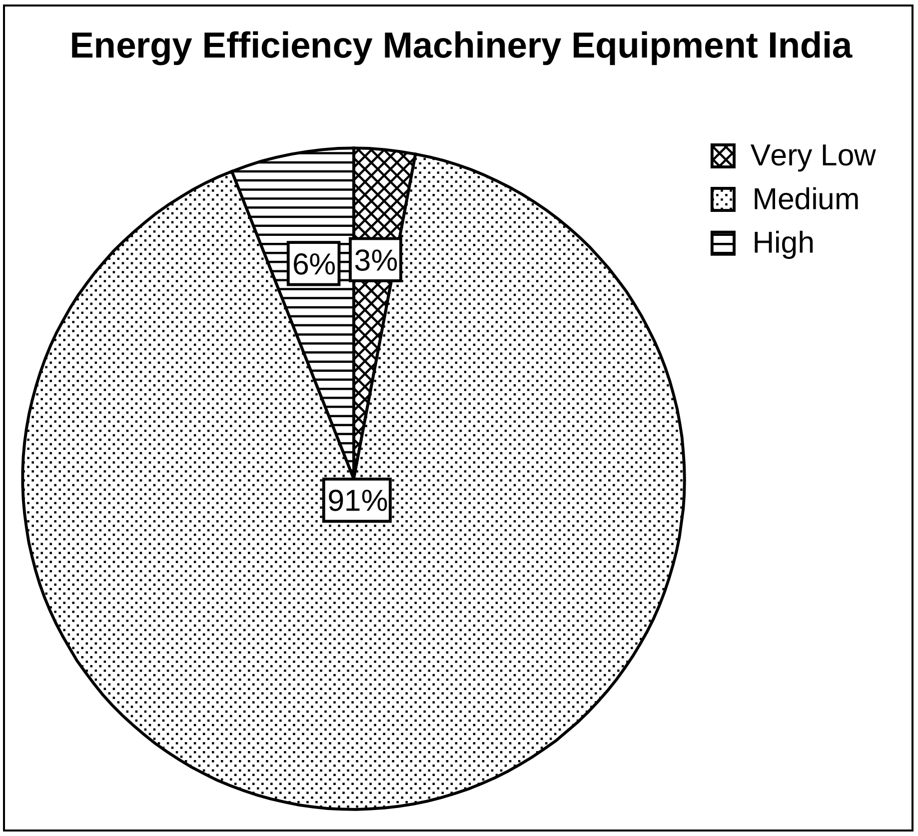


FIGURE 61: ENERGY EFFICIENCY OF MACHINERY EQUIPMENT IN INDIA

Control Equipment

Origin & Age of Control Equipment

Almost all inspected control equipment on the inspected plants is Indian brand – cabling, control panels, etc.. In very few cases, modern electronic sensors are imported from abroad.

About 45% of the inspected control equipment is less than 5 years old, about 21% is between 5 and 10 years old. Only about 34% of the equipment is more than 10 years old. Like structural and mechanical equipment, the age of control equipment is also relatively low. The average age of the inspected control equipment is about 7years.

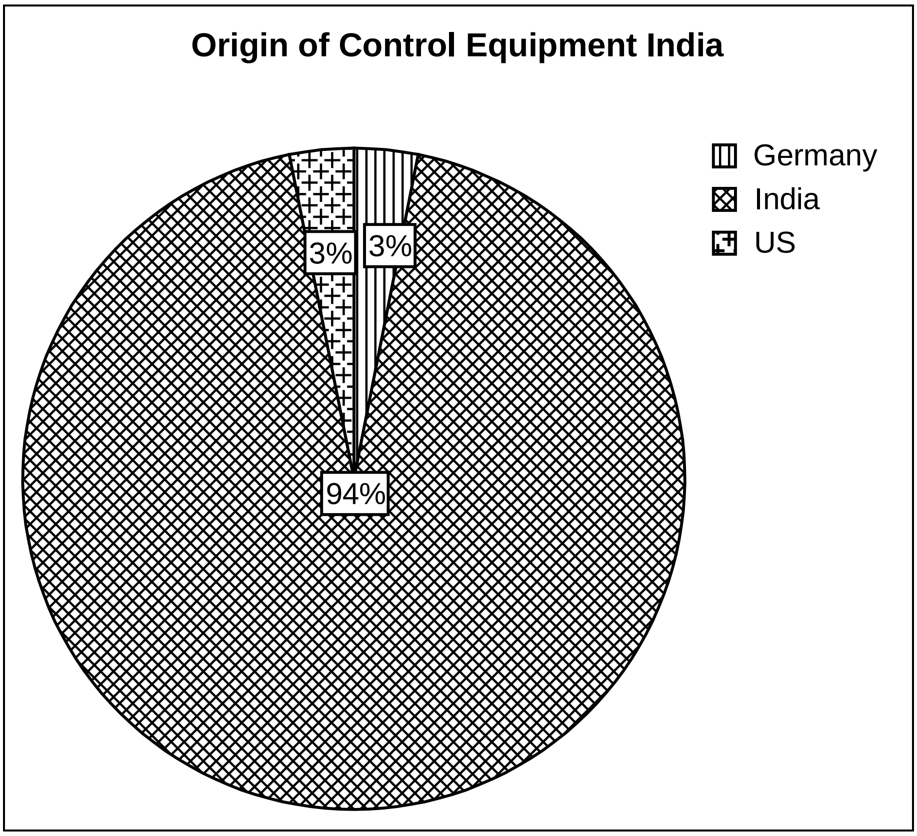


FIGURE 62: ORIGIN OF CONTROL EQUIPMENT IN INDIA

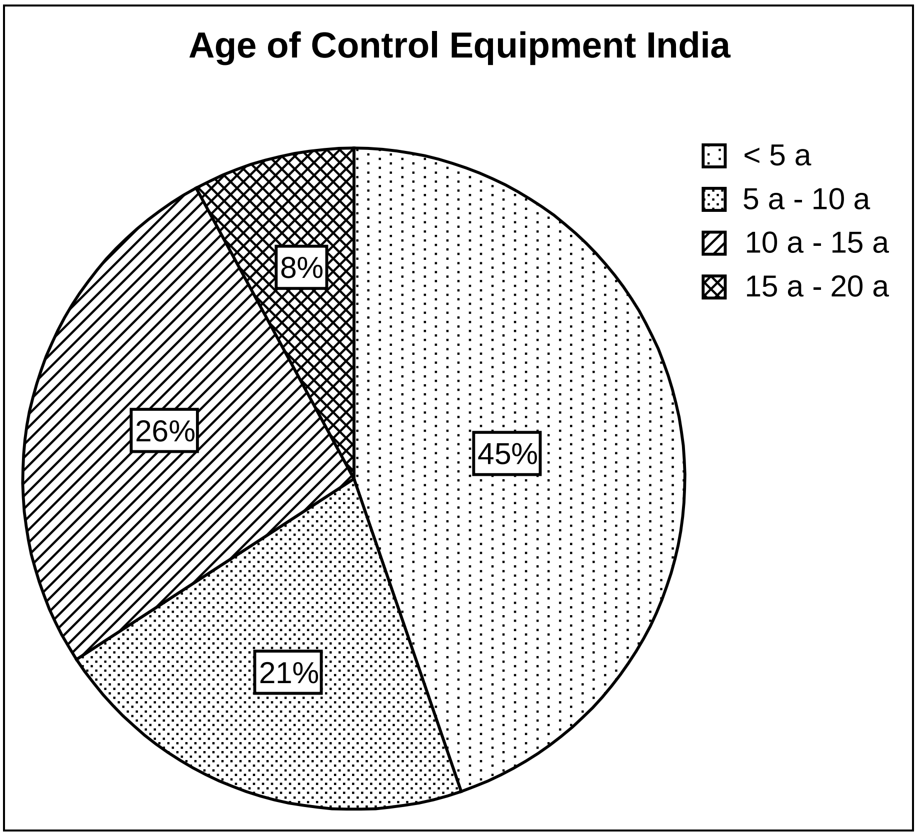


FIGURE 63: AGE OF CONTROL EQUIPMENT IN INDIA

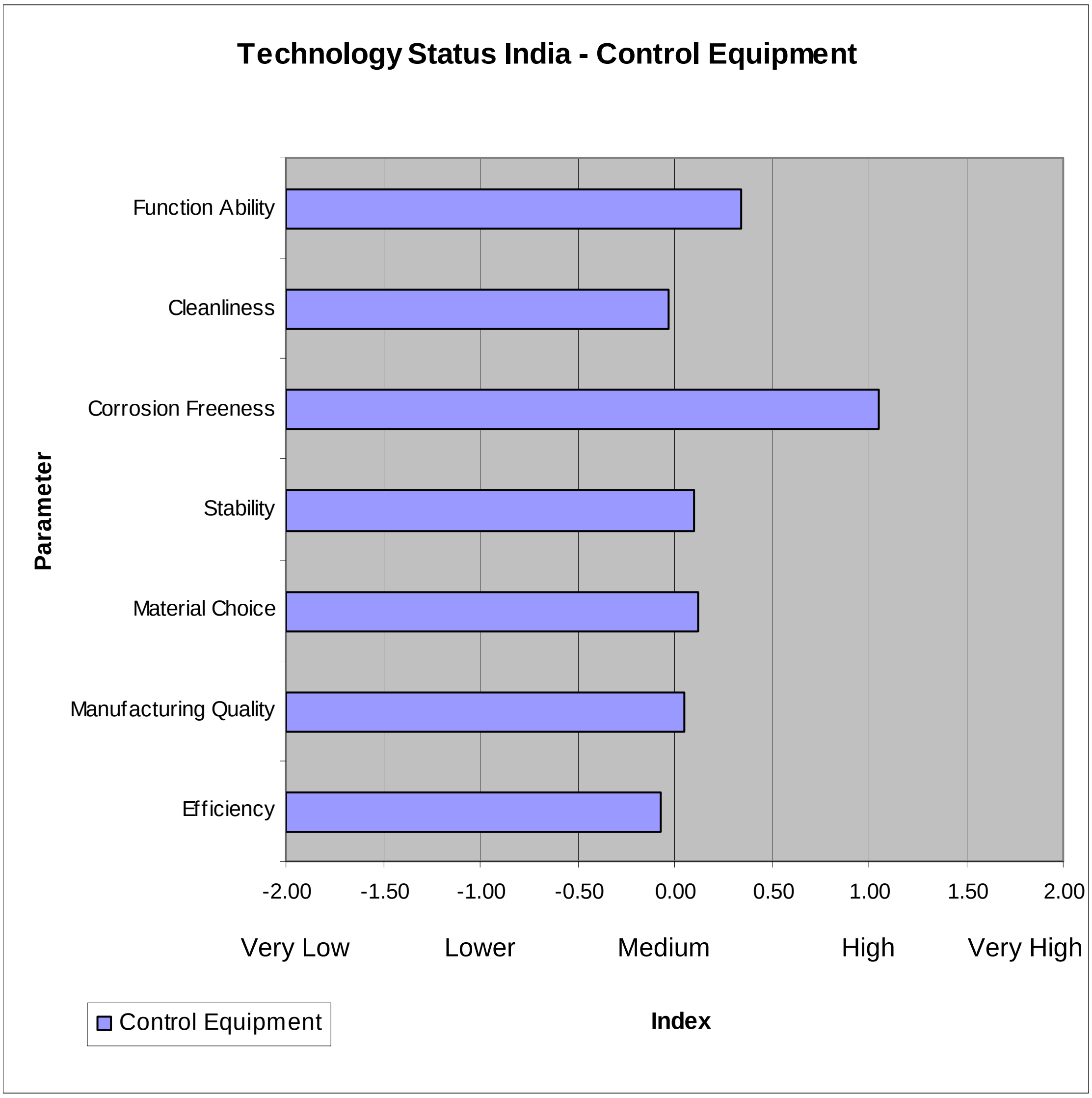


FIGURE 64: TECHNOLOGY STATUS INDIA – CONTROL EQUIPMENT

Naturally, it is hardly possible to determine the function ability of control equipment mainly from the outer appearance. Nevertheless, first indications can be gained looking at possible durability and mechanical/physical intactness. Although an index value of 0.34 could be determined, which is in the upper medium range, more detailed analyses are required in order to describe the function ability of the electrical equipment reliably.

Cleanliness is on the lower side of the category “medium” with an index value of -0.03. Control equipment is very often covered with dust and obviously not cleaned regularly. Critical in many cases is cabling along and between concrete tanks, as cable channel covers are very rare. Splashing water and dirt plus direct exposure to sunlight and that way heat and UV radiation are a potential danger for cable surfaces and connections.

Corrosion freeness is on a high level – severe fissures were hardly detected. In this regard, the relatively young age of most plants has to be considered. Control panels are coated in most plants - severely corroded panels are rare.

The stability of control equipment is above medium with an index value of 0.11. Control panels are of moderate stability and appear in some cases slightly overdimensioned regarding material thickness. Mechanical sensors like level measurement devices prior to measurement weirs are relatively stable. Problematic in many cases is cabling that is hardly fixed, as already mentioned above. Cables are very often just lying on the ground or are spanned over structures along ropes or bars.

The material quality of control equipment is in the medium range with an index value of 0.12. Very often mounting and support material of cabling is of medium or low quality so that corrosion could be detected especially in older plants. Cable channels are either out of galvanised steel or out of coated normal steel. Control panels are mainly made of coated normal steel. Stainless steel is not common neither indoor nor outdoor. Mechanical sensors are of coated normal steel. Plastic is hardly used.

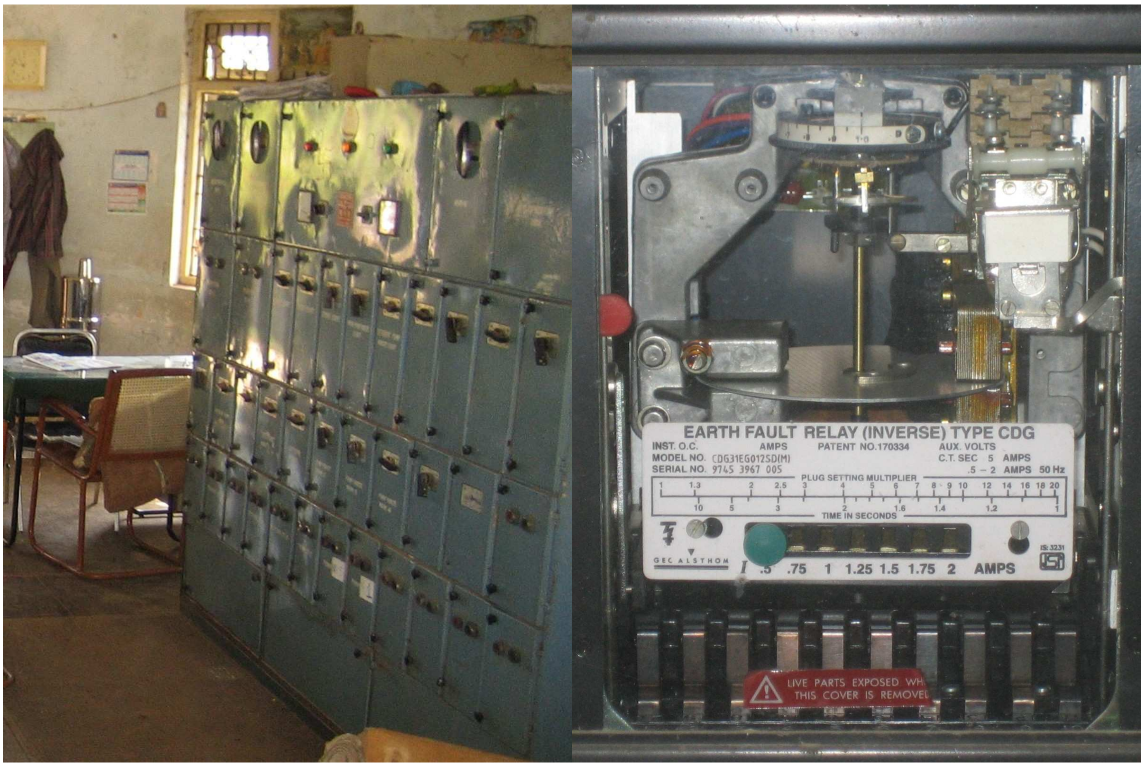


FIGURE 65: EXAMPLE CONTROL PANEL AND ELECTRICAL EQUIPMENT ON STPS IN INDIA

The manufacturing quality is in the medium range with an index value of 0.05. In general, relatively low dimension accuracy can be stated. Due to very often unorganised cabling, proper maintenance or repair works appear difficult, apart from the risk of cable damages and safety risks for the staff. In this regard also cables that are lying on the ground in humid or wet areas near pump systems or centrifuges represent a high potential safety risk on many plants.

FIGURE 66: CABLING – A CRITICAL ISSUE ON STPS IN INDIA

The efficiency of control equipment was determined with an index value of -0.07. Of special interest are the technology level and that way also the automation grade, and the material costs.

Level of Technology & Specific Material Costs

As visible in figure 67, the technology level is in the medium range. High-tech automation systems like SCADA control systems are very rare. The range of measured operation parameters is limited in many plants. Online measurement technology or electronic control instruments hardly exist. Operation values have to be determined in laboratories that are attached only to bigger treatment plants and the conventional chemical methods are time consuming. About 34% of the inspected control equipment is categorised as low and very low regarding the technology level, about 40% is in the medium range and only 26% is categorised as high or very high. For the technology level, an average value of -0.08 could be determined, which is in the medium range.

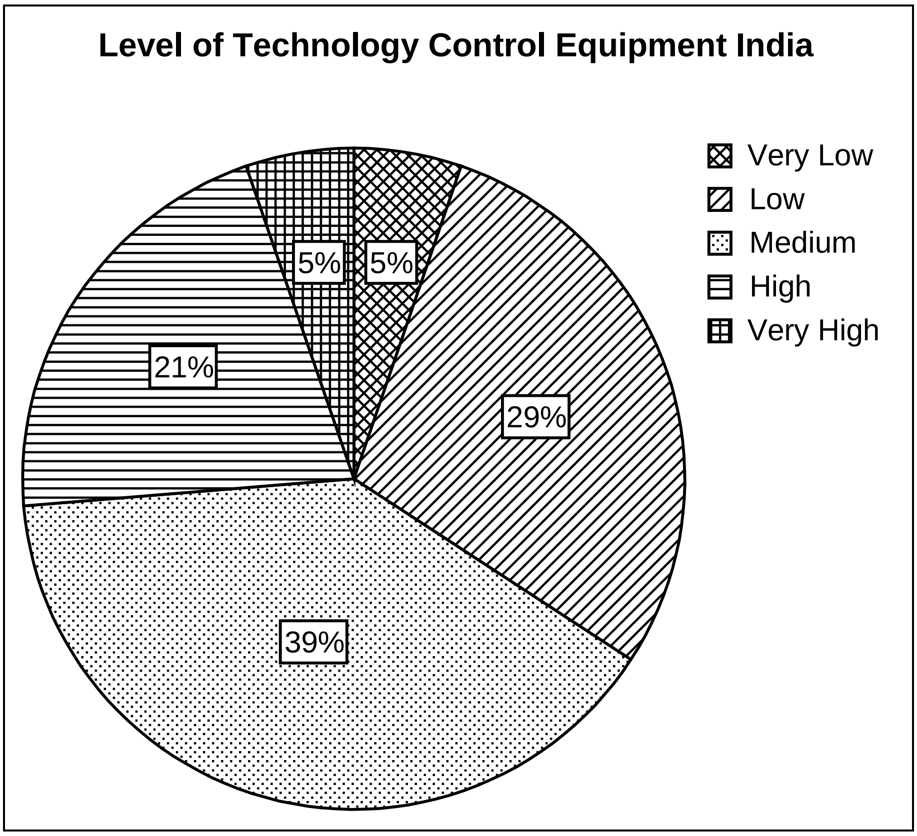


FIGURE 67: LEVEL OF TECHNOLOGY OF CONTROL EQUIPMENT IN INDIA

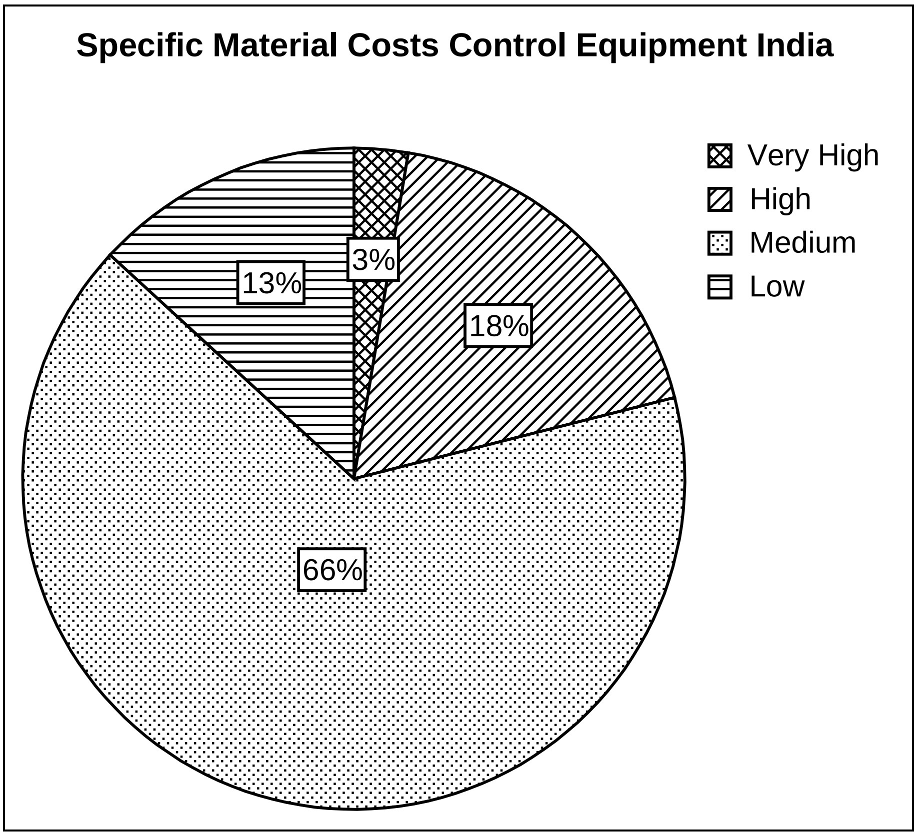


FIGURE 68: SPECIFIC MATERIAL COSTS OF CONTROL EQUIPMENT IN INDIA

The material/equipment costs of the control equipment are in the medium range. Due to the fact that most equipment is standard technology out of coated normal steel and almost all equipment is sourced in the Indian market, the costs are moderate. About 21% is in the upper costs range, 66% is average and 13% is in the lower cost range. An average value of -0.11 could be determined for the parameter “specific material costs”.

Treatment Plant Construction & Operation

Construction

Almost all STPs and ETPs are constructed by Indian companies. The Indian daughter of Degremont, OTV and SFC are the only European companies of which plants were inspected. The following table gives an outlook on the companies that constructed the inspected wastewater treatment plants. For the other plants, the mainly Indian construction companies could not be identified.

Constrution Company	Inspected WWTPs
Batliboi (India)	2
SFC (Austria)	1
Degremont India	4
Enviro Techno Consult Nagpur (India)	1
Geo Miller (India)	2
Gharpure Eng & Construction Pvt. Ltd (India)	2
Gia (India)	1
Hindustan Construction (India)	1
Hydraulic Engineers Mumbai (India)	2
Ion Exchange Ltd. (India)	1
GS Jolly (India)	1
M/s Rajkamal Builders Infrastructure Pvt. Ltd. (India)	1
SECET India Ltd.	1
SPML & OTV (French)	1
Sudarshan Chemicals Pvt. Ltd. (India)	1
Triveni Engineering and Industries Ltd. (India)	1
UEM India Ltd.	1

TABLE 29: CONSTRUCTION COMPANIES OF INSPECTED TREATMENT PLANTS IN INDIA

Most of the inspected plants were designed by Indian consultancy companies. One plant was designed by Advent Corporation (US), another one by Jacobs (Great Britain). Three plants were designed by Montgomery Watson Consultants India Pvt. Ltd.

Operation

As visible in figure 69, in more than 60% of the inspected STPs private contractors are in charge for operation and maintenance works. In very few cases, plants are operated by the respective construction company for an initial period of 2 years after construction. The inspected ETPs and CETPs are operated by own staff of the respective industry or special formed operating companies on behalf of the attached industries.

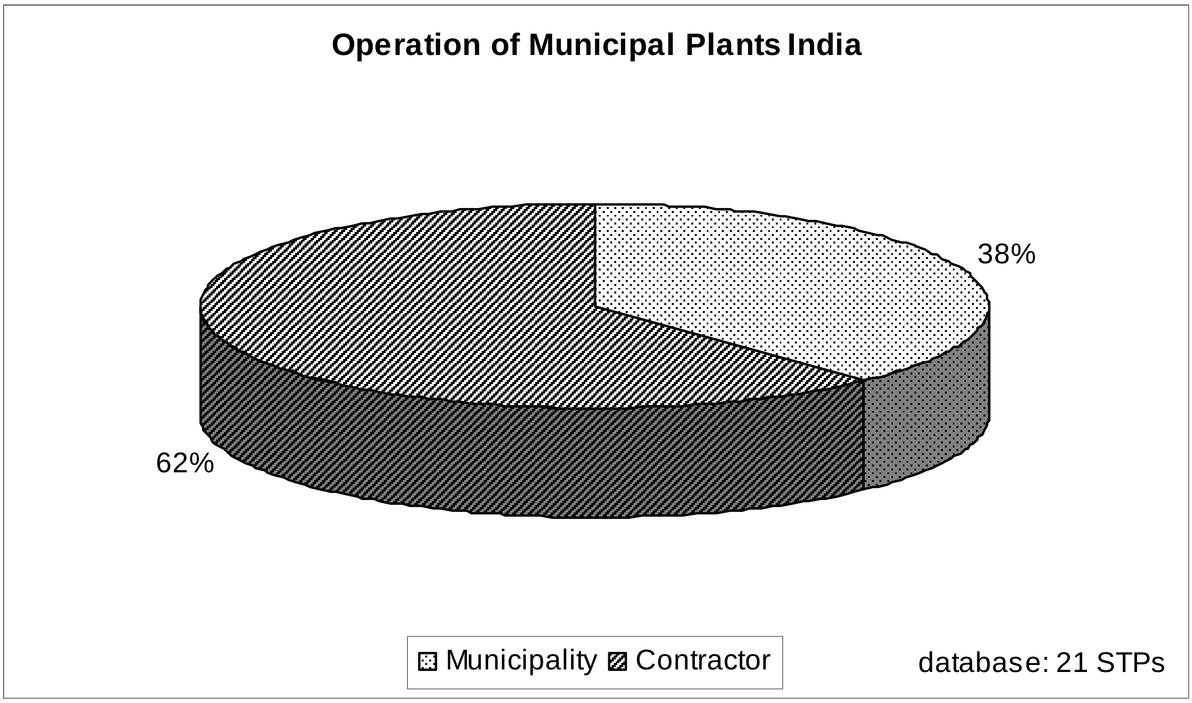


FIGURE 69: OPERATION OF MUNICIPAL STPS IN INDIA

Maintenance

Maintenance is organised very different in the inspected plants. Maintenance schedules exist in more than 40% of the inspected STPs and ETPs following the information gained in expert interviews with the plant management. In 10% of the plants, the interview partners reported, that maintenance works are planned based on equipment manuals - in almost half of the cases, maintenance is carried out only by experience.

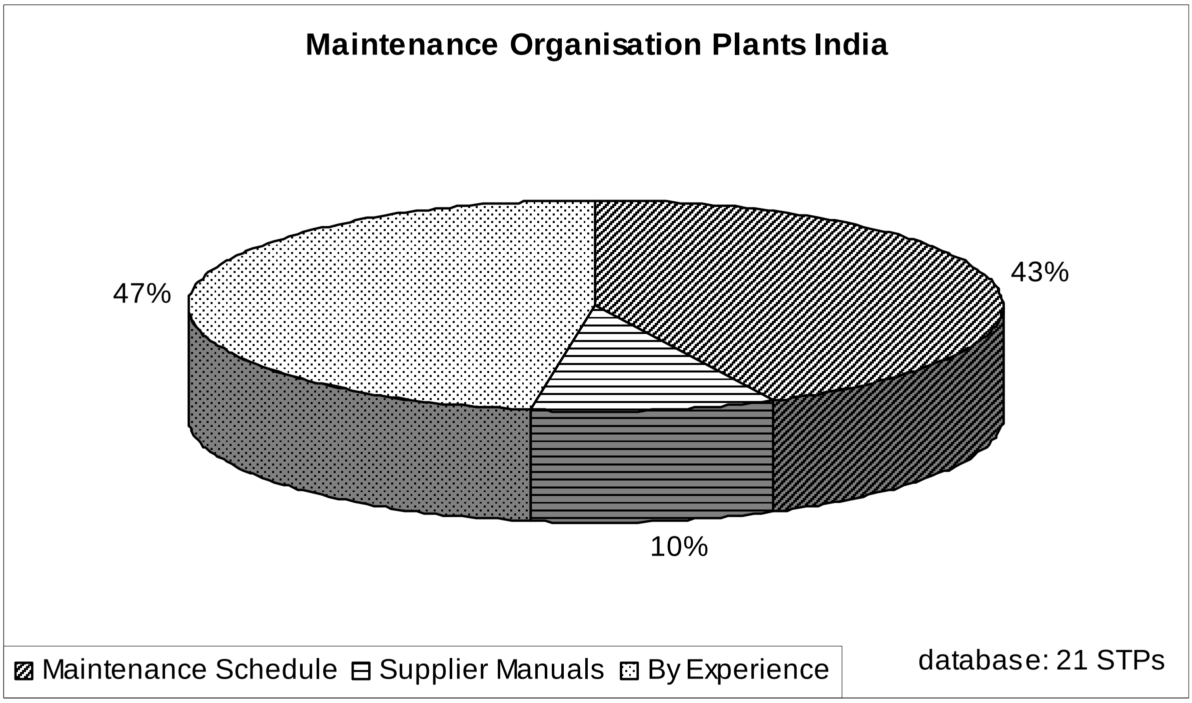


FIGURE 70: MAINTENANCE ORGANISATION OF STPS AND ETPS IN INDIA

Table 30 gives an outlook on typical maintenance works and intervals.

Equipment Type	Maintenance Interval
Oiling & Greasing	1 week, 1 month, 3 months
Oil Level Check	1 day, 1 week, 1 month, 3 months
Oil Change	2-4 months, 3-4 months, 6 months, 8-9months, 1 year, 2.000work hrs, only damage, if too thick
Leakage Check	1 day, 1 week
Gland Packing Change	5-6 months, only damage
Pump/Gland Packing Check	1 day, 1 week, 3 months, leakage, only damage
Motor Winding Check	1 week
Bearing Measurement	6 months
Bearing Temperature	1 month
Bearing Change	2.5 years, 5-10 years, only damage
Blower/Compressor Belt Check	1 day, 3 months
Compressor Belt Change	only damage
Bar screen Cleaning	1 day
Gutter Levels Check	1 month
V-notch Check	1 month
Isolation Check/Transformer Cleaning	6 months
Fuses Check	1 day, 1 week
Contacts Measurement	6 months

TABLE 30: TYPICAL MAINTENANCE WORKS AND INTERVALS ON INDIAN STPS AND ETPS

Great variations can be stated regarding the time intervals for preventive maintenance of different equipment types, based on the information given by plant managers and engineers. As visible, a wide range regarding the work intervals of specific maintenance works exist. In many plants, some maintenance works are never carried out – “maintenance only in case of damage”. A typical example is oil change of pumps and gear boxes of surface aerators. The time interval ranges between 2-4 months and 1 year, or it is never changed, according to the information given by the plant management. Most plants have some spare parts in stock, like bearings, gland packings or basic electric spares. In almost none of the plants severe problems with spare parts supply for Indian equipment was reported.

The following figure shows the distribution of problems that were reported by questioned treatment plant staff.

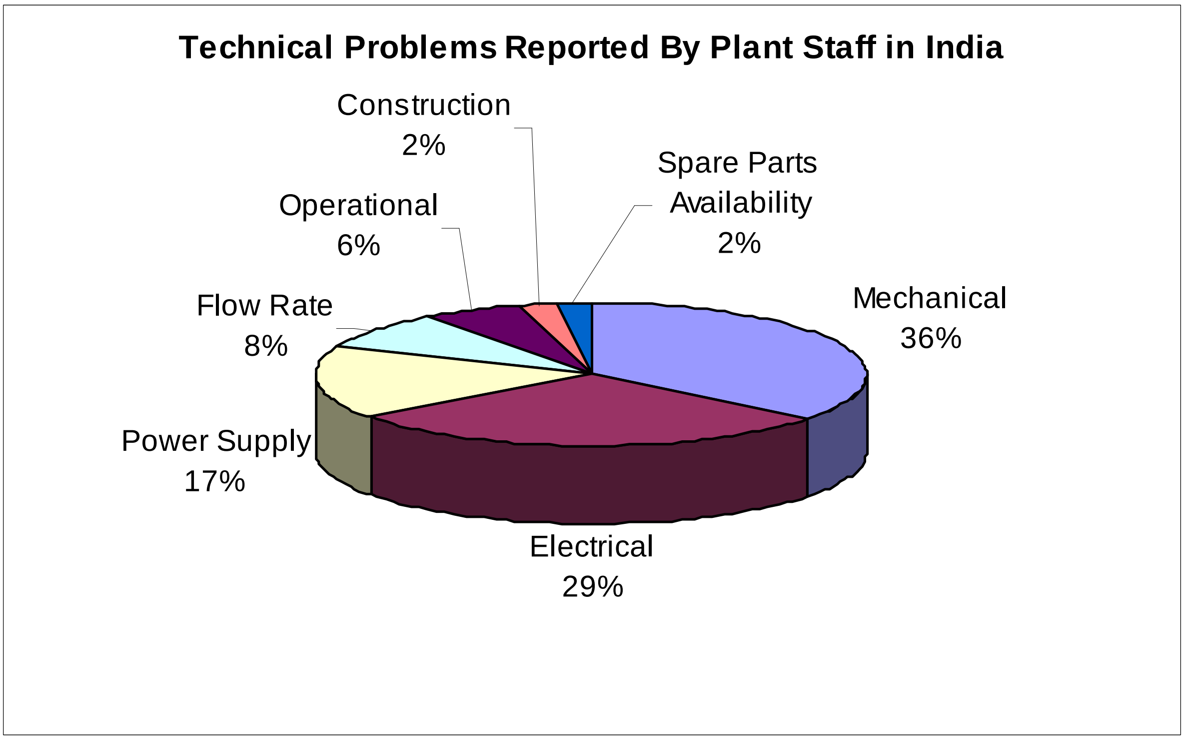


FIGURE 71: TECHNICAL PROBLEMS REPORTED BY PLANT STAFF IN INDIA

As visible in above figure, most problems that occur are from the electrical and mechanical field. Also power supply is a very common problem in many plants. Problems due to high flow rate are also mentioned by questioned staff. Also mentioned are problems related to operation, construction and spare parts availability.

7.1.2 Staff

Test Persons – General Information

In total, 42 test persons were questioned. The average age of the test persons is about 35years, the youngest is 20years, the oldest is 62years old. All test persons are male, 83% are married. 88% are are Hindus, 7% are Muslims, 1 person is Buddist and 1 person is Surd. About 70% of the test persons have children. In average, the questioned persons are in their job position since about 7years, the shortest employment time is 3months and the longest employment time is 22years. Of the 42 test persons, 10 are electricians, 10 are mechanics, 20 are operators and 1 is chemist.

Total Existing Staff on Inspected Plants

Figure 72 and 73 show specific staff use and plant capacity, as well as the proportion of the different staff groups on the respective municipal plants. Basically the total staff number increases with increasing plant capacity, but both specific staff use and the relative proportions of the staff groups vary in a great range. Plant I-M19 is the only municipal plant with a UASB stage followed by an anaerobic stage and has a design capacity of 480.000m³/d, whereas the total staff number is only 40. The determination of the specific staff use shows values of about 0.01 for plants of about 1.000m³/d (see figure 72). With higher plant capacity, the specific staff use decreases to values of less than 0.0005 for plants with about 100.000m³/d and higher capacity.

Looking at the relative proportion of the staff groups on the plants, unskilled workers represent the biggest staff group with 46% in average and a maximum part of 70% (plant I-M18). The group of technicians & operators follows with 33% in average. About 10% of the total staff on the inspected plants is engineers.

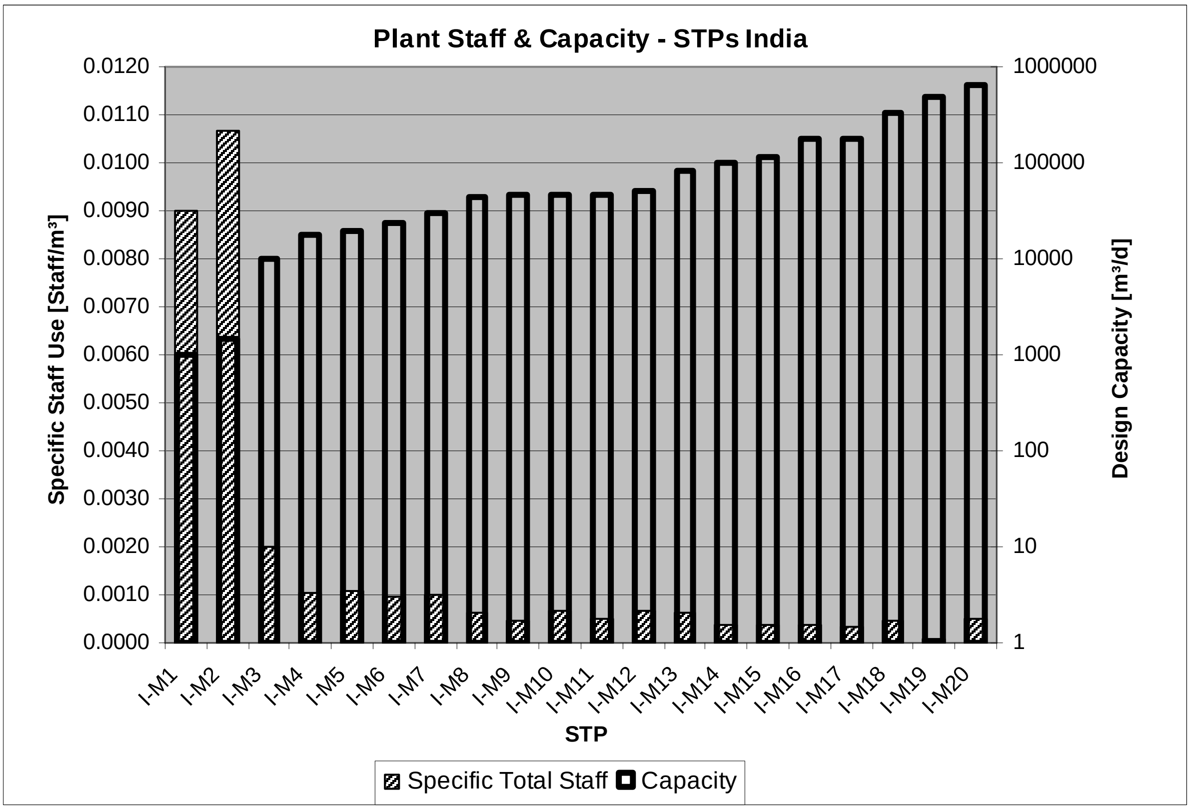


FIGURE 72: SPECIFIC STAFF USE AND CAPACITY ON STPS IN INDIA

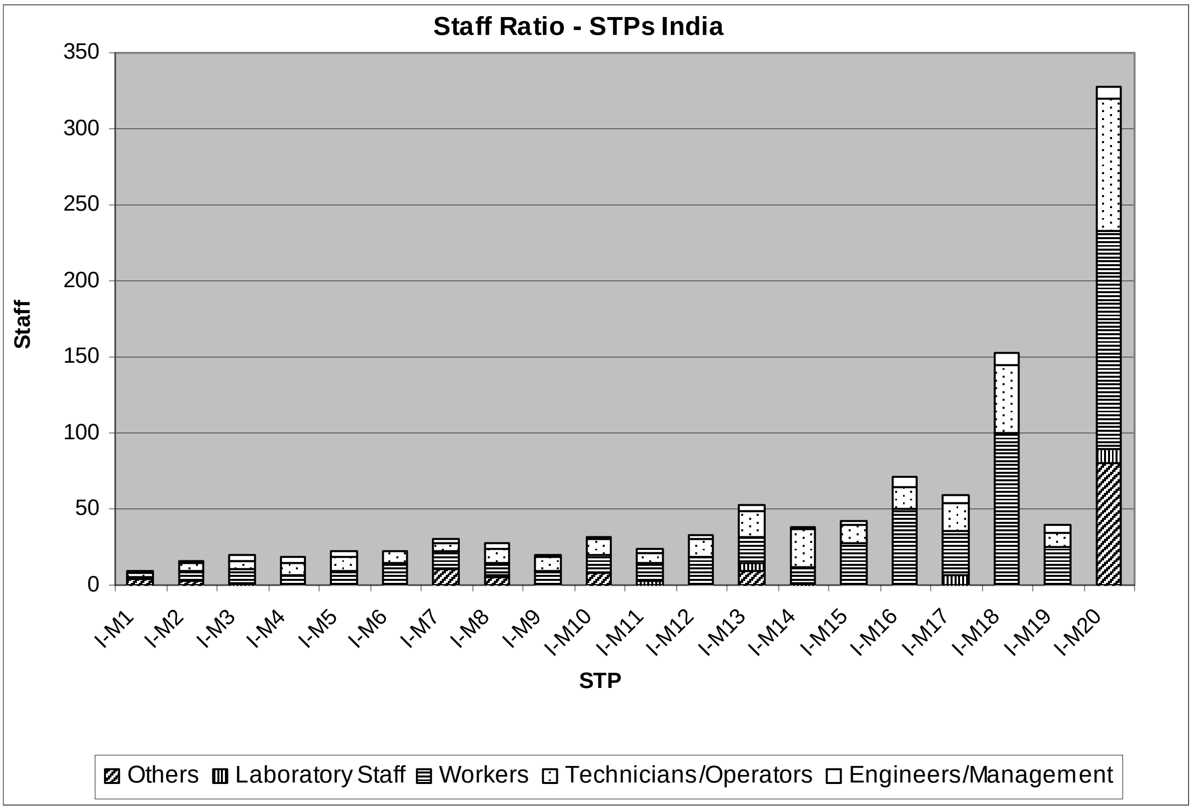


FIGURE 73: RATIO OF DIFFERENT STAFF GROUPS ON STPS IN INDIA

In the industrial field, strong variations could be stated. Smaller plants up to 200m³/d are characterised by specific staff numbers of more than 0,1 employees per m³ design capacity.

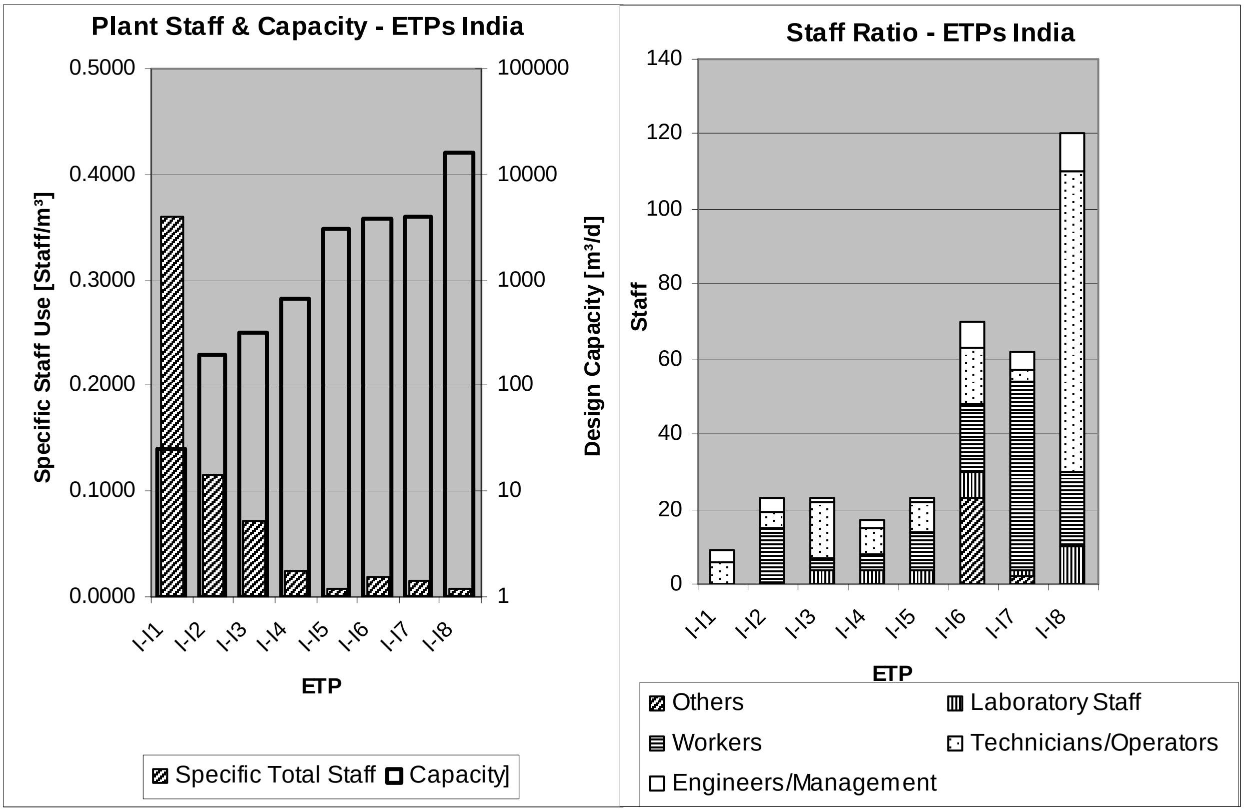


FIGURE 74: SPECIFIC STAFF USE AND STAFF GROUP RATIO ON ETPS IN INDIA

With increasing capacity, values of less than 0.02 were stated for capacities in a range of 3.000m³/d to 4.000m³/d. For a dye & textile industry with a design capacity of 16.000m³/d, a value of 0.0075 employees per m³ design capacity could be determined. The proportions of the different staff groups vary stronger than in municipal plants. The values of the workers part are between 0% and 81%, the values for technicians and operators are between 5% and 67%. Comparing the average values of the relative proportions of staff groups of industrial plants and municipal plants, a lower part of workers and a higher part of both technicians and engineers can be stated. In average, 34% of the staff are workers, 40% are technicians & operators and 12% are engineers. Figure 75 shows the salary distribution on Indian STPs and ETPs. Large income differences can be stated, both between different staff groups, within the staff groups, between ETPs/STPs and also between different regions. The average salary of operators and technicians - electricians/mechanics - is very similar with an average value of about 5.300Rs per month. The salary of helpers is about 3.700Rs per month. For engineers, an average monthly income of about 11.900Rs was stated, with a maximum of 20.000Rs, and a minimum of 5.500Rs. Looking at the income ratio between technicians and engineers, a value of 0.47 can be determined. The largest income differences were stated on the plant management level with an average value of about 21.000Rs and a maximum of 50.000Rs per month.

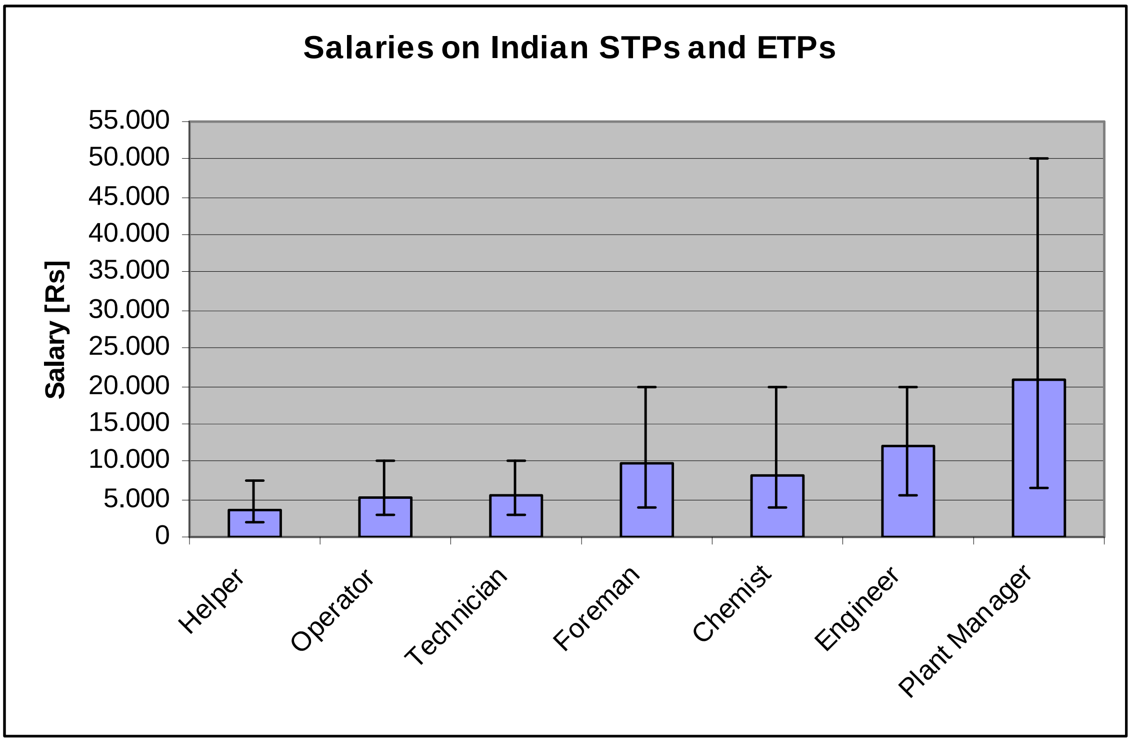


FIGURE 75: INCOME DISTRIBUTION ON INDIAN STPS AND ETPS

General & Operation Specific Knowledge

Figure 76 gives an outlook on the education level of the questioned treatment plant staff in India. As visible, most test persons passed secondary school as highest education level. 32% of the test persons passed elementary school or haven't visited any school. More than 50% of the questioned staff who passed secondary school passed a technical course in an ITI (see also Indian education system chapter 5.2.1).

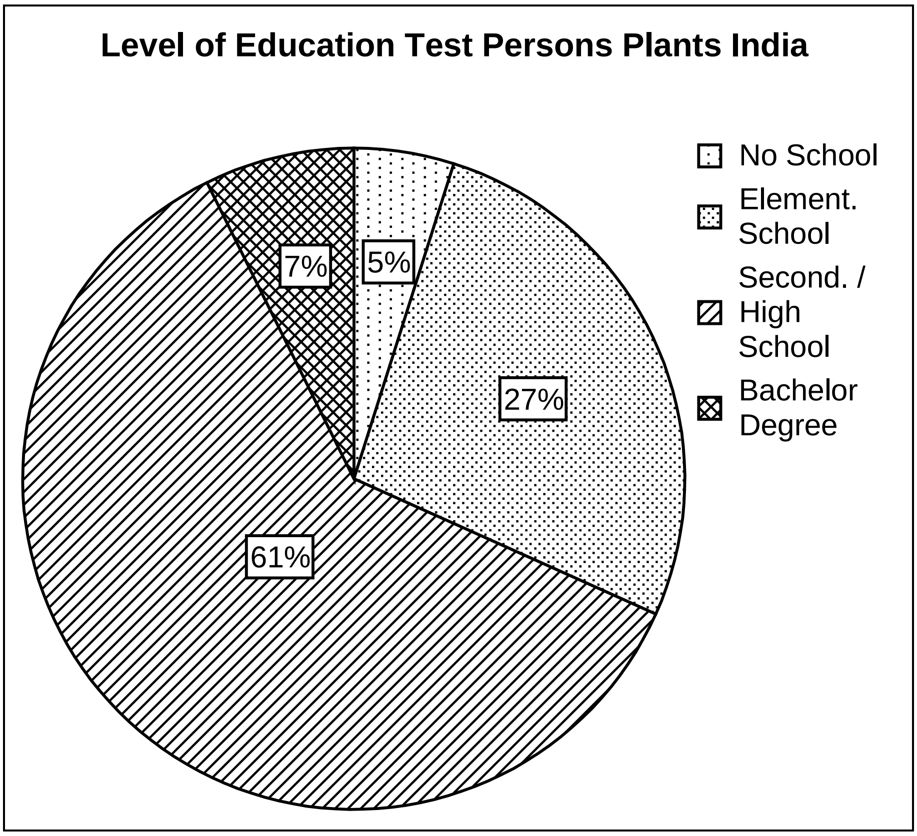


FIGURE 76: LEVEL OF EDUCATION OF QUESTIONED PLANT STAFF IN INDIA

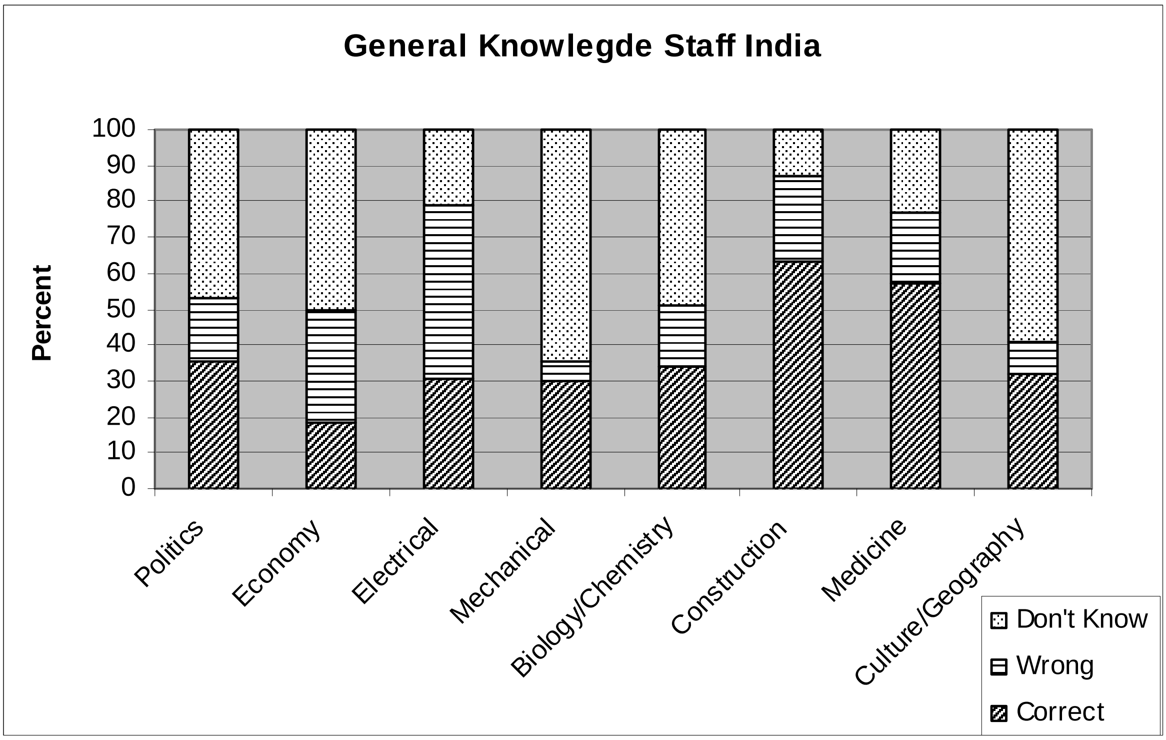


FIGURE 77: RESULTS GENERAL KNOWLEDGE OF QUESTIONED PLANT STAFF IN INDIA

Figure 77 gives an outlook on the results from the questioning regarding several different question fields. Three questions of different severity were asked for each field (all questions see appendix C).

Detailed Analysis

Regarding the general knowledge of the questioned staff (see question 23, appendix C), it has to be stated that most correct answers were given on the questions regarding construction (63%) and medicine (57%). Great awareness regarding the transmission of AIDS can be stated, for example. Questions regarding construction aspects mainly targeted on concrete – its fabrication and material characteristics, like corrosion proofness under water. Questions regarding politics included both Indian and world politic questions and were answered correctly to about 35%. From the field of culture and geography, 32% of the questions were answered correctly. This field included very general questions on Indian geography and history, famous scientists and musicians.

For wastewater treatment very interesting are the electrical and mechanical, as well as the biological/chemical field. Questions from the mechanical field targeted on basic elements, like tools, bearings and bolt data. Questions from the electrical field consisted of questions regarding motor protection, measurement instruments and connection principles. Specifically for the treatment plant operation, the questions from the field of biology/chemistry were of interest, consisting of questions regarding the characteristics of chlorine and nitrogen, but also one simple question regarding DNA. In the electrical and mechanical question field, about 30% of the questions were answered correctly. Of those staff members working in the electrical field, 53% answered questions from the electrical field correctly, 46% of the mechanics and fitters answered the questions from the mechanical field correctly.

34% of the questions from biology/chemistry were answered correctly. Very interesting is the relatively high proportion of wrong answers in the electrical field (48%), which is an indicator that the test persons obviously were guessing very often. As already mentioned, the severity of the questions was graded – each question package consisted of one very simple, one medium and one a bit more special question. Looking at the given answers more detailed depending on the professional field of the test persons, it is interesting to see, that for example only 30% of the electricians did give the correct answer regarding the purpose of a motor protection switch. The purpose of a volt meter was known by 70% of the test persons, the characteristics of three phase connection was known by 60% of the test persons.

Regarding the mechanical field, the purpose of a torque spanner is known by about 50%, the meaning of "M16" as description for a bolt with 16mm diameter was known by 40% and spherical roller bearings were known by only 20% of the mechanics and fitters, but here also the difficult translation of this question has to be considered. Regarding questions from biology/chemistry, the group of questioned chemists and operators, is considered. Only about 14% of the test persons know that nitrogen is not a toxic gas, whereas 67% give a correct answer regarding the toxicity of chlorine. DNA is known only to about 10% of the test persons.

In order to get information especially on job specific knowledge, different technologies and processes were mentioned to the test persons – screens, activated sludge process, SBR, SBBR, RID, trickling filter, anaerobic treatment, membrane technology and wastewater composting (see question 15, appendix C). The questions are designed in a way that the test persons are asked whether they know the respective technology and whether it is used on their plant. The following answer distribution could be determined:

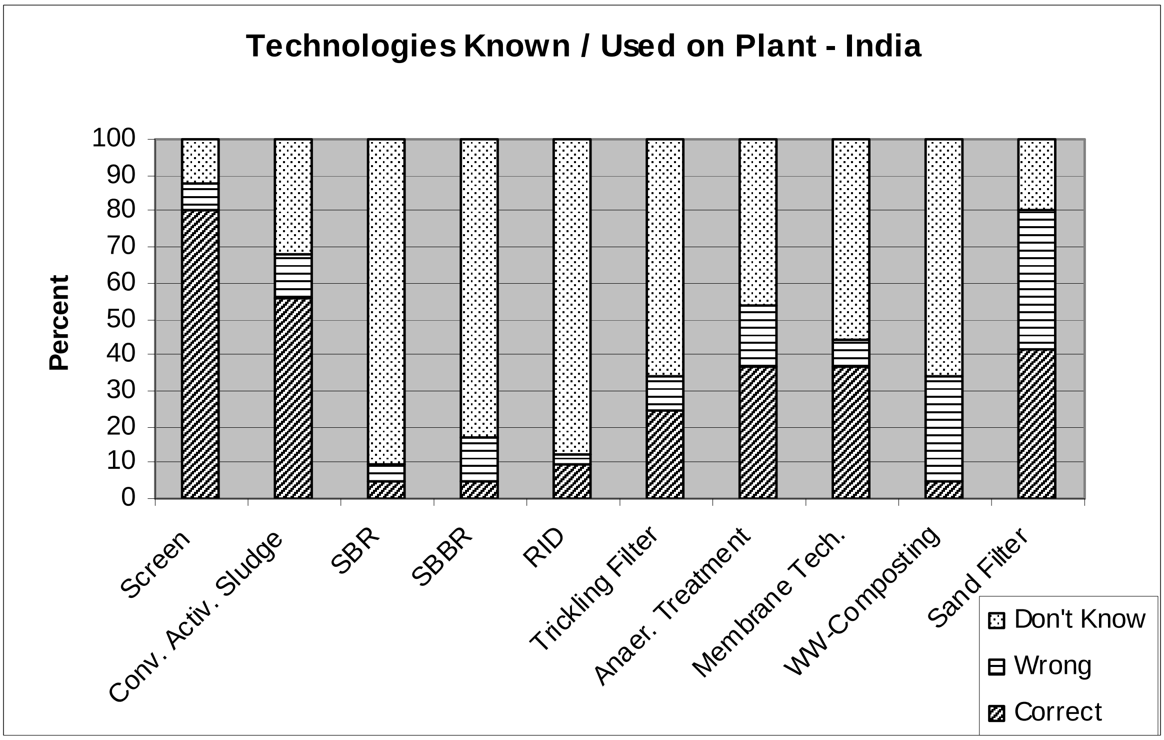


FIGURE 78: TECHNOLOGY KNOWLEDGE OF QUESTIONED PLANT STAFF IN INDIA

Regarding the knowledge on wastewater treatment technologies, it can be summarised that technologies that do not exist on or near the plant where the respective test person is working, are hardly known, even by name. Screens and activated sludge process are used in many plants, whereas SBR, SBBR and RID technology is practically unknown on Indian plants. More than 80% of the test persons from plant where conventional activated sludge system is not used don't know this technology or claim that it would exist on their plant. On plants with conventional activated sludge system, only about 37% of the test persons did not know this technology or claimed it would exist. Trickling filters, anaerobic treatment – mainly UASB or sludge digesters – and sand filtration exist in some plants. The proportion of correct answers is accordingly higher. In average, about 30% of the technology questions were answered correctly.

Similarly, the test persons were asked about the correctness of different statements on plant processes and safety measurements. The statements were targeting on aspects like solids removal, aeration, biomass, hygienic aspects regarding biological sludge, filtration, BOD, recirculation and flocculation (see question 16, appendix C). Figure 79 shows the answer distribution:

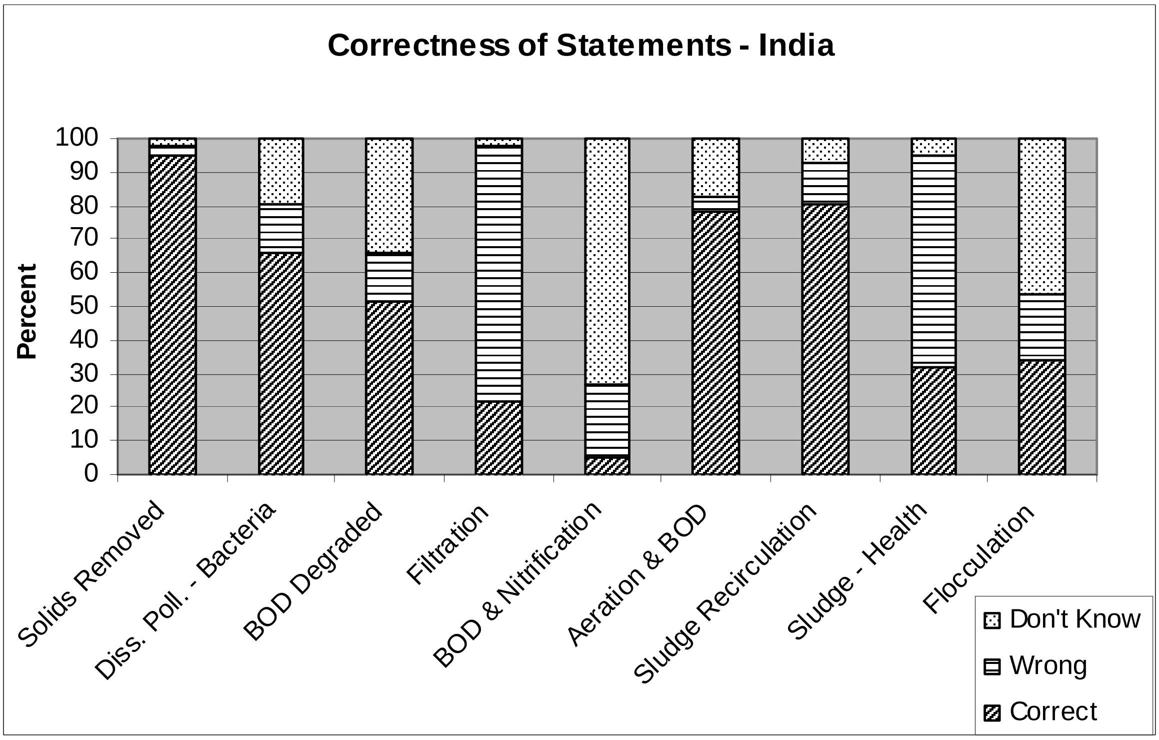


FIGURE 79: PROCESS KNOWLEDGE OF QUESTIONED PLANT STAFF IN INDIA

Regarding the statement that in their plant solids are removed from the wastewater, about 95% of the test persons gave a correct answer. Given the statement that dissolved pollutants are eaten by bacteria in their plant, 66% of the test persons gave a correct answer. Between 70% and 80% ranged the proportions of correct answers regarding the existence of an aeration system for BOD removal and the importance of sludge recirculation on the respective plant. The meaning of BOD is obviously not well known, which can be seen by the fact that the statement that BOD is degraded in their plant was answered correctly by only 51% of the test persons. The statement regarding nitrification is answered correctly only by 5% of the test persons, whereas it has to be considered that only two persons were questioned on a plant that is designed for nitrification. The claim that the wastewater sludge of the treatment plant cannot make anybody ill, was denied only by 32% of the test persons, which is a very good example for a relatively low awareness of staff regarding hygienic and work safety aspects. The reason for the relatively high proportion of wrong answers of 76% regarding the existence and importance of filtration can be seen in a communication problem – many test persons obviously associated with filtration purification and for that reason gave the wrong answer. The statement that flocculation is an important treatment step in the plant was answered correctly by 34% of the test persons.

Work Situation & Motivation

In order to get information on the work situation, the test persons were asked to choose from a series of possible work related wishes (see question 14, appendix C). They could choose between none and maximum three wishes that they should prioritise. It is assumed that the respective choice of the test person represents a deficit aspect for the test person. Looking at the results, both the frequency of choice split on ranks and total frequency is interesting to see.

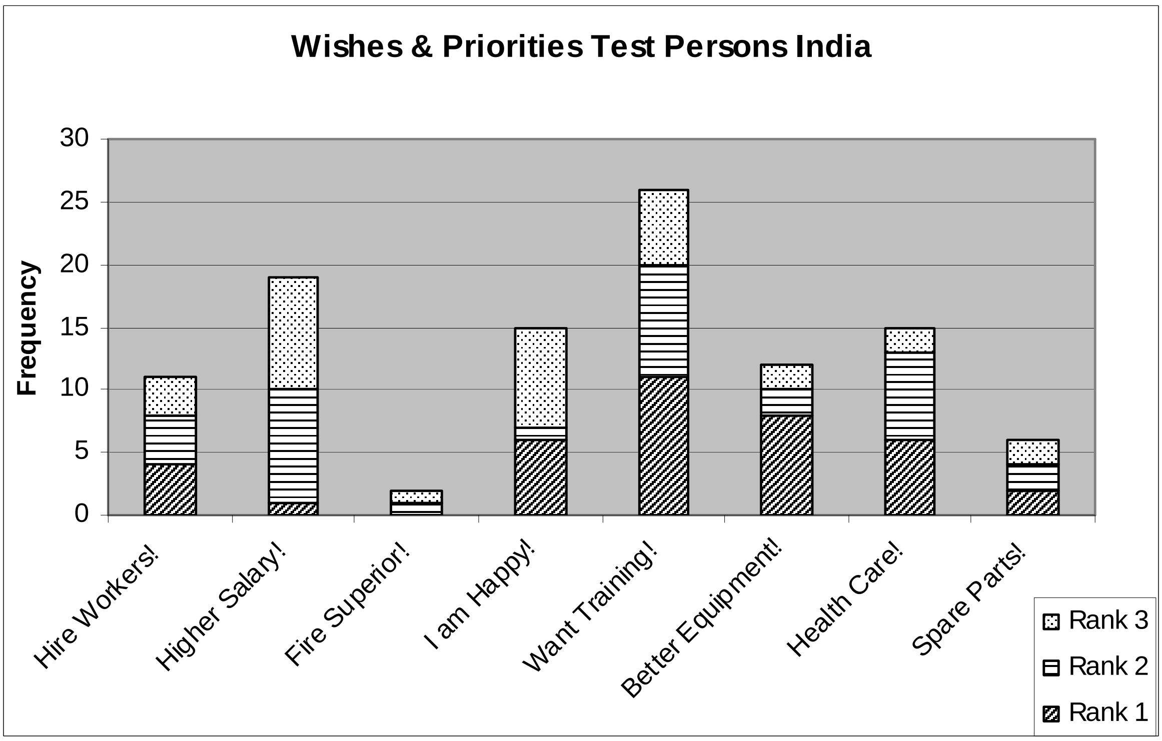


FIGURE 80: WISHES AND PRIORITIES OF QUESTIONED PLANT STAFF IN INDIA

As visible in figure 80, the wish to get training is expressed as strongest – the total frequency of choice is the highest. It is also named most often on rank 1. The wish for higher salary is on second position of total frequency, but interestingly hardly named on rank 1. Obviously, salary is of general importance, but other specific aspects are of higher priority. Health care is an important topic for the questioned test persons, which can be seen on the respective frequencies. The wish for better equipment is also relatively strong – it is on second position regarding the frequency of rank 1. Spare parts access problems don't seem to play a role for the questioned staff – improvements in this aspect were desired by 6 test persons. Regarding "I am happy with my job!", the frequency difference between the different ranks is interesting. It can be assumed that social desirability in the interview situation could have an influence. The wish for the employment of more workers is named with a frequency of 6 and is on position 6 regarding the total frequencies of namings. Difficult staff constellations cannot be stated – the wish that the superior should be fired is on last position. Summarising, it can be seen that a high intention for knowledge improvement seems to exist among the practically working staff.

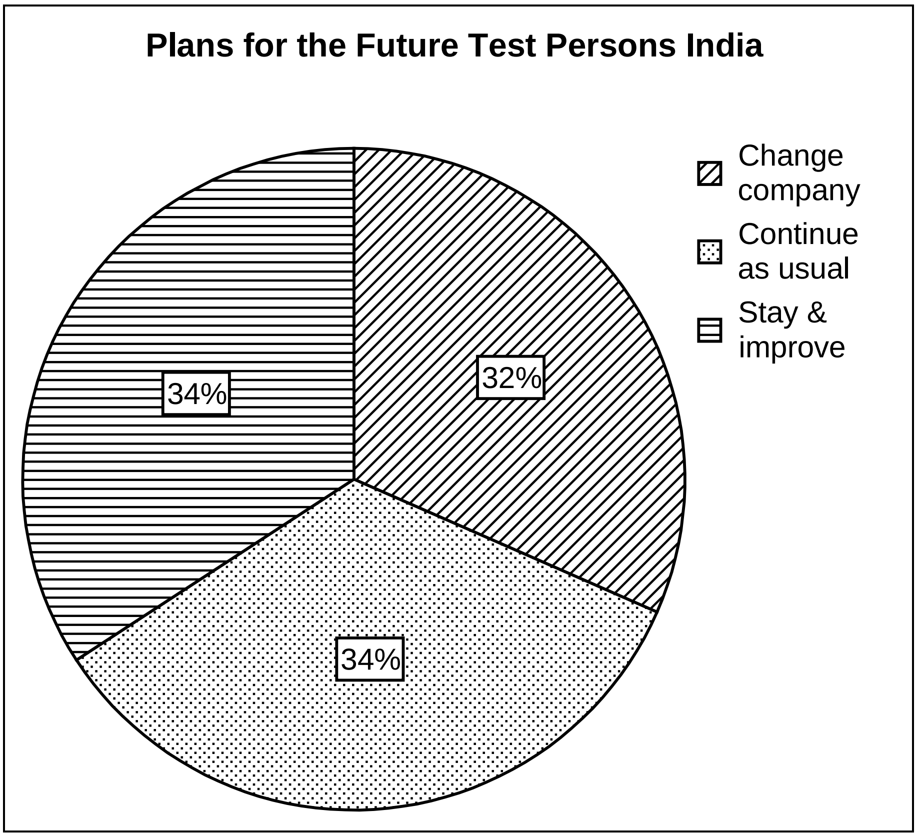


FIGURE 81: FUTURE PLANS OF QUESTIONED PLANT STAFF IN INDIA

As an indicator for the work motivation of the test persons, they were asked about their plans for the future (see question 28, appendix C). Almost 32% of the test persons want to change the work place, about 34% want to remain in the same job situation and 34% want to improve, means, they intend to develop in their company or municipal plant.

7.1.3 Expert Positions

In order to get up-to-date information on the position of experts on different aspects related to the use of wastewater technology in India, 42 experts were interviewed. Figure 82 shows the distribution of the different test person groups.

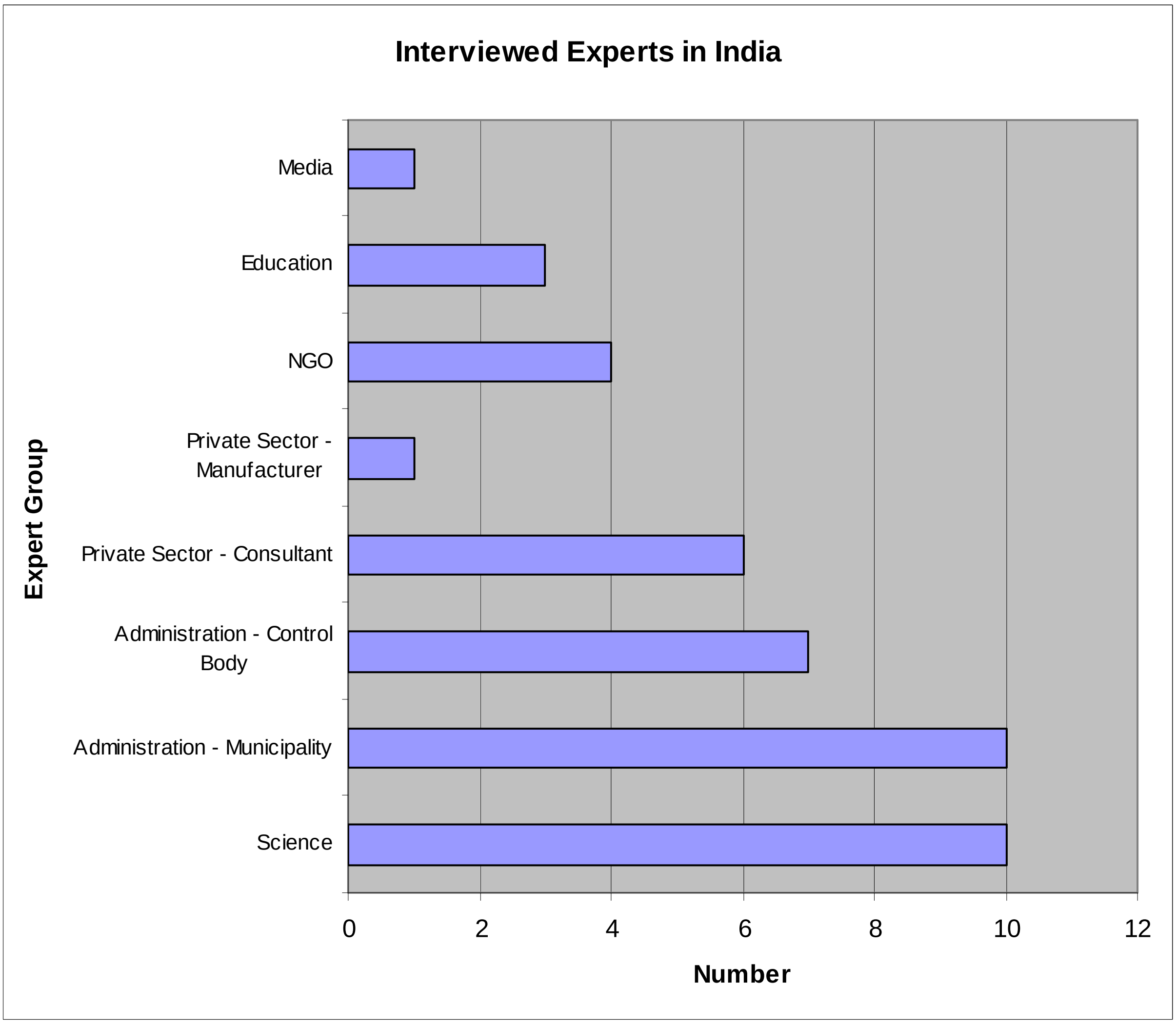


FIGURE 82: OUTLOOK INTERVIEWED EXPERTS IN INDIA

About 78% of the test persons are between 40 and 60 years old – the average age is 50 years. 5% are less than 40years, 7% are more than 60years old. All interviewed experts have long term experience in their work field. 86% of the test persons are working in the field of water & wastewater, 12% in the environmental field in general.

In the following paragraphs, the results in the different question fields are presented. In the outlook figures, those question fields were considered, to which at least 3 test persons gave a statement.

Environment & Water Pollution in General

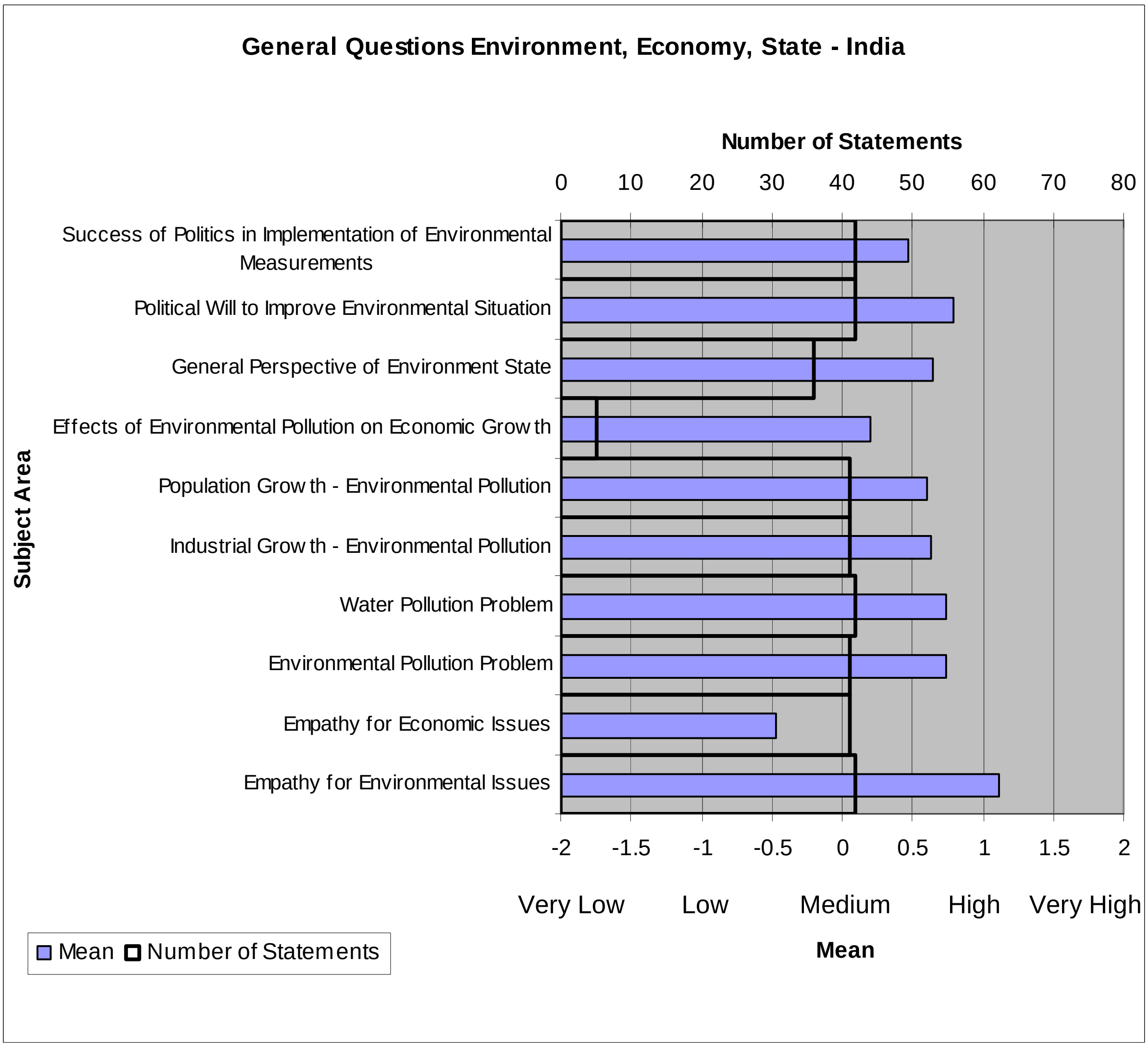


FIGURE 83: EXPERT POSITIONS ON GENERAL ASPECTS IN INDIA

In general, a relatively high empathy of the interviewed experts for environmental issues could be stated, with a mean value of 1.12. The environmental pollution, especially the water pollution problem is seen very critical by more than 70% of the experts. As major reasons, both industrial growth and population growth were named by many experts. As visible in figure 84, about 51% of the interviewed experts who gave a statement on this topic, consider the municipalities to be more or only responsible for environmental and water pollution. 27% see the municipal and industrial wastewater as equally responsible and only 22% consider the industry to be more or exclusively responsible for the pollution situation. Especially experts from science point out the strong influence of the population growth.

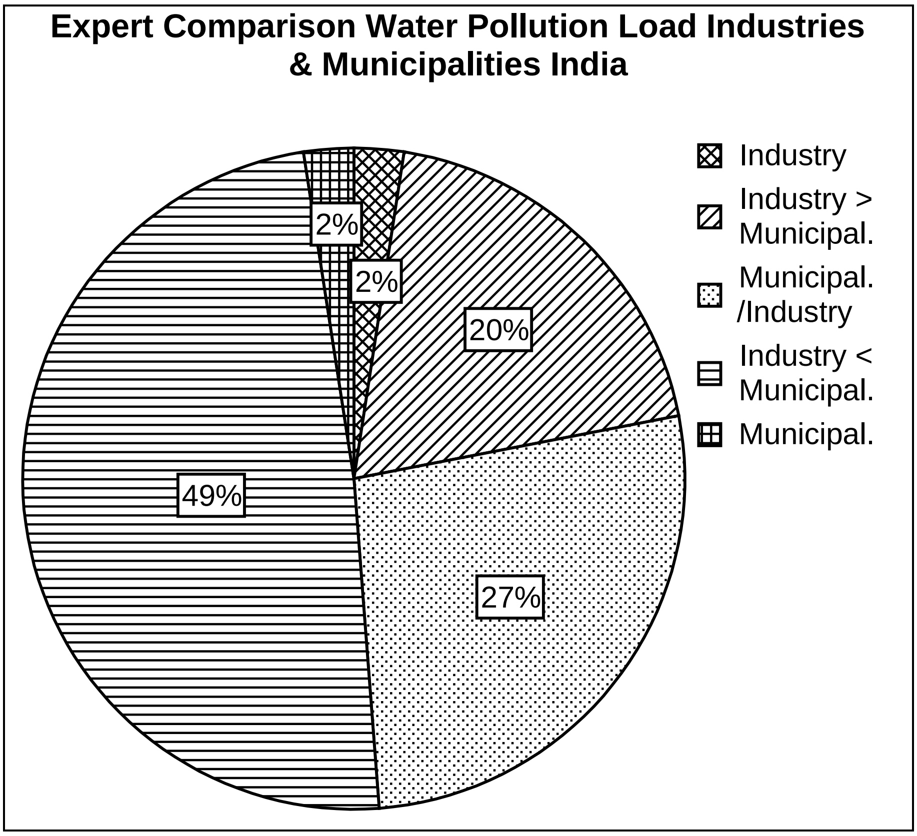


FIGURE 84: EXPERTS COMPARISON OF WATER POLLUTION LOAD INDUSTRIES AND MUNICIPALITIES IN INDIA

"The urban population is increasing very fast, so local authorities are unable to satisfy the requirement and basic need of the citizens" (Scientist - Expert Interview India No.5).

In the opinion of many experts, industries are also very polluting in many regions of the country, but as industries generate point source pollution, control is much easier than to control municipal water pollution as non point source, in the opinion of many experts. However, many experts think that industries are considered as easy targets compared to municipalities.

"We tend to blame the industry. Industry is an easier culprit to blame… Why don't they blame the municipal corporation?" (Consultant – Expert Interview India No.3).

Negative effects of environmental pollution on the economic growth are not seen by many interviewed experts. Deficits are seen in the implementation of measurements of environmental protection in the actual situation, although the existing laws and guidelines are considered to be suitable. A consultant explained this problem with the following words:

“Nobody is there to explain the industry that it is our moral or legal duty to to comply with the pollution control board act. This is the reason for the late start of the implementation of the water act. Second reason is that government authorities are not strict. No law to countercheck, if they are implementing or not. Third is that the law is not implemented strictly by industry or by pollution control board” (Consultant – Expert Interview India No.6).

Regarding the future development of the environment, the interviewed experts are optimistic and see a strong political will in the country to improve the situation, with a mean value of 0.79.

Wastewater Treatment Technology

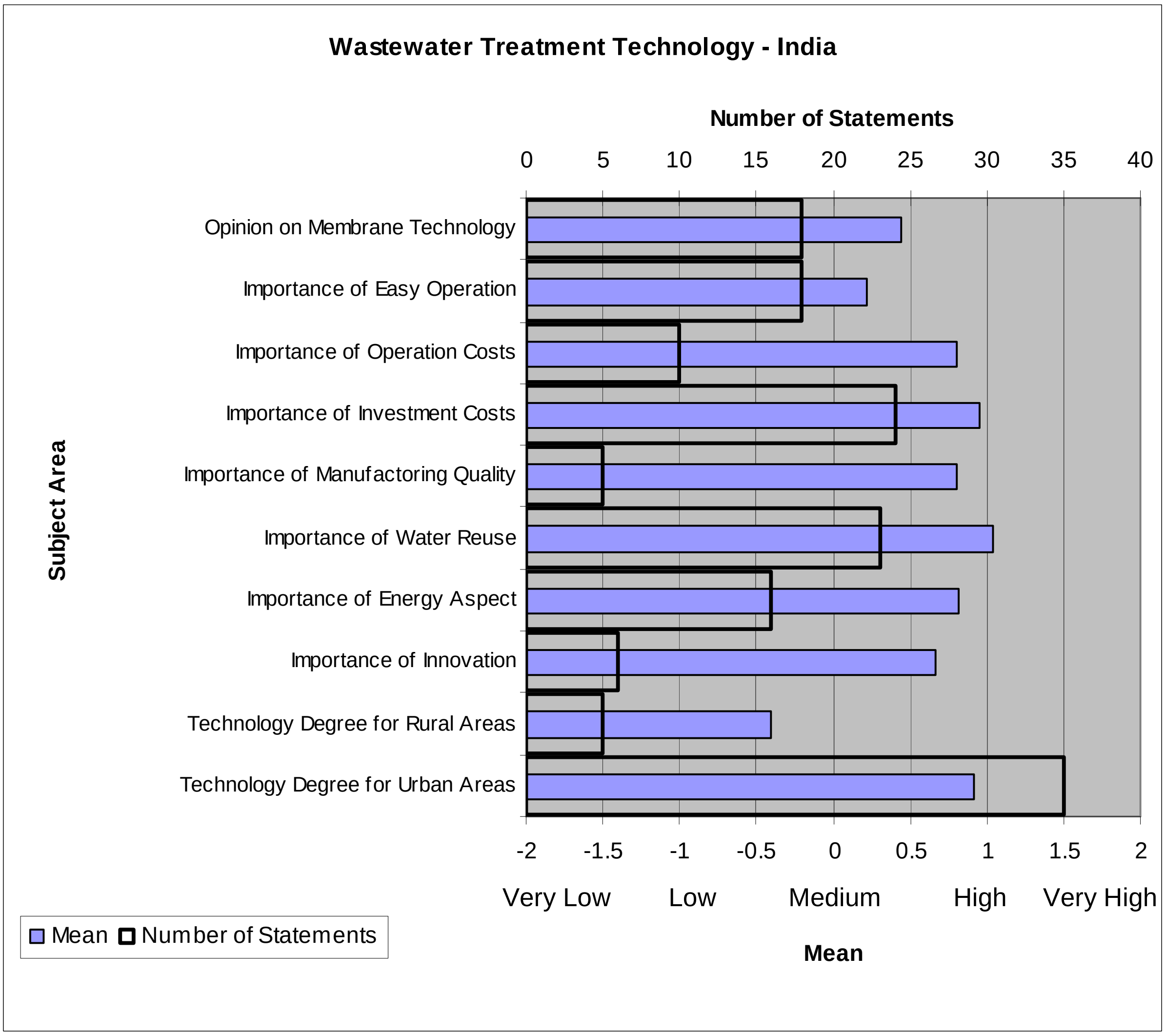


FIGURE 85: INDIAN EXPERT POSITIONS ON WASTEWATER TREATMENT TECHNOLOGIE

Expert positions on technical aspects are presented in figure 85. A basic question is the technology degree that means the complexity of technical solutions. In urban areas, a clear focus of decision makers on big centralised systems can be stated, whereas aspects of easy operation play a minor role for most experts. For the technology degree for urban areas, a mean value of 0.91 could be determined for the expert opinions of interviewed Indian experts. As suitable technical systems mainly activated sludge system is mentioned. Reuse of treated wastewater is an important topic for many interviewed Indian experts, which can be seen in the high value of 1.04. Regarding the use of membrane technology, some experts expressed doubts regarding operation and maintenance. Decentralised solutions like the ECOSAN concept are practically unknown to the interviewed experts, although from the discussions during the interviews a trend for water reuse can be stated independent from the technology.

“We cannot say we should go for anaerobic digestion or we should go for activated sludge process, or we should go for microfiltration. It depends… it will depend on the… because we are bringing the concept or wastewaster reuse – recyle. So we have to think of the technology. It will depend on what type of output you require. If you suppose you want to let the water into the sea, then secondary treatment is sufficient. Then you can go for activated sludge process only. But if you want to reuse this water for power purpose, using the water in the boiler, or for cooling purpose, then we have to go for tertiary treatment and then definitely we have to go for microfiltration or reverse osmosis. So it will depend on the quality of water you require.“(Chief Engineer Drainage Department Municipal Corporation – Expert Interview India No. 32).

More natural and basic treatment system, like oxidation ponds, wetlands or lagoon systems are considered to be suitable for rural areas. Some experts are also sceptic regarding the implementation of very technical systems in urban areas, due to expected operation and maintenance problems. Investment costs are considered as a major criterion by the interviewed experts, as the relatively high value of 0.96 shows. Running costs are a bit less in the focus compared to investment cost.

Economic Aspects of Technology and Knowledge Transfer

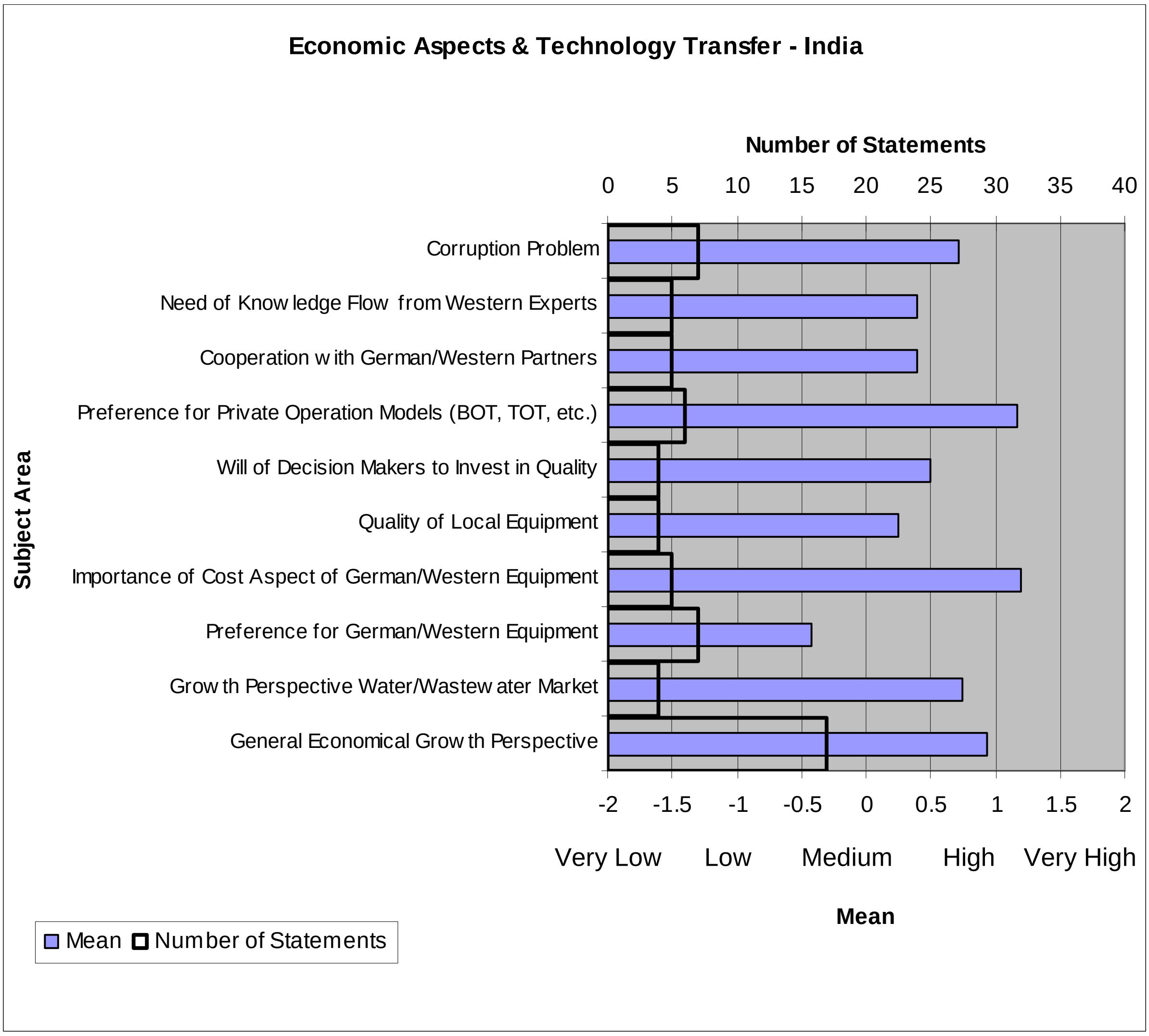


FIGURE 86: INDIAN EXPERT POSITIONS ON ECONOMIC ASPECTS AND TECHNOLOGY TRANSFER

The general economic growth perspective is seen very positive – many of the interviewed experts expect a further industrial growth and consider this as very beneficial for the country, so that a value of 0.94 could be determined. The development of the water and wastewater market is also considered to be very positive, as visible at a value of 0.75.

Very few interviewed experts comment on German water and wastewater technologies. In general, a relatively low preference for western equipment can be stated (value -0.43). As main reason, the high investment costs - especially of German equipment - are mentioned. From the discussions also with Indian partners of German companies, a very good reputation of equipment made in Germany can be stated.

Several interviewed experts report about problems with western technology in India. One test person gave the example of an imported waste incineration plant that could not be operated because of the low content of combustible material.

“Because the actual, I mean, combustable element, that is much less. Because what happens in India, all the paper is selected for recycling, various other things are segregated out and what is let out is some inert, which has no calorific value. But we have imported the technology that has been installed – it is of no use. So we have to see what is available in your way. Accordingly we have to develop the technology.” (Industry Expert - Expert Interview India No. 39).

Most test persons described the cooperation with western project or business partners positive – only one interviewed Indian expert reported about very negative experience. Western partners are considered to be work-focused and competent. A need for knowledge transfer from Western countries is seen only by some experts. Corruption is seen as a big problem, with a value of 0.71, although many experts avoid speaking about this topic in the interview.

“Very honestly speaking, no, I should not … I mean … speak that point so openly. But corruption is one of the biggest things in India. And even the higher officers also just if the industrial is placing something, then he is not…water pollution is create… so that is of the things that are going on in some parts. So, judiciary teeth should be more strong.” (Scientist - Expert Interview India No. 33).

Some experts criticise also knowledge deficits of decision makers. Although only few experts comment on privatisation in the wastewater sector, a trend for private models and private-public partnerships can be stated, with a value of 1.17. This can be seen also by the fact that several relatively new plants in cities like Delhi or Bangalore are operated by the daughters of international enterprises like Degremont for example. Conservation of natural resources is mentioned as one advantage, which shows the following statement of an Indian consultant with activities in international organisations like World Bank:

“If you bring in some ideas from the private sector that… will manage the sewage treatment plants and find a way to make money out of it, then probably that increases the private sector participation. It also means that you conserve on natural resources…” (Consultant - Expert Interview India No. 10).

Awareness & Professional Education

In the following, the detailed consideration of aspects of awareness, education and motivation is carried out.

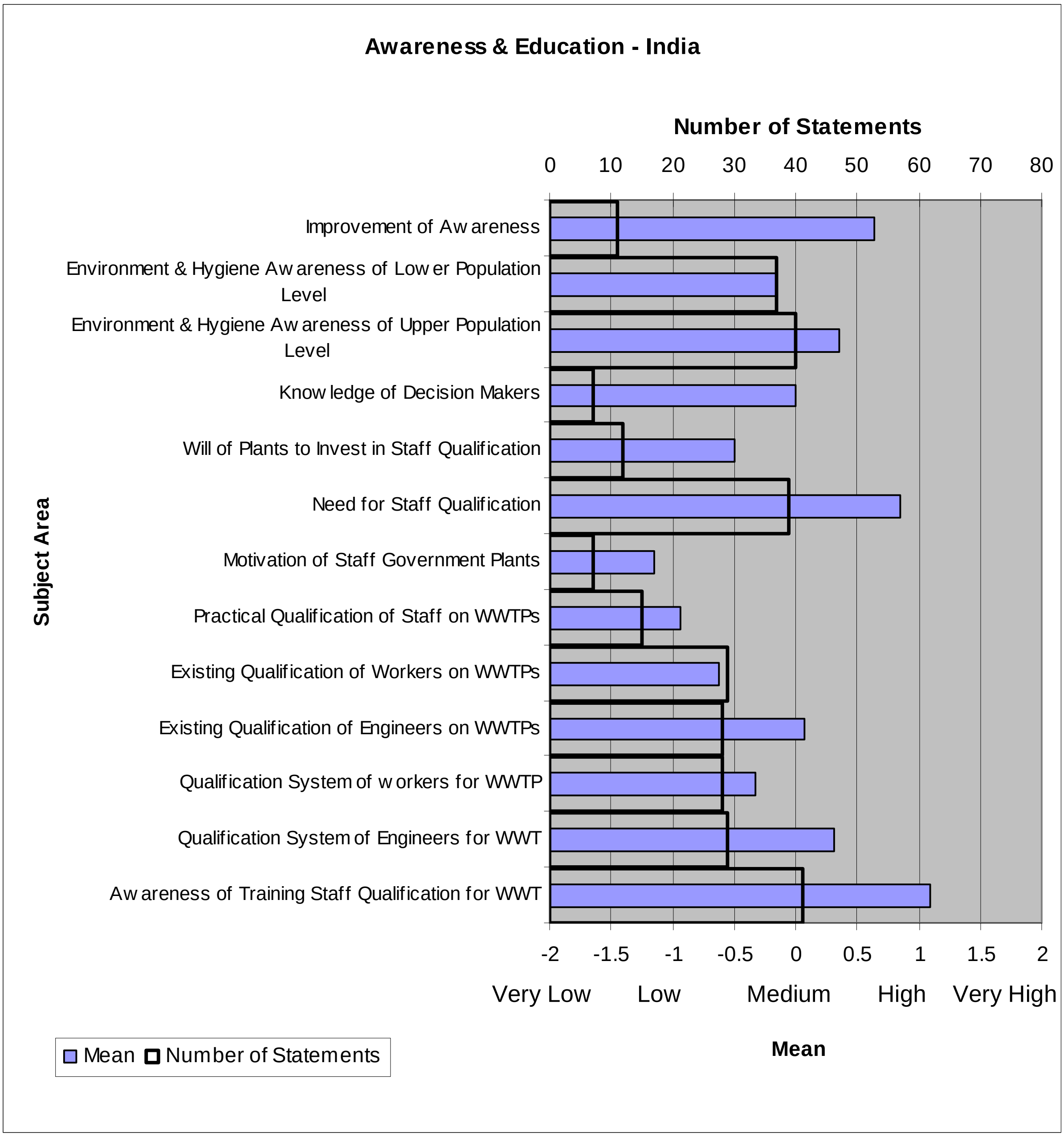


FIGURE 87: INDIAN EXPERT POSITIONS ON AWARENESS AND PROFESSIONAL EDUCATION

In order to get first hints on the basic position of the population regarding environmental and hygienic aspects, the interviewed experts were asked how they see the different populations groups in this regard. In most cases, the awareness of the upper population level is considered to be moderately developed, or at least improving, which shows the value of 0.35. Regarding the lower population level, the environmental awareness is seen relatively low by most experts (value -0.16). The priority of elementary material aspects and lack of education are seen as major reasons. A former head of the All India Institute of Hygiene and Public Health describes the situation with the following words:

“You see among the poorer section and little illiterate section of the population, awareness is very low. Among the educated mass, again there are a section, like health professionals, there are sections who are environmentally concerned activists, their awareness is increasing. But if you look into ordinary business man, traders, even the villagers doing agriculture, then their awareness level is still not at the desirable level” (Scientist – Expert Interview India No. 35).

Most of the interviewed experts express a high awareness for the qualification of staff – both on the engineer and practically working staff level, which is visible in a high value of 1.10. Asked both about the existing qualification of engineers and working staff on wastewater treatment plants, most interviewed experts consider the academic staff to be well qualified with an average value of 0.07 in the medium range. Compared to this, the qualification of the practically working staff – workers, technicians and operators – is seen significantly lower by the interviewed experts with an average value of -0.62. The following statement of the director of a well known research institute with strong cooperation with industries illustrates the situation:

“Technology, I don’t think is the big problem. Only thing is maintenance, operation maintenance. Particularly the technicians, they are lower level people. They are working without understanding the process” (Scientist – Expert Interview India No. 24).

Asked about the present qualification systems for the staff of wastewater treatment plants in India, academic education is considered to be on a high level by most test persons (value 0.31).

“We have ability to design… ability to design the plant of the capacity and the quality… of that standard, which the… advanced countries in the world they are doing” (Chief Engineer Drainage Department Municipal Corporation – Expert Interview India No. 32).

In the private sector, however, also deficits are seen in the academic education, due to lack of real references.

“Training is done only in colleges. Otherwise from other side it is not much. Because here the consulting engineers, Indian consulting engineers they do not have much knowledge, as contracting firms or turnkey contractors" (Manufacturer – Expert Interview India No. 2).

Critically is seen the qualification system for practical plant staff (value -0.32). Employment practices on wastewater treatment plants are criticised and high need for staff qualification is expressed by the interviewed experts (value 0.85).

"Now what happens unfortunately at present, we are not so much careful about selecting the people. Anybody who passes twelfth exam is appointed to handle the machinery. And they are less aware about the engineering aspect of those machineries, which they are handling. They know superficially how to operate…...pushing the button, getting the reading on the dial, so, that is very much superficial. And, in order to have better maintenance and operation of the machines, they should be at least diploma holders, of that branch" (Scientist – Expert Interview India No. 33).

The motivation on the treatment plants, especially of the workers and technicians, is another interesting topic. As visible in figure 87, the interviewed experts describe the motivation very critical on municipal plants (value -1.14). Financial constraints and lack of development perspectives can be figured out as main reasons.

"People working in water supply and … sewage treatment plant, they are not happy about their job*… (Interviewer: Why are they not happy about their job?) …*They don't have opportunity to work there and because of the same type of job, they are supposed to to same type of job*… (Interviewer: Has it something to do with the payment or with the motivation?)* Motivation… Payment aspect we keep aside. First, we require the attitude to work, the motivation. Because of the limitations of the money they are not getting the opportunity to work for better environment, number one, and for better project you can say"(Chief Engineer Drainage Department Municipal Corporation – Expert Interview India No. 32).

Identification of Major Position Differences between Expert Groups

In addition to the overall analysis of the expert interviews, a comparison of the opinions of the following major expert groups is carried out:

- Control & Administration (pollution control boards and municipalities)
- Private Sector (consultants and manufacturers)

- Science

Figure 88 shows those topics, where interesting differences between the different expert groups could be determined.

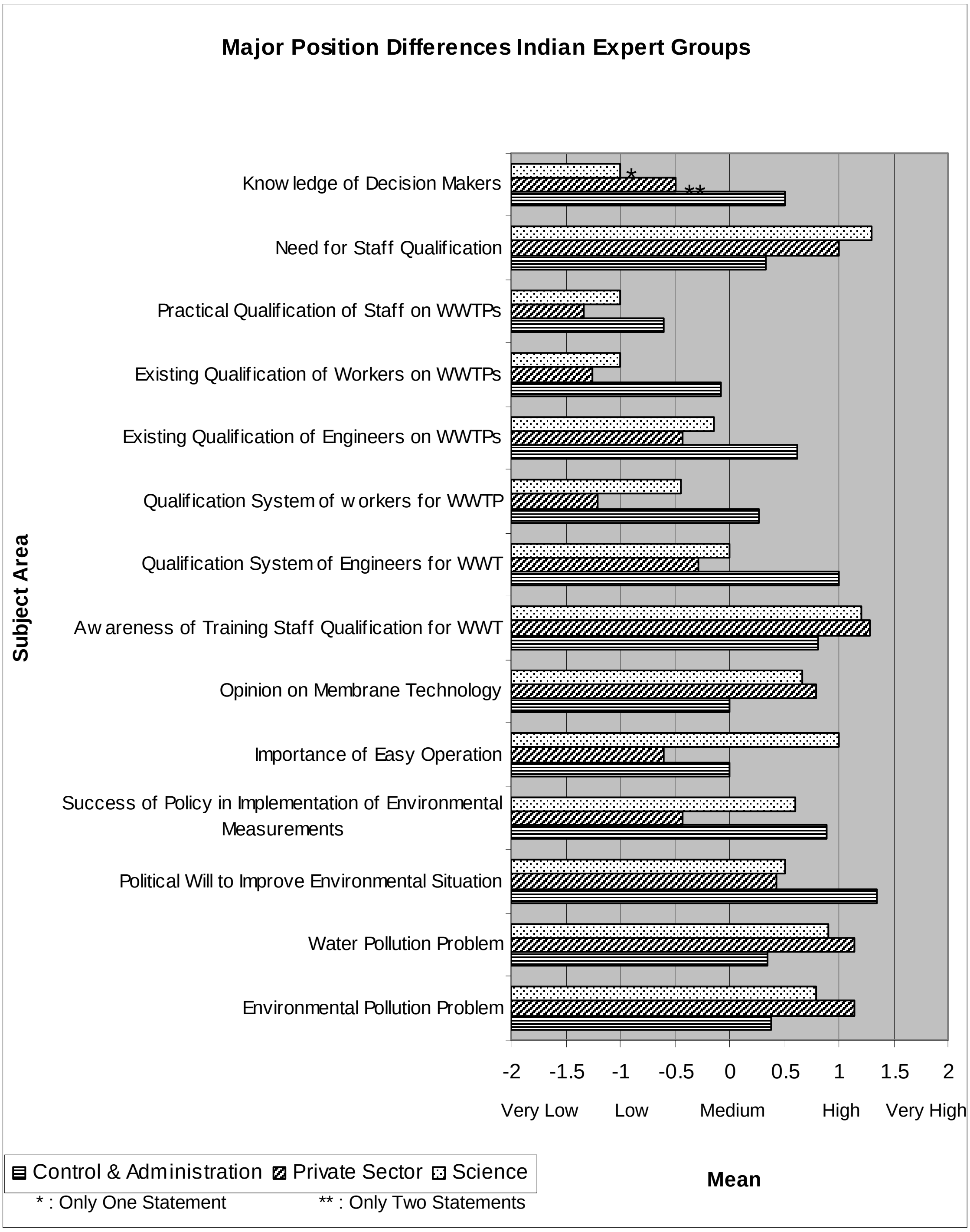


FIGURE 88: MAJOR POSITION DIFFERENCES OF DIFFERENT EXPERT GROUPS IN INDIA

Comparing the expert opinions regarding existing qualification of treatment plants staff – both engineers and practical staff – especially the private sector considers the situation problematic (value -1.25), whereas the experts from control institutions and administration obviously don’t consider the situation as severe (value -0.08). Especially regarding the qualification and the qualification system of practical staff, the very positive opinion of experts from the public sector compared to the private sector surprises. Also the need for staff qualification is seen less important by representatives from the public sector (value 0.33) than by experts from science and the private sector (value 1.0, resp. 1.3). Interestingly, easy operation is less important for experts from the private sector than for experts from the public sector and scientists.

Very interesting is the comparison of the expert opinions regarding the knowledge of decision makers, which means mainly representatives of administrations in municipalities. Especially the science and private sector considers the knowledge of decision makers as relatively low (values -0.5, resp. -1.0). Doubts regarding the success of politics in implementation of environmental measures are expressed mainly by the private sector (value -0.43). Interviewed experts from the public sector see the success and the will of politics to improve the environmental situation much more positive than experts from the private sector.

Interesting is the relatively high preference of membrane technology in the private sector (value 0.8) and among scientists (value 0.67), compared to the public sector, which shows that the relatively strong technology orientation (see figure 85) is based mainly on the private sector and science.

7.1.4 Summary & Discussion

Treatment Plant Efficiency & Processes

As shown in chapter 7.1.1, municipal wastewater treatment in India is currently focussing on BOD-removal. Further treatment with nitrification or even denitrification is very rare. However, disinfection by chlorine gas or hypochlorite is common, if the treated water is reused.

In this study, an average BOD-removal efficiency of 89% could be determined for STPs, based on the information given by the respective plant management (see figure 40). The COD removal efficiency could be determined as between 80% and 90%, SS removal efficiency as between 90% and 95% for the inspected plants in the current study (see chapter 7.1.1). The gained information on the treatment efficiency of sewage treatment plants in Delhi corresponds with analysis data published by the Central Pollution Control Board (CPCB). Comparing the efficiency values of the different STPs with performance data from November and December 2003, a slightly higher efficiency regarding BOD removal could be stated for most inspected plants in Delhi in the current study, based on the information given by the respective plant managers (see figure 40). The performance report of the CPCB mentions efficiency values for BOD between 75% and 95% for most plants, COD removal efficiencies between 70% and 90% and for TSS removal efficiencies between 70% and 95% (CPCB 2004). Also regarding COD and TSS, the determined treatment efficiencies for the plants in Delhi are slightly higher in the current study, whereas the fact has to be considered that almost all data are based on the information given by the respective plant management. Table 31 gives an outlook on the compliance with the required discharge standards based on a CPCB-report from 2005.

State	**STPs studied by CPCB**	**STPs that achieved general standards for discharge in surface waters***	**STPs that did not achieve general standards**
Bihar	3	3	0
Chandigarh	2	1	1
Chhattisgarh	3	2	1
Delhi	26	20	6
Gujrat	9	6	3
Haryana	7	2	5
Himachal Pradesh	5	5	0
Karnataka	4	2	2
Madhya Pradesh	2	1	1
Maharashtra	4	0	4
Punjab	4	4	0
Rajasthan	1	0	1
Uttar Pradesh	25	8	17
Uttaranchal	2	1	1
West Bengal	18	15	3
TOTAL	**115**	**70**	**45**

TABLE 31: STATEWISE SUMMARY OF PERFORMANCE STATUS OF STPS (CPCB 2005)

Regarding the compliance of STPs with national discharge standards, the results from the plant inspections in this study are very positive. Only 3 out of 20 STPs, of which performance data are available - that means about 15% - don’t meet the required standards.

As visible in table 31, about 70 out of 115 inspected STPs comply with the required standards for the discharge into surface water bodies, that means that in average about 39% of the STPs don’t match the required standards set by CPCB (standards see table 3, chapter 5.1.1). Great regional differences exist regarding the compliance. In Delhi, 20 out of 26 plants comply with the standards, whereas in Uttar Pradesh only 8 out of 25 plants comply with the standards. The reason for the relatively high compliance rate in the current study has to be seen in the fact that almost only plants with high capacity in the major development centres were taken into account, where sewage treatment is on a higher level than in smaller or remote areas of the country. As already mentioned, the fact has to be considered that in the current study, almost all performance data are based on the information given by the plant management – no samples were taken.

Table 32 gives an outlook on existing treatment plant processes of Class I cities in India. As visible in table 32, activated sludge process is by far the most common biological treatment process in Class I cities – about 60% of the total treated wastewater is treated by any of the different variations of activated sludge process, about 26% is treated by an anaerobic UASB process (Upflow Anaerobic Sludge Blanket). Although several plants based on UASB-technology are in operation for sewage treatment, the technology is controversial among Indian experts. Operational problems and odour problems exist in many plants. This show both the results of the actual plant inspections and interviews on expert level in India. Studies of the CPCB on existing and recommended treatment processes state operation deficits especially for UASB processes (CPCB 2005).

S. No.	Technology	No. of plants	% age as number	Combined capacity, MLD	%age as capacity	Average size, MLD
1	Activated sludge process (ASP)					
	...PST+ASP	*42*	*28.0*	*3059.63*	*52.6*	*72.8*
	…ASP-Ext. Aer.	*3*	*2.0*	*63.36*	*1.1*	*21.1*
	…ASP-Ext. Aer.+ Ter. Sed.	*7*	*4.7*	*58.04*	*1.0*	*8.3*
	...High rate ASP+Biofilter	*1*	*0.7*	*181.84*	*3.1*	*181.8*
	…Aerated lagoon+fish pond	*3*	*2.0*	*49.50*	*0.9*	*16.5*
	…Facultative lagoon + ASP	*1*	*0.7*	*44.50*	*0.8*	*44.5*
	ASP (sum of all above)	57	38.0	3456.87	59.5	60.6
2	Fluidized aerobic bio-reactor (attached growth)	5	3.3	66.00	1.1	13.2
3	Trickling Filters or Biofilters	6	4.0	192.62	3.3	32.1
4	UASB+Activated sludge process	1	0.7	86.00	1.5	86.0
5	UASB					
	…Grit channel or PST+UASB+PP	*24*	*16.0*	*1229.73*	*21.2*	*51.2*
	…UASB+Sedimentation	*1*	*0.7*	*126.00*	*2.2*	*126.0*
	…Grit channel or PST+UASB	*5*	*3.3*	*158.17*	*2.7*	*31.6*
	UASB (sum of above)	30	20.0	1513.90	26.0	*50.5*
6	Waste Stabilization Ponds	42	28.0	327.53	5.6	*7.8*
7	Oxidation Pond (single stage)	3	2.0	69.00	1.2	*23.0*
8	Anaerobic digester + Trickling filter	1	0.7	4.45	0.1	*4.5*
9	Karnal Technology (plantation)	2	1.3	12.46	0.2	*6.2*
10	Only primary treatment	3	2.0	84.00	1.4	*28.0*
	Total	150	100%	5812.83	100%	

TABLE 32: TECHNOLOGIES EMPLOYED IN STPS OF CLASS I CITIES IN INDIA ACCORDING TO CPCB (CPCB 2005)

In Class II cities and smaller towns, many STPs consist only of a primary treatment stage without biological step, as table 33 shows.

S. No.	Technology	No. of plants	% age as number	Combined capacity, MLD	%age as capacity	Average size, MLD
1	ASP (preceded by primary sedimentation)	1	3.4	12.5	5.6	12.5
2	Grit channel or PST+UASB+PP	3	10.3	23.83	10.6	7.9
3	Waste Stabilization Ponds	21	72.4	161.26	71.9	7.7
4	Trickling Filters	2	6.9	16.68	7.4	8.3
5	Karnal Technology (for plantation)	2	6.9	10.13	4.5	5.1
	Total	29	100%	224.4	100%	

TABLE 33: TECHNOLOGIES EMPLOYED IN STPS OF CLASS II CITIES IN INDIA ACCORDING TO CPCB (CPCB 2005)

For Class II Cities mainly waste stabilisation ponds are used - about 72% of treatment capacity is achieved by waste stabilisation ponds. Activated sludge plants hardly exist in Class II cities. UASB technology holds a proportion of about 11%. As the results of the expert interviews show, a trend for more technical solutions, as well as decentralised solutions can be expected. Due to space restrictions and more stringent discharge standards and their implementation, the parameter footprint will become more and more important. The development centres of the country are growing fast and the costs for land are today already extremely high in cities like Delhi or Mumbai.

In industrial wastewater treatment, a large variety of treatment processes according to the respective wastewater can be found. Very problematic in the current situation is the effluent from distilleries, the textile & dye sector, leather processing, paper and metal processing. It has to be stated that vast investments have been done in treatment technology. “Cleaner Production” is more an important topic for all bigger companies. Figure 89 gives an outlook on the increasing compliance of large industries.

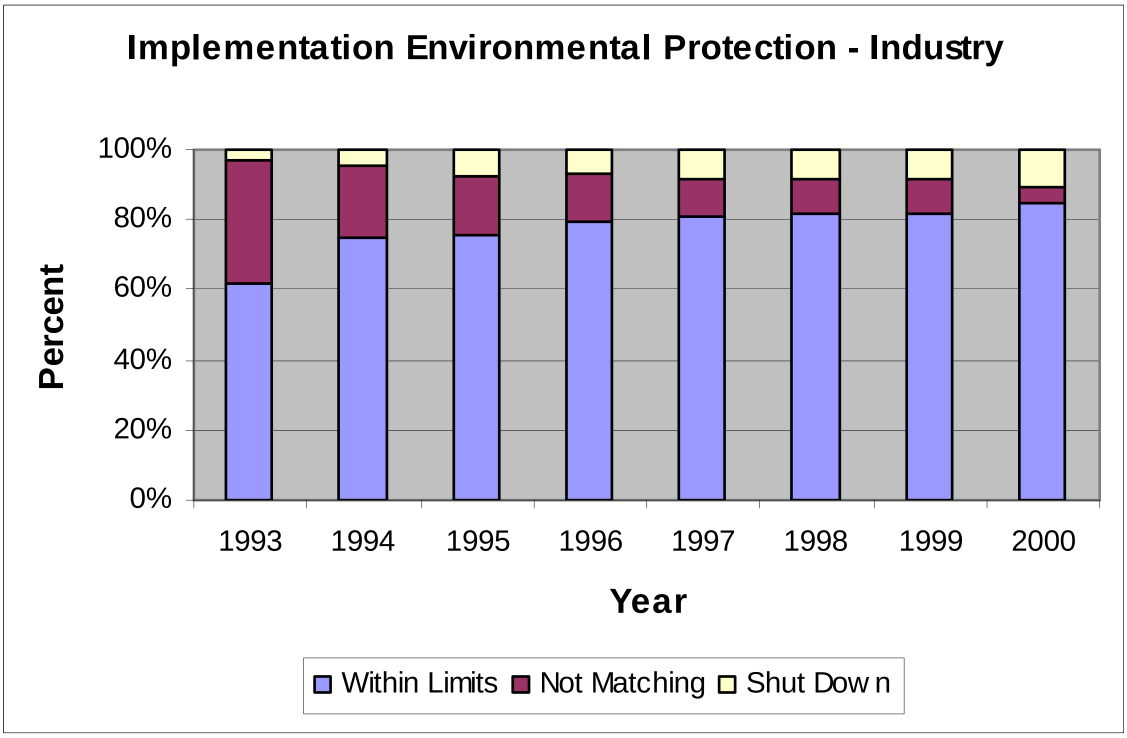


FIGURE 89: INCREASING COMPLIANCE OF LARGE SCALE INDUSTRIES IN INDIA (CPCB 2000)

In the industrial field, the treatment efficiencies could be determined as between 80% and 98% in terms of BOD-removal in the current study (see figure 40, chapter 7.1.1). For COD-removal, a treatment efficiency between 73% and 99%, for SS-removal, a treatment efficiency of more than 90% could be stated. In this study, three out of eight inspected ETPs and CETPs don’t match the required discharge standards – one small ayurvedic factory, one textile industry and one CETP treating dye and dye intermediates effluent. The results of this study can be compared with the results of a performance report on 78 CETPs carried out by CPCB mainly based on data from 2004 and 2005. The report states that only 20% of the inspected industries could meet the required discharge standards for BOD, COD and SS, but 15 industries could not meet the standards for TDS. That means that only 6.4% of the industries did fulfil all standards (CPCB 2006). Comparing the treatment efficiencies of the dye factory based on the treatment plant inspections with the values of this plant mentioned in the CPCB-report, the outlet value for BOD beginning 2006 was 275mg/l BOD compared to only 160mg/l BOD in 2004 (CPCB 2006). The discharge values for COD in 2004 and beginning 2006 are very similar. What can be stated is that the values beginning 2006 are remarkably higher – up to 100% in one case - than the values from 2004 also for other CETPs, although the report shows the efforts that have been made in order to improve the discharge values. Looking at the respective values for the textile industry that did not match the required discharge standards, only minor changes can be stated compared to the results given in the CPCB-report.

For the performance considerations of ETPs and CETPs, the company size plays an important role. For the CPCB-report from the year 2006, industries with a daily effluent between 35m³/d and 55.000m³/d were analysed. In the current study, plants with a daily flow between 25m³/d and 16.000m³/d were considered. In the report from the year 2000, mainly large scale industries were taken into account. For that reason, it comes to a much more positive result – more than 80% of the large scale industries comply with the required discharge standards in the year 2000 (CPCB 2000). Figure 89 illustrates the efforts that have been made in the implementation.

What has to be considered is the fact that small scale industries are hardly considered in the different studies, although they account to about 40% of the industrial output (Shankar 2001). More and more efforts are being made to develop CETPs in order to treat the effluent of several small industries.

Following estimations of the CPCB, about 300.000 small scale industries (less than 10 million Rs capital investment) exist in India. Roughly estimated, less than 10% of the SSI are connected to a CETP, although the industries have to bear only 20% of the investments costs. The compliance of CETPs is very low – about 20% comply with all standards except TDS, whereas less than 7% of the CETPs comply with all discharge standards (CPCB 2006). The CPCB study on the compliance of 78 of existing 88 CETPS in India, worked out during 2002-2005, concludes:" High TDS in the raw influent reaching CETPs and, as a result, in treated effluent of CETPs is a major cause of concern.“ (CPCB 2006).

“Cleaner Production” is a very promising way in recent years for improvements in the industrial field. The National Cleaner Production Centre, which was established with assistance of United Nations Industrial Development Organisations (UNIDO), has the task to promote the concept of Cleaner Production. Instead of conventional end-of-pipe-treatment, the pollution potential of an industry is already reduced within the production by various reuse processes, process modifications and reformulation of the product (Anjaneyulu 2005). Pollution control becomes a value, as resources and that way production costs are reduced parallel to pollution control.

Technology Status

Regarding type and status of treatment plant equipment, a large variety exists, ranging from very simple completely corroded screens to modern automatically operated systems in stainless steel, as shown in chapter 7.1.1. Machinery equipment in India is in most cases made in India (see figure 51, chapter 7.1.1). Imported products are very rare. In average, the electrical and mechanical equipment is about 5-10 years old (see figure 52 and 63, chapter 7.1.1). Processes and machines are of moderate technology level (see figures 48, 59 and 67, chapter 7.1.1) and are below western standard in average. As shown in the previous technology analysis, machinery equipment is of medium manufacturing quality, but stable in most cases, if not corroded (see figure 57, chapter 7.1.1). Normal steel is used as standard material - a trend for the use of more stainless steel equipment could be identified, what can be seen in the use of more and more stainless steel screens.

Maintenance is a major problem what could be shown especially by the parameters corrosion freeness and dirt freeness in chapter 7.1.1. Metal surfaces and connections are very often not well protected with coatings and damaged areas are not repaired so that corrosion proceeds very fast once started (see figure 54 and 55, chapter 7.1.1). Very problematic are equipment parts that are in the connection area air-water, also the mounting of handrails on concrete structures (see figure 46, chapter 7.1.1). Very often equipment is obviously not cleaned regularly, or not cleaned in the right way. As visible in figure 70, in more than 50% of the plants, maintenance is carried out without schedules. Maintenance intervals for certain equipment vary in a great range – from daily controls to several months (see table 30, chapter 7.1.1). Very critical has to be seen that for some equipment the plant management openly mentions that no maintenance is carried out until damage occurs.

Operation and maintenance are more and more recognised as critical issues in the water sector, especially where highly technical solutions are used. “Most of the 117 desalination plants commissioned in eight states by government agencies became non-operational due to lack of technical manpower for maintenance and improper selection of membrane” (Kumar 2004). Limited availability of experienced consultants and lack of operator training are seen as main reasons for operation problems especially with anaerobic treatment processes (Kansal 1998). Regarding the status of CETPs in India, a CPCB-report states:” In general, the performance of CETPs has been found to be very unsatisfactory, largely because of poor operation and maintenance” (CPCB 2006).

Publications on basic operational aspects of processes like activated sludge process in nationwide magazines for professionals on the academic level indicate increasing awareness. Although the deficits in operation and maintenance are realised more and more, what could be detected also in the expert interviews carried out in this study (see chapter 7.1.3), possible solutions are hardly developed - neither on administration side, nor on the plant management side.

Environmental Awareness

Environmental awareness is seen on a high level on the upper population level by the interviewed experts in this study (see figure 87, chapter 7.1.3). On the lower population level, the awareness is seen on a much lower level due to low education. However, the large number of NGOs in this field shows an increasing awareness in the society. The increasing number of eco-clubs shows that environmental issues gain in importance among the the population.

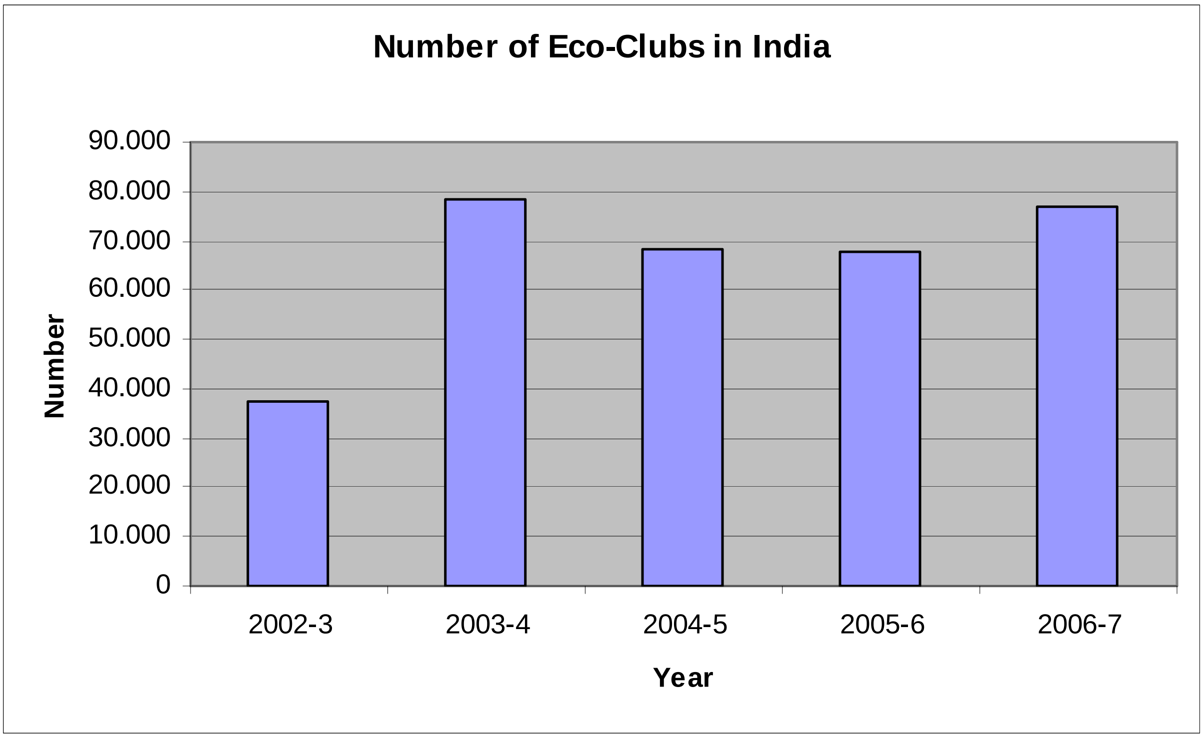


FIGURE 90: NUMBER OF ECO-CLUBS IN INDIA (MOEF 2007)

Also on government level, more and more awareness for the relations between environmental pollution, awareness creation and education seems to develop. In 2006-07, the National Environment Awareness Campaign (NEAC) was initiated, during which activities of awareness creation in the environmental field were supported financially, so that an increase of more than 9.000 NGOs and other organisations could be stated. Beside the seminars and awareness creation events, the production of films and regular TV magazines on environmental issues are supported financially by the government (MoEF 2007).

Manpower Status

Characteristic for the staff situation on Indian STPs and ETPs is the high proportion of unskilled workers and a relatively low education level of the practical staff in general (see figure 73, chapter 7.1.2). In the vocational education system, no courses exist for treatment plant operation. As shown, 46% of the staff are workers without any special technical education (see figure 73, chapter 7.1.2). Only 33% of the staff are skilled technicians and operators, which have a technical education in an ITI or another vocational training institution in most cases. The results of the general knowledge questions indicate that that the knowledge in the electrical and mechanical field is very superficial (see figure 77, chapter 7.1.2).

Also for employees from the respective profession fields, limited knowledge could be stated. The results were presented in detail in chapter 7.1.2. The results of the technology and process specific test questions indicate that the theoretical background of wastewater treatment is missing (see figure 78 and 79, chapter 7.1.2). Although activated sludge process is the dominating process in most of the inspected plants, less than 60% of the questioned staff is aware whether this process exists in the own plant. Beside mechanical solids-liquid separation by screens, other processes like filter process, RID, SBR or SBBR systems are hardly known. Also the meaning of process descriptions, like BOD-removal or nitrification is hardly known (see figure 79, chapter 7.1.2).

Very critical is the low awareness about aspects of hygiene and work safety. Protection clothes, like special overalls, safety shoes with steel toe cap, breathing masks or helmets do not exist or are not worn. Most workers carry out works in simple slippers. A study carried out on Indian STP staff states an increased incidence of hepatitis E among STP staff and requires: “Strict adherence to good working practices must take top priority for protection of these workers from sewage pathogens” (Vaidya, Tilekar et al. 2003).

On expert level, different positions regarding the manpower situation on Indian STPs and ETPs could be detected. Especially the private sector criticises low qualification of practical plant staff and sees a strong need for staff qualification, whereas the topic is less important for interviewed experts from the public sector (see figure 88, chapter 7.1.3).

As shown in chapter 7.1.2, strong salary differences exits between and within the staff groups (see figure 75, chapter 7.1.2). In the current study, an average salary of about 5.300Rs was determined for operators and skilled technicians. Considering that the income of a taxi driver is more than 6.000Rs (Vaswani 2008), the income of skilled treatment plant staff is very low.

Economy & Market

Both for the general economic development, as well as for the water and wastewater market, Indian experts see high growth potentials (see figure 86, chapter 7.1.3).

In the current five year plan (11th plan 2007-2012), a raise of the average growth rate to close to 9 % is expected and the need for enormous investments into the infrastructure sector - including water and wastewater – is recognised (Singh 2006). In total, the Ministry of Environment and Forests has allocated a total sum of 13.51 billion Rs for the period 2007-08, of which 2.20 billion Rs were allocated for the environmental sector (MoEF 2007). Of the total market volume of the water technology sector of about 5 billion US$, the market volume of wastewater technology is estimated to about 700 million US$ by the Confederation of Indian Industries. The sewage generation from class I and class II cities – in total 893 cities – is more than 29 million m^3/d, whereas installed treatment capacity is 6.19 million m^3/d (CPCB 2005). That means that a gap of almost 23 million m^3/d has to be filled, not considering further population growth and urbanisation.

Following an A.T. Kearney comparising report on the foreign direct investment confidence index, India ranks on position 2 behind China with a clear distance to the US, which are on third position (A.T.Kearney 2007). Looking at India trading partners, Germany is currently on position 6 in terms of cumulative FDI, after Mauritius, US, UK, Netherlands and Japan (IGCC 2007). For the German consultancy sector the FDI decreased about 74% within one year to a value of about 19.53 million Rs for the period from April 2006 to march 2007. For the German industrial machinery sector, a slight increase of FDI to India of about 5% with a value of 120.74 million Rs is reported for the same period (IGCC 2007). Following the information of the Indo-German Chamber of Commerce, about 500 Indo-German business cooperations exist in this sector.

Vast regional differences can be stated as visible in the following figure. Leading regions for German investments are Delhi, Karnataka and Maharashtra.

Region-wise break up of German investment inflows: (in Rs. mil.)		
S.No.	State	Apr.'06-Mar.'07
1	Andhra Pradesh	237.90
2	Gujarat	1.23
3	Karnataka	1403.30
4	Maharashtra	1186.54
5	Tamil Nadu	329.29
6	Kerala	2.63
7	Delhi	2078.11
8	Goa	12.92
9	Chandigarh	1.20
10	State not indicated	145.11
	Grand total	**5398.23**

TABLE 34: REGION-WISE GERMAN INVESTMENT INFLOWS TO INDIA (IGCC 2007)

Although the economic chances in the field of wastewater treatment have to be seen positive, existing opinions among interviewed experts lead to a very complex picture. Main parameters that are mentioned by many experts are the investment costs and the operation costs of treatment technology (see figure 85, chapter 7.1.3). The cost aspect is even more important when it comes to German equipment and represents a very critical factor (see figure 86, chapter 7.1.3). Discussions with potential clients of German treatment technology show the enormous cost differences between Indian equipment and German equipment. The communication climate with western experts is described moderately positive by Indian experts (see figure 86, chapter 7.1.3).

Regarding suitable technologies for wastewater treatment, an emphasis of technical solutions is expressed, especially for urban areas (see figure 85, chapter 7.1.3). A high emphasis is put on reuse aspects. Investment costs are extremely important for the interviewed Indian experts. Considering the fact that many experts expressed a relatively low preference for German products and a medium intention to invest in quality products, the conclusion can be drawn that in the current situation, especially products of moderate quality at moderate price level have good market chances. To this conclusion comes also a market study carried out by the German Office for Foreign Trade (Alex 2007).

In the annual review of the Indo-German Chamber of Commerce the authors conclude that “India along with China will become one of the most attractive countries for renewable energy projects” (IGCC 2007). With regard to the wastewater sector the conclusion can be drawn that more and more energy efficient solutions and ideally solution that generate energy will have good chances in the market. This corresponds to the relatively high emphasis of energy efficiency for wastewater technologies by the interviewed Indian experts in the current study (see figure 85, chapter 7.1.3).

In this actual study, a relatively high preference for private operation models could be stated (see figure 86, chapter 7.1.3) among the interviewed Indian experts. Other authors consider privatisation efforts to be in the beginning stage. This includes the transfer of water and wastewater treatment plants into private companies, as well as the market opening for investors from other countries. According to above mentioned branch study, carried out by the German Office for Foreign Trade, private companies hesitate to engage in this business field. Also foreign companies are careful, although market growth rates of 15-20% are expected. Critical is seen that until now no clear guidelines for public private partnership projects exist, so that investors are confronted with long negotiations for each new project (Alex 2007). The same study states that the US are main supplier in the wastewater sector on the market for water and wastewater technology and have excellent relations to municipal operators (Alex 2007). Based on the data gained in the plant inspections of the actual study, a dominant position of US companies as leading supplier of foreign wastewater technology could not be confirmed (see figure 51 and 62, chapter 7.1.1).

Corruption is seen as a critical topic by the interviewed experts in this study (see figure 86, chapter 7.1.3). In 1995 India signed the agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS). Patent protection was introduced in 2005. Until 2005, only the manufacturing process, but not the final product was protected. In a study carried out among German companies in India, the authors criticise that the judiciary system works very slowly, which leads to very long processing times. Many German companies don’t feel protected enough against corruption (Kaufmann, Panhans et al. 2006). In the ranking of the corruption perception index India is on position 72 together with China (TI 2007). Both countries come off below average with an index value of 3.5. Compared to the year 2000, a slight improvement of the situation can be stated (TI 2007). The Bribe Payers Index ranks Indian and Chines companies on position 30 and 29 of 30 ranked countries (TI

2006). Widespread corruption is considered as an argument against business activities in India although the advantages for a business engagement prevail (Waldkirch 2006). In the environmental field, corruption is discussed openly even in basically technical magazines for professionals targeting on asking serious ethical questions. The environmental legislation is strongly criticised and a lack of consensus of the parties involved in the implementation is stated. Not only is the environmental damage seen, but the damage to the society. The more stringent standards are, the higher is the tendency to violate the law due to lack of affordability (Mohanasundaran 2005). The summarising conclusion can be drawn that corruption recognised as a big problem, but a positive change can’t be seen.

7.2 Wastewater Technology Status & Trends in China

7.2.1 Efficiency, Technologies & Treatment Plant Operation

Most of the inspected plants were built in the last 10years, which shows the fast development in wastewater treatment in China. Of 16 inspected plants, 4 plants are based on oxidation ditches, 6 plants on conventional activated sludge systems, 3 plants are AB plants (activated sludge process followed by oxidation ditch), 2 plants are SBR plants and 1 plant uses aerated biological filters as main treatment step.

Efficiency

In the following, the treatment efficiency regarding the parameters BOD, COD, Ammonia and Total Phosphorous is given based on the information given by the plant management of 14 plants. An outlook on the discharge standards in China is given in table 7, chapter 5.1.2.

As visible in figure 91, the inlet BOD of most plants is in a range of 100-250mg/l. In one case, the inlet BOD is only 50mg/l. The treatment efficiency is about 80-95% in most plants. All plants meet the National Standard II regarding BOD. For some plants National Standard I B or even higher outlet quality is required. Two plants don’t meet the required discharge standard for BOD. Figure 92 shows the treatment efficiency for COD.

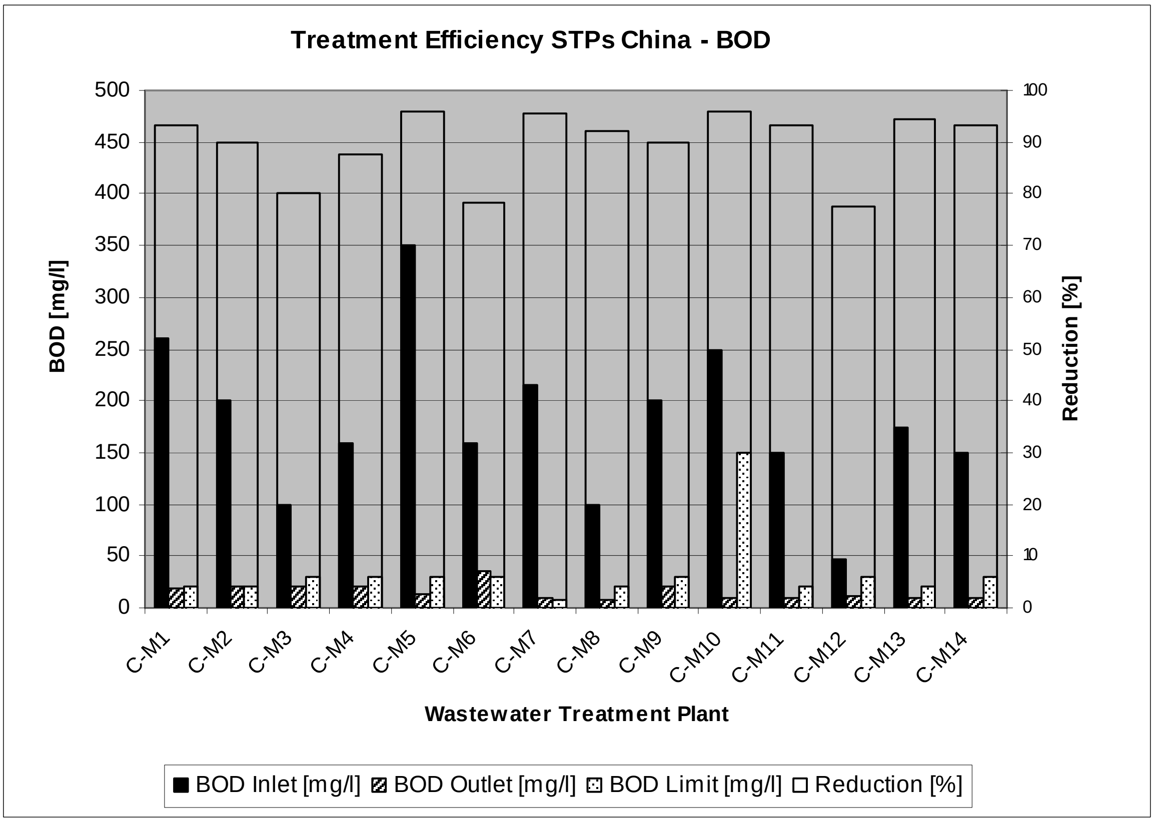


FIGURE 91: TREATMENT EFFICIENCY STPS CHINA – BOD

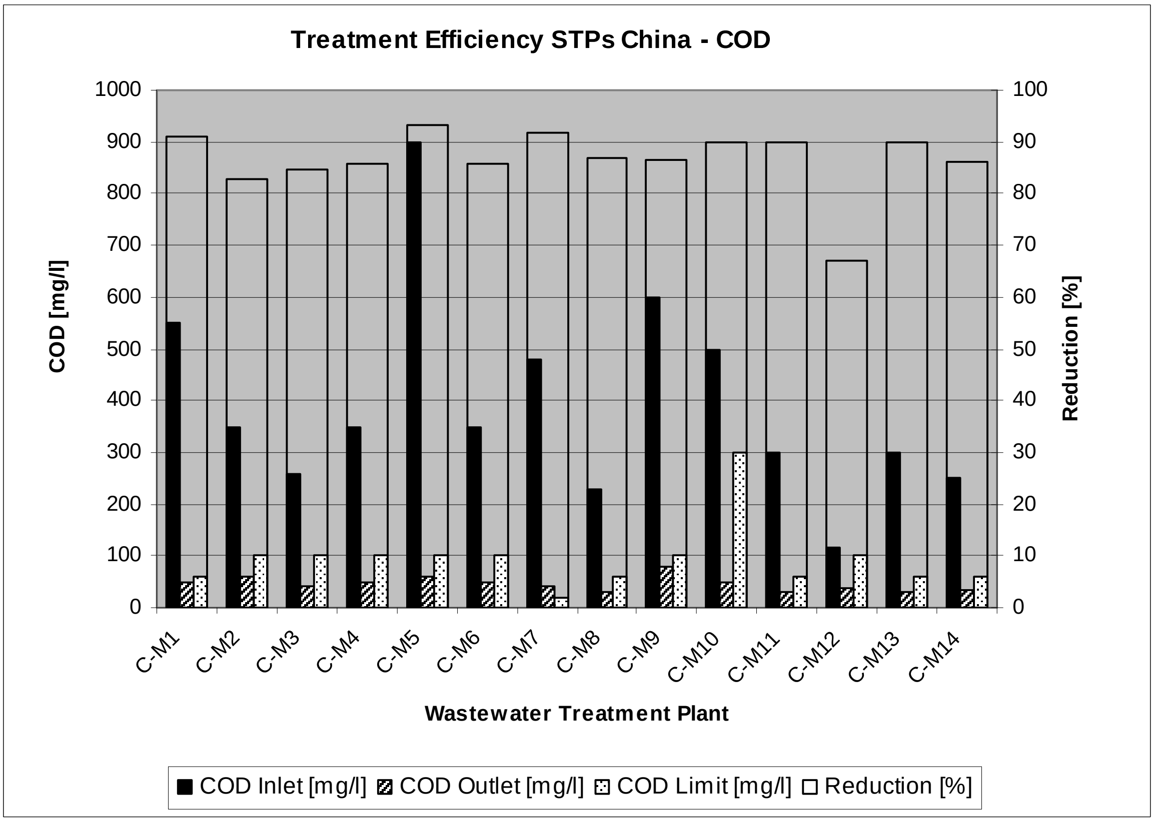


FIGURE 92: TREATMENT EFFICIENCY STPS CHINA - COD

The inlet values for COD are in a range between 200mg/l and 600mg/l in most of the plants. The COD to BOD ratio is about 2-2.5 in most of the plants. In some plants up to 50% of the wastewater is generated by various industries that discharge into the sewer system. Almost all visited plants are below the required outlet limits – only one plant exceeds the discharge standard (plant C-M7). The treatment efficiency is in a range between 80-90% in most of the plants, based on the information given by the plant managements. Figure 93 shows the treatment efficiency for ammonia. The inlet values of ammonia are in a range between about 20mg/l and 45mg/l. Depending on discharge standard and inlet values, the treatment efficiencies vary in a great range. All visited plants meet the required outlet values. Figure 94 gives an outlook on the treatment efficiencies for phosphorous removal.

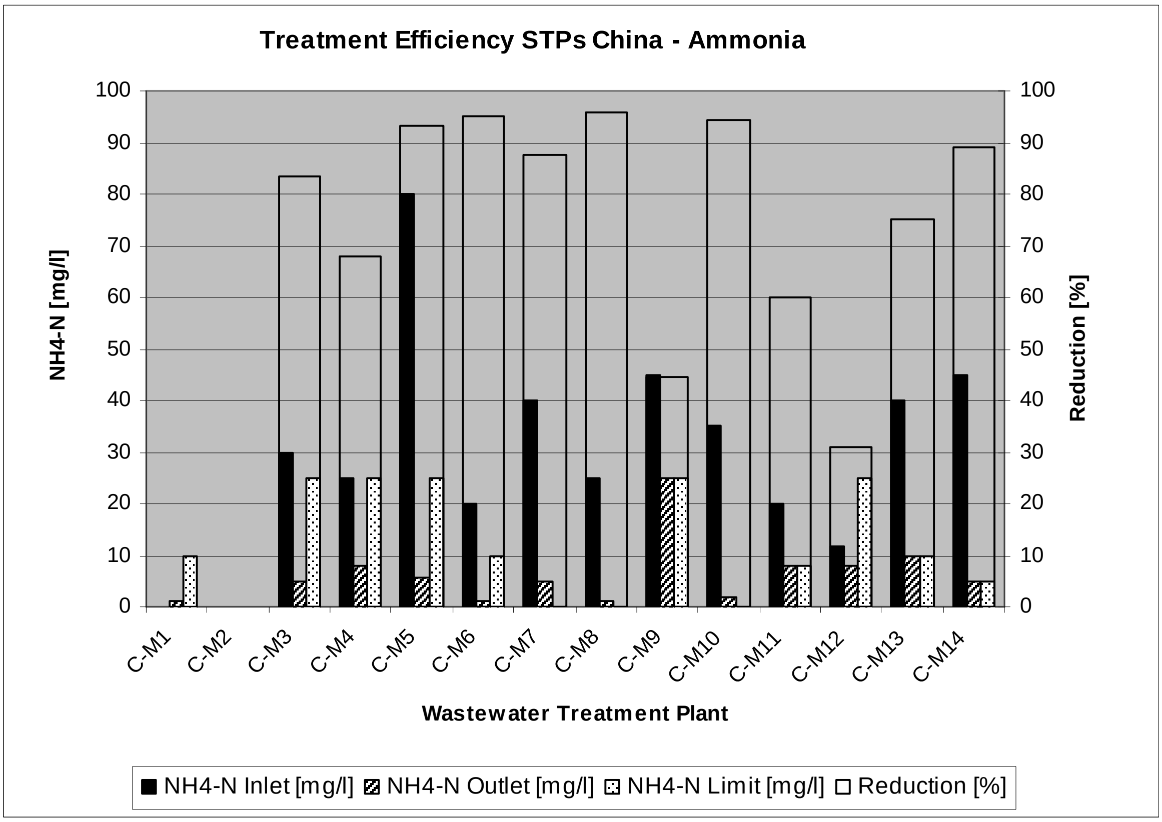


FIGURE 93: TREATMENT EFFICIENCY STPS CHINA – AMMONIA

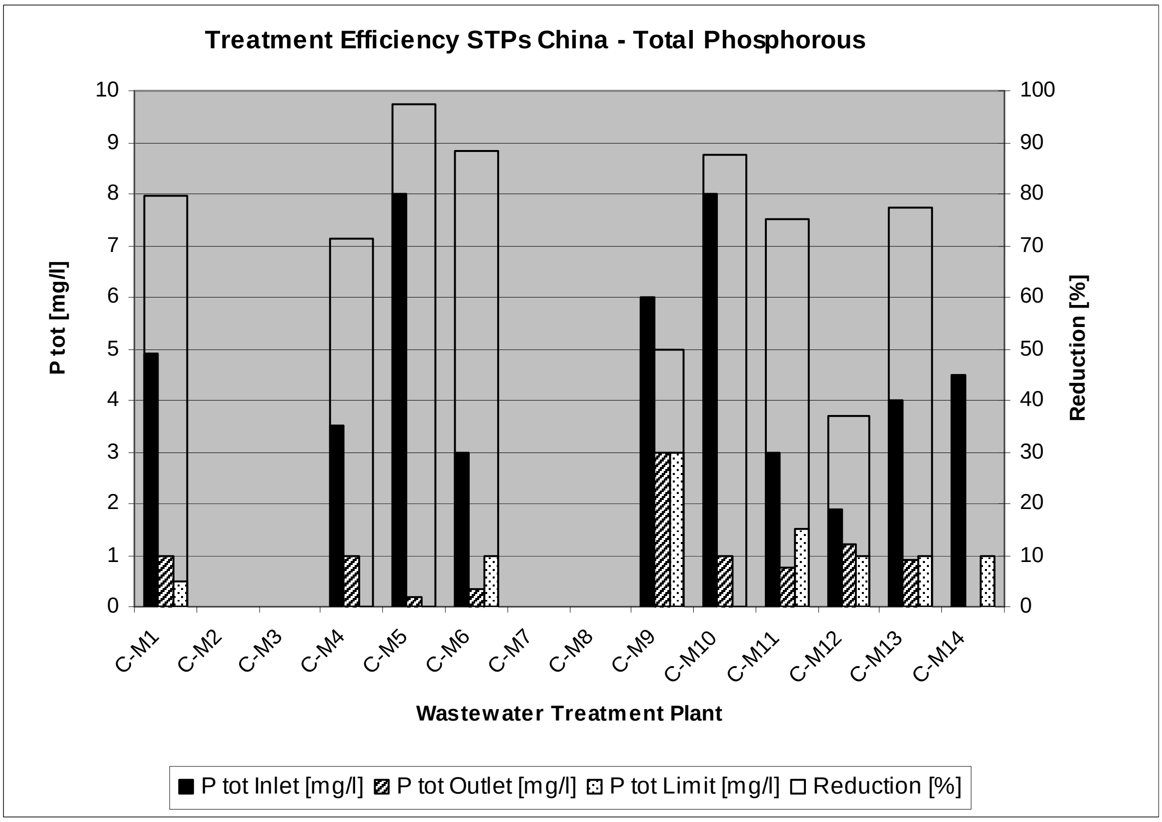


FIGURE 94: TREATMENT EFFICIENCY STPS CHINA – TOTAL PHOSPOROUS

Technologies

Like for the description of the Indian equipment, structural, machinery and control equipment are considered separately. Figure 95 shows the distribution of the inspected equipment on which the photographic analysis of the technology in this study is based. In the following, the results of the analysis regarding the criteria listed in chapter 6.1.3 are presented.

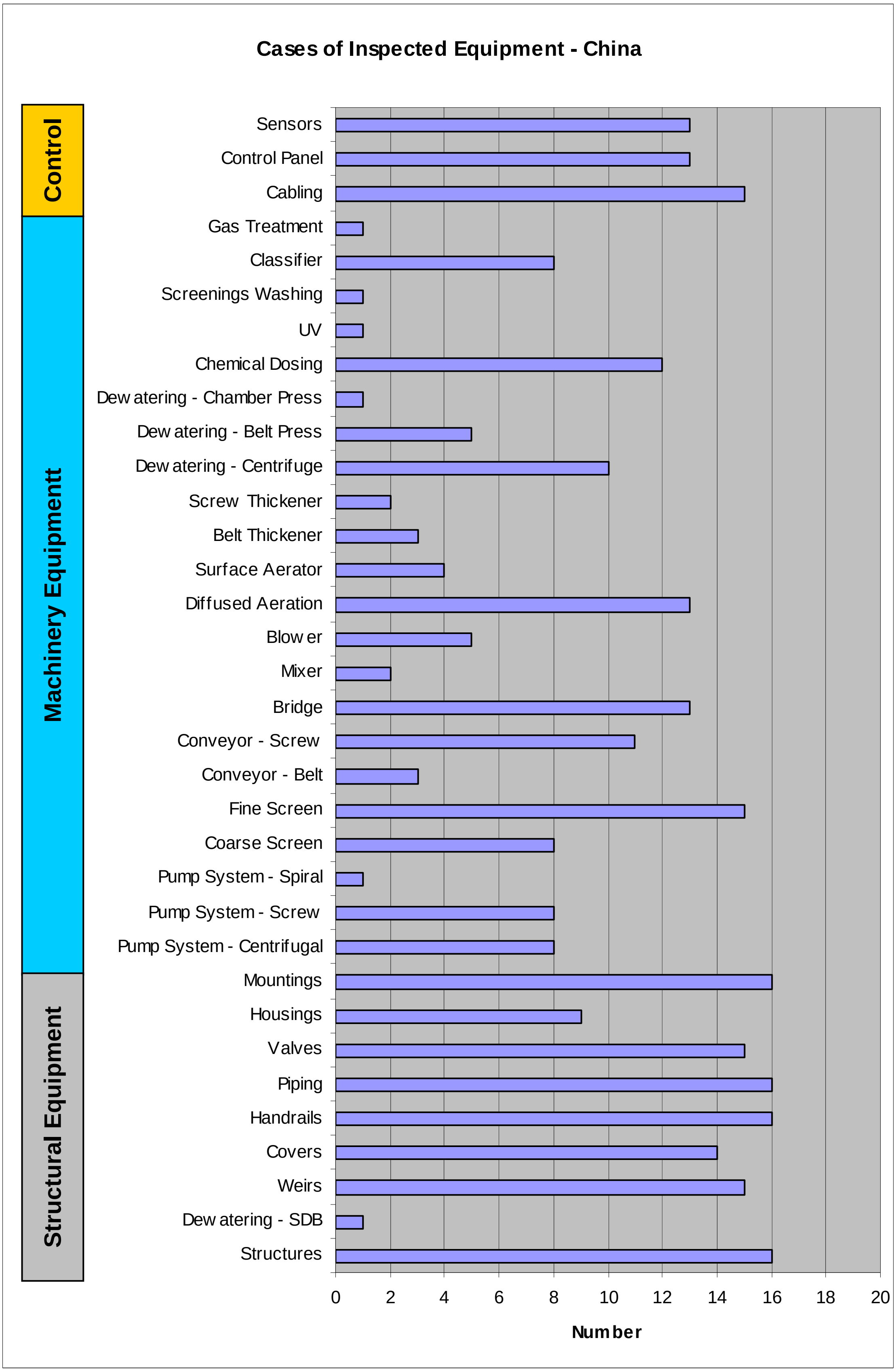


FIGURE 95: CASES OF INSPECTED EQUIPMENT IN CHINA

Structural Equipment

Age of Structural Equipment

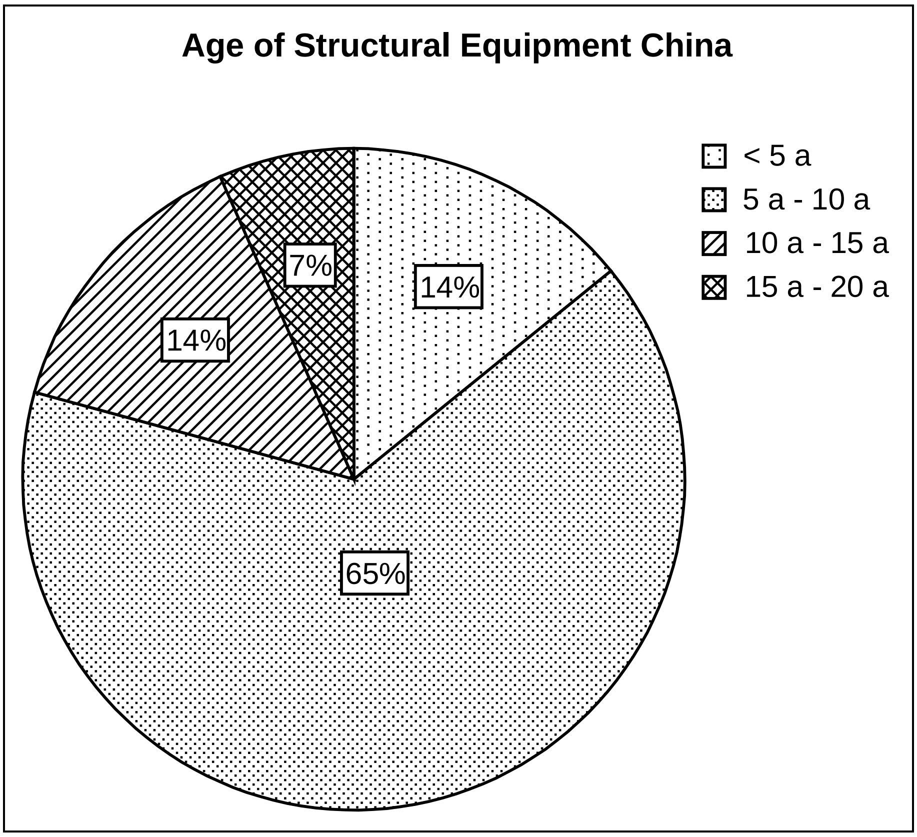


FIGURE 96: AGE OF STRUCTURAL EQUIPMENT IN CHINA

As visible in figure 96, about 14% of the inspected structural equipment is less than 5 years old, about 65% is between 5 and 10 years old, which is relatively young. This is an important factor that has to be considered in the detailed equipment considerations. The average age of the inspected structural equipment is about 8 years.

The following figure 97 gives an outlook on the expression of the main technology parameters that were determined for the inspected structural equipment in China.

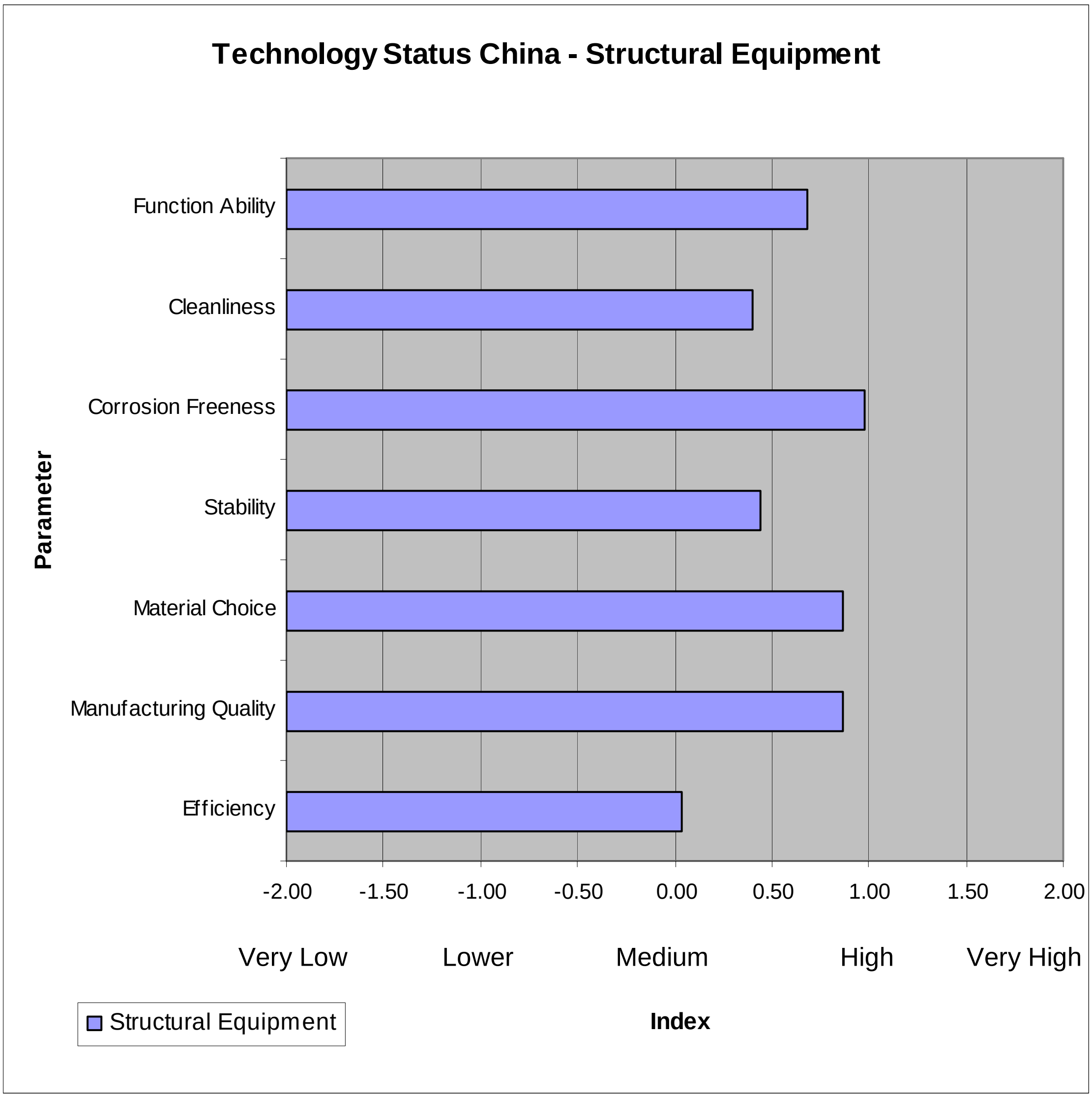


FIGURE 97: TECHNOLOGY STATUS CHINA – STRUCTURAL EQUIPMENT

For the function ability of structural equipment on the inspected plants in China an index value of 0.68 could be determined. Most structural elements are physically intact, but the durability is doubtful very often. Considering corrosion and the relatively low age of most plants, a medium to low durability for many structural elements – also for concrete structures – can be assumed.

Cleanliness as one major indicator for maintenance motivation is the upper medium range with an index value of 0.40. In most plants, the surface cleanliness of the structural equipment is on a medium to high level. Regarding detail/technical cleanliness, some deficits could be stated.

FIGURE 98: HANDRAILS ON STPS IN CHINA

Great differences could be detected regarding corrosion freeness. Problematic in many cases is equipment out of normal steel and also galvanised steel (see figure 100). Very high corrosion freeness could be determined for components, like piping and handrails out of stainless steel. In several plants, concrete structures are problematic. Flaking and corroded steel reinforcement could be detected on several concrete structures, due to insufficient concrete covering and low concrete quality (see figure 99). In total, an index value of 0.98 could be determined for the parameter "corrosion freeness" for structural equipment (see figure 97). For stability, an index value of 0.44 was determined, which is in the upper medium range. The static design of almost all structural equipment is on a high level. The material thickness of stainless steel handrails is relatively low in many cases. In several cases covers are of relatively low material thickness which results in bendings and potential safety dangers in case of additional corrosion (see figure 100). Material quality is on a high level. As already mentioned, stainless steel is widely used for handrails, piping and also certain mountings. For covers, mainly galvanised steel, in some cases also plastic is used. In several plants, the galvanised steel covers are obviously of very low material quality, which can be seen by the fact that in plants that are between 5 and 10 years old, covers are already extremely corroded (see figure 100). In few cases, plastic material is used for handrails. A problem that was observed is the mix of different materials. In several cases, stainless steel components were fixed or connected with screws of normal steel, so that the advantages of stainless steel are lost looking at the oberall stability and durability (see figure 100). In total, an index value of 0.87 could be determined for the parameter “material quality”.

FIGURE 99: FISSURES AND FLAKINGS OF CONCRETE STRUCTURES IN CHINA

FIGURE 100: CORROSION ON GALVANISED COVERS AND BOLT CONNECTIONS IN CHINA

For the parameter “manufacturing quality” an index value of 0.87 could be determined (see figure 97). In general, a relatively high accuracy degree of concrete structures, piping and housings can be stated. Piping is fixed very accurately, weir edges are manufactured with high accuracy in the inspected plants (see figure 101). Surface quality is also on a high level in most cases. Deficits could be detected regarding repairs and modifications that are obviously not carried out with enough precision and in an improvised way, which can be seen on improper screw and welding connections (see figure 100).

FIGURE 101: WEIR EDGES AND BRIDGE IN CHINA

For the parameter “efficiency” an index value of 0.04 could be determined (see figure 97). In the following paragraphs, space demand of structures, as well as level of level of technology and energy efficiency of the overall process are considered in detail.

Level of Technology, Specific Space Demand & Energy Efficiency

A relatively high level of the treatment processes on the inspected plants in China could be stated (see figure 102). About 70% of the plants are characterised by a high treatment level – plants designed for partial or complete nitrification. About 25% of the plants are designed for nitrification/denitrification process and are on a very high treatment level. An average index value of 1.19 could be determined, which is relatively high, compared to the plants in India (see also figure 48, chapter 7.1.1).

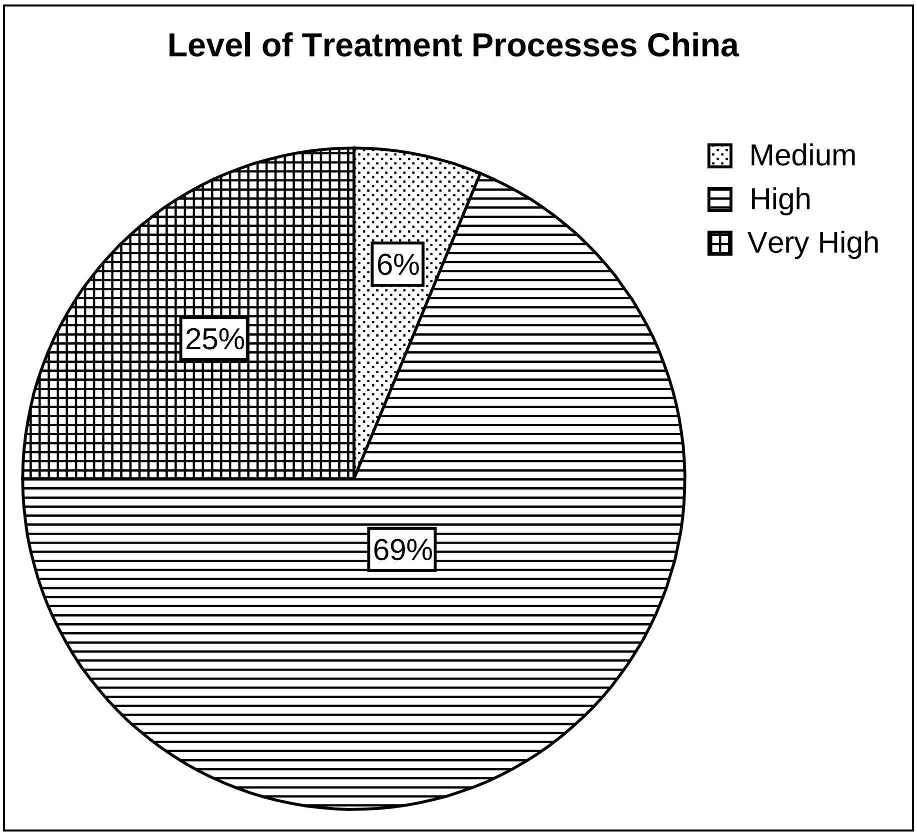


FIGURE 102: LEVEL TREATMENT PROCESSES IN CHINA

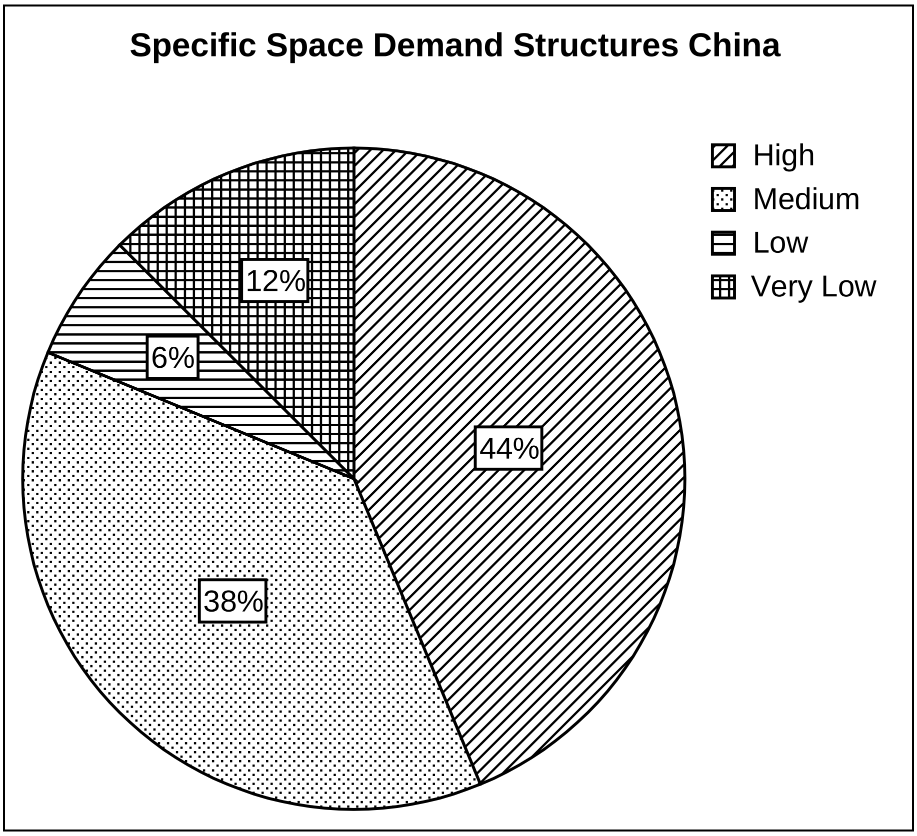


FIGURE 103: SPECIFIC SPACE DEMAND OF STRUCTURES IN CHINA

As visible in figure 103, about 20% of the inspected plants are characterised by low and very low space demand. This are plants in very urbanised areas, based on activated sludge process or aerated biofilter in a very compact design and without sludge drying beds. About 38% of the plants have a medium space demand and about 44% have a high space demand – conventional activated sludge plants with large distances between the different tanks. An average index value of -0.13 could be determined, which is in the medium range.

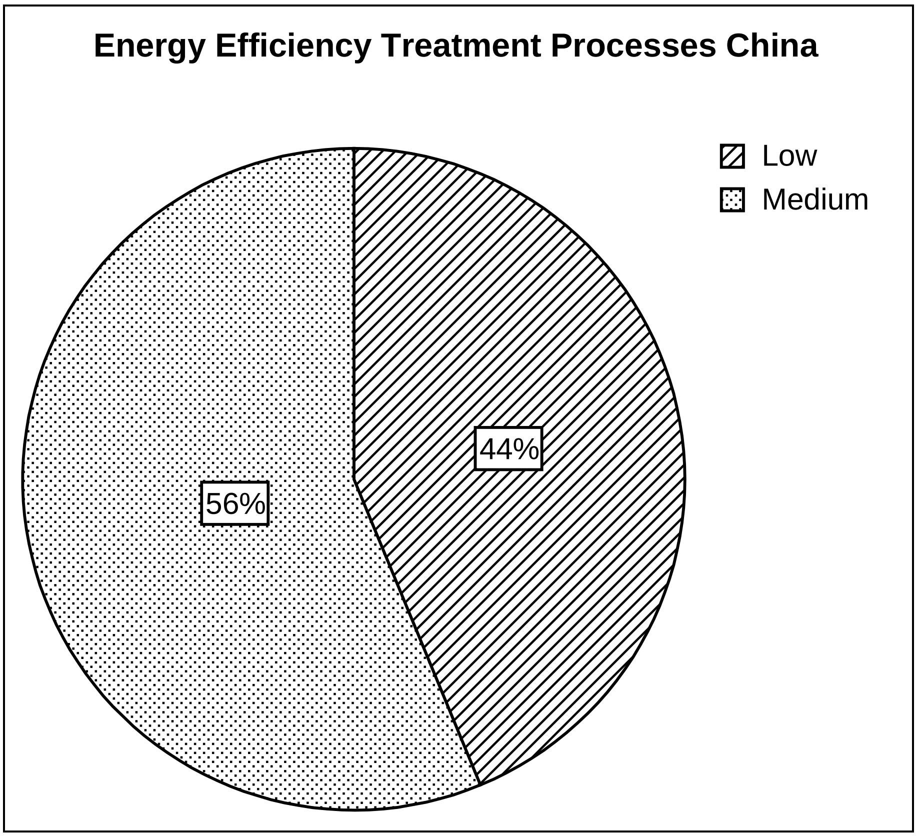


FIGURE 104: ENERGY EFFICIENCY OF TREATMENT PROCESSES IN CHINA

Regarding the energy efficiency of the treatment processes, about 44% of the inspected plants are characterised by low energy efficiency. These are activated sludge plants without energetic excess sludge use (digestion/incineration). The majority of the inspected plants – 56% - are activated sludge plants with energy generation by energetic sludge use. An average value of -0.44 could be determined, which is relatively low.

Machinery Equipment

Origin and Age of Machinery Equipment

As visible in figure 105, about 61% of the inspected machinery equipment is from Germany and 7% is from other European countries. Here, the fact has to be considered that the machinery equipment of 7 out of 16 inspected plants was financed by the German KFW bank. About 29% of the machinery equipment is Chinese brand. About 3% of the equipment is from the US and other countries.

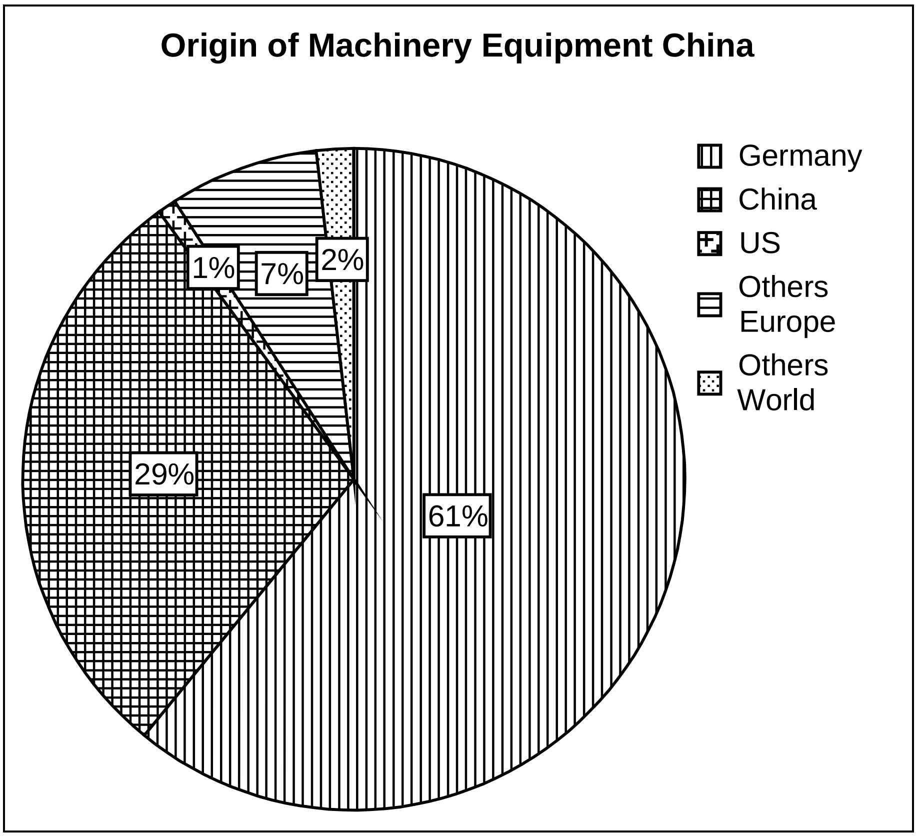


FIGURE 105: ORIGIN OF MACHINERY EQUIPMENT IN CHINA

Figure 106 shows the age distribution of the machinery equipment on the inspected plants in China. As visible, 90% of the equipment is less than 10years old. The average age of the inspected machinery equipment is about 7 years.

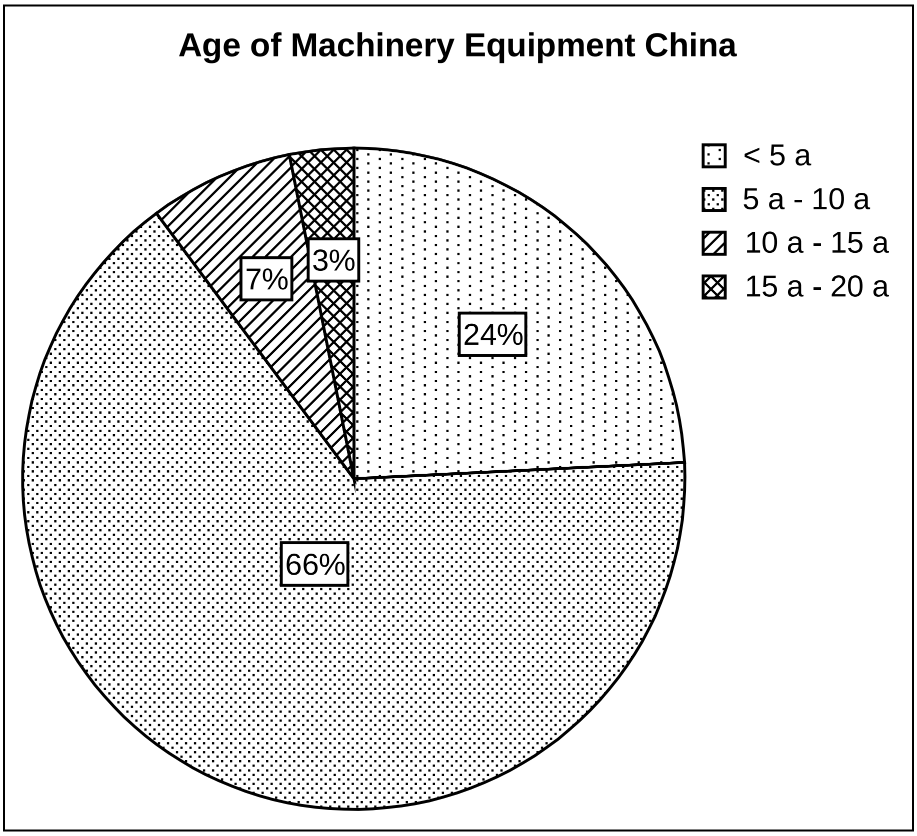


FIGURE 106: AGE OF MACHINERY EQUIPMENT IN CHINA

Figure 107 gives an outlook on the expression of the main technology parameters than were determined for machinery equipment.

The function ability of the machinery equipment is on a high level with an index value of 1.06. Physical intactness is high for most inspected equipment components. In several cases important wearing parts, like brushes of screw conveyors, were not replaced, which led to function deficits. In several cases screw conveyors connected to inlet screens obviously were modified by the staff, because blockings occurred (see figure 108). In one case a press zone should be created, although the machine was not foreseen for this - complete destruction of the screw conveyor was the consequence. A high durability could be expected for many components, especially due to the use of stainless steel.

Regarding cleanliness, deficits in detail/technical cleanliness could be detected, whereas surface cleanliness is on a high level for the majority of the inspected machinery equipment. Outlet zones of screens or screw conveyors are obviously not cleaned on a regular basis in many cases (see figure 108). In total an index value of 0.82 could be determined for the parameter “cleanliness”.

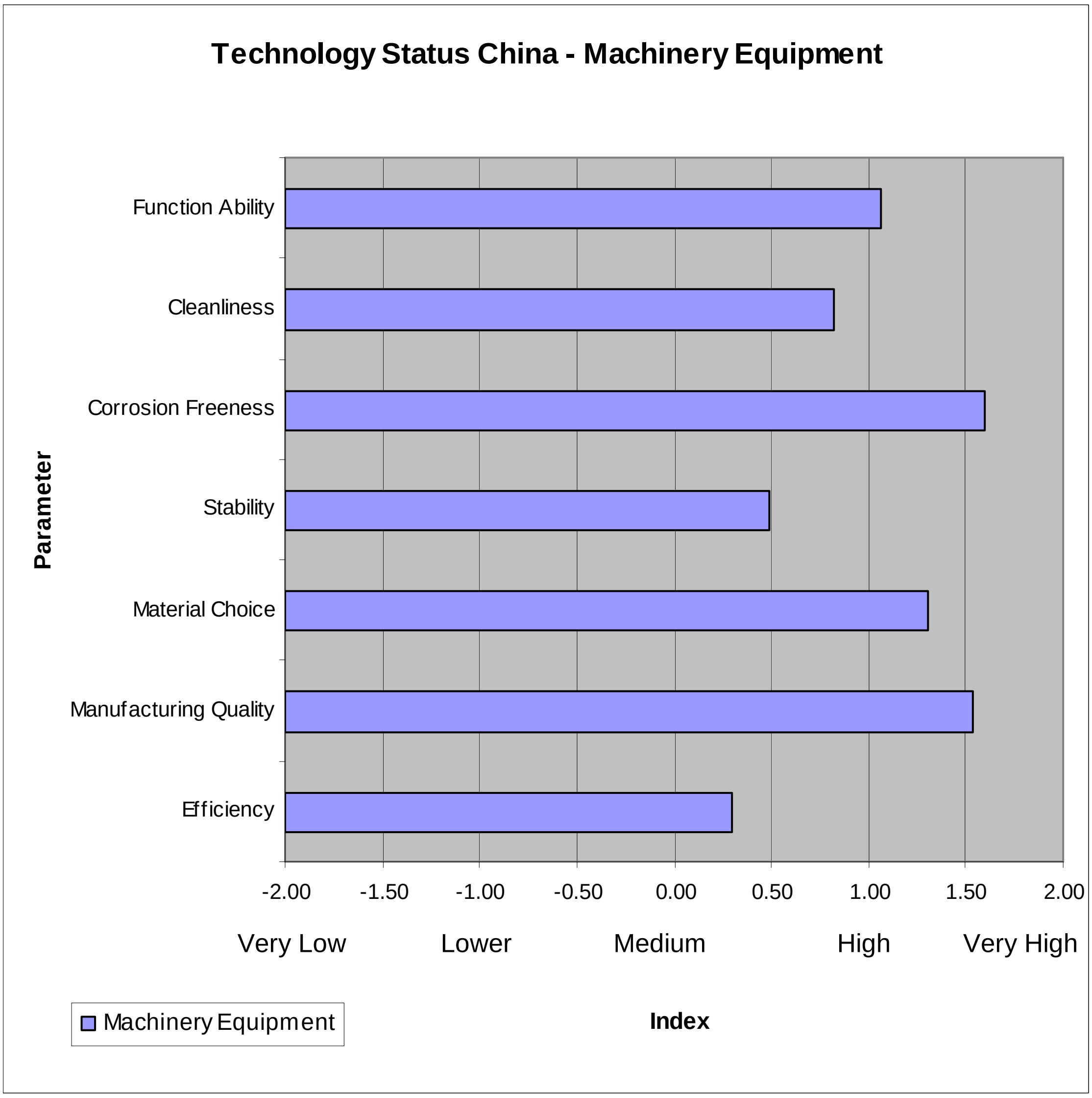


FIGURE 107: TECHNOLOGY STATUS CHINA – MACHINERY EQUIPMENT

Corrosion freeness is very high, mainly because stainless steel is widely used for machinery equipment. Machinery equipment is protected very often against rain and direct sunlight by roofing. Problematic are motor cases that are not protected against rain and that are very often severely corroded (see figure 109). In total, an index value of about 1.60 was determined for the parameter “corrosion freeness”.

For stability, an index value of 0.49 could be determined, which is on the upper medium level. Static design of the machinery equipment – both from China and imported equipment from Europe is on a high level in most inspected plants. At some machinery equipment from China, like free standing classifiers out of stainless steel, the mounting of support elements on the settling tank is not ideal and the material thickness is relatively low, leading to a low overall stability of the machine.

For material quality, an index value of 1.30 was determined, which is on on the upper side of “high” (see figure 107). Stainless steel is widely used, especially for equipment that is imported from Germany (see figure 110). Screening systems that are completely out of stainless steel, as well as screens, where only those parts in contact with wastewater are out of stainless steel or plastic material, are very common on the inspected plants. Screening systems from China are very often of coated normal or galvanised steel with plastic sieving surface (see figure 111). Coatings are of relatively good quality in most cases, if the respective equipment is protected by roofing. Coating of free standing equipment shows very often damages and corrosion. However, also Chinese components out of stainless steel could be found.

The manufacturing quality of the inspected German equipment is on a very high level and is characterised by a very high dimension accuracy, as well as very high surface quality. Regarding the inspected Chinese machinery equipment, also high dimension accuracy could be stated for most components (see figures 111). In many cases, differences regarding the surface quality could be stated – welding connections, edges and angles are less accurate than at the inspected German equipment. In total, an index value of 1.53 could be determined for the parameter “manufacturing quality” (see figure 107).

FIGURE 108: PROBLEMATIC DETAIL DIRT ON MACHINERY EQUIPMENT IN CHINA

FIGURE 109: CORRODED DRIVE COMPONENTS IN CHINA

FIGURE 110: GERMAN STAINLESS STEEL SCREENING SYSTEMS IN CHINA

FIGURE 111: CHINESE SCREEN (LEFT) AND GERMAN SCREEN (RIGHT) IN CHINA

FIGURE 112: IMPORTED ROTARY PISTON VALVE COMPRESSORS IN CHINA

For the parameter “efficiency” an index value of 0.29 was determined, which is in the upper medium level. In the following, a closer look at the technology level, specific material costs and energy efficiency shall be taken.

Level of Technology

As visible in figure 113, about 49% of the inspected machinery equipment can be categorised being on a very high technology level. Modern machinery equipment like rotary piston valve compressors, various machine types for sludge thickening and dewatering, high quality dosing systems, different screen types and pumping systems can be found on many plants, especially on plants that were financed by KFW bank. About 42% of the equipment is of high technology level, about 9% of the inspected equipment is of medium and low technology level. An index value value of 1.39 could be determined for the parameter “technology level” of machinery equipment, which very high compared to Indian equipment (see also figure 59, chapter 7.1.1).

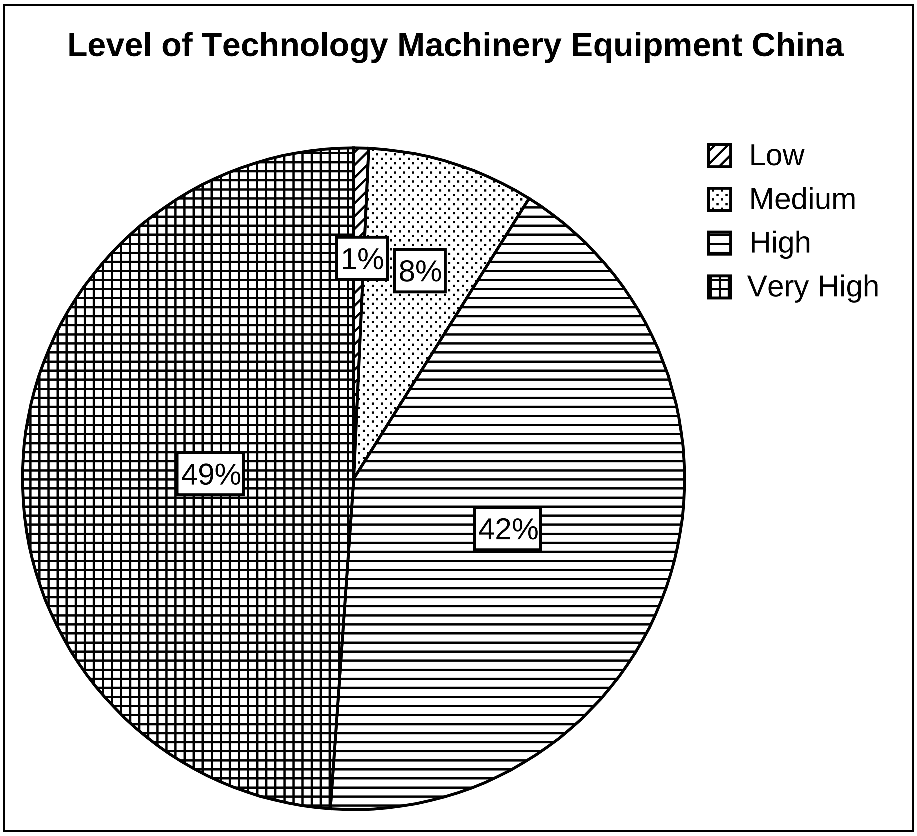


FIGURE 113: LEVEL OF TECHNOLOGY OF MACHINERY EQUIPMENT IN CHINA

Specific Material Costs

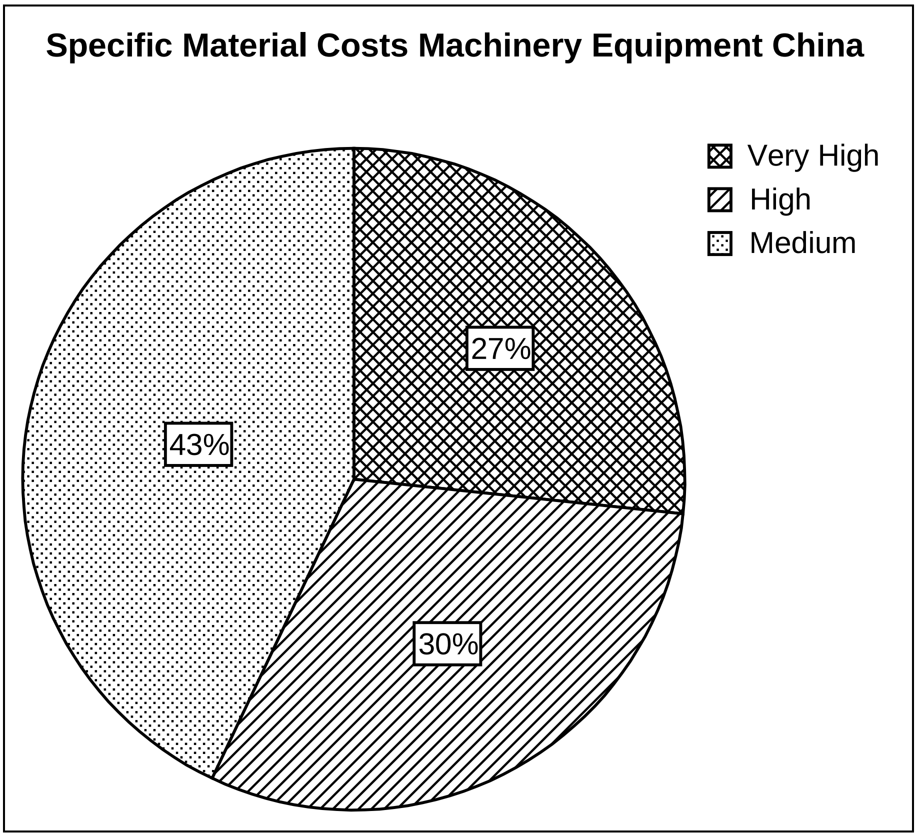


FIGURE 114: SPECIFIC MATERIAL COSTS OF MACHNIERY EQUIPMENT IN CHINA

Regarding the parameter “specific material costs” about 27% of the inspected machinery equipment is classified as very high, mainly because of the use of stainless steel. About 30% of the inspected equipment is characterised by high specific material costs, like screening systems that are partially out of stainless steel and coated normal steel frame. About 43% of the equipment is of medium specific material costs – coated normal steel. An average index value of -0.84 was determined.

Energy Efficiency

The energy efficiency of about 85% of the inspected machinery equipment is in the medium range (see figure 115). Machines and processes that are highly energy consuming – about 7% - are basically decanter centrifuges. About 7% of the equipment is categorised as high energy efficient. An average index value of -0.09 could be determined, which is in the medium range.

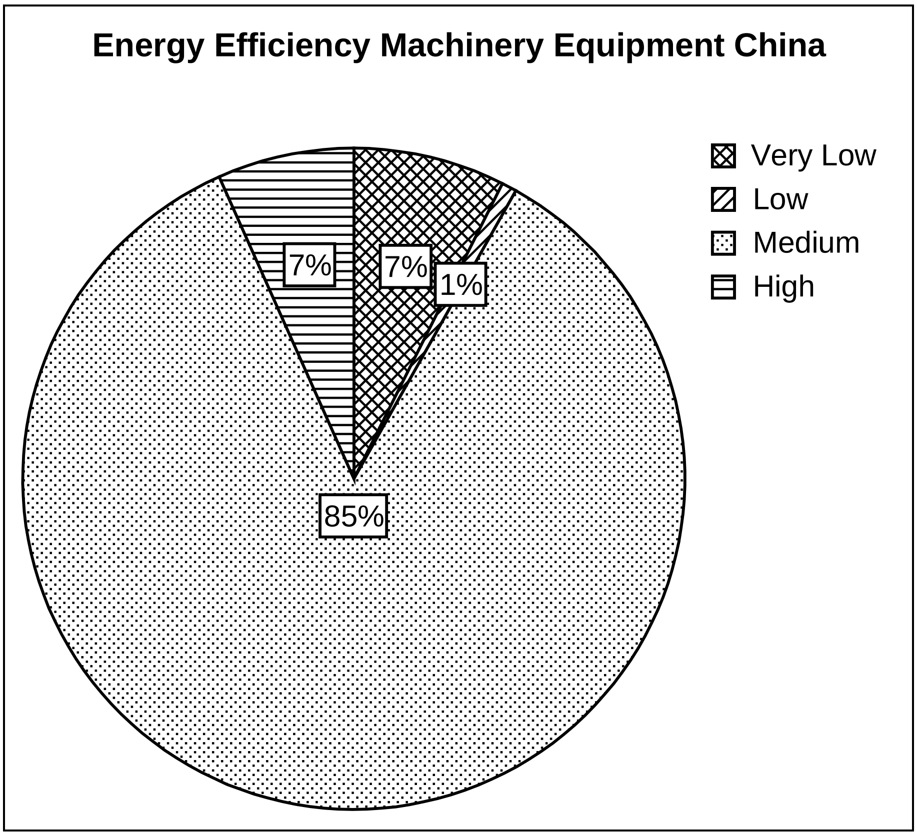


FIGURE 115: ENERGY EFFICIENCY OF MACHINERY EQUIPMENT IN CHINA

Control Equipment

Origin & Age of Control Equipment

As visible in figure 116, more than 50% of the control equipment in the inspected treatment plants in China is from Germany. About 47% is from China. Control equipment from other nations was not observed. Similar to the machinery equipment, the age of the control equipment is relatively low (see figure 117). About 19% of the equipment is less than 5 years old, about 68% of the equipment is between 5 and 10 years old. Only about 14% is more than 10 years old. The average age of the inspected control equipment is about 7 years.

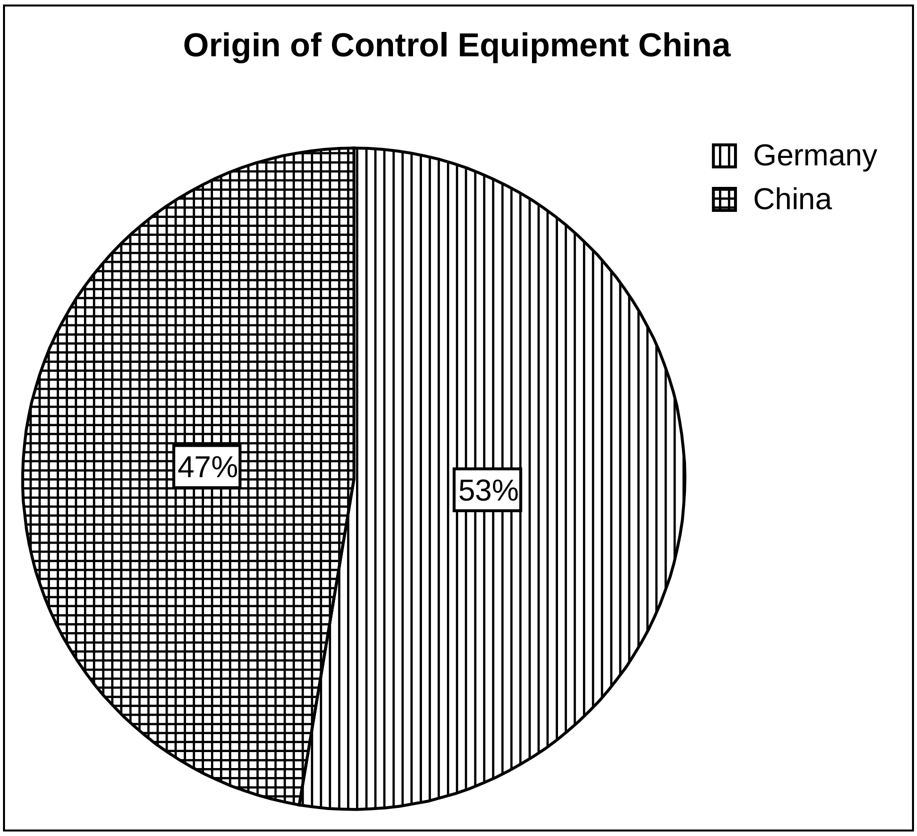


FIGURE 116: ORIGIN OF CONTROL EQUIPMENT IN CHINA

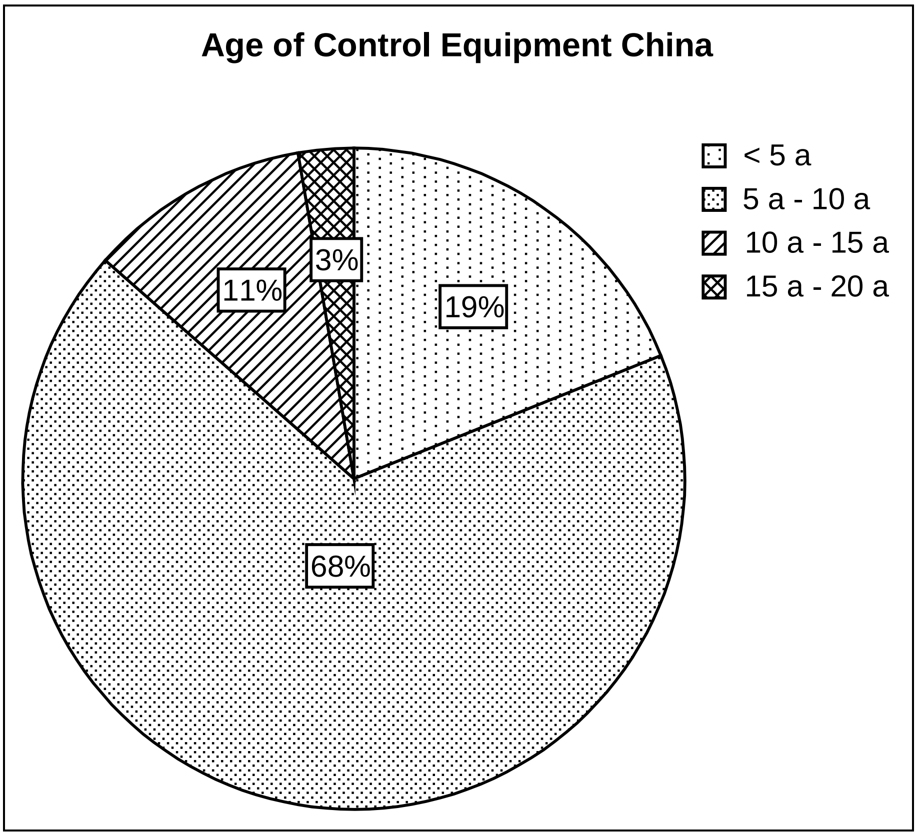


FIGURE 117: AGE OF CONTROL EQUIPMENT IN CHINA

The following figure gives an outlook on the technology state of the control equipment in the inspected plants.

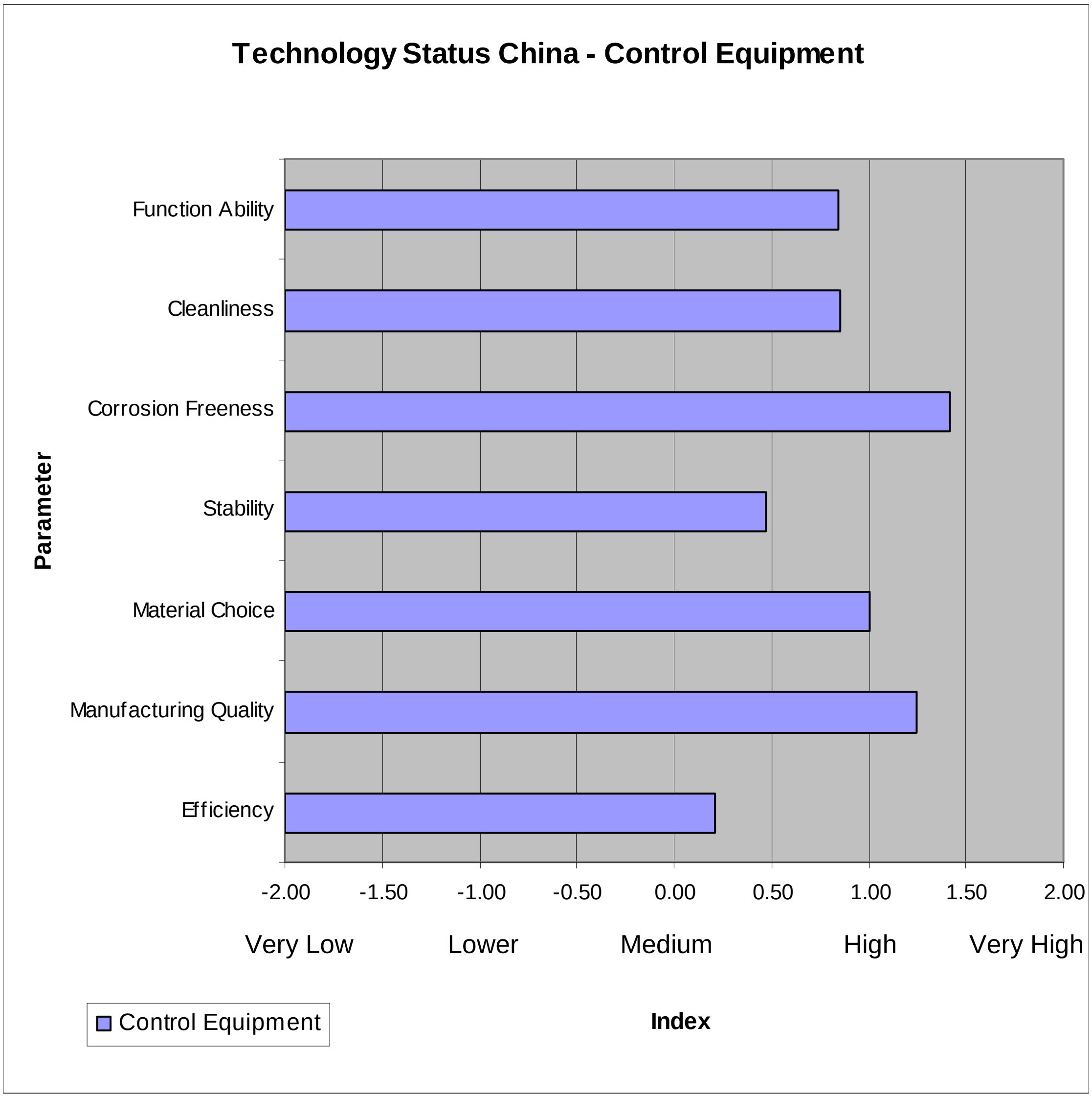


FIGURE 118: TECHNOLOGY STATUS CHINA – CONTROL EQUIPMENT

As already mentioned in chapter 7.1.1, the determination of the parameter "function ability" with the chosen methods in this study has to be seen as a rough estimation for a comparison with India and Germany. For a detailed consideration, other methods are required. For the control equipment of the inspected treatment plants in China, an index value of about 0.84 was determined. Mechanically, almost all equipment is intact. Problematic is in many cases the obvious low durability of cabling and cable connections, both due to very fast aging of plastic protections and improvised repairs (see figure 119 and 121). For control panels and sensors a relatively high function ability can be assumed. Problematic are outdoor control panels with a reduced durability due to casings out of coated normal steel.

For the parameter “cleanliness” an index value of 0.85 could be determined that is in the upper medium range. Surface cleanliness is on a high level for most components. Slight deficits could be stated regarding detail/technical cleanliness of cabling, control panels and sensors in some cases.

Corrosion freeness is on a high level with an index value of 1.41. Most sensors on the inspected plants are imported from Germany and don’t show almost any sign of corrosion or weathering. For outdoor control panels, a mixed picture exists. Many control panels out of stainless steel don’t show any corrosion, whereas control panels out of coated normal steel – mainly made in China - show severe corrosion in some plants (see figure 120). Indoor control panels are mainly corrosion free.

Stability is in the upper medium range with an index value of about 0.48. Most equipment is acceptably mounted (see figure 119-122). No severe deficits neither regarding static design, nor material thickness could be stated.

FIGURE 119: CABLING ON STPS IN CHINA

The material quality of control equipment varies in a wider range. As already mentioned, many control panels made in China are of coated normal steel, which leads to corrosion problems in outdoor applications. Control panels of imported outdoor machinery equipment are mainly out of stainless steel, indoor control panels are also of stainless steel or of high quality coated normal steel. Imported sensors are of corrosion/UV proof material – plastic and special steel (see figure 121). In some cases, plastic material is used for cable protections, which is not UV proof. In total, an index value of 1.00 could be determined for the parameter “material quality”. For the manufacturing quality of control equipment, an index value of 1.24 was determined. Especially imported control panels and sensors are characterised by very high dimension accuracy and surface quality. For control equipment made in China medium to high dimension accuracy can be stated. Cabling is basically accurate in large scale, but in detail or at repairs unstructured cabling could be observed (see figures 119-122).

FIGURE 120: OUTDOOR AND INDOOR CONTROL PANELS ON STPS IN CHINA

FIGURE 121: SENSORS FOR ONLINE MEASUREMENT IN CHINA

FIGURE 122: CENTRAL CONTROL ROOM AND OUTDOOR CONTROL PANEL IN CHINA

For the parameter “efficiency” of the control equipment on the inspected plants, an index value of 0.21 could be determined.

In the following, the criteria technology level and specific material costs will be considered more in detail.

Level of Technology

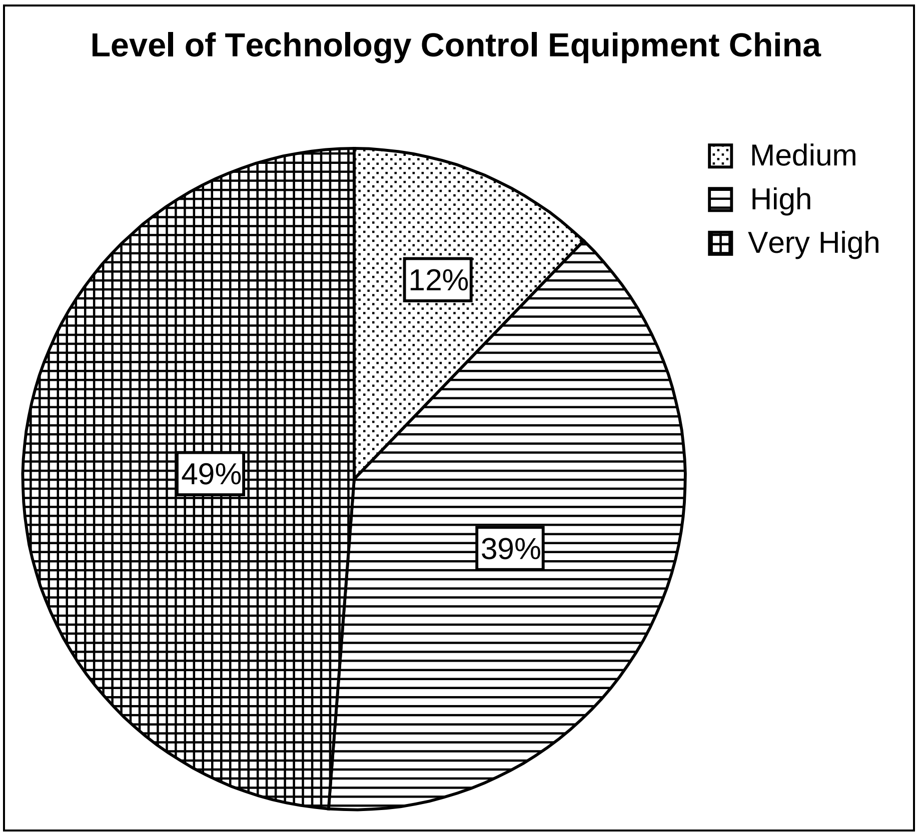


FIGURE 123: LEVEL OF TECHNOLOGY OF CONTROL EQUIPMENT IN CHINA

As visible in figure 123, a relatively high technology level can be stated. About 49% of the inspected equipment is of very high, about 39% are of high technology level. Most plants are highly automated, with modern central control rooms (see figure 122). Control panels are of modern and functional design. Sensors are also on a very high technology level – probes for online measurement of the main operation parameters exist in most plants (see figure 121). Only about 12% of the inspected control equipment is categorised as medium technology level. An index value of 1.37 could be determined.

Specific Material Costs

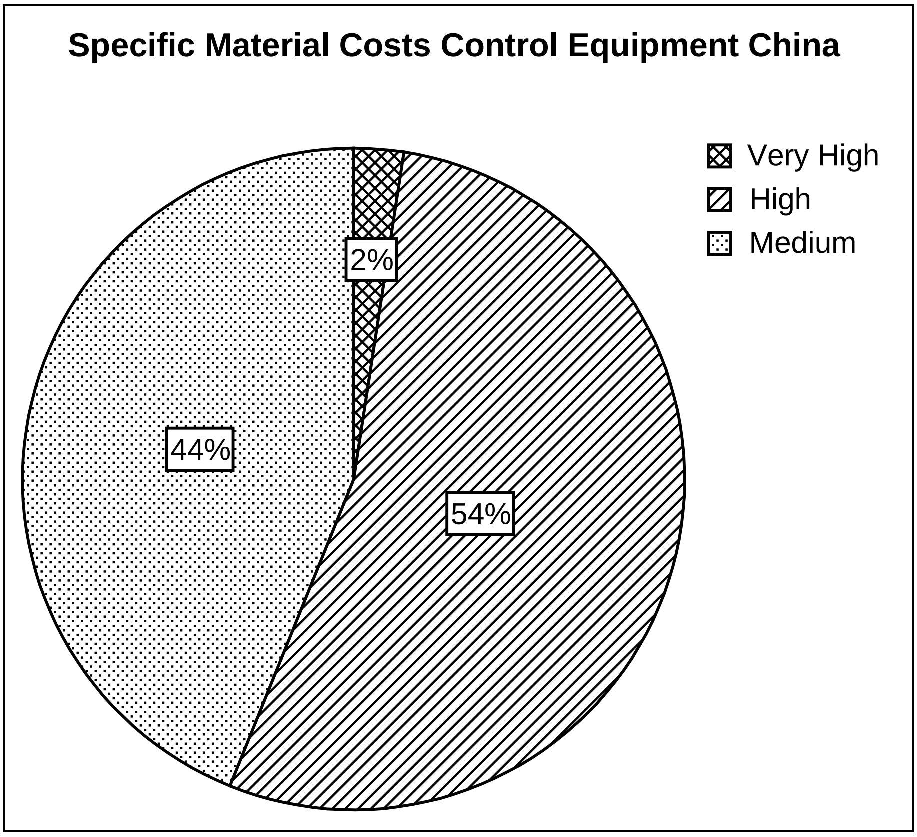


FIGURE 124: SPECIFIC MATERIAL COSTS OF CONTROL EQUIPMENT IN CHINA

About 44% of the control equipment is characterised by medium material costs. For about 56% of the equipment high and very high material costs have to be assumed, due to a high automation degree and the use of high quality material. An average index value of -0.59 could be determined.

Treatment Plant Construction & Operation

Construction

Almost all inspected treatment plants in China were constructed by construction departments of the respective local government. As already mentioned, seven plants were built in Sino-German cooperation. From the German side, mainly the companies Kocks Consult and IGIP were involved in planning and realisation. Regarding the technical equipment supply, equipment of Linde, Preussag Noell, Huber Technology, Passavant-Rödiger, Passavant-Geiger, Egner, Flottweg, Aerzen, Endress + Hauser and other German suppliers is applied on the inspected treatment plants. Degremont Germany realised the plant that is based on biological aerated filter technology. This plant was constructed outside the Sino-German development cooperation.

Operation

The inspected government plants are operated and maintained by government staff. As already mentioned, four plants are operated in Public Private Partnership (PPP). Both in the municipal and the industrial field a trend for privatisation can be detected.

Maintenance

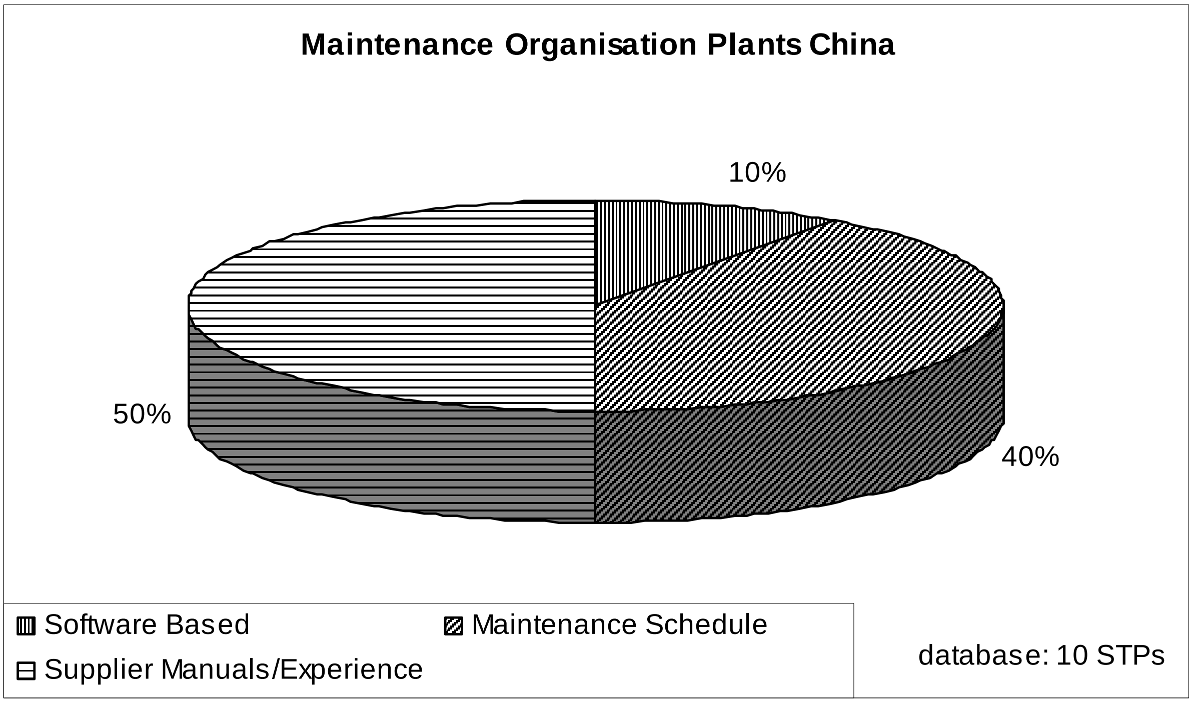


FIGURE 125: MAINTENANCE ORGANISATION OF STPS IN CHINA

In 10 inspected plants, information regarding the maintenance organisation could be gained. Maintenance schedules exist only in 50% of the plants, including one plant that has also automated maintenance planning using software. In 50% of the plants, maintenance is carried out only as per experience or with the use of supplier manuals. Many plants, both staff and management complained about language problems, as most technicians don’t speak English.

Figure 126 shows the main problem fields that were mentioned by the questioned staff in China. Asked which typical problems occur on the plant, the questioned staff mentioned operational problems to about 41%, mechanical problems to about 36% and problems with foreign equipment to about 23%. Repair and spare part supply of foreign equipment are problematic in the opinion of the staff.

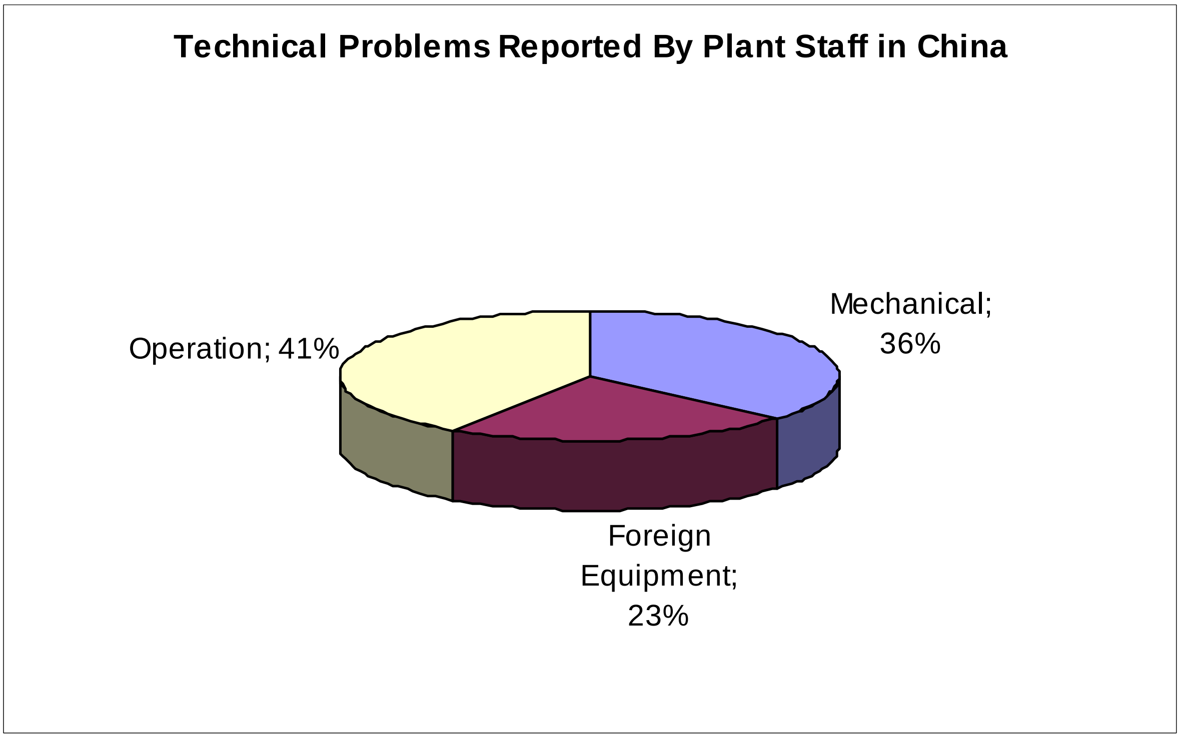


FIGURE 126: TECHNICAL PROBLEMS REPORTED BY STAFF IN CHINA

7.2.2 Staff

In total, 26 persons were questioned. The average age of the questioned test persons is 33years, whereas the youngest questioned employee is 24years old and the oldest is 49years old. 24 test persons are male, 2 test persons are female. Except one person, all test persons mentioned that they don't belong to any religion. 22 test persons are married. About one third of the test persons has one child – no person has more than one child. The average time period that the questioned test persons are in their current professional position is about 7years, in a range from 1year to 20years. Regarding the professional field, 4 persons are electricians, 9 test persons are mechanics and 13 test persons are in charge for plant operation.

Figure 127 and 128 show specific staff use and plant capacity, as well as the proportion of the different staff groups on the respective municipal plants. Basically the total staff number increases with increasing plant capacity, but both the total staff and the relative proportions vary in a great range.

For the inspected plants with a design capacity ≥ 100.000m³/d, an average value of about 0.0005 can be determined. At a plant capacity between 300.000m³/d and 1.000.000m³/d, the specific staff use on Chinese plants is about half compared to Indian plants in the similar capacity range. A higher degree of automation and more efficient staff management can be assumed as major reasons. The private operated plants show very low values for specific staff use. Staff is obviously used very efficiently in these plants, compared to government plants. Regarding the relative distribution of the different staff groups, a very inhomogeneous picture is visible. In most plants, the proportion of workers is less than 30%, which is relatively low, compared to plants in India. Instead, high proportions of technicians/operators of up to 90% and engineer staff of up to 32% can be stated, which is much higher than on the inspected Indian plants.

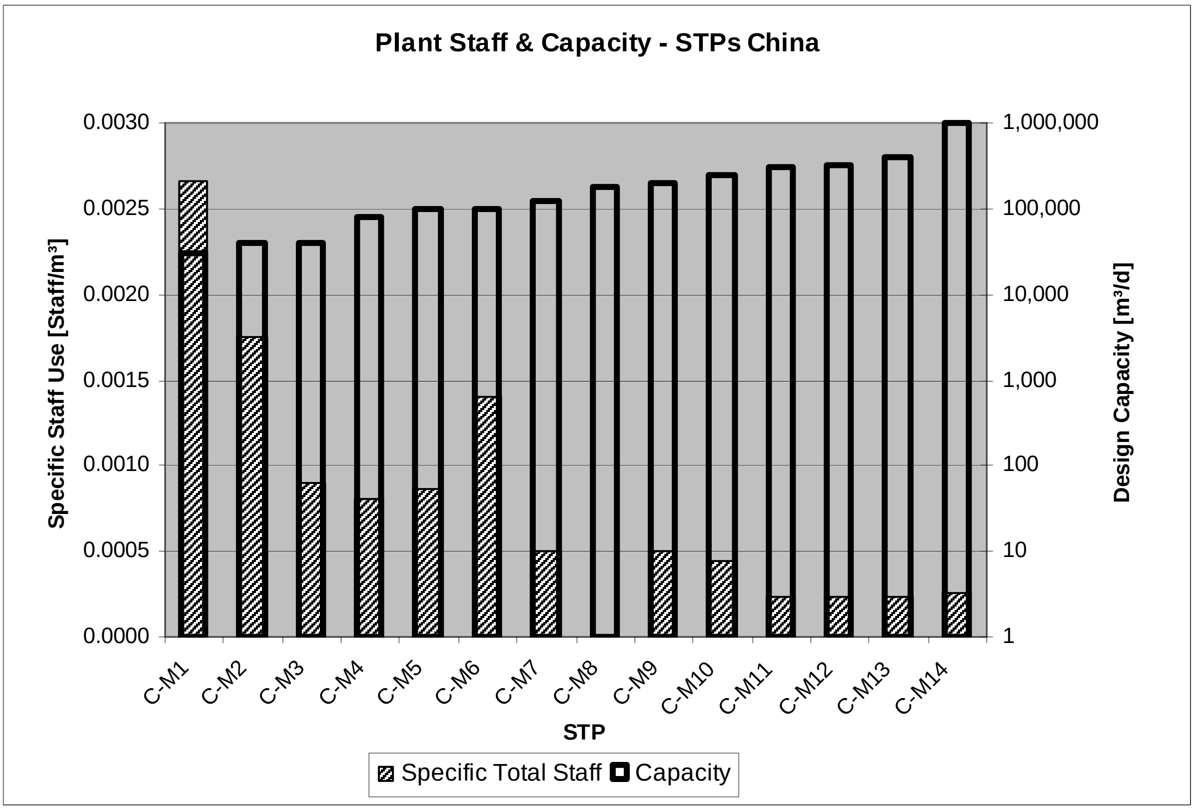


FIGURE 127: PLANT STAFF AND CAPACITY STPS IN CHINA

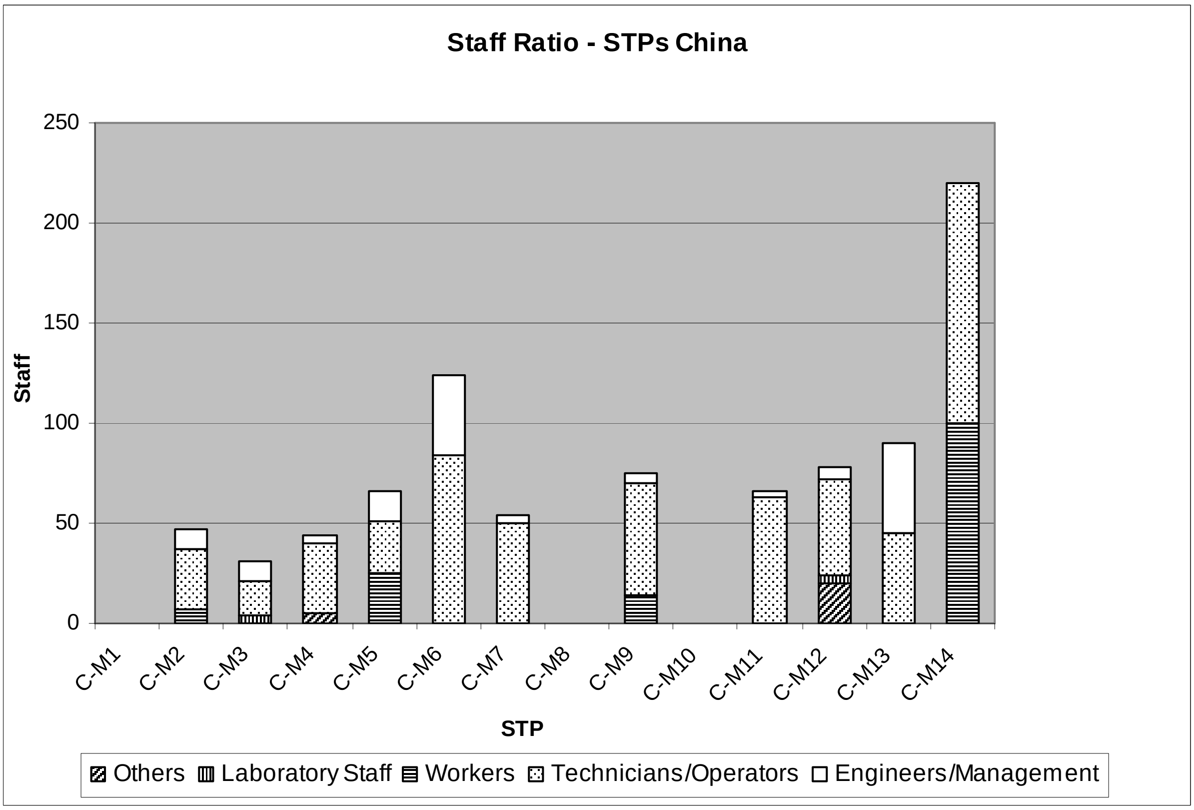


FIGURE 128: STAFF RATIO STPS IN CHINA

In the following paragraphs, the results from the questionnaire based staff interviews are presented.

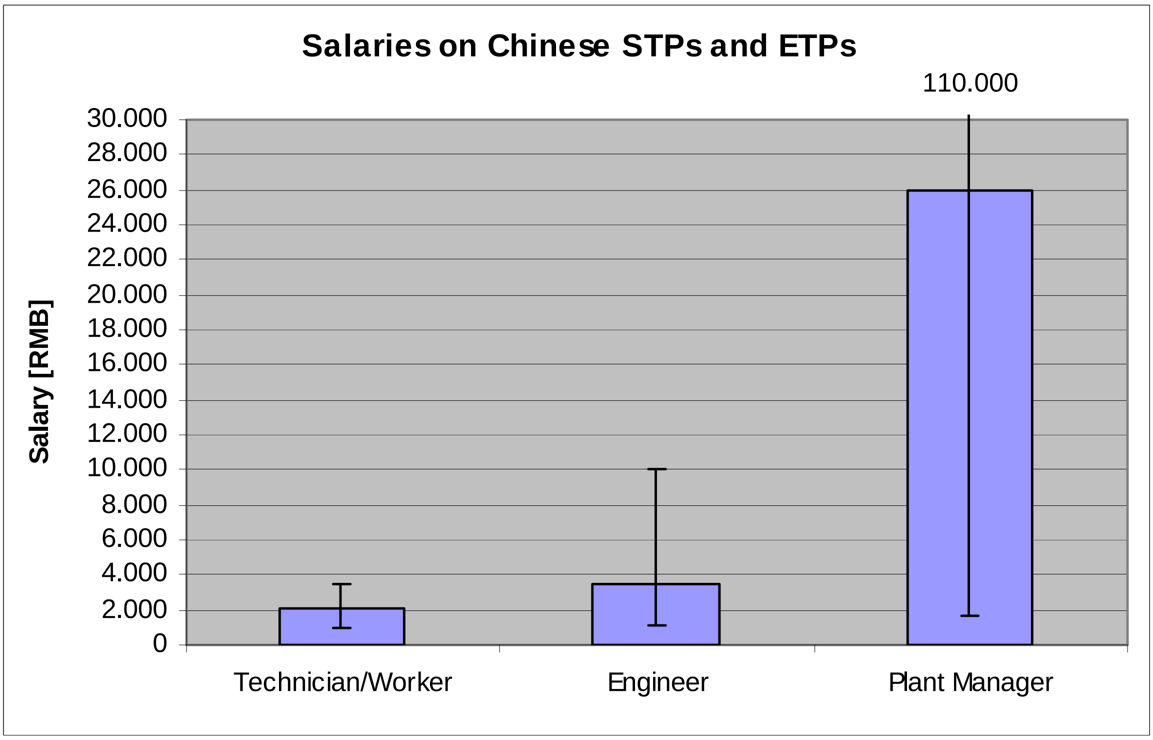


FIGURE 129: INCOME DISTRIBUTION ON CHINESE STPS

As visible in figure 129, the income of technicians on the inspected plants varies in a range between about 900RMB and 3.500RMB, with an average value of about 2.000RMB. On the engineer level, the average income is about 2.000RMB with deviations of more than 6.000RMB. For the plant management, an average income of about 26.000RMB could be determined. Out of 8 plants managers, 2 have a salary of 80.000RMB or more. The salaries of the majority of the plant managers are 4.000RMB or less on the inspected government plants. For the salary ratio between technicians and engineers, a value of 0.57 could be determined.

Figure 130 gives an outlook on the level of education of the test person group.

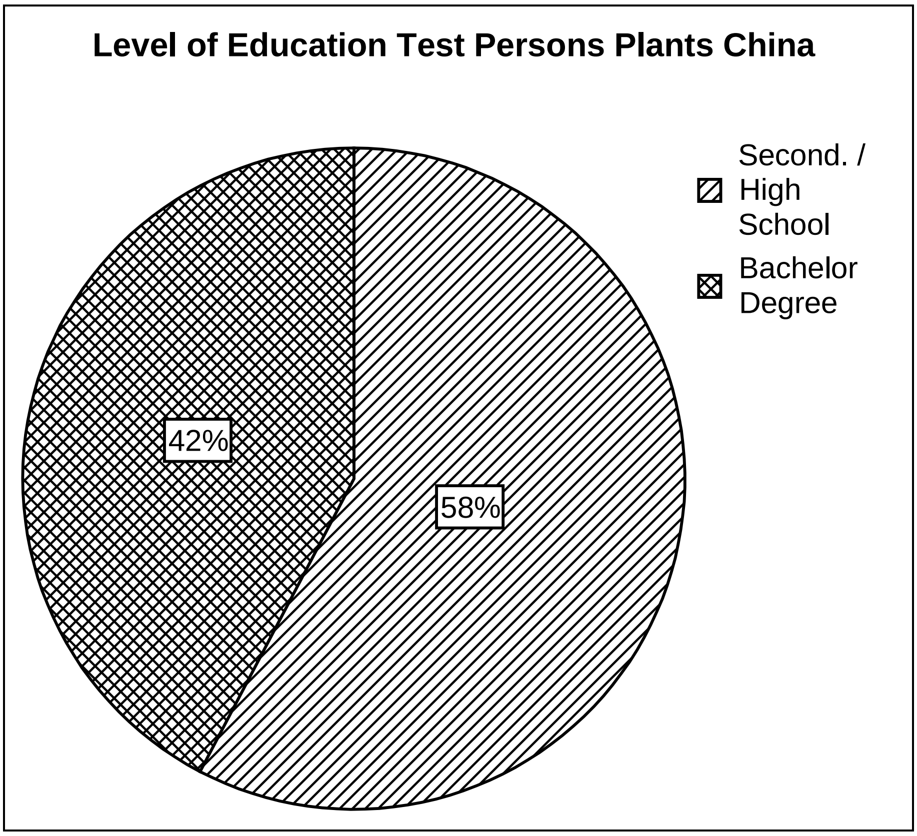


FIGURE 130: LEVEL OF EDUCATION OF QUESTIONED PLANT STAFF IN CHINA

Very interesting is the fact that, although almost only practically working staff was questioned, more than 40% are bachelor degree holders. As expert talks with plant managers showed, many degree holders are employed even for very basic practical works. Regarding the quality of the education, its suitability for the respective practical work and the effects on the job situation and work results, a more detailed discussion will be given later.

General & Operation Specific Knowledge

Figure 131 gives an outlook on the results from the questioning regarding several different question fields. Like in India and Germany, three questions of different severity were asked for each field (see question 23, appendix C). As already mentioned, the same questions were used in India, China and Germany. Only two questions were adapted to the specific cultural background.

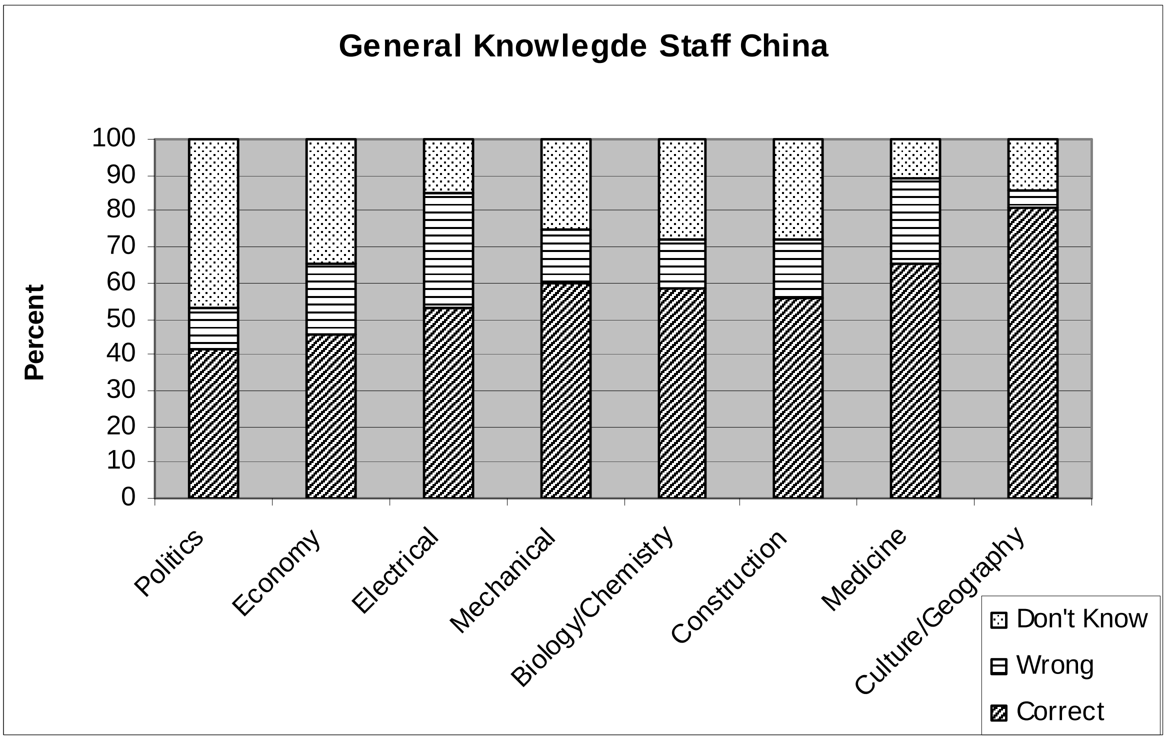


FIGURE 131: GENERAL KNOWLEDGE OF QUESTIONED PLANT STAFF IN CHINA

Detailed Analysis

In average, 58% of all questions were answered correctly, which is significantly higher than in India, where only 38% of almost the same questions were answered correctly (see chapter 7.1.2). Looking more into the detail, the highest values of correct answers can be found in the fields of culture/geography (81%) and medicine (65%). Questions from the field of mechanics, electrics and biology/chemistry were answered correctly in a range between 53% and 60%, which is also much higher than in India, where the values ranged between 30% and 34%. Only in the field of construction, the Chinese staff answered less answers correctly than the questioned Indian staff. Looking more into detail, staff working in the electrical field could answer 33% of the questions from this field correctly, which is much less than in India (53%).

In the mechanical field, 63% of the mechanics could answer the questions from the mechanical field correctly, compared to 46% in India.

Like in India, different technologies were mentioned to the test persons and they were asked whether they know the respective technology and if yes, whether it is used on their plant (see question 15, appendix C). The following answer distribution could be determined:

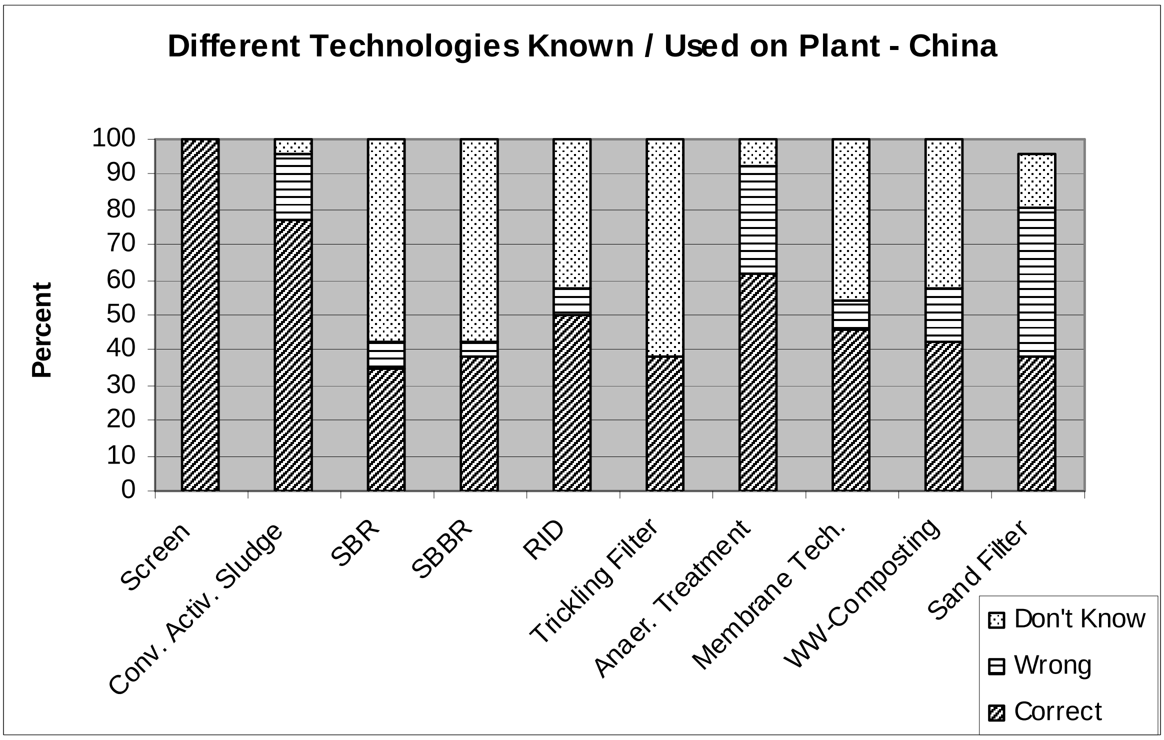


FIGURE 132: TECHNOLOGY KNOWLEDGE OF QUESTIONED PLANT STAFF IN CHINA

In average, about 53% of the test persons answered the technology questions correctly, compared to only 30% in India. 34% of the test persons did not know the respective technology, compared to 56% in India. Screening systems and activated sludge process are well known by the staff on Chinese plants, also anaerobic treatment. Other than in India, other systems are also known to certain extent. The answer regarding the use of RID technology is answered correctly by about 50% of the test persons in China – in India, only 10% answered correctly (see figure 78, chapter 7.1.2.

Figure 133 shows the results of the question regarding the correctness of different statements on plant processes and safety measurements (see question 16, appendix C). In average, 77% of the process questions were answered correctly, which is remarkably higher than in India with 51% correct answers. In average, about 9% of the test persons don't know the processes – in India, 23% don't know the asked processes. The question is why more test persons know that dissolved pollutants are eaten by bacteria than that solids are removed from the wastewater. Language and translations difficulties seem to play a role. Very interesting is an obvious high awareness for hygienic aspects, which is expressed in the fact that all test persons considered wastewater sludge to be harmful to men. In India, only 32% of the test persons answered correctly (see figure 79, chapter 7.1.2). The meaning of common terms like BOD or nitrification are much more known on Chinese plants than in India, which is expressed in the questions regarding the degradation of BOD and BOD/nitrification, with 84% resp. 69% of test persons that answered correctly. For the question regarding filtration, language problems have to be assumed as reason for the relatively low value of correct answers.

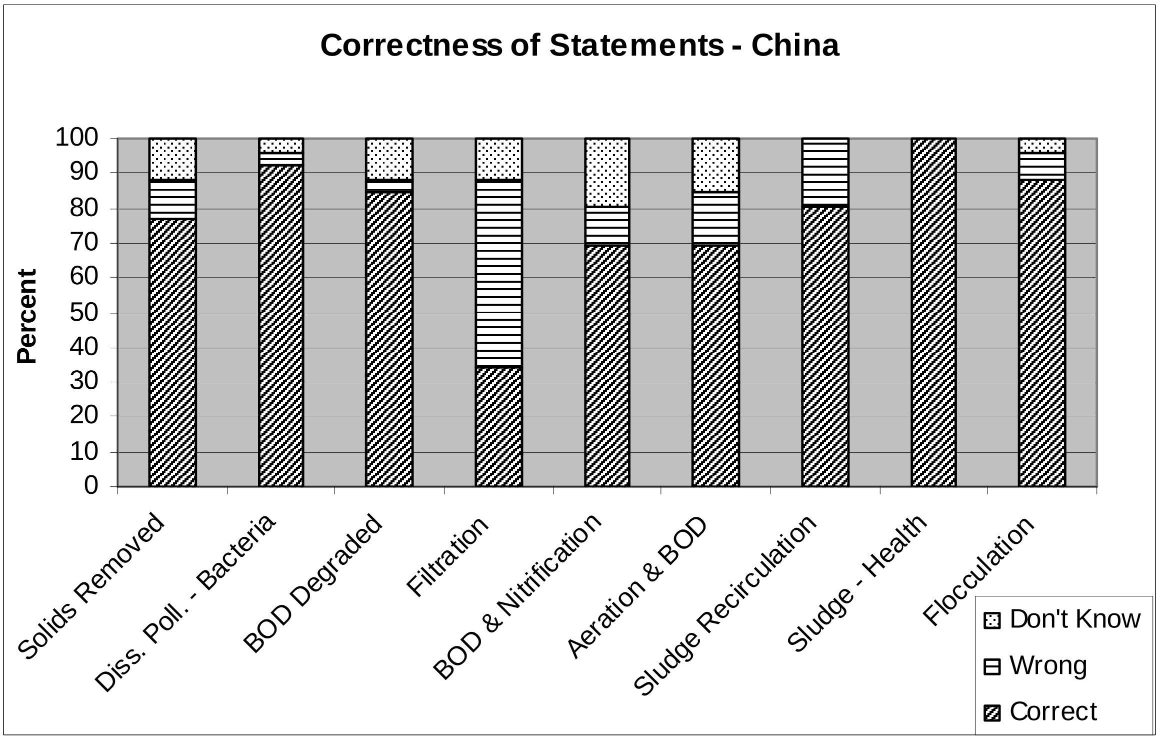


FIGURE 133: PROCESS KNOWLEDGE OF QUESTIONED PLANT STAFF IN CHINA

Work Situation & Motivation

Figure 134 shows the results of the question regarding the wishes and priorities of the Chinese test persons (see question 14, appendix C). Like in India, the test persons were asked to choose between maximum three wishes and to prioritise the different wishes. Like in India, the wish for training is expressed with the highest total frequency (see also figure 80, chapter 7.1.2). On second position of rank 1, like in India, the wish for better equipment is expressed. Considering the total frequency, the wish for higher salaries is on second position. Other than in India, the wish for the employment of more workers is hardly expressed. Instead, spare parts supply is considered as a problematic topic, which is also mentioned by several plant managers.

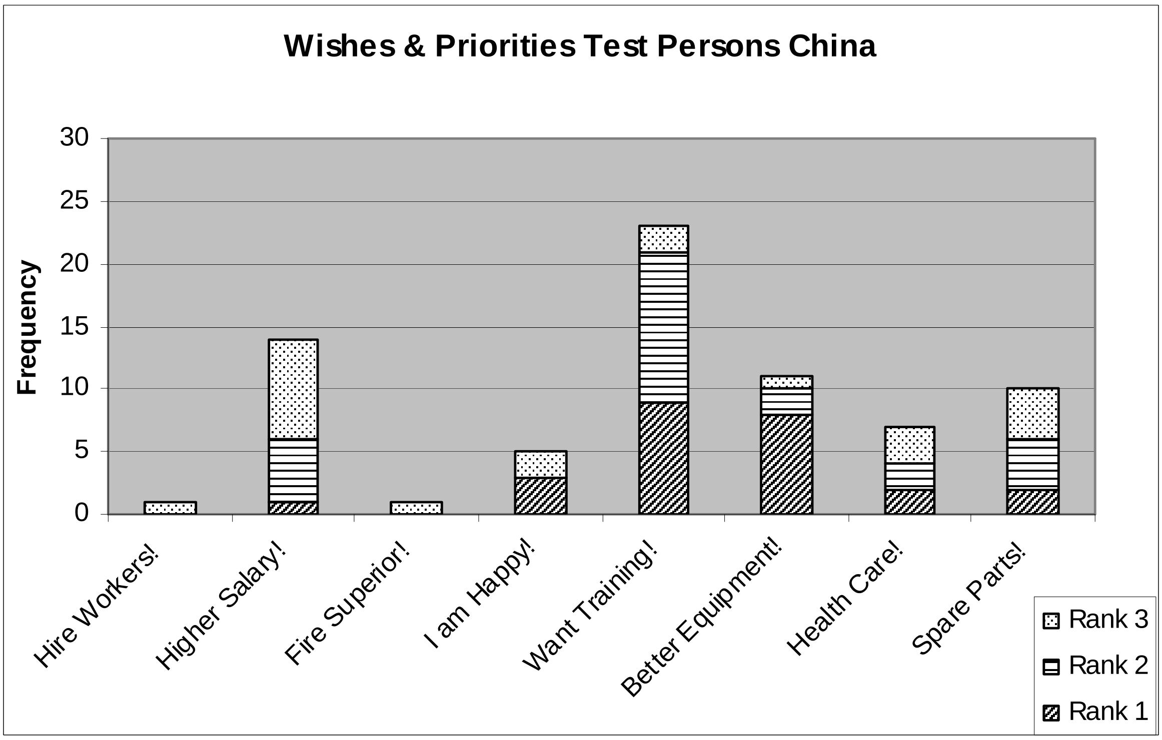


FIGURE 134: WISHES AND PRIORITIES OF TEST PERSONS IN CHINA

Figure 135 shows the plans for the future of the test persons, as indicator for the work motivation. About 24% of the questioned staff intends to change the company, 32% mentioned to continue as usual and 44% intends to stay and improve, which indicates that the motivation among the staff is slightly higher than in India (see figure 81, chapter 7.1.2).

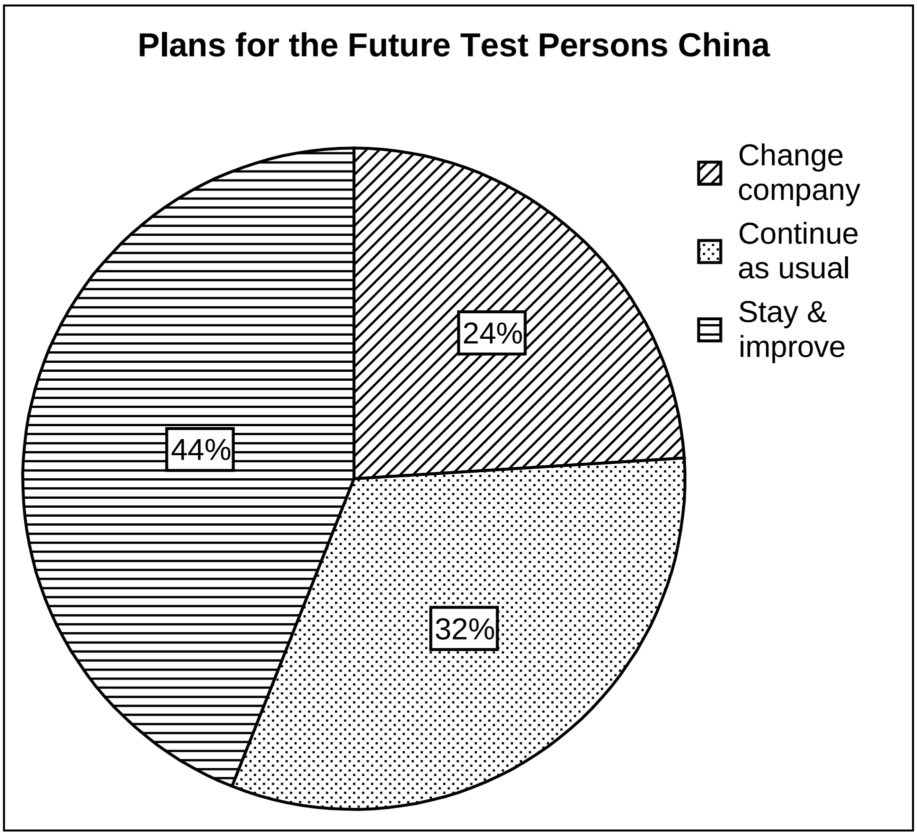


FIGURE 135: FUTURE PLANS OF QUESTIONED PLANT STAFF IN CHINA

7.2.3 Expert Positions

In order to get actual information on the position of experts on different aspects related to the use of wastewater technology in China, 19 experts were interviewed. Figure 136 shows the distribution of the different test person groups. The interviewed experts from the private sector are working in Chinese subsidiaries of German companies. About 47% of the test persons are between 31 and 40 years old, another 47% are between 41 and 50 years old and one test person is more than 50 years old. All interviewed experts have long-term experience in their work field. 84% of the test persons are working in the field of water & wastewater, 11% in natural science and 5% in the environmental field in general.

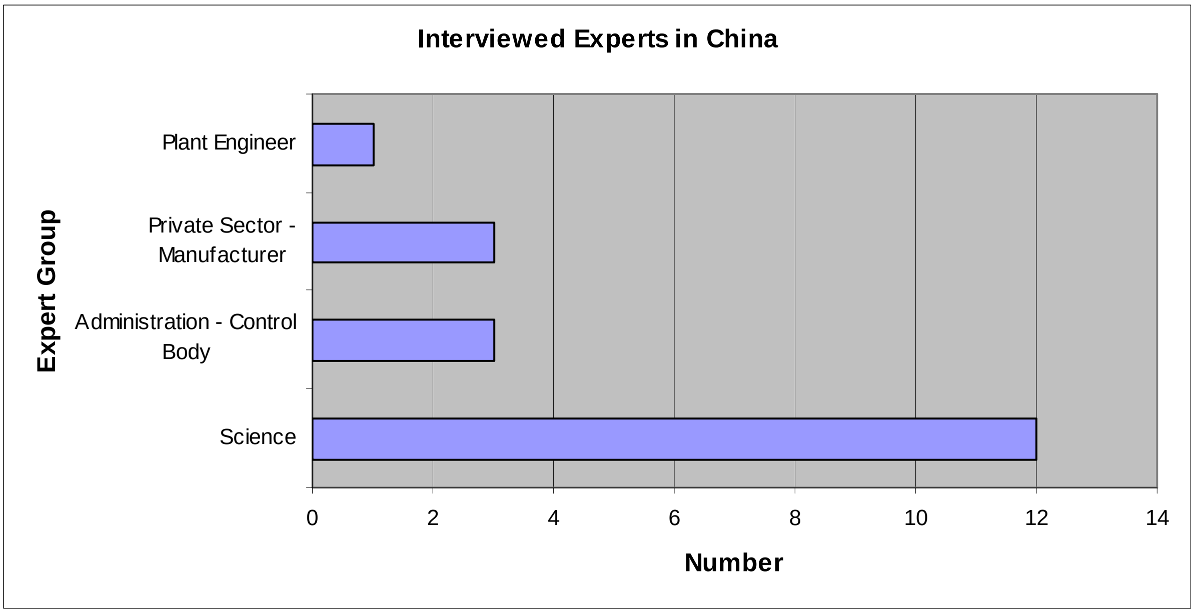


FIGURE 136: OUTLOOK INTERVIEWED EXPERTS IN CHINA

In the following paragraphs, the results in the different fields are presented. In the outlook schemes, those question fields were considered, to which at least three experts gave a statement.

Environment & Water Pollution in General

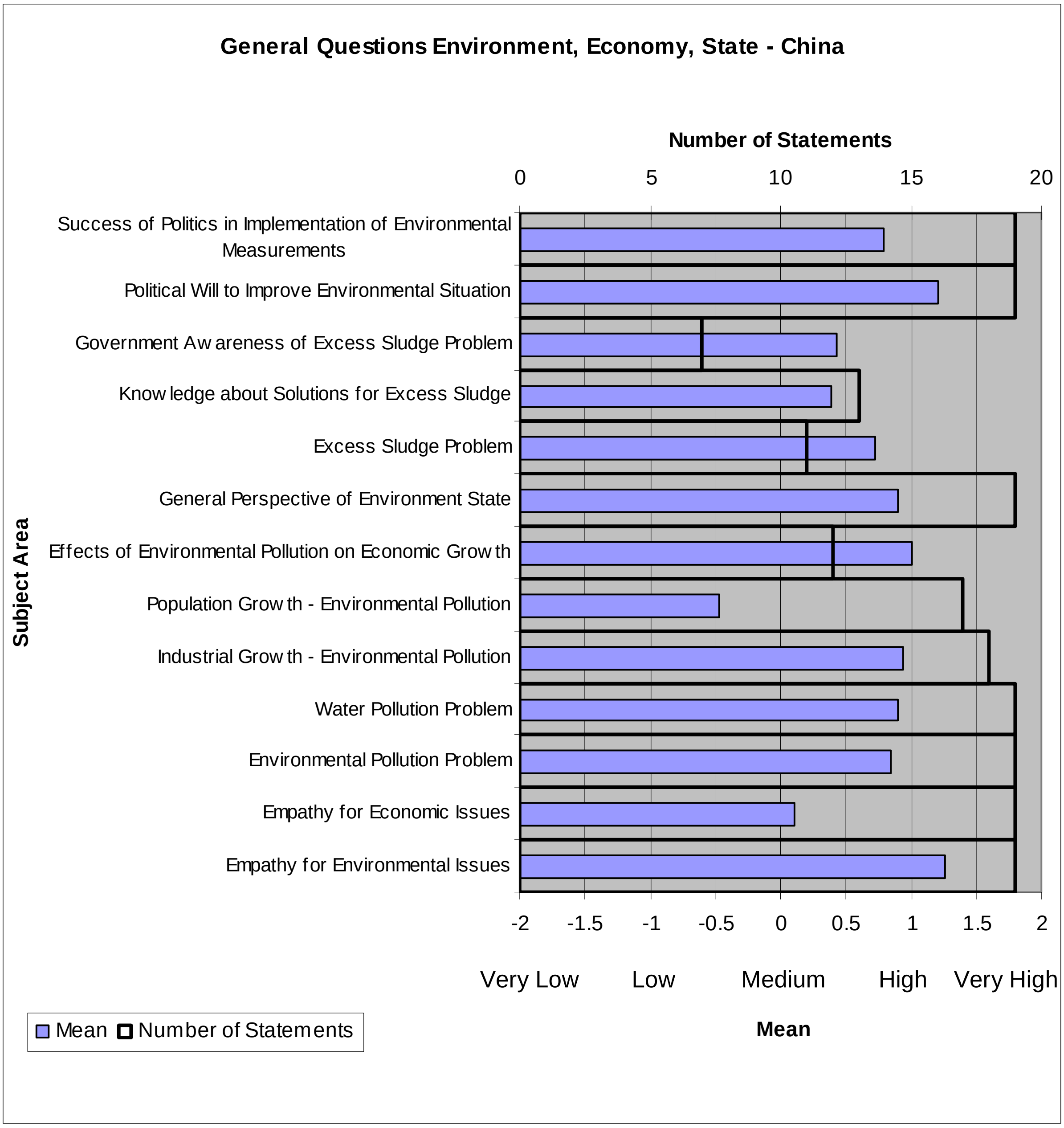


FIGURE 137: EXPERT POSITIONS ON GENERAL ASPECTS IN CHINA

Looking at aspects of environment and water pollution in general, water pollution is considered to be high with an average value of about 0.89. As visible in figure 137 and figure 138, industry is considered as the main pollution source in the country, whereas the municipal wastewater is hardly seen as a severe pollutant. About 67% of the test persons are convinced that the industry giving a higher pollution load than the municipal wastewater. This is a great difference compared to India, where only about 22% of the interviewed experts consider the industry to be the more or the only severe pollution source (see figure 84, chapter 7.1.3).

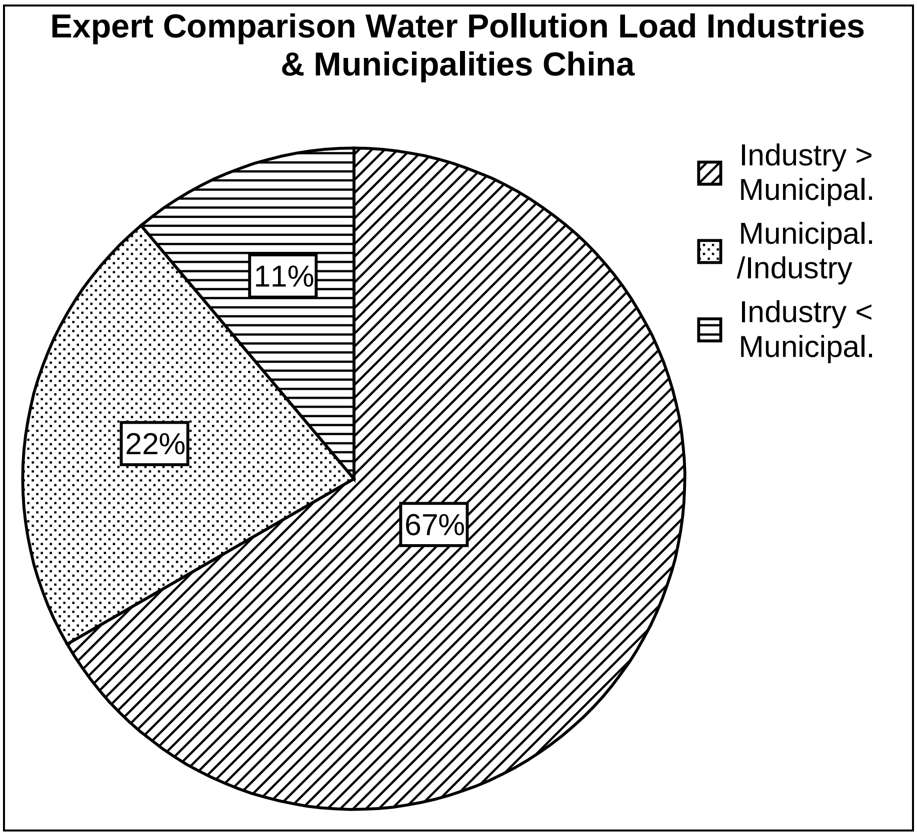


FIGURE 138: EXPERTS COMPARISON OF WATER POLLUTION LOAD INDUSTRIES AND MUNICIPALITIES IN CHINA

The future perspective of the environmental state is seen very positive by the interviewed experts with an average value of about 0.90. Fast improvements in this field are expected in the near future.

“Now…the government, the government pay much more, even much more attention on the environment, even much more attention... I think with the rapid developing for the economy the environmental situation in most districts will be better…”(Scientist – Expert Interview China No.7).

Most interviewed experts state a relatively high political will of the Chinese government to improve the environmental situation, so that a index value of 1.21 could be determined. The success of the government in the improvement of the environmental situation is also considered relatively high (index value 0.79). Among Indian experts the respective index value is only 0.48 (see figure 83, chapter 7.1.3).

Excess sludge is considered as a problem, but it is not seen as too severe or to urgent in average (index value 0.73). For the government awareness about the excess sludge problem, an index value of 0.43 could be determined. This surprises a little, considering the excess sludge situation and common disposal practices in many cities of the country. Sludge – very often undigested – is very often just dumped in landfills or emptied fish ponds. Especially scientists point out the high pollution potential and danger for the environment.

FIGURE 139: DUMPING OF EXCESS SLUDGE IN FISH PONDS

The knowledge regarding solutions for excess sludge handling can be determined as medium with an index value of about 0.38. Interviewed experts of research institutions basically see three possibilities, which are incineration, anaerobic digestion, and dumping in landfill, whereas the dumping in landfill is seen very critical by the majority of interviewed experts. Many research institutions are working on solutions.

“The sludge from wastewater plant… in Shanghai, all over China, it’s a big problem“ (Scientist – Expert Interview China No.7).

Wastewater Treatment Technology

The following figure shows the positions of interviewed Chinese experts regarding technical subject fields of wastewater treatment.

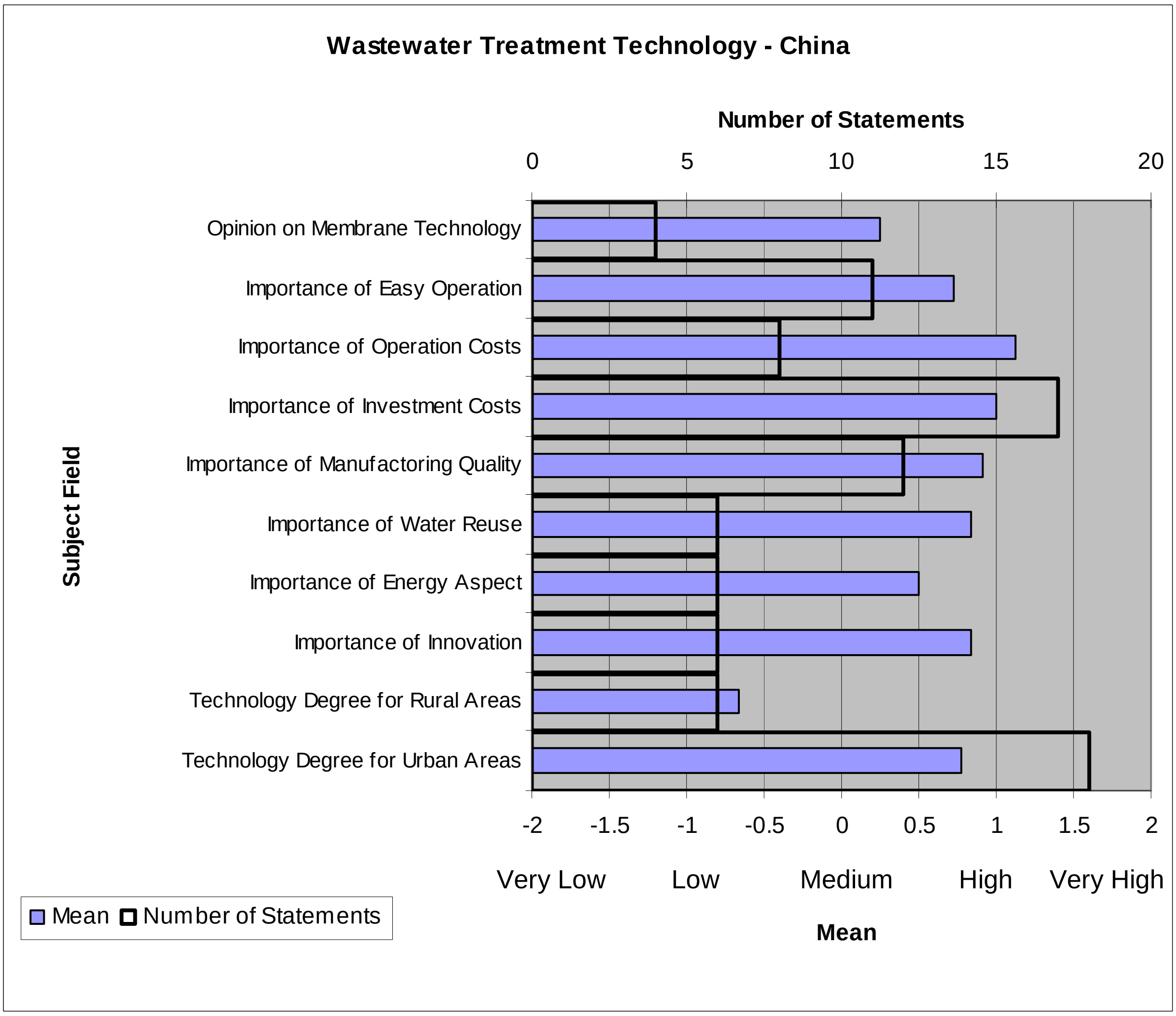


FIGURE 140: CHINESE EXPERT POSITIONS ON WASTEWATER TREATMENT TECHNOLOGIE

Regarding the technology degree for urban areas, the interviewed Chinese experts consider very technical solutions to be suitable - an index value of 0.78 could be determined. This is slightly lower than in India (see figure 85, chapter 7.1.3). About 78% of the test persons who gave a statement on this topic consider a high technology degree to be suitable for urban areas, whereas 22% think that medium level technology is suitable. For rural areas, very basic technologies are considered to be suitable (index value -0.67). About 67% of the test persons who gave a statement on this topic consider low tech solutions, 33% consider medium technology to be suitable for rural wastewater treatment. An experienced scientist gave the following typical comment, which is representative for many experts in China:

“In Shanghai, in Beijing, in Guangzhou, big cities, I think should use advanced technology about wastewater treatment, about sludge treatment and disposal… should be in big cities, but in small city, in the middle small city in China, because of the economy...because of the economy… not so advanced technology is suitable” (Scientist – Expert Interview China No. 7).

Regarding the importance of aspects of easy operation, an index value of 0.73 could be determined, which is higher than the respective value that could be determined for the Indian experts (index value 0.22).

For the manufacturing quality of technical equipment, an index value of 0.92 could be determined. However, cost aspects are very important for the interviewed experts, whereas for operation costs the highest index value could be determined (index value 1.13). Energy demand is of moderate importance for the interviewed experts (index value 0.5). The following statement of a Chinese scientist shows the importance of cost aspects and an increasing awareness about operation aspects.

“So in my opinion,…a good technology in China should be, firstly, economical, that means cheap, then simple, stable. I don’t think complicated technology is a good choice in China” (Scientist – Expert Interview China No. 9).

Economic Aspects of Technology and Knowledge Transfer

Figure 141 shows the expert positions regarding economic aspects and technology transfer. Regarding the economic perspective of the water and wastewater market, Chinese experts are very optimistic and see high market chances for the future (index value 1.0). Especially the strong political will to improve the environmental situation, as well as further industrial growth are mentioned by many experts. Moderate chances can be assumed in excess sludge handling (index value 0.17), where especially solutions with low investment costs are required.

The preference for German or western equipment in general is moderate (index value 0.0). Although the quality of German machinery equipment is appreciated, the high investment and maintenance costs are seen critical by many interviewed experts.

“In some place we can use some of the European ways, because the European solutions…not always, but…quite expensive for us. So we must find some affordable ways. That is the first problem. And second, if it is too high technical, it’s not easy to use for low educated people” (Scientist – Expert Interview China No. 11).

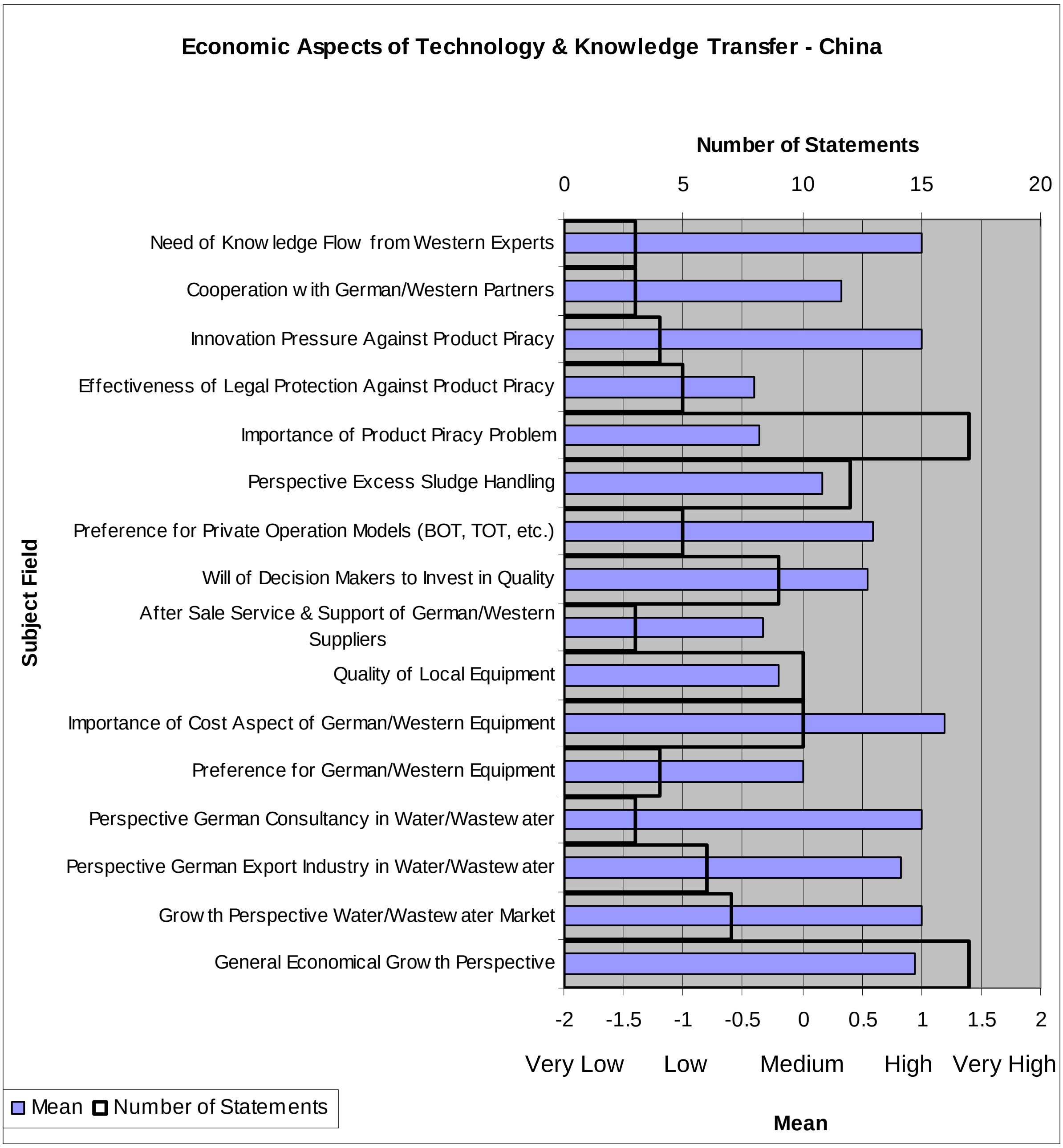


FIGURE 141: CHINESE EXPERT POSITIONS ON ECONOMIC ASPECTS AND TECHNOLOGY TRANSFER

The cooperation with German business partners is seen mixed by the interviewed experts (index value 0.33). One interviewed expert reported about bad experiences with western partners, two interviewed experts see the cooperation very positive. The statement of a Chinese plant engineer, with long term experience with German partners:

"I think we have a very big space to cooperate, cooperate with the European technology, and China...every city, some towns. We have very big space to cooperate" (Plant Engineer – Expert Interview China No. 13).

However, the following statement of a scientist who was involved in Sino-German negotiations on a wastewater project indicates that lack of cultural sensitivity seems to exist at German partners in some cases.

“I don’t know how to express...in English also in German...maybe can say...the America know Chinese well, they know how to cooperate, how can together, how to work together with a Chinese. America know me well, but you (German), you know me not so well. They know what the Chinese need, what the China market need” (Scientist – Expert Interview China No. 7).

Like in India, many experts consider privatisation in the water and wastewater sector as a suitable way to improve the existing environmental situation, especially because financial constraints can be overcome (index value 0.6).

“Because…for the waste water treatment, the most important is the funding. If you get funding, you can…if you get funding, you can put into wastewater treatment. Technology is important, but the funding is more important*…(Interviewer: Where is the funding coming from?)* From the government, from the company, from the different… ways… *(Interviewer: You think of BOT?)* Yes, BOT” (Scientist – Expert Interview China No. 10).

Product piracy is not seen as a critical issue by most experts (index value -0.35). The illegality of copying of machinery equipment is seen, but is obviously not considered as a morally wrong act. The reasons for the low awareness about this topic can be seen both in the fact that the interviewed Chinese experts are not directly affected and cultural differences. Considering the education tradition, imitation is characteristic in China (see also chapter 5.2.2). In that sense, a good copy is – traditionally – nothing wrong.

“So you needn’t worry about this. Just do your, do your work very well. Every day maybe you can, you can improve your technology every day, every time. So never stop with your technology. That’s more important. That’s better than protect your own technology” (Plant Engineer – Expert Interview China No. 13).

Awareness & Professional Education

In the following, the detailed consideration of aspects of awareness, education and motivation is carried out.

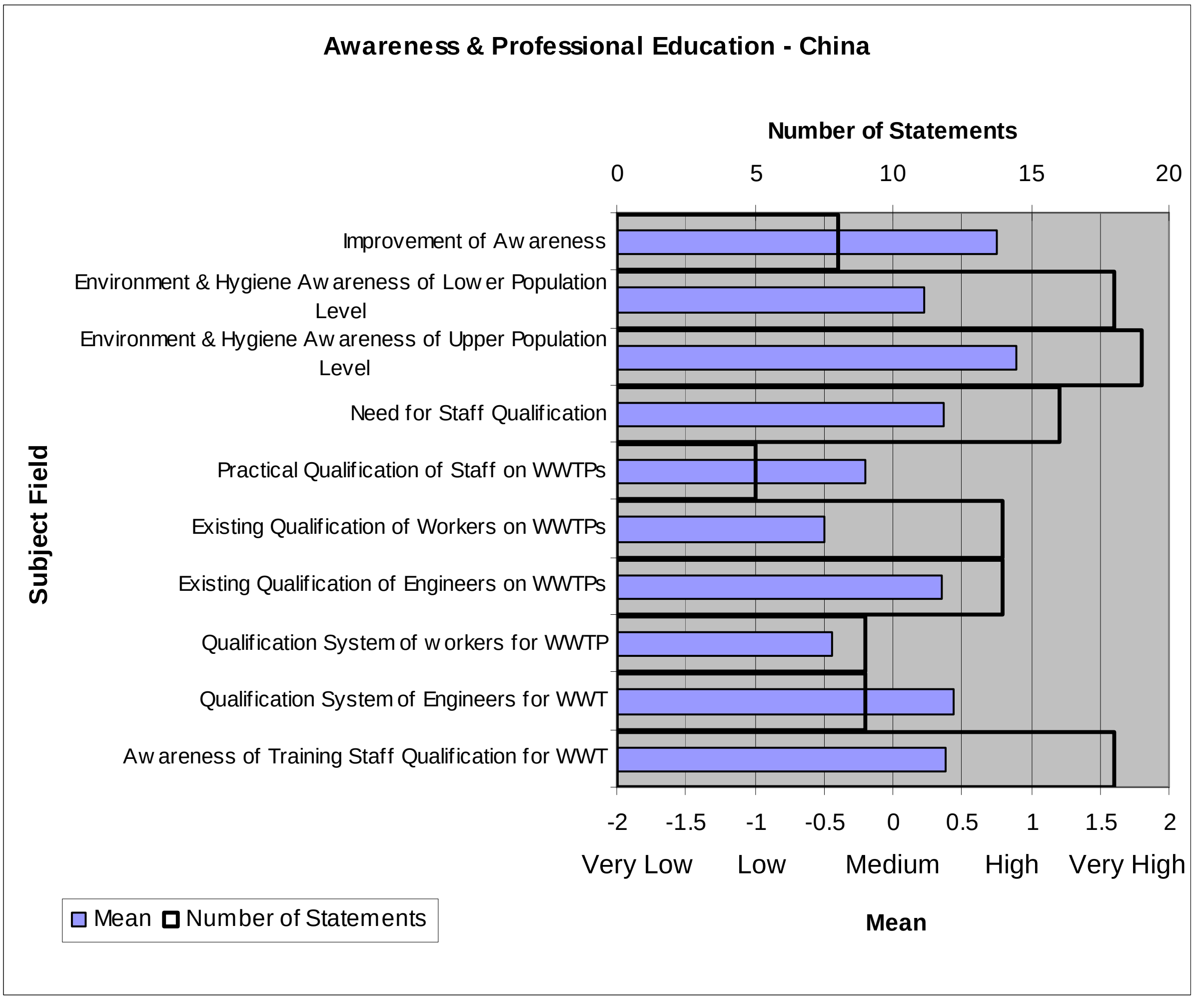


FIGURE 142: CHINESE EXPERT POSITIONS ON AWARENESS AND PROFESSIONAL EDUCATION

The awareness of the population on environmental issues with an index value of 0.90 for the upper population level is seen remarkably higher that in India with a value of only 0.35 (see figure 87, chapter 7.1.3). Similarly, the awareness among the lower population level is seen higher in China than in India. The existing qualification of the treatment plants staff on the engineer level is considered to be moderate with an index value of 0.36, whereas the qualification on practical staff level is considered very low (index value -0.5). Both values are remarkably higher than the respective values in India (see figure 87, chapter 7.1.3). Looking at the qualification system, the Chinese experts consider the qualification system for the engineer staff moderately positive (index value 0.44) and for the workers level low (index value -0.44). The need for staff qualification in the field of wastewater treatment is recognised (index value 0.38), but is expressed not as strong as in India (index value 0.85). Also the following statement of am interviewed plant engineer shows that the need for staff qualification – at least to certain extent - is recognised on expert level.

“Also we can not require so much for popular workers, because their knowledge is limited. But … but we can do some training for them. Just fit...fit their works, fit their operation works. We can not require them know everything about this…sewage treatment plant. But…what we can do this? Training them, how to do their work, how to do their work in this sewage treatment plant and how to work together to make this plant running very well. That’s enough. That’s enough” (Plant Engineer – Expert Interview China No. 13).

Identification of Major Position Differences between Expert Groups

In addition to the overall analysis of the expert interviews, a comparison of the opinions of the following major expert groups is carried out:

- Control & Administration (pollution control boards and municipalities)
- Private Sector (consultants and manufacturers)
- Science

Figure 143 shows those topics, where interesting differences between the different expert groups could be determined. As in many cases only very few expert statements were given, the results can show only possible tendencies.

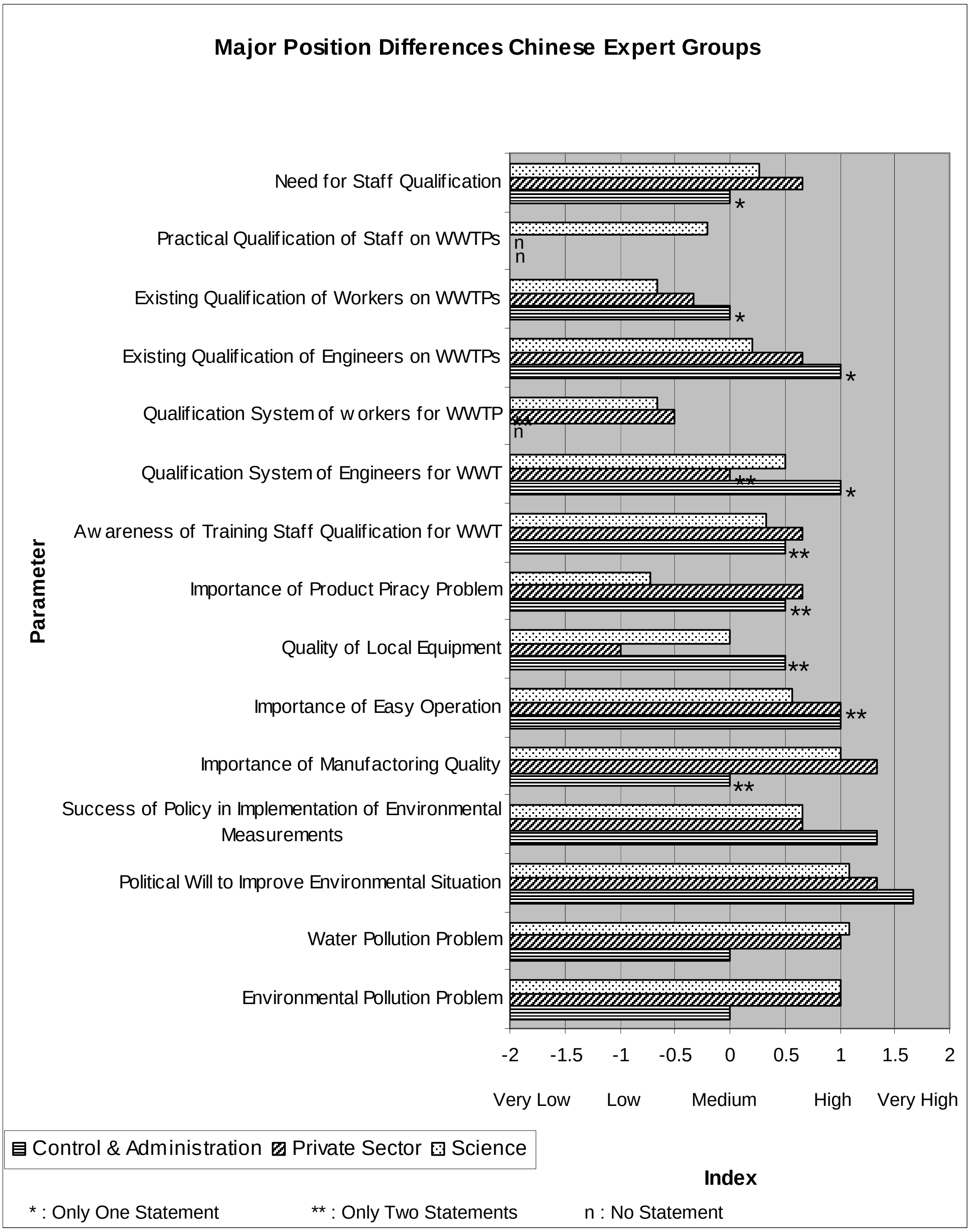


FIGURE 143: MAJOR POSITION DIFFERENCES OF DIFFERENT EXPERT GROUPS IN CHINA

Similar like in India, the qualification of practical staff and engineers is considered to be on a lower level by the interviewed experts from the private sector and science than by experts from the public sector. The results indicate that experts from the private sector and science also see a stronger need for staff qualification than experts from the public sector (see figure 143).

The quality of local equipment is considered to be relatively low, whereas the fact has to be considered that the experts from the private sector are working for Chinese subsidiaries of German companies. Product piracy is seen as a problem by interviewed experts from the public (index value 0.5) and the private sector (index value 0.67), whereas in the interviews aspects of "social wishfulness" might have played a role. Regarding the importance of manufacturing quality of technical equipment, the results indicate that in the public sector (index value 0.0) this aspect is much less relevant than for experts from science and private sector (index values 1.0 resp. 1.33).

Interestingly, the political will, as well as the success of politics regarding the implementation of environmental measures is considered to be relatively high by all expert groups, with the highest values among experts from the public sector (index value 1.67 resp. 1.33). Regarding environmental and water pollution, both interviewed scientists and experts from the private sector see high problems, whereas for interviewed experts from control administrations the pollution problems are obviously not very severe (index value 0.0).

7.2.4 Summary & Discussion

Treatment Plant Efficiency and Processes

Regarding the treatment processes and treatment technologies, a strong focus is set in China on activated sludge systems and oxidation ditches. In this study 15 municipal wastewater treatment plants and 1 industrial wastewater treatment plant were inspected. Of the municipal plants, 8 plants are activated sludge plants (5 single stage plants, 3 AB plants), 4 are based on oxidation ditches, 2 are SBR systems and 1 plant uses biological aerated filter as main treatment step. The inspected industrial plant is based on activated sludge technology (single stage). About 40% of the wastewater treatment plants in China are single stage activated sludge plants, 25% are AB plants, 20% are SBR plants and about 15% are oxidation ditches (Chen, Leinhos et al. 2004).

Twelve plants are operated by the state, out of which 7 plants were co-financed by KFW-bank. Three plants are operated in Public Private Partnership (PPP). The industrial plant is operated by own staff of the industry. As shown in chapter 7.2.1, 2 plants exceed the required discharge values for BOD (see figure 91, chapter 7.2.1), only one of the inspected plants exceeds the required outlet standards regarding COD (see figure 92, chapter 7.2.1). An average COD removal rate of about 87%

could be determined. In 1999, the average COD removal efficiency on 283 Chinese treatment plants was only about 75%, with an average inlet COD of about 344mg/l (Yang 2002). Based on the information given by plant engineers and plant managements, one plant exceeds the value for total phosphorous (see figure 94, chapter 7.2.1) and three plants exceed the discharge values for suspended solids. A report of the State Environmental Protection Administration (SEPA) on the performance of sewage treatment plants comes to the result that 100 of 535 plants have operation deficits and that 14 of these 100 plants have severe deficits like severe exceedings of the required discharge standards or very problematic plant stages (Meierjohann 2007). Experts from KFW-bank report about similar problems with plants that were co-financed by KFW-bank. Comparing the compliance of the plants in the current study with the results of SEPA and the experience of KFW, the results in the current study appear very positive.

Technology Status

As shown in the previous analysis regarding treatment plant equipment, a relatively high proportion of imported equipment from Germany can be stated (see figures 105 and 116, chapter 7.2.1) on the inspected plants. The age of the equipment is only about 5 -10 years in average (see figures 106 and 117, chapter 7.2.1). Considering this background information, the results of the status analysis have to be seen critically. The manufacturing quality of most inspected machinery equipment is on a high level especially due to very modern imported western equipment (see figures 107 and 118, chapter 7.2.1). For equipment made in China moderate manufacturing quality could be stated that is on a higher level than of plant equipment in India (see chapter 7.1.1). Problematic has to be seen a relatively low quality of concrete structures, which indicates lack of quality control and quality awareness (see figure 99, chapter 7.2.1).

Operation and maintenance deficits are visible in several ways. As many equipment parts are made of stainless steel, corrosion is much less a problem than in India for example. Problematic has to be seen the fact that equipment is obviously cleaned but that important interior parts are not maintained as required (see figure 108, chapter 7.2.1). Repair works are very often carried out in a very improvised way and in low quality (see figure 109, chapter 7.2.1). Reduced equipment efficiencies and durabilities are the consequence.

Less than half of the inspected plants have maintenance schedules – in most plants maintenance works are carried out as “per experience” (see figure 125, chapter

7.2.1). In some plants the information was given that repairs are only carried out, if a problem is stated, which shows deficits regarding preventive maintenance. In several plants, damaged foreign equipment was not repaired, taken out of service or was removed without replacement without considering the negative effects on the overall treatment process. As reasons both lack of skills of the staff to repair damaged equipment, spare part supply and after sale service of suppliers could be determined from discussions with treatment plant staff and experts (see also figure 126, chapter 7.2.1). The fact that the equipment was not even replaced by local equipment indicates a limited awareness and understanding about plant operation. The authors of a report on treatment plant operation in China see the major problems in limited spare part supply due to limited local availability of financial means, the use of Chinese products that don't meet international standard and limited experience with maintenance and repair works for modern imported technologies (Chen, Leinhos et al. 2004). In his considerations on transcultural technology transfer, Irrgang (2006) states a lack of adequate quality control of Chinese companies.

Based on the results of the technology analysis in chapter 7.2.1, as well as above considerations, the conclusion can be drawn that operational and maintenance problems exist in large dimension on Chinese wastewater treatment plants.

Manpower Status

The results of the staff questionings show a much higher general knowledge of the Chinese practical staff than in India. All questioned staff passed at least secondary/middle school (see figure 130, chapter 7.2.1). Like in India, no courses for wastewater treatment plant operation exist in the formal vocational education system (see chapter 5.2.2). The staff of seven inspected plants that were financed in Sino-German cooperation was trained for three months in a training centre in Qingdao that was created within the German development cooperation by KFW.

In the electrical, mechanical and biological/chemical field, more than 50% of the questions could be answered correctly by the staff in average (see figure 131, chapter 7.2.2). Also in the respective professional groups – electricians and mechanics – much higher theoretical basic knowledge could be stated than in India. The results of the questions about technologies and processes indicate that workers and technicians are aware about basic treatment processes and know which processes exist on their plant (see figures 132 and 133, chapter 7.2.2). Terms like BOD and nitrification are much more known than on Indian plants. Processes like SBR, SBBR, RID and trickling filter are known only by about 30-50% of the staff, which is also more than in India. The organisation structure is characterised by moderate hierarchies. The staff is basically separated in technicians, foremen, engineers and management. Other than in India, the proportion of unskilled staff is very low, whereas up to 90% of the staff are technicians (see figure 128, chapter 7.2.2). The number of staff on Chinese plants depending on the plant capacity is very similar to the situation in India in range of about 0.0005 employees/m³ and below for plants > 100.000m³/d (see figure 127, chapter 7.2.2). Among Chinese experts, especially the private sector considers the existing qualification of the practical staff level as low, and sees a high need for staff qualification (see figure 143, chapter 7.2.3). The qualification opportunities for practical staff are seen critically by most interviewed Chinese experts (see figure 142, chapter 7.2.3). That at administration level operational problems are recognised, too to certain extent, can be seen in the participation of SEPA Shandong in a training centre that was founded in 2007. Private operators also see a demand for manpower qualification – and develop staff on their own. One plant manager reported about a mix of experienced practical workers and inexperienced bachelor degree holders for practical works and reported about good results. Critical is obviously a low motivation of many degree holders in practical positions, as plant managers and German service technicians report. Work motivation and job satisfaction are a little higher than in India, which indicate the results regarding the future planning (see figures 81, chapter 7.1.2 and figure 135, chapter 7.2.2).

In this study, an average income of about 2.000RMB could be determined for technicians on STPs in a range between 900RMB and 3.500RMB (see figure 129, chapter 7.2.2). The average yearly income of employees in urban areas is about 21.000RMB in the year 2006 (Blume 2007).

Economic & Market Perspective

As shown in chapter 7.2.3, the market perspective in the wastewater field is seen very positive by the interviewed experts in this study (see figure 141, chapter 7.2.3). Enormous investments in this sector are expected in the next years. In 2005, more than 36 billion RMB were invested only in sewerage projects, more than 19 billion RMB were invested in wastewater treatment and a sum of about 15 billion RMB was invested in sanitation projects (NBSC 2006). Studies on the machinery sector forecast a very high potential for the export of machinery equipment also in the environmental sector. Today, already 7.2% of the overall German machinery equipment is exported to China (Auer 2007). Regarding the investments in sludge treatment, the results of the expert interviews show basically a high demand for solutions for excess sludge handling, but they show also that the topic hasn't reached yet enough awareness on the decision making level (see also figure 137, chapter 7.2.3). This conclusion can also be drawn from the results of a Sino-German seminar on excess sludge handling solutions held in June 2007 in Beijing. Possible solutions offered also from German suppliers are still in the test and demonstration phase. However, experts come to the conclusion that the co-incineration is a promising way, but a general strategy can't be identified. Mainly because of unsolved financial challenges and the fact that the wastewater fees are much too low, a change of the sludge situation can be expected only middle and long term (Abele 2007). In the current study, both incineration and anaerobic digestion are considered as suitable solutions by the interviewed experts, however the high investments for structures and equipment are seen critical.

Although German equipment has basically an excellent reputation, the analysis of the expert interviews in this study show, that Chinese equipment is preferred in many cases. Two main factors can be determined as reasons: First of all the high investment costs of western, especially German equipment compared to Chinese equipment are critical factors (see figure 141, chapter 7.2.3). And second, after sale service is seen critically by many plant managers. The following statement of a German test person with long term experience in China shows this very drastically:

"There is absolute incompetence in the subsidiaries of German companies here. Especially with German companies I had this experience…. Chinese employees who represent the German company…. technically incompetent, have problems to communicate with the German head office to discuss the problem and tell the customer: "This is not possible" or they don't answer" (Engineer - Expert Interview Germany No. 24).

In several interviews and discussions with plant managements and plant staff, after sale service is considered as a very important factor by the interview partners. In many cases, the almost typical situation is described that equipment from Germany or other European countries can't be repaired by the plants staff, and that required service technicians and spare sparts from abroad are too expensive.

A trend for privatisation in the wastewater sector could be detected in the expert interviews (see also figure 141, chapter 7.2.3). This corresponds to other literature sources. Enterprises like Veolia engage strongly in this growing market field in China – both in the municipal and the industrial sector. Currently, about 10% of the existing sewage treatment plants in China are built and operated on BT or BOT basis by

Chinese companies in most cases. Chinese industries outsource the treatment of their effluents very often to private contractors, which is an interesting market for international companies in this field. Very often, joint ventures are formed to enter the Chinese market (Haoting 2006). Product piracy is not considered as a major problem by Chinese experts – instead the importance of ongoing innovation rather than protection is emphasised (see figure 141, chapter 7.2.3). Figure 144 shows the dimension of the product piracy problem from the perspective of investors. Threats to intellectual property rank on top position, before concerns due to unpredictable political or legal environment.

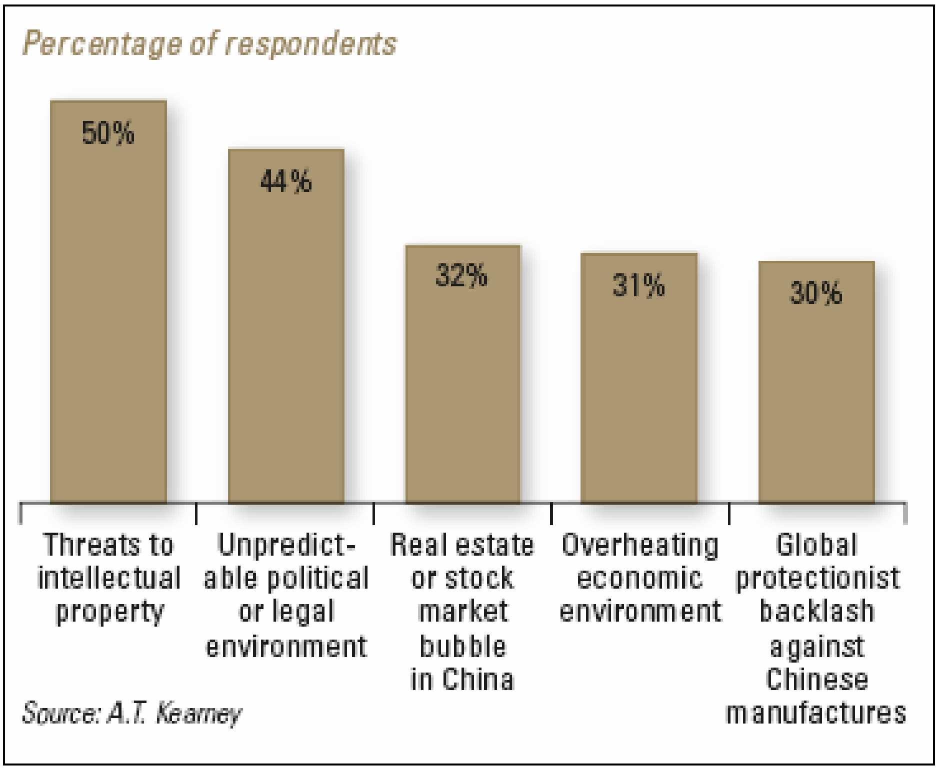


FIGURE 144: TOP RISKS TO FURTHER INVESTMENTS IN CHINA DURING THE NEXT FIVE YEARS (A.T.KEARNEY 2007)

Although the Chinese government has introduced adequate laws for the protection of intellectual property after the accession to WTO in 2003, they are not consequently implemented (Breitschuh and Wöller 2007).

7.3 Wastewater Technology Status & Trends in Germany

7.3.1 Efficiency, Technologies & Treatment Plant Operation

Regarding the age of the inspected treatment plants in Germany, a completely different picture can be seen compared to the inspected plants in India and China. Many of the visited plants in Germany exist since several decades and have been upgraded in several steps. The oldest plant exists since 1913. The average age of the inspected plants is about 35years. The oldest plants that were erected at the beginning of the last century started without a biological step. Biological steps and further treatment steps like nitrification and phosphorous removal were added 10-20years ago in most plants. In most plants the last modification or renovation was carried out about 10-15 years ago. Regarding the used treatment process, one plant is based on biodisk technology – all other plants are activated sludge plants.

Efficiency

For an outlook on the treatment efficiency regarding COD, Ammonia and Total Phosphorous, data of 10 plants treating municipal sewage are available that are shown in the following figures. As in Germany COD is used as major efficiency parameter for C-removal, in several plants no information regarding BOD could be given by the interviewed plant managers and plant engineers. For that reason the efficiency consideration based on COD removal is chosen.

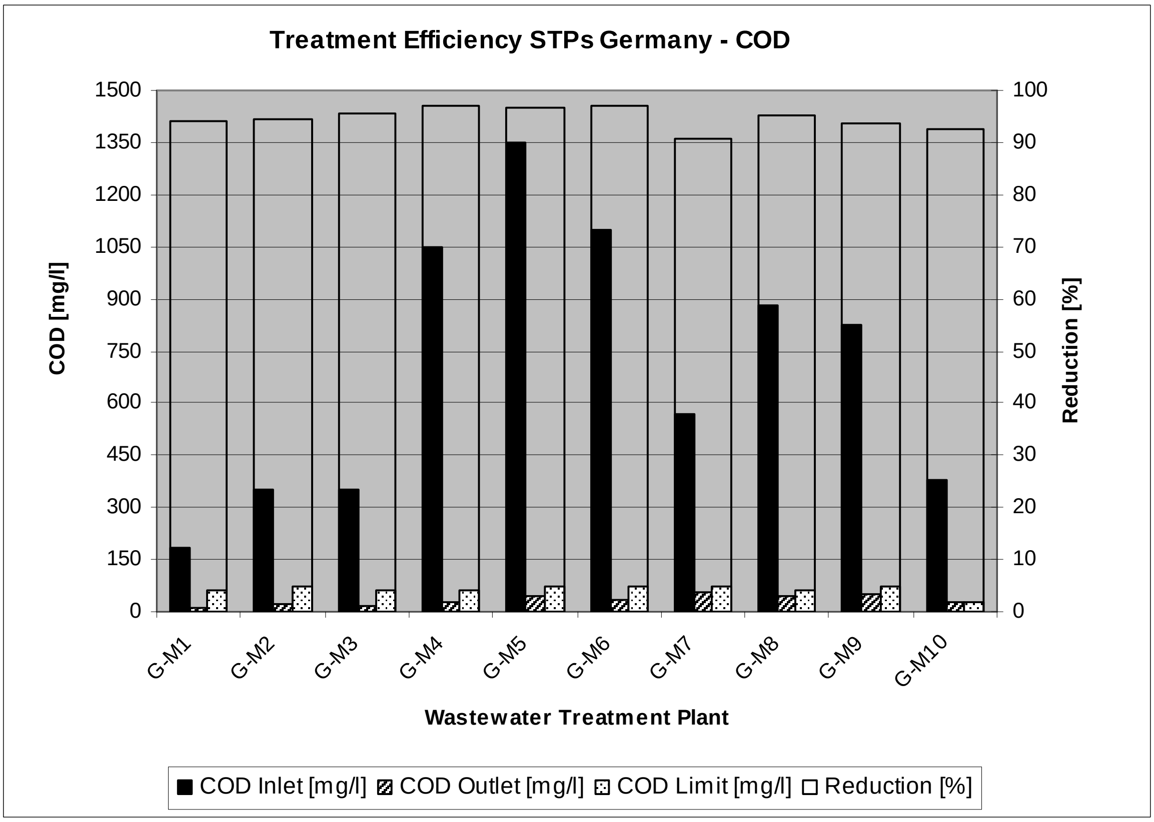


FIGURE 145: TREATMENT EFFICIENCY STPS GERMANY - COD

As visible in figure 145, all inspected municipal plants meet the required outlet values for COD. In average, a COD reduction rate of 95% could be determined for the inspected municipal plants. Other than in India or China, the discharge limits become stricter with increasing plant capacity (see table 10, chapter 5.1.3). Also all required discharge values for ammonia and total phosphorous are met by the municipal plants, except one plant that exceeds the required discharge value for total phosphorous. For ammonia removal, an average reduction rate of about 97% could be determined. For phosphorous removal, a reduction rate of more than 85% could be determined for most plants.

All inspected industrial wastewater treatment plants meet the required discharge values for COD. For plant number G-I3 (paper industry), the discharge limit is 4.000kgCOD/t paper, which means a limit of about 400mg/l COD. For all three industrial plants, the removal efficiencies are 95% and higher.

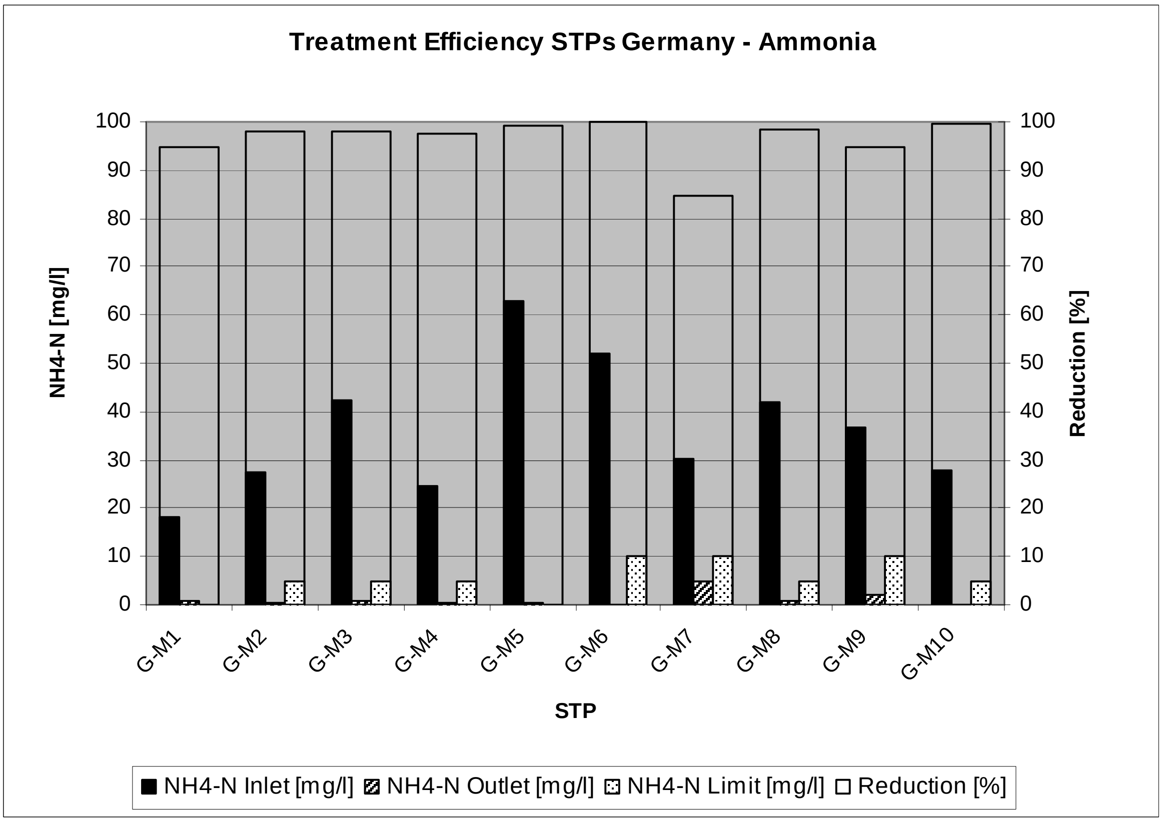


FIGURE 146: TREATMENT EFFICIENCY STPS GERMANY - AMMONIA

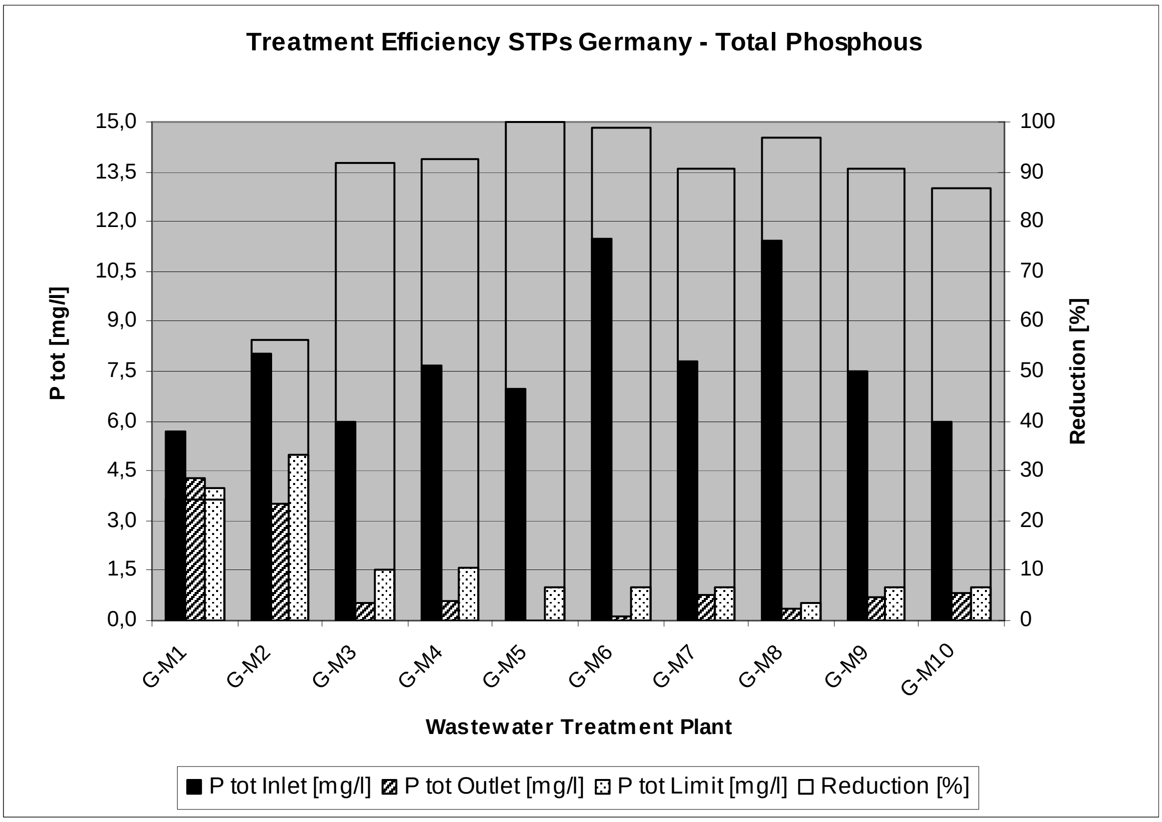


FIGURE 147: TREATMENT EFFICIENCY STPS GERMANY – TOTAL PHOSPHOROUS

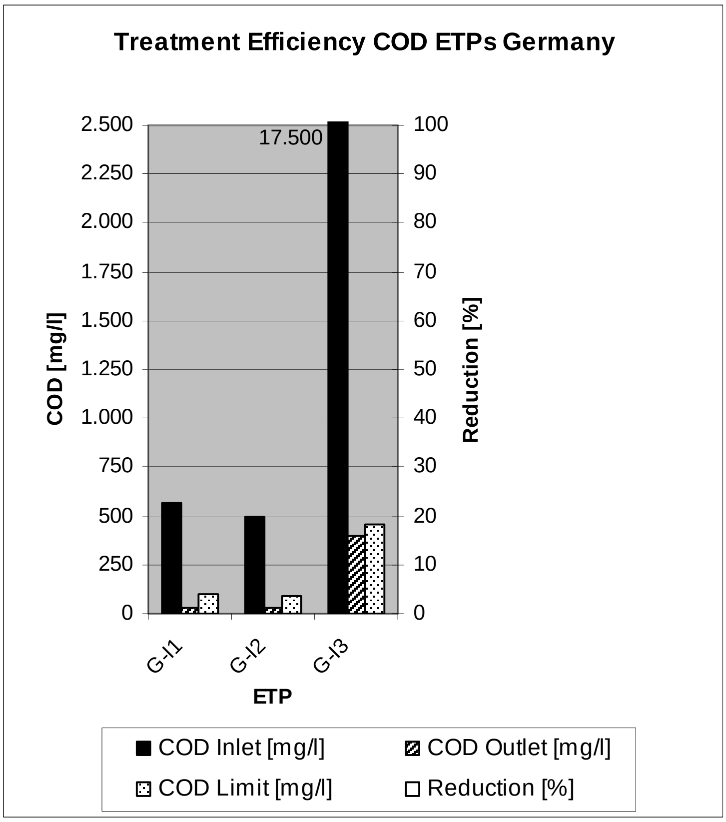


FIGURE 148: TREATMENT EFFICIENCY ETPS GERMANY - COD

Technologies

In the following paragraphs, the status of treatment plant technologies on the inspected treatment plants in Germany is described. Like for the description of the equipment in India and China, structural, machinery and control equipment is considered separately.

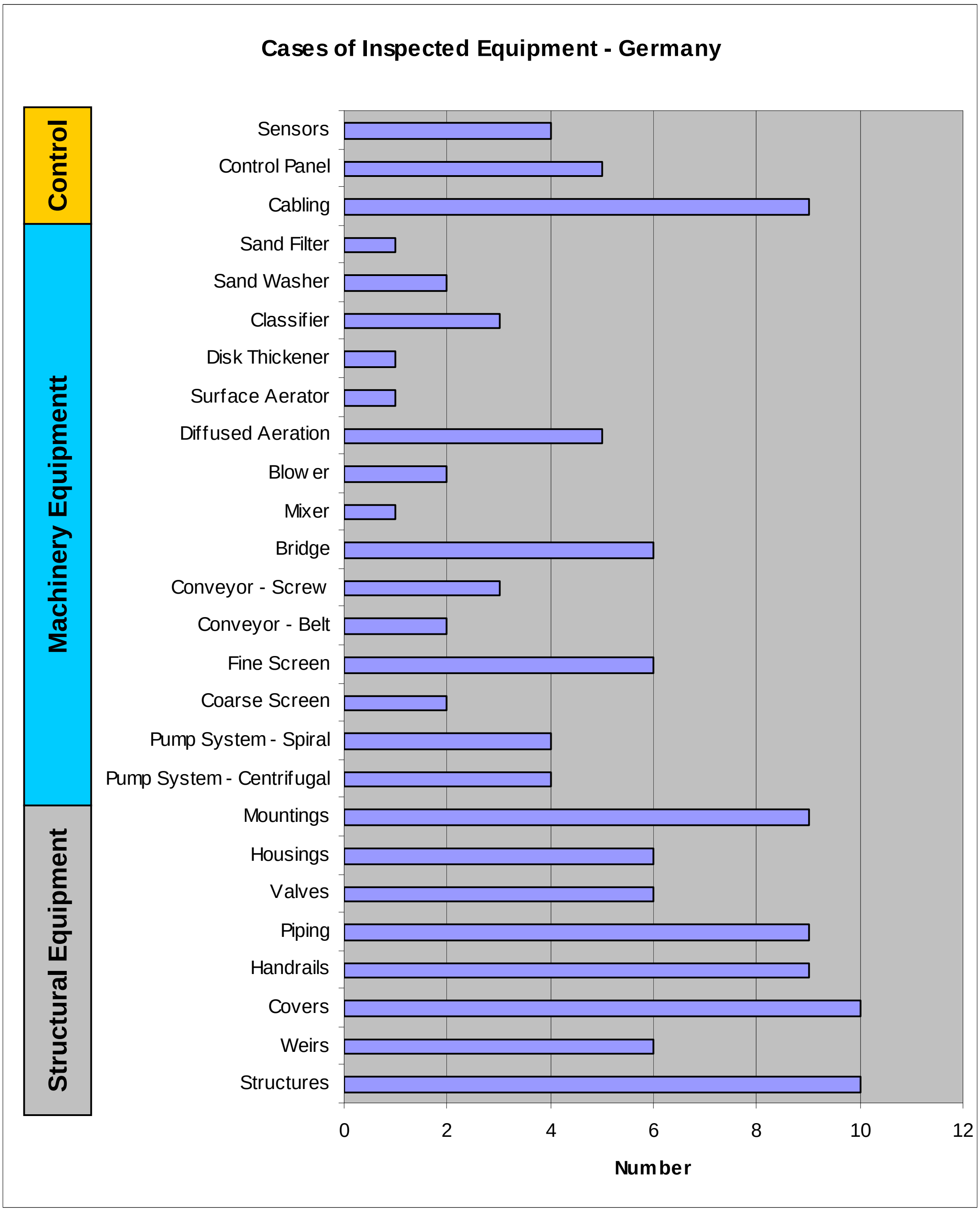


FIGURE 149: CASES OF INSPECTED EQUIPMENT IN GERMANY

Age of Equipment

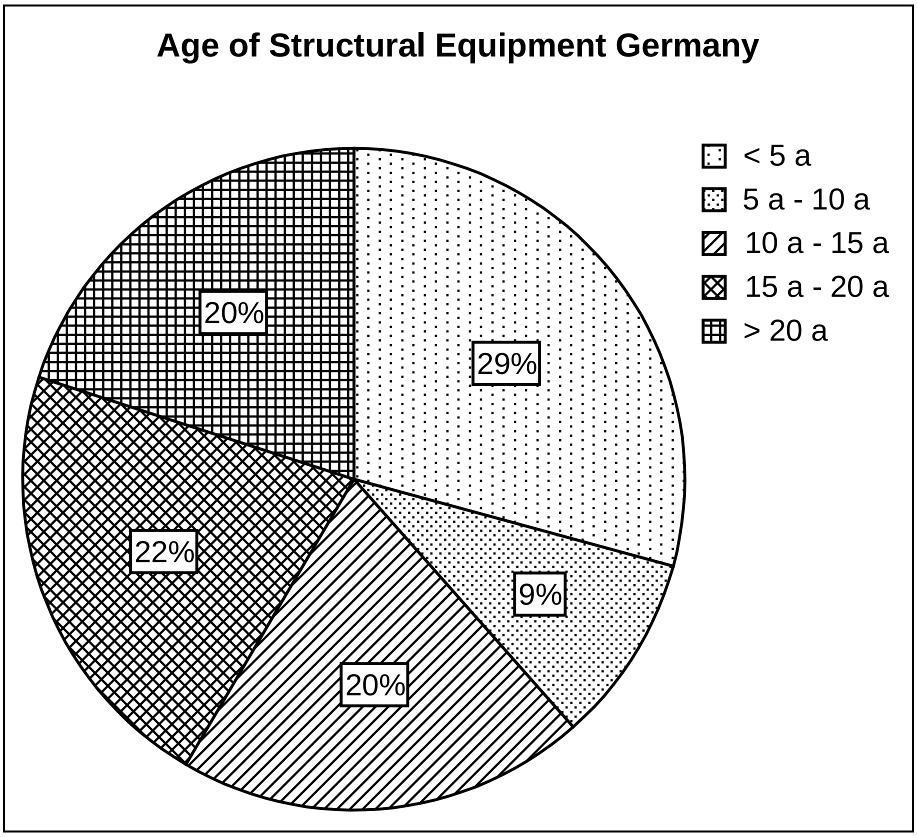


FIGURE 150: AGE OF STRUCTURAL EQUIPMENT IN GERMANY

Only about 29% of the inspected structural equipment is less than 5 years old. About 9% of the equipment is between 5 and 10 years old, 20% is 10 to 15 years old and 22% is between 15 and 20 years old. These numbers and the fact that 20% of the structural equipment is more than 20 years old show that German wastewater treatment has much longer tradition than in India and China. The average age of structural equipment is about 10years. The relatively high age of the equipment has to be considered for the detailed technology considerations.

Detailed Analysis

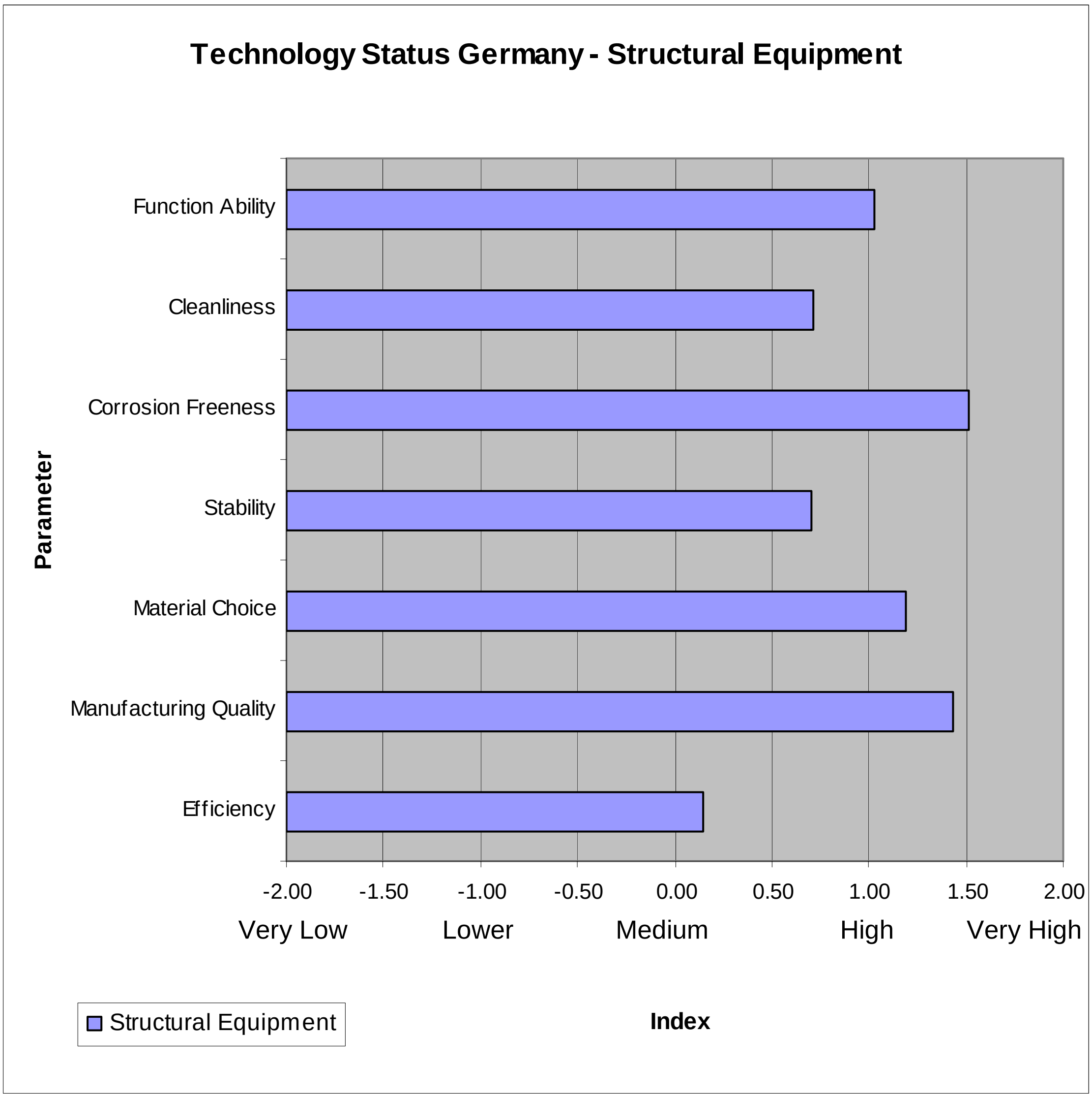


FIGURE 151: TECHNOLOGY STATUS GERMANY - STRUCTURAL EQUIPMENT

For the parameter "function ability" of structural equipment an index value of 1.03 could be determined, which is on a high level. Almost all structural equipment is mechanically intact. Durability is also on a high level for almost all equipment.

Cleanliness is on the lower range of the category high with an index value of 0.72. Surface cleanliness is on a high level in most plants (see figures 152-155). In some older plants, minor deficits could be stated regarding detail/technical cleanliness.

FIGURE 152: CONCRETE STRUCTURES ON STPS IN GERMANY

For corrosion freeness an index value of 1.52 was determined, which is on a very high level. At equipment of normal steel or of stainless steel, corrosion was hardly detected. Fissures or flaking wasn't detected – neither at concrete structures, nor at metal surfaces (see figures 152 and 153).

Stability is also in the range of the category high with an index value of 0.70. Static design is on a high level for almost all structural equipment. In most cases, material thickness is in the medium range. Overdimensioned equipment or extreme material thicknesses were not observed.

Material quality is on a high level. Stainless steel dominates as standard material either for complete machines or for equipment components that are in direct contact with wastewater or sludge. For handrails also aluminium is used in some plants instead of stainless steel. Weir edges are almost always in stainless steel, mountings are either of stainless steel or plastic in most plants (see figures 152-155). For outdoor housings, also stainless steel is used as standard material. In total an index value of 1.19 was determined.

For the parameter "manufacturing quality" an index value of 1.43 was determined. Both dimension accuracy and surface quality are on a high level for almost all inspected structural equipment.

FIGURE 153: WEIR EDGES AND HANDRAILS ON STPS IN GERMANY

FIGURE 154: CLEANLINESS OF PLANT EQUIPMENT IN GERMANY

FIGURE 155: PIPING AND MOUNTINGS ON STPS IN GERMANY

For the overall efficiency, comprising specific construction demand, specific space demand, specific material costs, energy efficiency and level of technology, an index value of 0.15 was determined. A Positive factor is the relatively high technology level with high treatment efficiencies, negative factors are moderate energy efficiencies and high material costs.

In the following paragraphs, space demand of structures, as well as level of technology and energy efficiency of the overall process are considered more in detail.

Level of Technology

All inspected treatment plants that are taken into account for the visual analysis are designed for nitrification/denitrification process, so that regarding the overall process the technology level was determined as very high.

Specific Space Demand

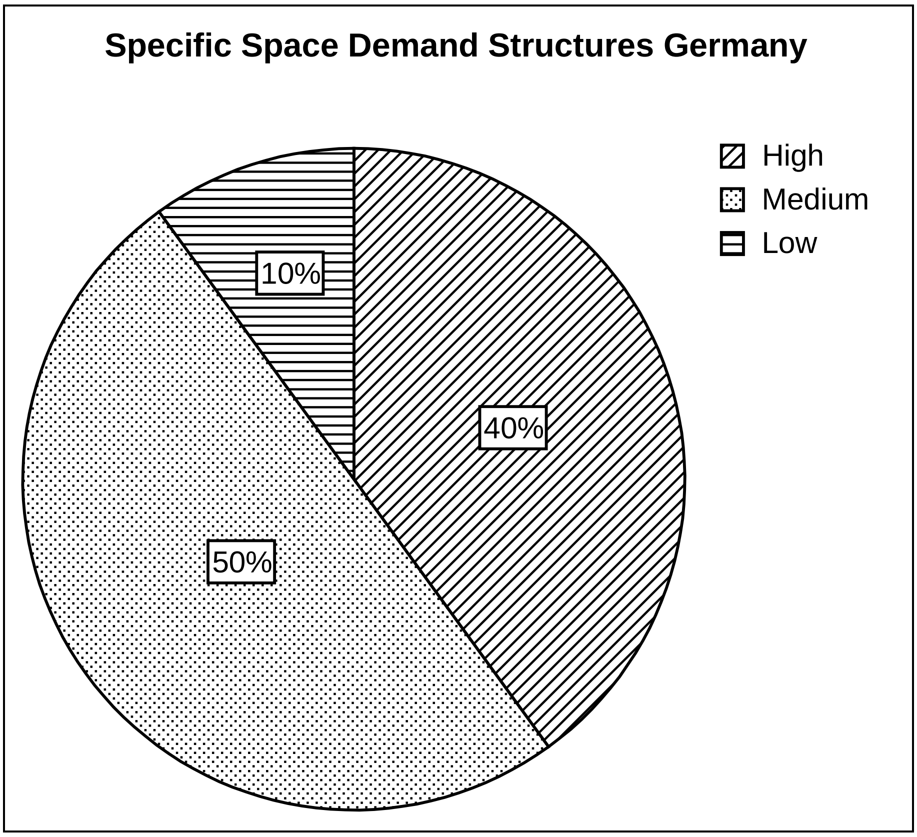


FIGURE 156: SPECIFIC SPACE DEMAND OF STRUCTURES IN GERMANY

The specific space demand of the inspected plants varies. About 40% of the plants are characterised by a high space demand – activated sludge plants with primary clarifier. About 50% of the inspected treatment plants have a medium space demand. These are activated sludge plants without primary clarifier (stabilisation plants) or very compact conventional activated sludge plants. Only one plant has a low space demand. An index value of about -0.3 could be determined for the parameter space demand, which is in the lower medium range.

Energy Efficiency

The energy efficiency of 70% of the inspected plants is in the medium range (see figure 157). About 20% of the plants are characterised by very low energy efficiency – plants without energetic sludge use. About 10% of the plants have high energy efficiency – a Rotating Immersion Disk plant (RID). An average value of about -0.3 could be determined, which is in the lower medium range.

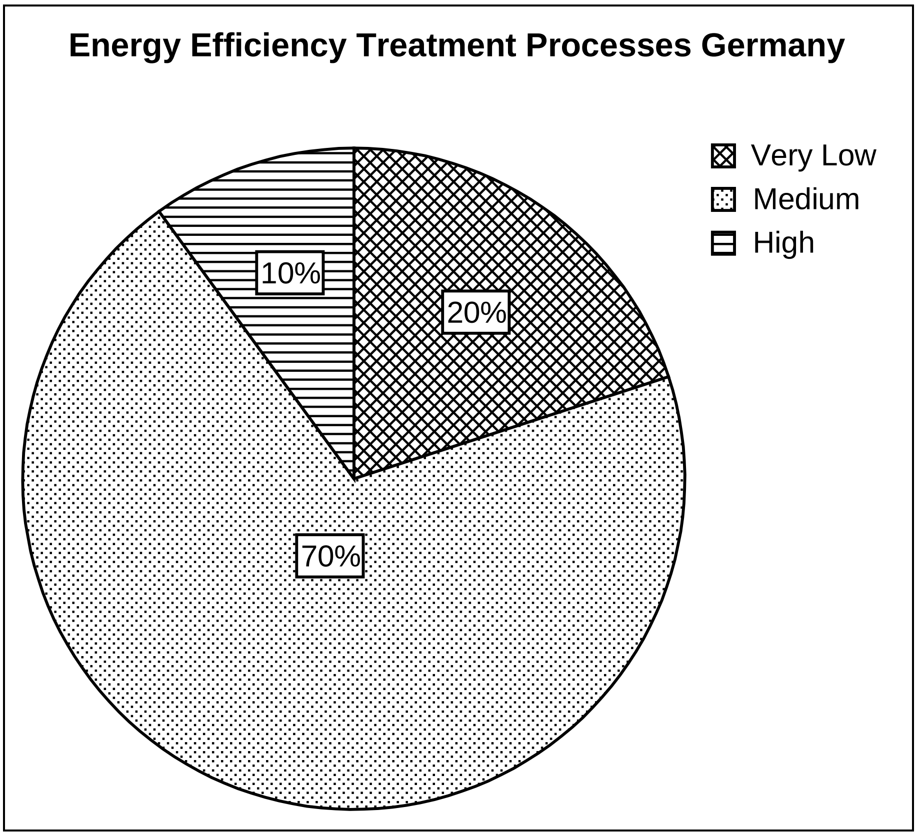


FIGURE 157: ENERGY EFFICIENCY OF TREATMENT PROCESSES IN GERMANY

Machinery Equipment

Origin & Age of Machinery Equipment

As visible in figure 157, almost all inspected machinery equipment is German brand. Equipment from the US or Asian countries was not found in any of the inspected plants. About 48% of the inspected machinery equipment on the visited plants in Germany is less than 5 years old (see figure 159). About 12% is between 5 and 10 years old, 7% is between 10 and 15 years old and about 21% is between 15 and 20 years old. The average age of the machinery equipment is about 8years. About 12% of the inspected machinery equipment is more than 20 years old.

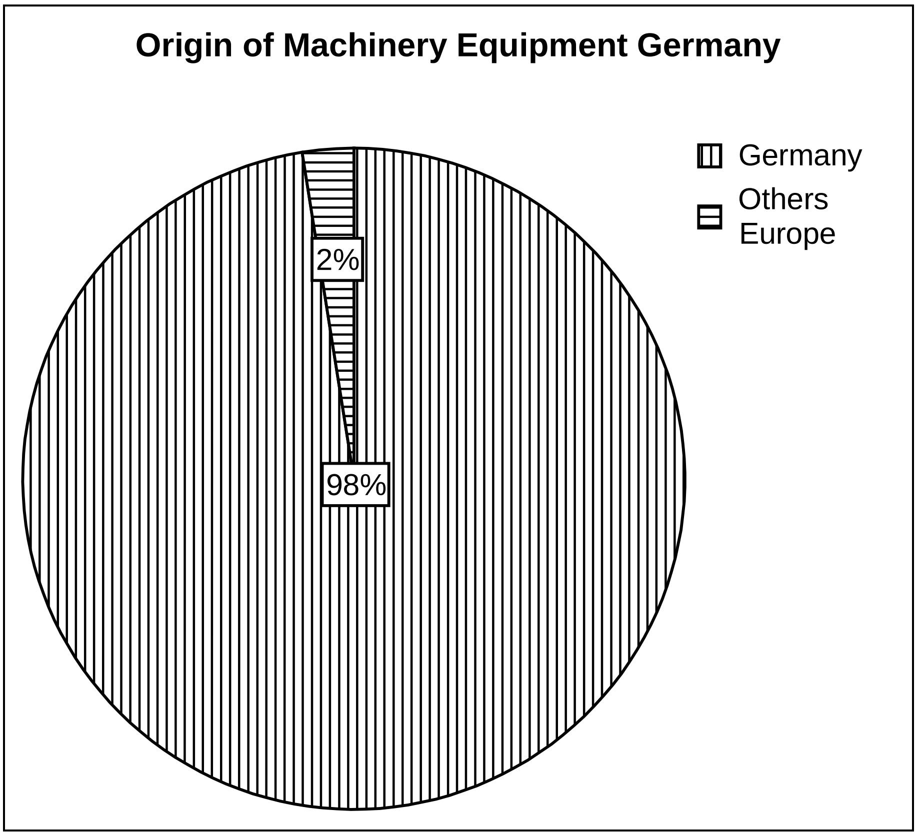


FIGURE 158: ORIGIN OF MACHINERY EQUIPMENT IN GERMANY

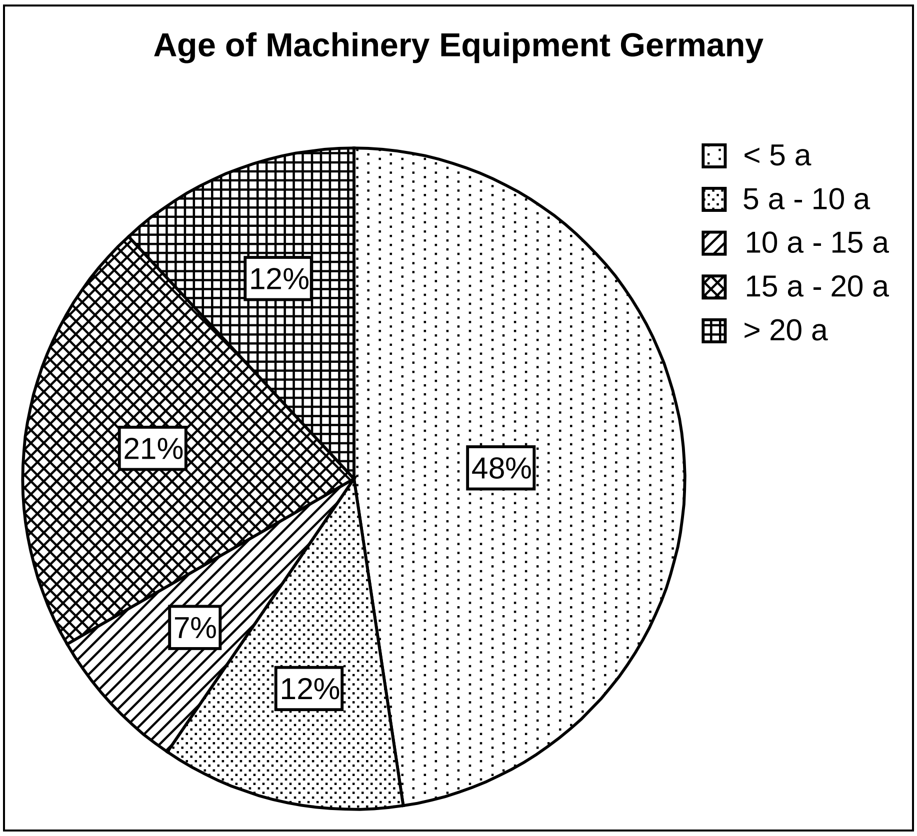


FIGURE 159: AGE OF MACHINERY EQUIPMENT IN GERMANY

Detailed Analysis

Figure 160 shows the index values of the technology parameters for machinery equipment. For the function ability of the inspected machinery equipment, an index value of 1.18 was determined, which is on a high/very high level. Almost all equipment is mechanically intact, unnormal noise or vibrations of moving elements or aggregates were not detected. A very high durability could be stated for most machinery components, mainly because of the use of durable materials like stainless steel especially in outdoor applications.

Cleanliness is is also on a relatively high level with an index value of 1.00 (see figures 161-164). Surface cleanliness is high even in most inspected older plants. Deficits regarding detail/technical cleanliness were observed only in very few cases.

For corrosion freeness, an index value of 1.64 could be determined, which is on a very high level. Even machinery components that are not of stainless steel are obviously well maintained – neither surface corrosion nor fissures or flaking were observed in larger scale at any inspected machinery equipment (see figure 161).

Stability of machinery equipment is on a level between medium and high. Static design is on a high level for most equipment, material thickness is moderate. In total an index value of about 0.52 could be determined for this parameter.

For material quality, an index value of about 1.32 was determined, which is on the upper end of the category "high". Stainless steel is used as standard material for most machinery equipment, especially components that are in direct contact with wastewater or sludge. Plastic material is of high quality – severe weathering wasn't detected in any of the inspected plants (see figures 161-164). Coatings of normal steel components are of high quality, flaking even at older equipment was hardly detected. Manufacturing quality is very high with an index value of 1.65. Dimension accuracy is extremely high, tolerances are very low (see figures 163 and 164). Also surface quality of most machinery equipment is very high.

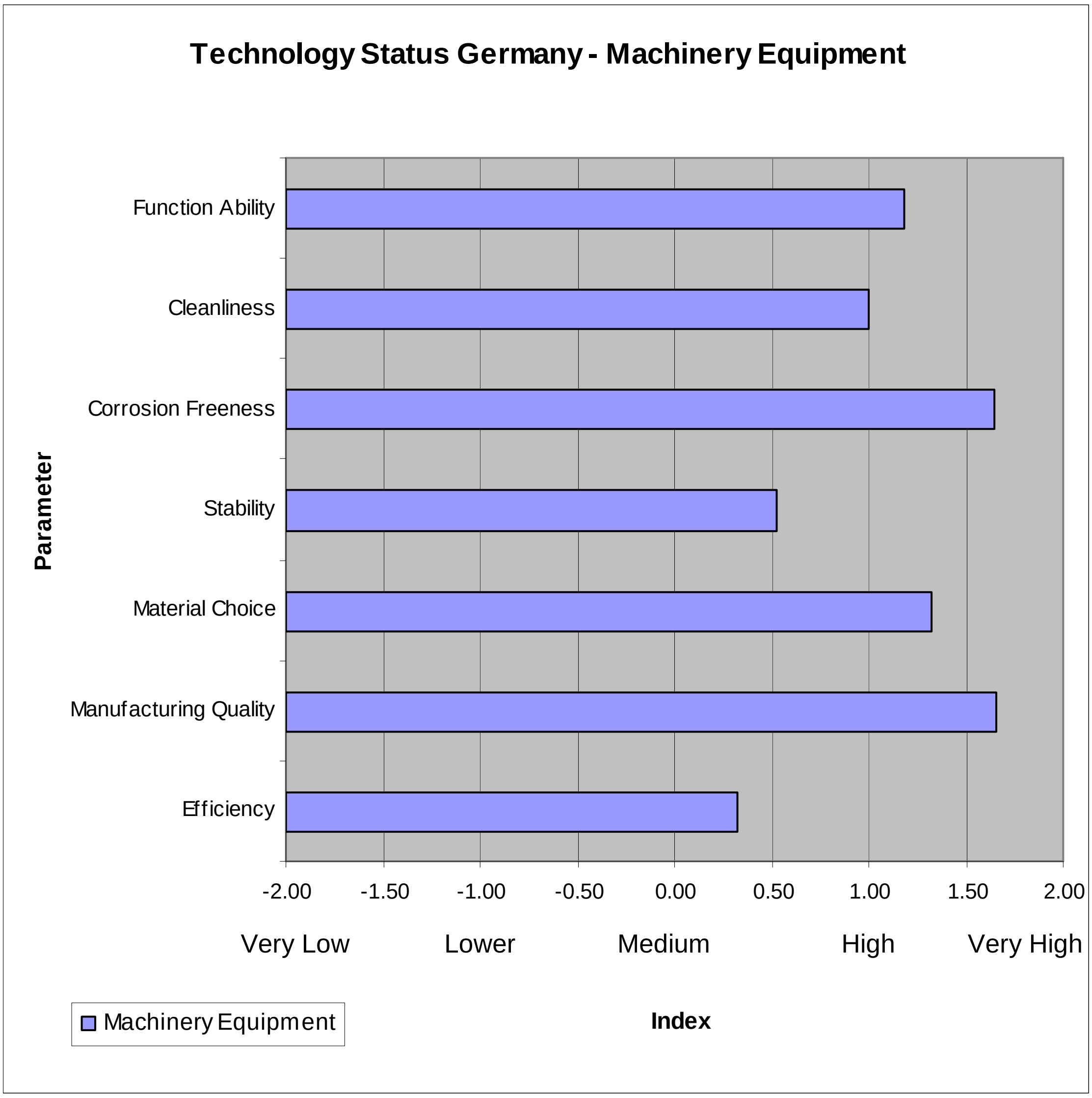


FIGURE 160: TECHNOLOGY STATUS GERMANY – MACHINERY EQUIPMENT

FIGURE 161: SCREENING SYSTEMS AND BELT CONVEYORS IN GERMANY

FIGURE 162: WELL MAINTAINED PLANT EQUIPMENT IN GERMANY

FIGURE 163: CORROSION RESISTANT MATERIAL OF MACHINERY EQUIPMENT IN GERMANY

FIGURE 164: MANUFACTURING QUALITY OF MACHINERY EQUIPMENT IN GERMANY

For the parameter “efficiency” of machinery equipment, an index value of about 0,32 could be determined, which is in the upper medium range.

In the following, the criteria technology level, specific material costs and energy efficiency will be considered more in detail.

Level of Technology, Specific Material Costs & Energy Efficiency

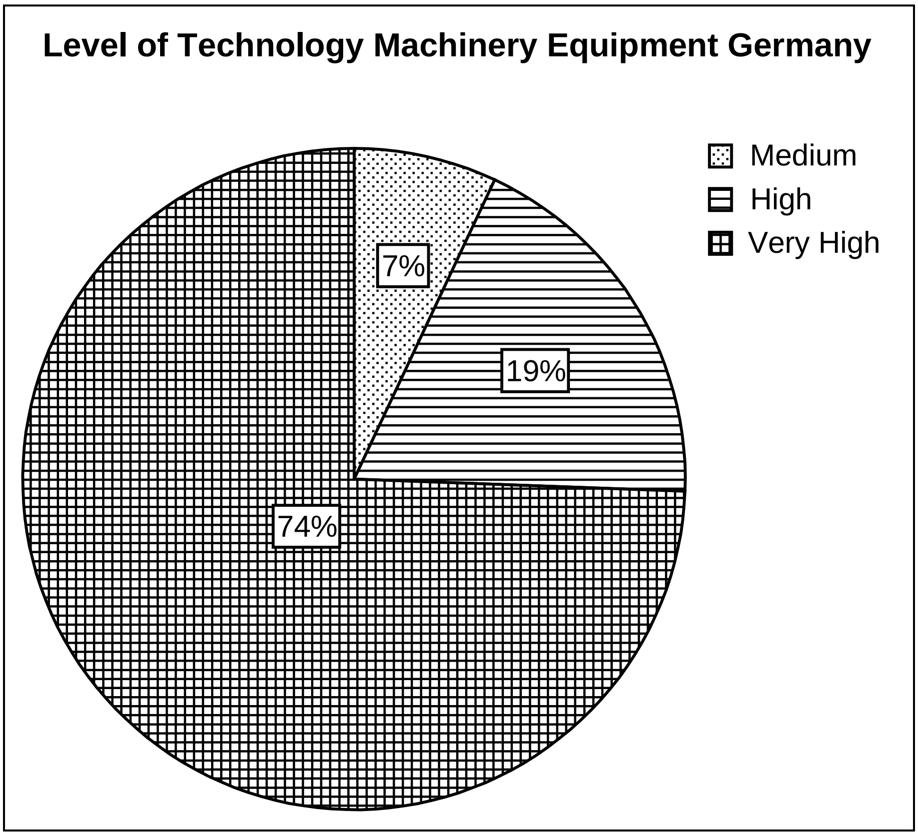


FIGURE 165: LEVEL OF TECHNOLOGY OF MACHINERY EQUIPMENT IN GERMANY

The technology level of the inspected machinery equipment is very high – for about 74% of the equipment, a very high technology level could be stated. Fine screens have small and very defined spacings and that way a very high separation efficiency, freestanding stainless steel classifiers are designed for high separation efficiency, high throughput and minimal space demand. For aeration systems, modern rotary piston valve compressors are used (see figure 162). An index value of 1.67 could be determined for the technology level.

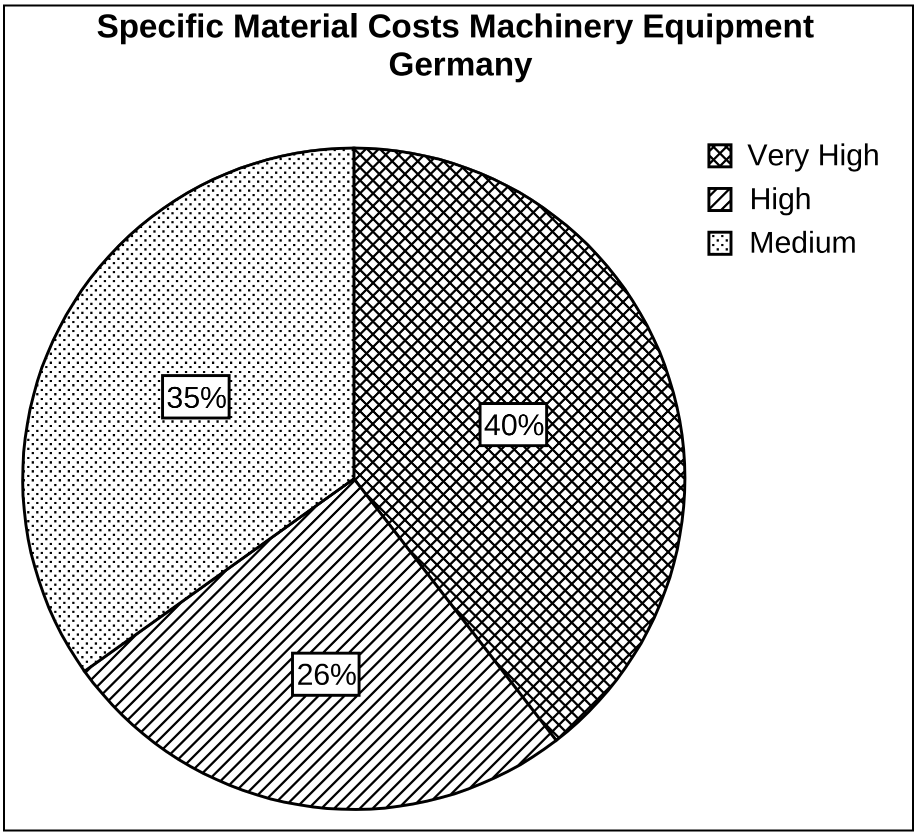


FIGURE 166: SPECIFIC MATERIAL COSTS OF MACHINERY EQUIPMENT IN GERMANY

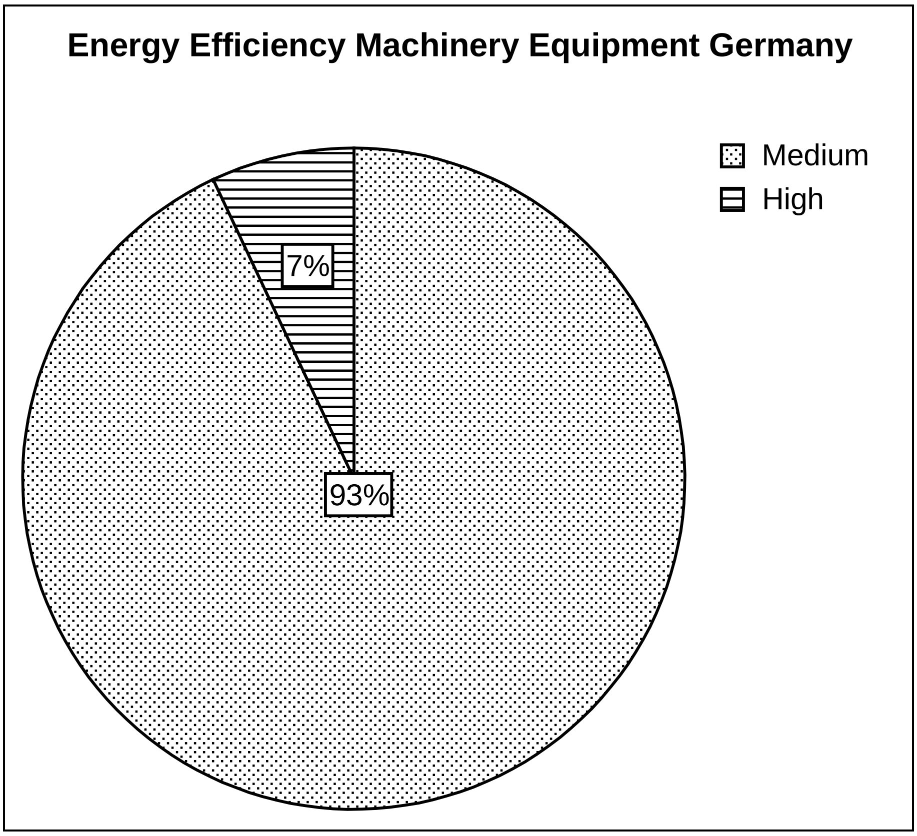


FIGURE 167: ENERGY EFFICIENCY OF MACHINERY EQUIPMENT IN GERMANY

The specific material costs of most inspected machinery equipment are high or very high (see figure 166). Only about 35% of the equipment is in the medium range regarding the material costs. An average value of -1.05 could be determined, which means high material costs. This picture can be explained both by the wide use of stainless steel and the fact that manufacturing costs of German equipment are relatively high. Energy efficiency of most inspected machinery equipment is in the medium range (see figure 167). Only about 7% of the equipment is characterised by high energy efficiency. An average value of 0.07 could be determined, which means medium energy efficiency.

Control Equipment

Origin and Age of Control Equipment

All inspected control equipment on the inspected treatment plants in Germany is of German brand. As visible in figure 168, about 47% of the control equipment is less than 5 years old. About 48% of the equipment is between 5 and 20 years old. Only about 6% is more than 20 years old. The average age of the control equipment is about 8years.

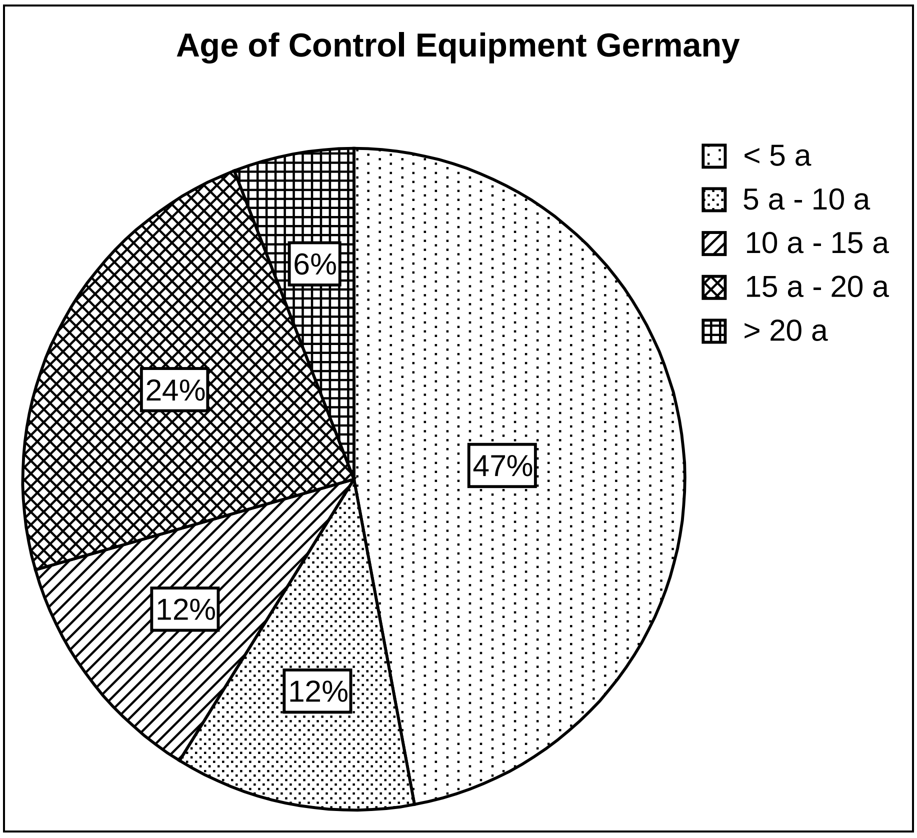


FIGURE 168: AGE OF CONTROL EQUIPMENT IN GERMANY

Detailed Analysis

Figure 169 shows the index values of the technology parameters that were determined for control equipment.

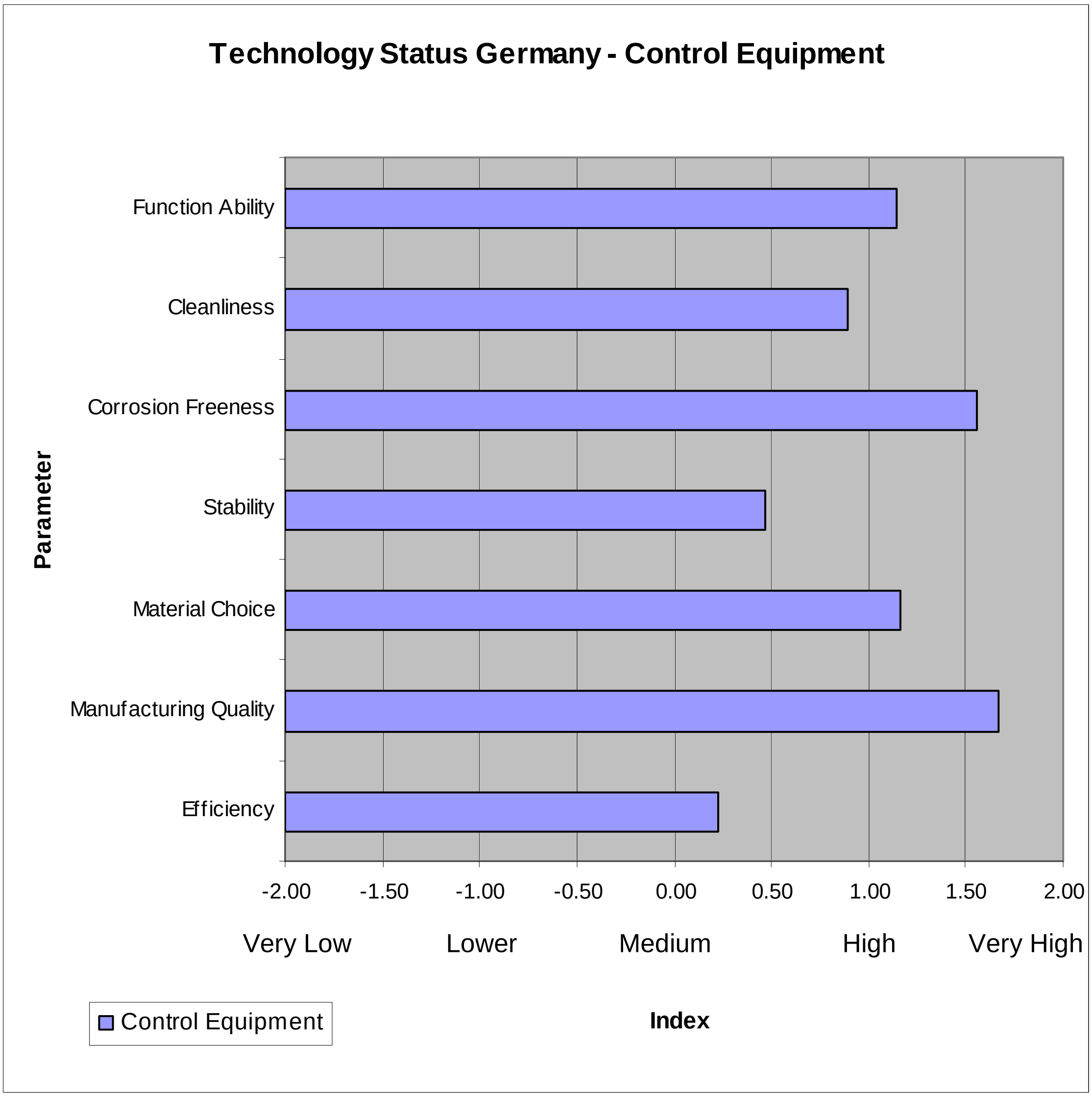


FIGURE 169: TECHNOLOGY STATUS GERMANY – CONTROL EQUIPMENT

As already mentioned in chapter 7.1.1 and chapter 7.2.1, the visual description of the control equipment can only give hints regarding the potential function ability. Other methods are required to describe the function ability more in detail. For the parameter “function ability”, an index value of about 1.14 was determined for the inspected control equipment in Germany. Both physical intactness and durability are on a high level.

Cleanliness is also on a high level with an index value of about 0.89 (see figure 169). In several cases, detail cleanliness of cabling is in the medium range. Detail cleanliness of sensors and control panels is spread both on the medium and the high level. For corrosion freeness an index value of about 1.56 could be determined. In almost all cases, cabling, control panels and sensors don't show any corrosion, which is an indicator both for good material choice and good maintenance (see figures 170 and 171). Stability is on the upper medium level with an index value of about 0.47. Static design is on a high level for most control equipment, material thickness is mainly in the medium range.

For material quality, an index value of about 1.17 could be determined. Outdoor control panels are mainly out of stainless steel, sensors are of highly corrosion resistant special steel or plastic. Cabling was categorised as standard material quality in most cases (see figures 170 and 171). Manufacturing quality is on a very high level with an index value of about 1.67. Highest dimension accuracy of control panels, cabling and sensors, as well as highest surface quality are characteristic for almost all inspected plants. For the parameter "efficiency", an index value of about 0.23 could be determined for the inspected control equipment (see figure 169).

FIGURE 170: OUTDOOR CONTROL PANELS AND CABLING IN GERMANY

FIGURE 171: ONLINE MEASURE EQUIPMENT IN GERMANY

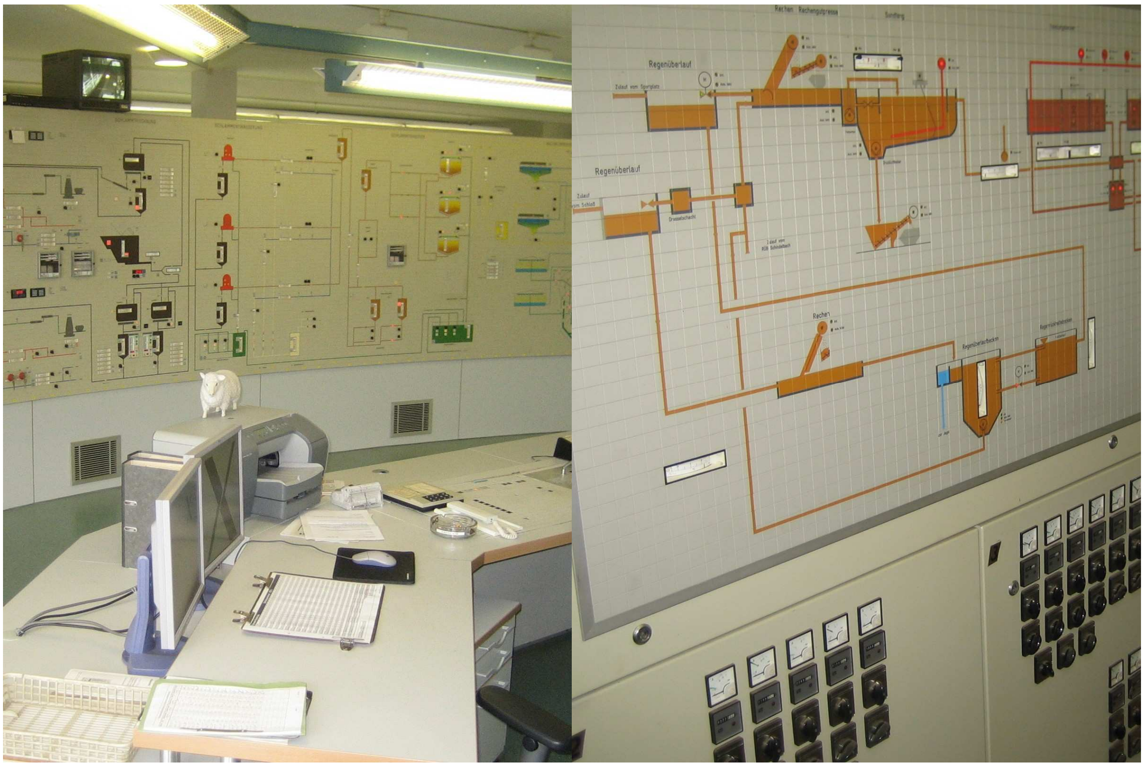


FIGURE 172: CENTRAL CONTROL ROOMS IN GERMANY

In the following, the criteria “technology level” and “specific material costs” will be considered more in detail.

Level of Technology

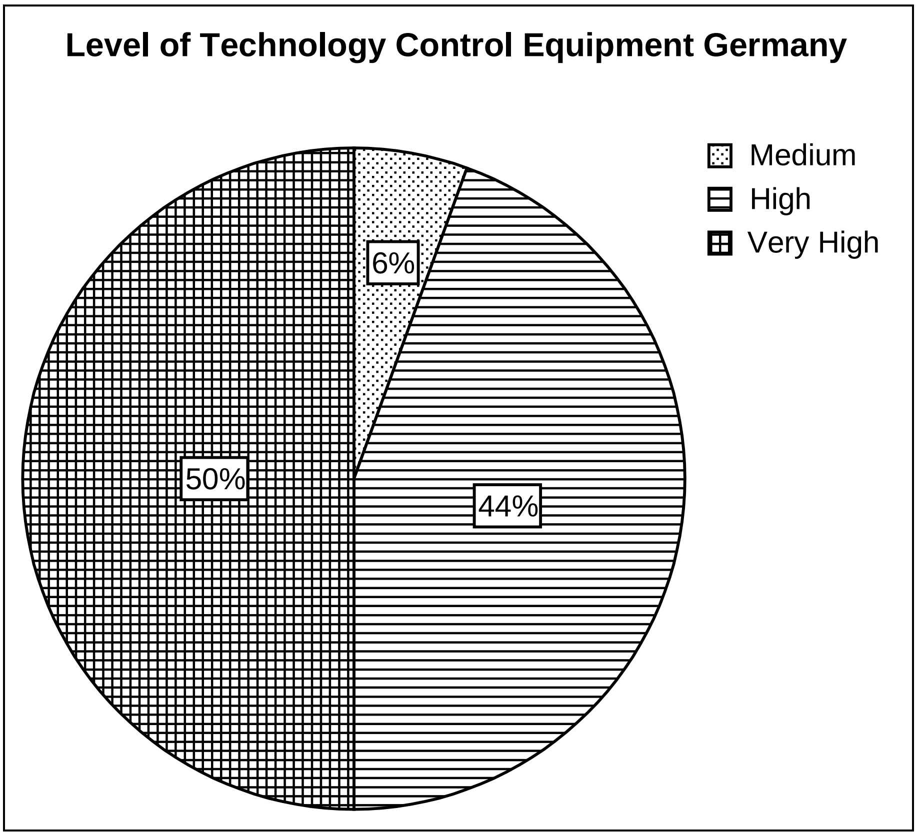


FIGURE 173: LEVEL OF TECHNOLOGY OF CONTROL EQUIPMENT IN GERMANY

For the technology level of control equipment, an index value of 1.47 could be determined. About 94% of the inspected control equipment is characterised by a high or very high technology level. In general, a very high grade of automation even for small plants can be stated. Online measuring and control equipment is standard in most plants (see figure 171 and 172).

Specific Material Costs

The specific material costs of the control equipment are high – about 33% are in the category “high”, for about 56%, very high costs have to be stated (see figure 174). Main reasons are the use of stainless steel especially for outdoor control panels and the high automation degree, which means high investment costs. An index value of about -0.6 could be determined.

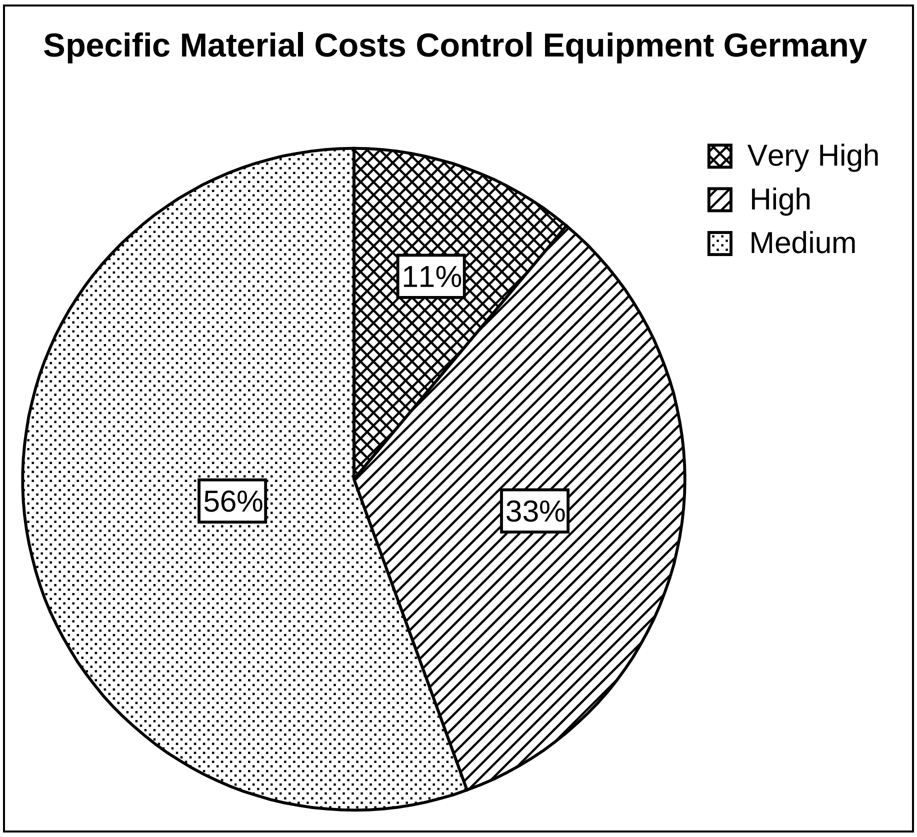


FIGURE 174: SPECIFIC MATERIAL COSTS OF CONTROL EQUIPMENT IN GERMANY

Treatment Plant Construction & Operation

Construction

As already mentioned, most plants were modified or extended since their existence, so that different construction companies were involved. Most construction companies are German enterprises. In some cases European companies with subsidiaries in Germany were involved in plant construction or modifications.

Operation

Almost all municipal plants are operated by the respective municipality or by so called “wastewater administration associations” that are financed by the participating municipalities. The industrial plants are operated by the respective industries. In one case, the industry is treating also the wastewater of the adjacent municipality.

Maintenance

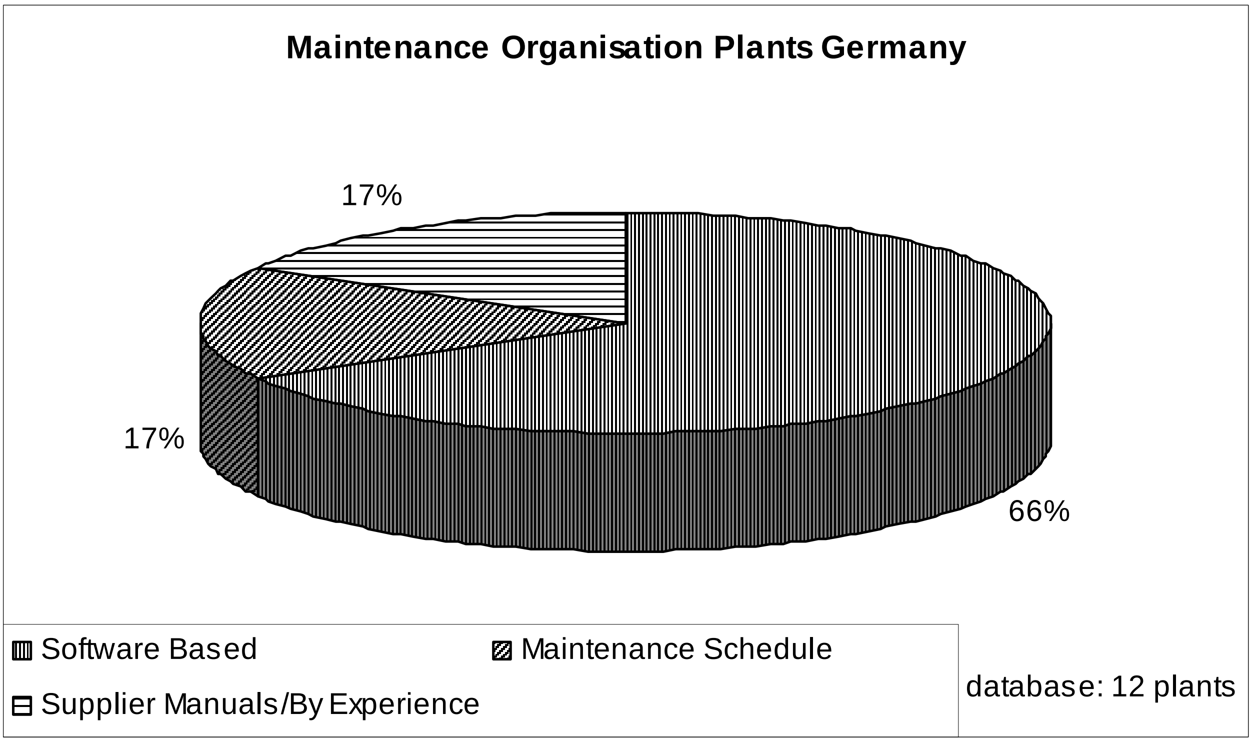


FIGURE 175: MAINTENANCE ORGANISATION ON STPS AND ETPS IN GERMANY

As visible in figure 175, most of the inspected plants in Germany use schedules for maintenance organisation. Especially plants of higher capacity use software solutions for maintenance planning. Smaller plants use paper schedules for maintenance planning.

7.3.2 Staff

In the following, the staff constituency on wastewater treatment plants in Germany is taken into more detailed considerations.

Figure 176 shows the specific staff use and the design capacity of the inspected municipal wastewater treatment plants. With increasing design capacity, the specific staff use decreases and reaches a value of about 0.0005 for plants ≥ 100.000m³/d design capacity. This is about the same value like for comparable plant sizes in India and China with values of about 0.0004, resp. 0.005. For the smallest plants – a biodisk system with about 38m³/d design capacity, only one non professional worker is in part time in charge for the treatment system. Regarding the relative distribution of the different staff groups, a very low proportion of workers can be stated. In smaller plants with less than 30.000m³/d design capacity, less than 10% of the staff are workers – the major group are technicians/operators with proportions up to 90%. In bigger plants, the proportion of workers is higher and reaches a value of up to 23% in the biggest inspected plant, although large variations between the different plants can be stated, also regarding the proportion of technicians/operators. The proportion of technicians/operators is in a range of 60% to 96% (see also figure 177). The proportion of engineer positions is between 4% and 10%.

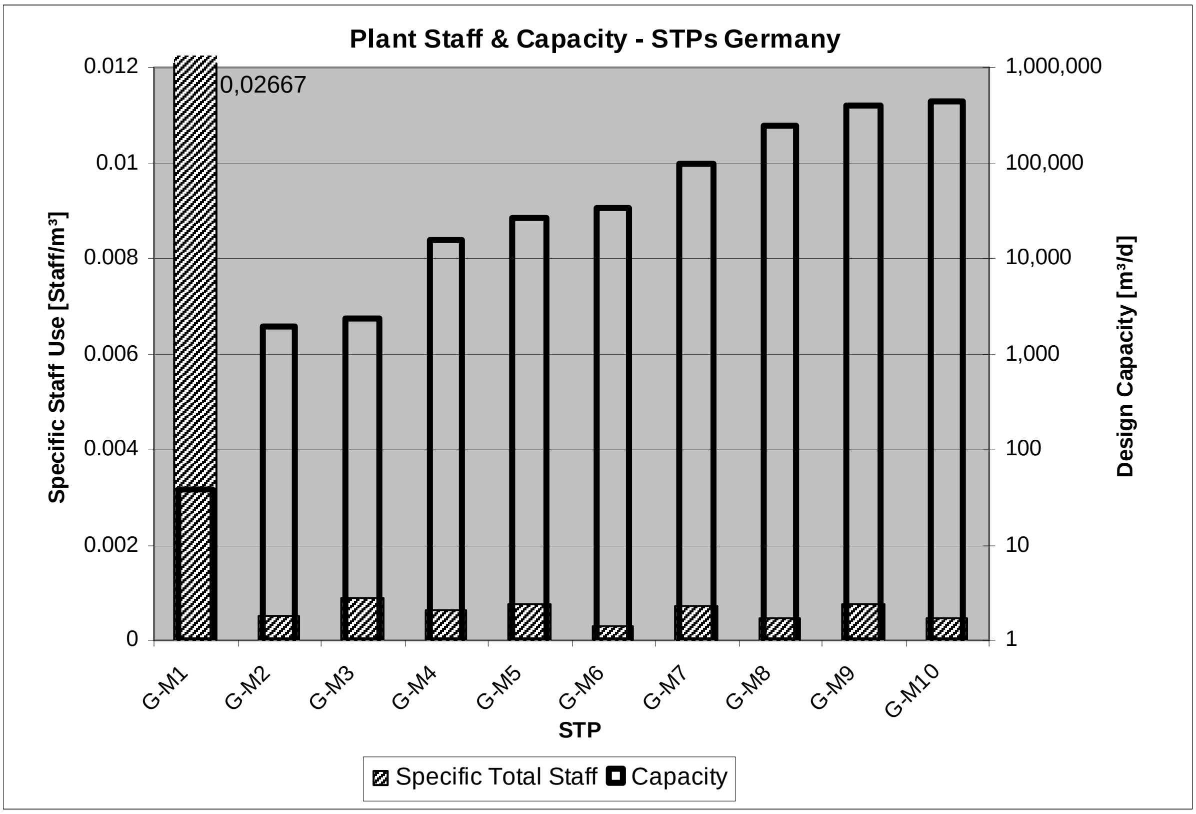


FIGURE 176: SPECIFIC STAFF USE ON STPS IN GERMANY

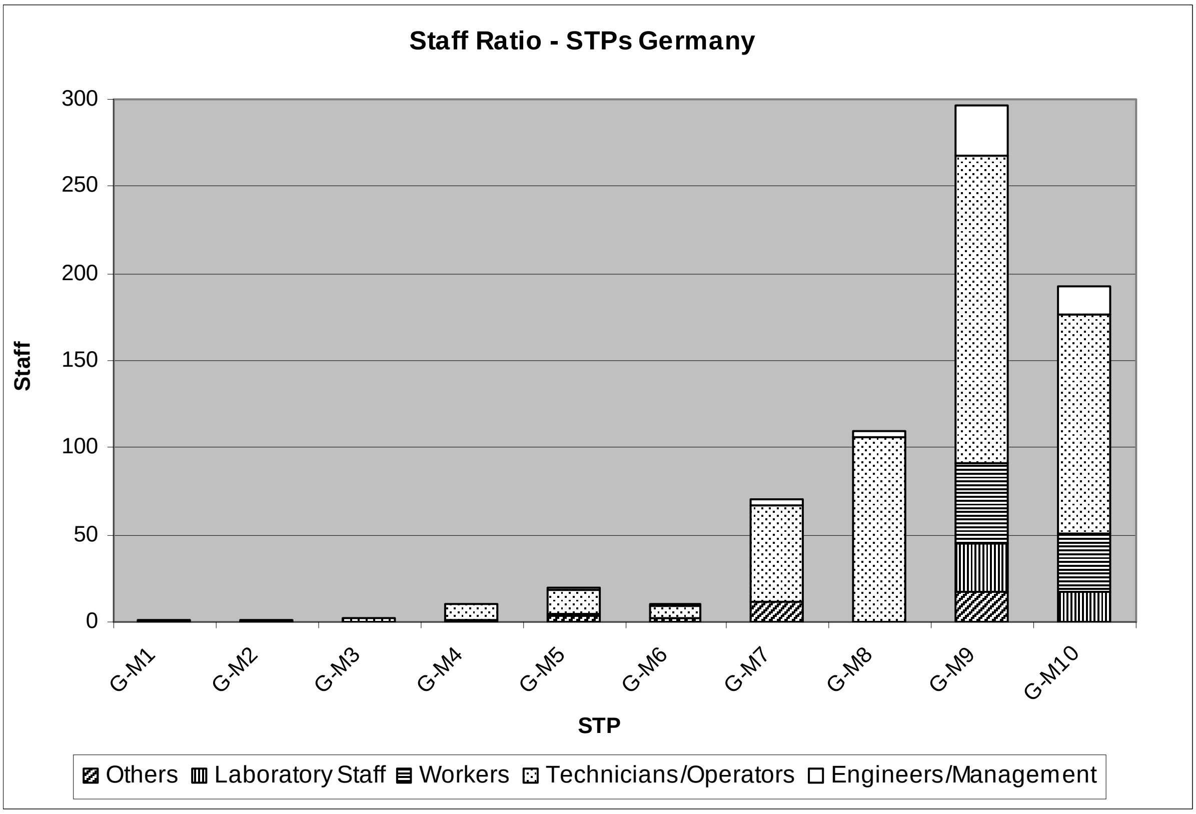


FIGURE 177: RATIO OF DIFFERENT STAFF GROUPS ON STPS IN GERMANY

Figure 178 shows Plant staff and capacity, as well as the staff ratios on the industrial plants. All plants are based on activated sludge technology in combination with other technologies. Regarding the staff use, large variations can be stated between the different industries, with values between 0.00036 and 0.00653 for the specific staff use. This is about the similar range like on the inspected municipal plants in Germany, but remarkably less that on the inspected ETPs in India. As visible in figure 178, the proportion of workers varies very much. In two of the inspected plants, no workers are working in the wastewater treatment plant and between 86% and 98% of the staff of the wastewater treatment plant are technicians/operators. In plant G-I3, 75% of the staff are workers and only 13% are technicians/operators. The proportion of engineer positions is between 2% and 14% of the plant staff.

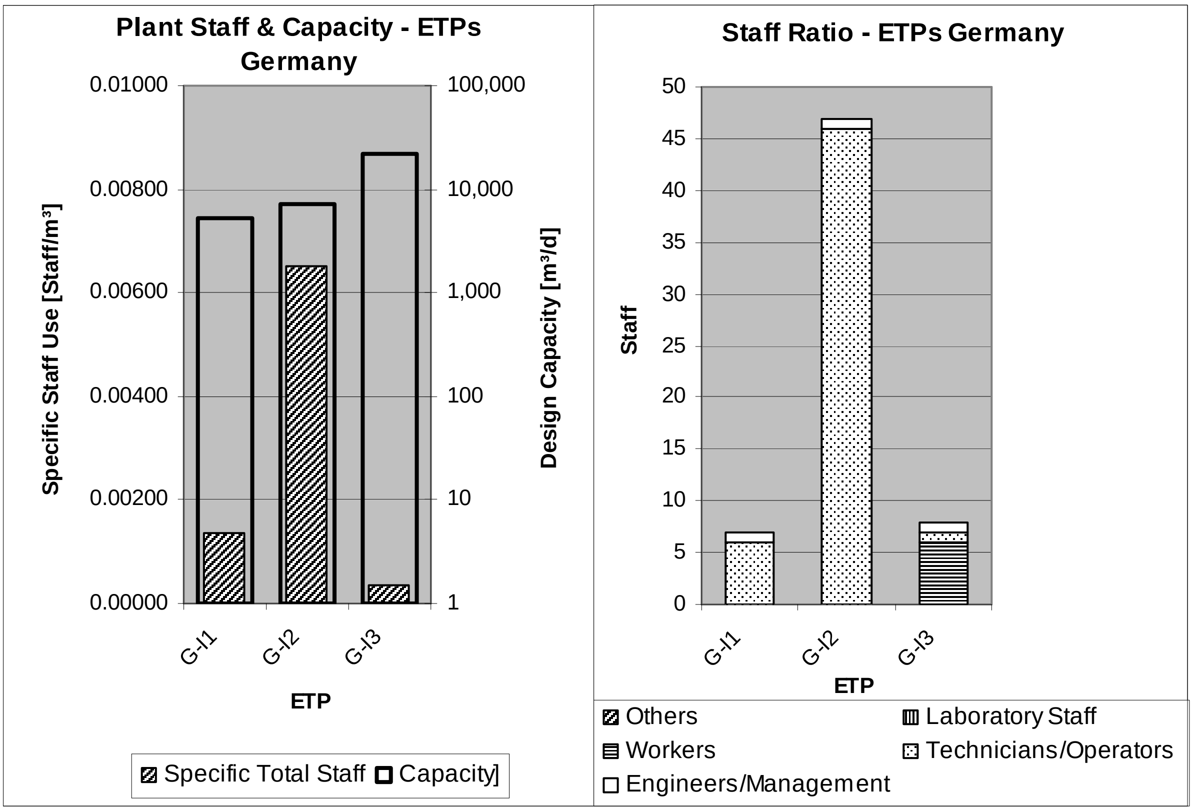


FIGURE 178: SPECIFIC STAFF USE, CAPACITY AND STAFF RATIO ON ETPS IN GERMANY

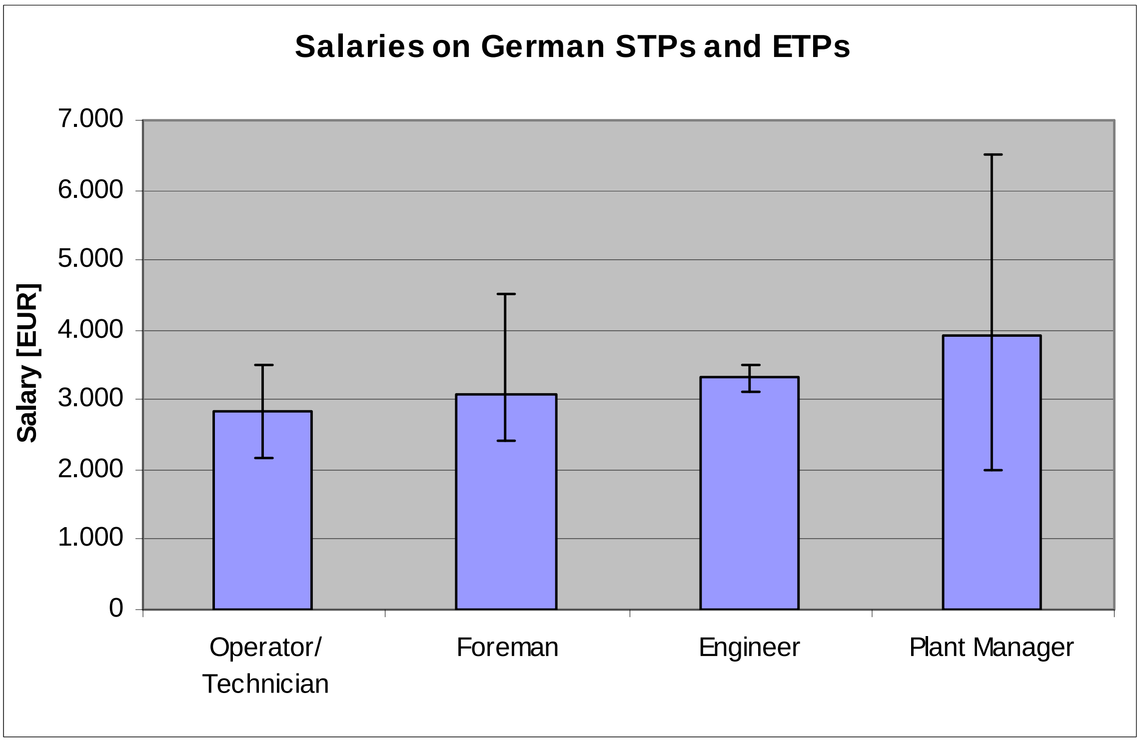


FIGURE 179: INCOME DISTRIBUTION ON GERMAN STPS AND ETPS

Based on the expert interviews with plant managers, an average income of operators and technicians of about 2.900EUR could be determined, with a maximum of

3.500EUR and a minimum of 2.200EUR (see figure 179). The average salary of foremen is slightly higher in average with a value of about 3.100EUR, but a larger range. The average salary of engineers was determined as about 3.300EUR, plant managers earn about 3.900EUR in average, with maximum incomes of 6.500EUR and a minimum income of 2.000EUR. Two frame conditions have to be considered: For small plants, very often only one or two persons are in charge for the whole operation process, so that in these plants, the technician or foreman is the plant manager. This is the case 3 plants of the plants that were taken into account for the salary considerations. The salary ratio between operators/technicians and engineers is about 0,86, which is remarkably higher than in India (0.47) and China (0.57).

Detailed Analysis

As shown in chapter 6.2.1, 23 test staff members were questioned – 2 helpers, 12 technicians/operators, 6 group leaders and 3 division leaders (see also figure 32, chapter 6.2.1).

Regarding the education level of the test persons, 22 persons passed secondary school – one test person passed high school (German education system see chapter 5.2.3). None of the test persons is a degree holder, but almost all test persons have a special qualification in wastewater treatment. This qualification is either a complete wastewater specific 3 years course based on the German dual education systems (see chapter 5.2.3) or a short-term course of several months in addition to a mainly technical learning profession, like mechanic, fitter or electrician. This is a very different scenario compared to the qualification structure in India and China.

General & Operation Specific Knowledge

Figure 180 gives an outlook on the results of the staff questioning regarding different question fields of general knowledge. Like in India and China, three questions of different severity were asked for each field (see question 23, appendix C).

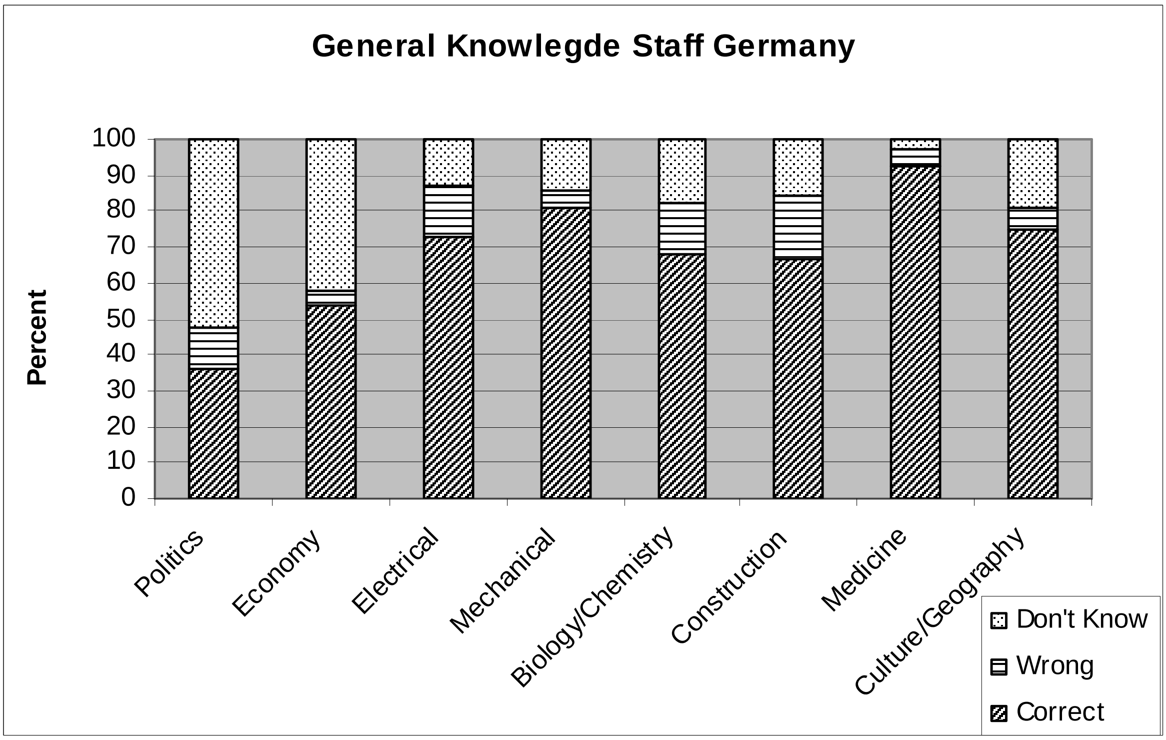


FIGURE 180: GENERAL KNOWLEDGE OF QUESTIONED PLANT STAFF IN GERMANY

In total, the test persons answered 68% of the general questions correctly. The comparable value from the questionings in China is 58%, in India only 38% of the questions were answered correctly by the interviewed staff (see chapter 7.1.2 and chapter 7.2.2). The highest values were reached in the fields of medicine with more than 90% of correct answers. In the mechanical field, more than 80% of the questions were answered correctly – in the electrical field, about 73%, in biology/chemistry, 68% of the answers were answered correctly. The respective values for the mechanical, electrical and biological/chemical field in India are 30%, 31% and 34%, in China the respective values are 60%, 53% and 59% (see figure 77, chapter 7.1.2 and figure 131, chapter 7.2.2). The lowest value of correct answers can be stated in the field of politics with only 36% of correctly answers, compared to a value of 35% in India and 41% in China. The results indicate a moderate general knowledge, but a high job specific knowledge that goes beyond the actual work situation and work contents.

Figure 181 shows the results of the questions regarding the knowledge about different treatment technologies for wastewater (see question 15, appendix C). Like in India and China, the test persons were asked whether they know the respective technology and whether it is used on their plant.

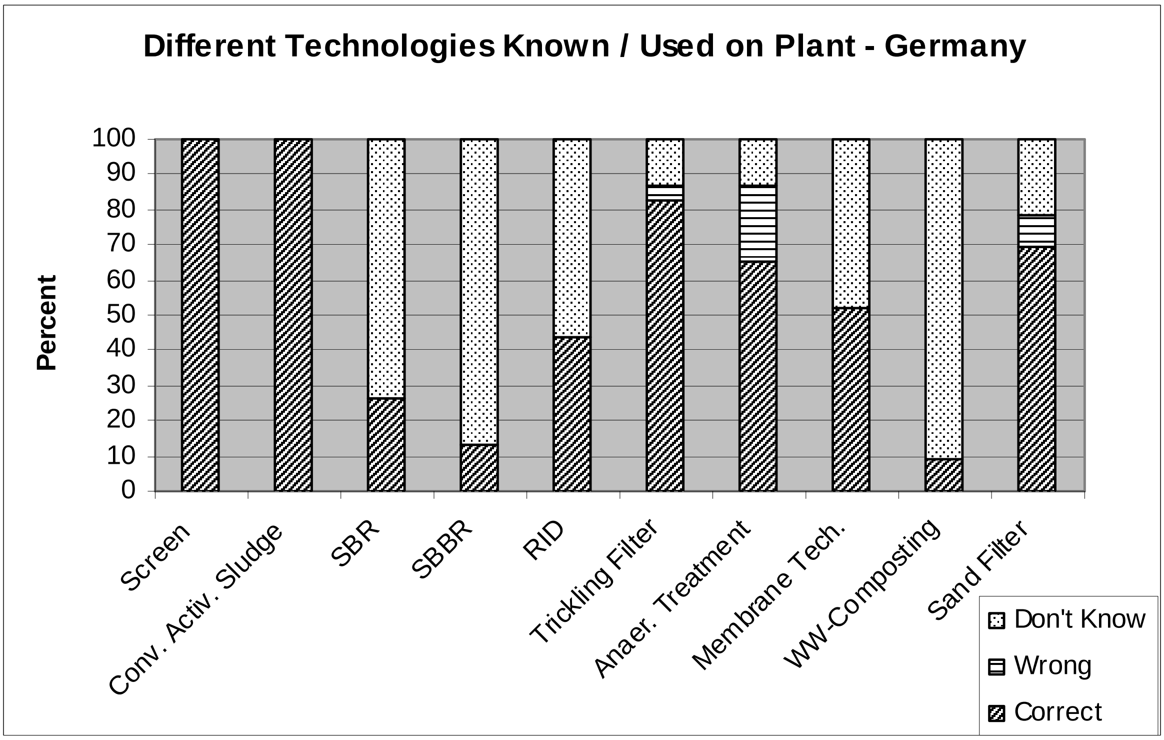


FIGURE 181: TECHNOLOGY KNOWLEDGE OF QUESTIONED PLANT STAFF IN GERMANY

In total, 56% of the questions were answered correctly by the test persons. The use of screens and activated sludge system is known to all questioned test persons. The questions regarding the use of trickling filters, sand filters and anaerobic treatment methods were answered correctly to about 65% to 85%, although these systems partly don't exist on the inspected plants. SBR and SBBR systems are not known by 74%, respectively by 87% of the test persons, compared to respectively 58% in China and respectively more than 80% in India (see figure 78, chapter 7.1.2 and figure 132, chapter 7.2.2). The use of membrane bioreactor is known by 52% of the test persons in Germany, compared to 37% in India and 46% in China.

Figure 182 shows the results regarding the correctness of statements about different processes in wastewater treatment (see question 16, appendix C). In total, 89% of the questions were answered correctly – none of the questions was answered correctly to less than 78%. This is by far the best result compared to the scenario in India and China where only about 30% respectively 78% of the questions were answered correctly in average (see chapter 7.1.2 and chapter 7.2.2).

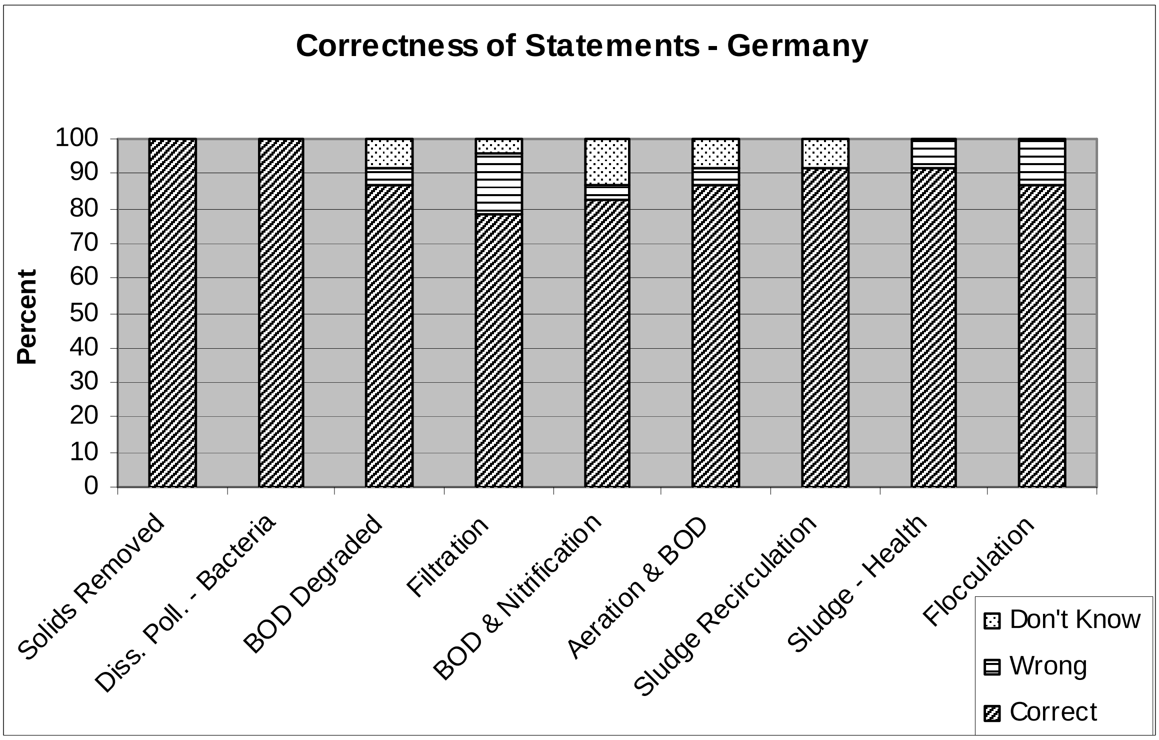


FIGURE 182: PROCESS KNOWLEDGE OF QUESTIONED PLANT STAFF IN GERMANY

Work Situation & Motivation

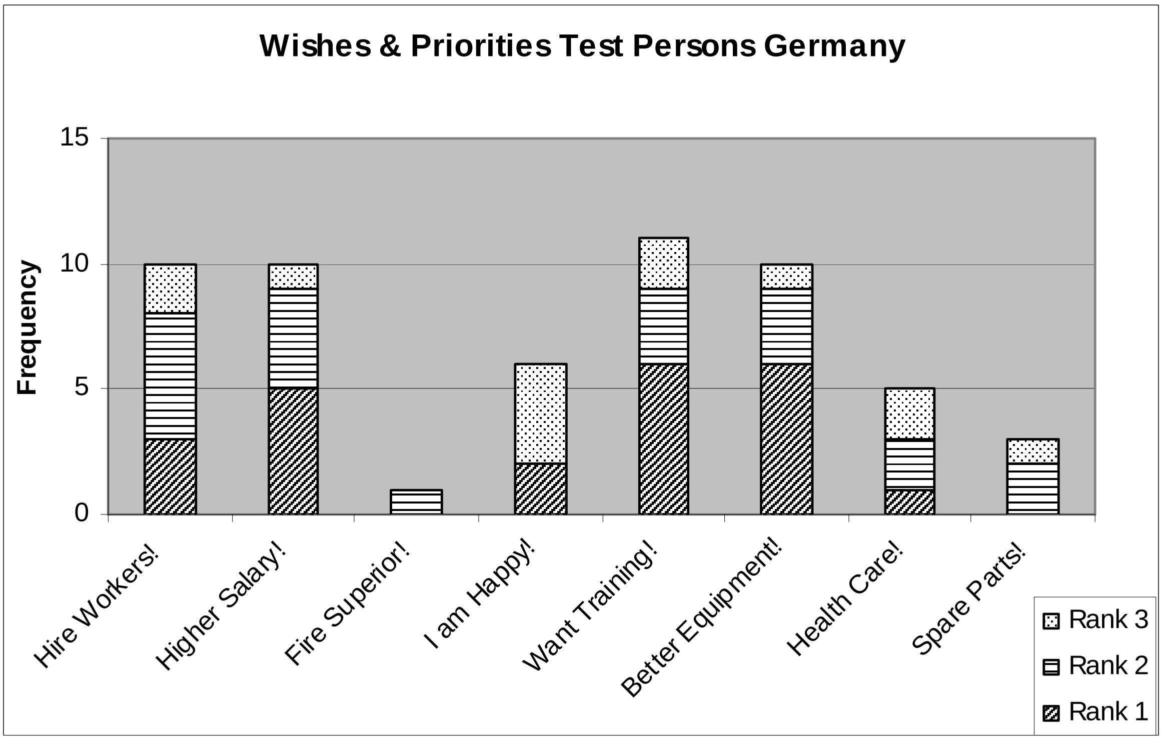


FIGURE 183: WISHES AND PRIORITIES OF TEST PERSONS IN GERMANY

Figure 183 gives an outlook on the wishes and priorities of the questioned plant staff. The test persons could choose up to three aspects that they should rank (see question 14, appendix C). Like in India and China, the wish for training is expressed with highest frequency both regarding rank 1 and total frequency, but the frequency distance to the following topics is less than in India and China. Looking on the total frequency, employment of more staff, higher salaries and better equipment are equally on second position. Other than in China, spare parts supply is not a critical topic on the inspected wastewater treatment plants in Germany – the respective wish is expressed with second last frequency.

Other than in India and China, a relatively high job satisfaction can be stated on German wastewater treatment plants. About 43% want to remain in the same job situation and 57% want to improve, means, they intend to develop in their company or municipal plant. This is a sign for a very high job satisfaction.

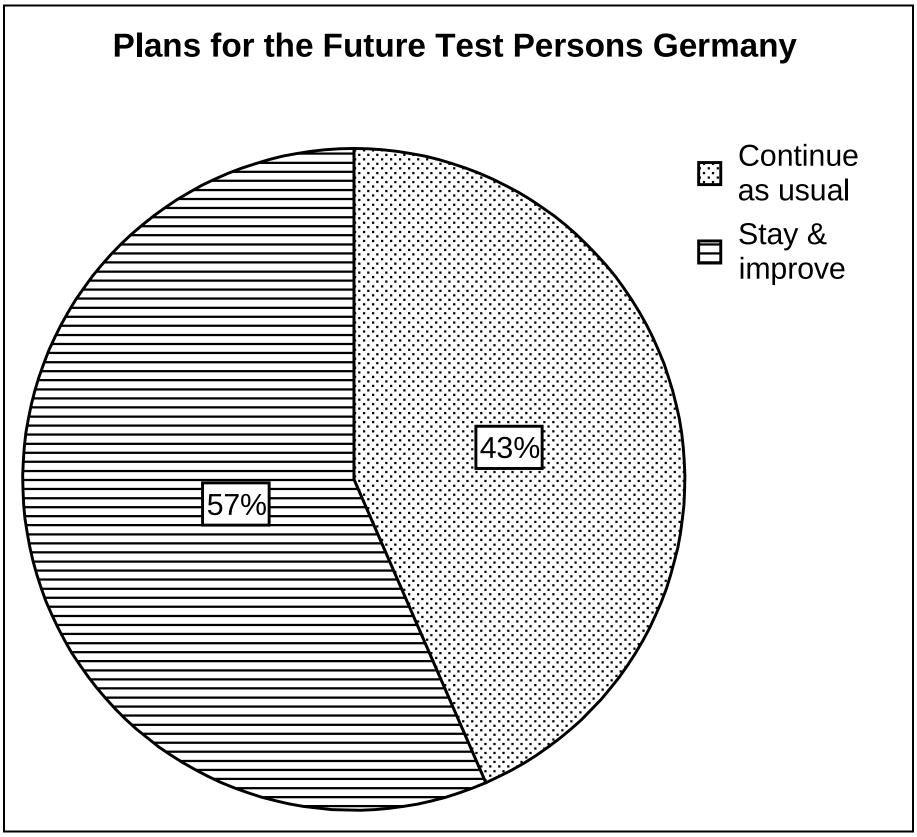


FIGURE 184: FUTURE PLANS OF QUESTIONED PLANT STAFF IN GERMANY

7.3.3 Western Positions on Developing & Newly Industrialising Countries

In the following paragraphs, the results of the interviews with western experts are presented. As shown in chapter 6.2.2, 26 test persons from Germany, 3 test persons from France, 1 test person from Denmark and 1 test person from the US were interviewed.

Figure 185 shows the distribution of the interviewed experts regarding their main regional focus in the interviews.

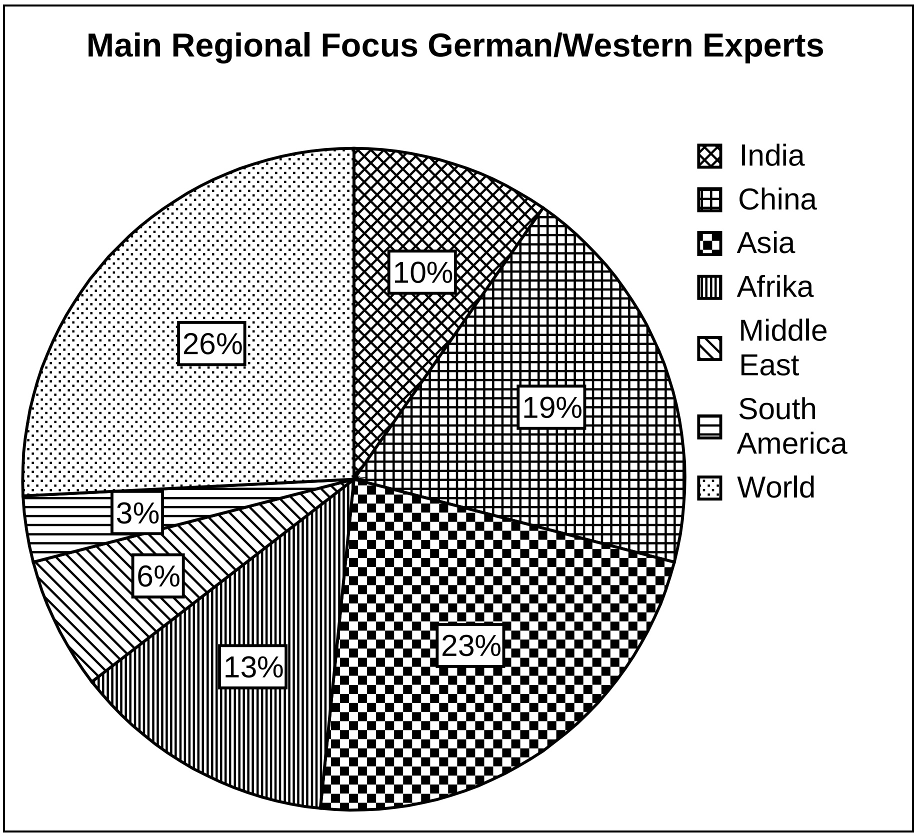


FIGURE 185: MAIN REGIONAL FOCUS OF INTERVIEWED WESTERN EXPERTS

In the following paragraphs, the detailed results of the expert interviews are presented, grouped in

- Environment and water pollution in general
- Wastewater treatment technology
- Economic aspects of technology transfer
- Awareness & professional education

Environment & Water Pollution in General

For the further data analysis, all interviewed western experts are considered.

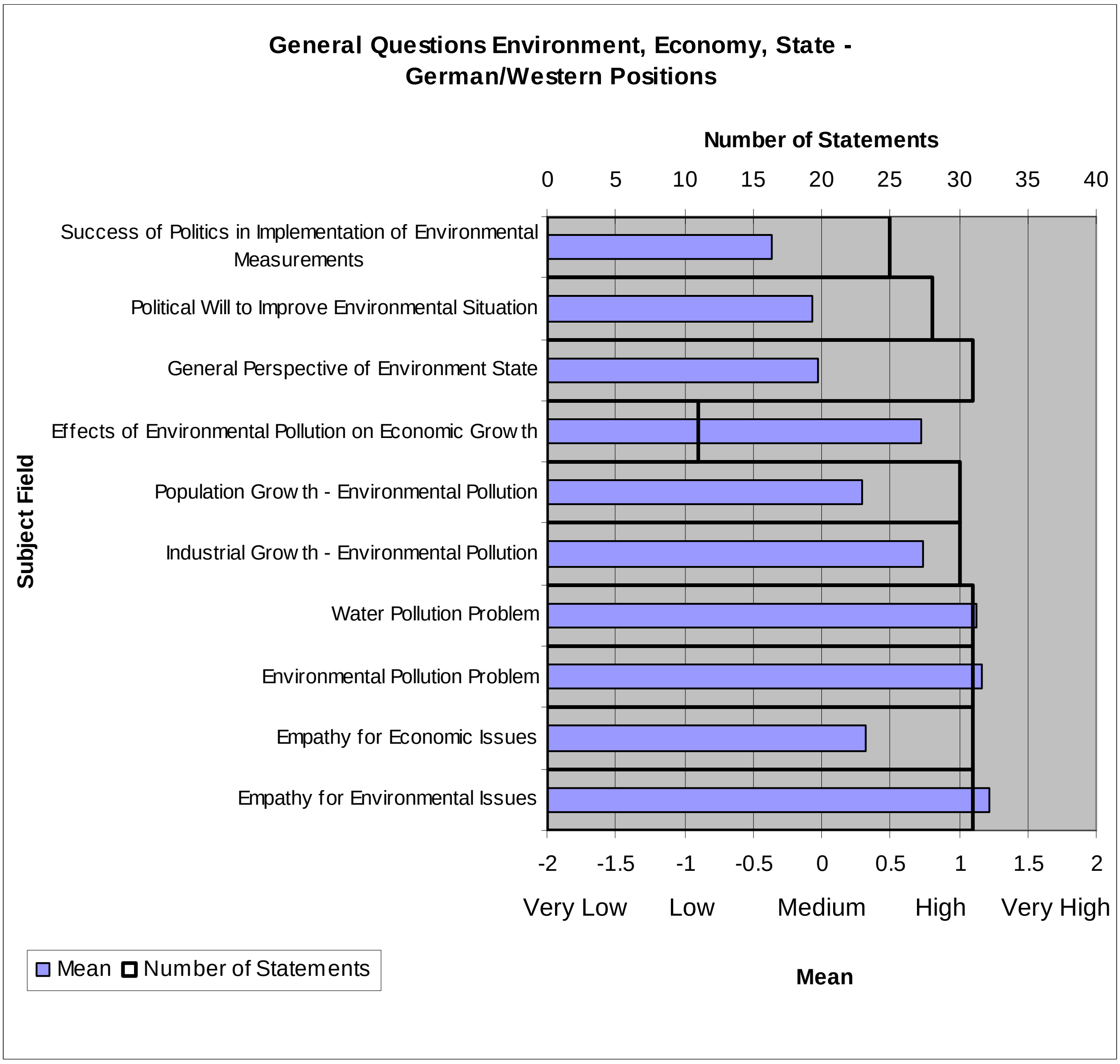


FIGURE 186: GENERAL QUESTIONS ENVIRONMENT, ECONCOMY, STATE – GERMAN/ WESTERN POSITIONS

The water pollution problem in developing and newly industrialising countries is considered as a big problem by the interviewed western experts. An index value of 1.13 could be determined. The respective value from the Indian experts is 0.74, the respective value from the Chinese experts is 0.90 (see figure 83, chapter 7.1.3 and figure 137, chapter 7.2.3). Regarding the general perspective of the environmental state in developing and newly industrialising countries, western experts are relatively sceptic (index value -0.03) compared the interviewed Indian and Chinese experts. Indian experts see the picture much more positive (index value 0.64), also Chinese experts (index value 0.90). The political will and the success of politics in the implementation of environmental measures to improve the environmental situation is not seen optimistic by the western experts (index value -0.07 resp. -0.36). Very often, deficits are seen in the implementation of laws.

“In India there is always a problem between the existing law and its implementation. Legislation worked already. A relatively strict environmental law exists. But the executive can’t follow. There is no implementation“ (Economy Expert – Expert Interview Germany No. 5).

Industrial growth is considered to be the major reason for environmental pollution. Also population growth is seen as an important reason by the interviewed western experts (index value 0.3).

The integration of the State Environmental Protection Administration (SEPA) in the administration structure is seen as a major problem for implementation and control deficits in China, as the following statement shows.

“Environmental protection is controlled centrally. For our (German) perspective the environmental authorities are control authorities…. Here they can’t be this, because they are integrated false in the structure. In the political hierarchy they are on the same level like the water supply and wastewater authorities.” (Engineer – Expert Interview Germany No. 24).

Wastewater Treatment Technology

In a detailed consideration, the technology degree that interviewed western experts consider to be suitable for urban areas in developing and newly industrialising countries was determined regarding the regional focus of statements on this topic, whereas the low number of statements has to be considered. For India and China, medium level technologies are mentioned by the interviewed western experts (see figure 187). The technology degree that Indian experts consider to be suitable for urban aeras is much higher (index value 0.9, see figure 85, chapter 7.1.3). Also interviewed Chinese experts consider more technical solutions to be suitable for urban areas in their country (index value 0.78, see figure 140, chapter 7.2.3). With a focus on Africa, a lower technology degree is seen more suitable by western experts (see figure 187). More complex technologies are considered to be applicable in the Middle East region and in South America, whereas only one interviewed expert focussed on South America.

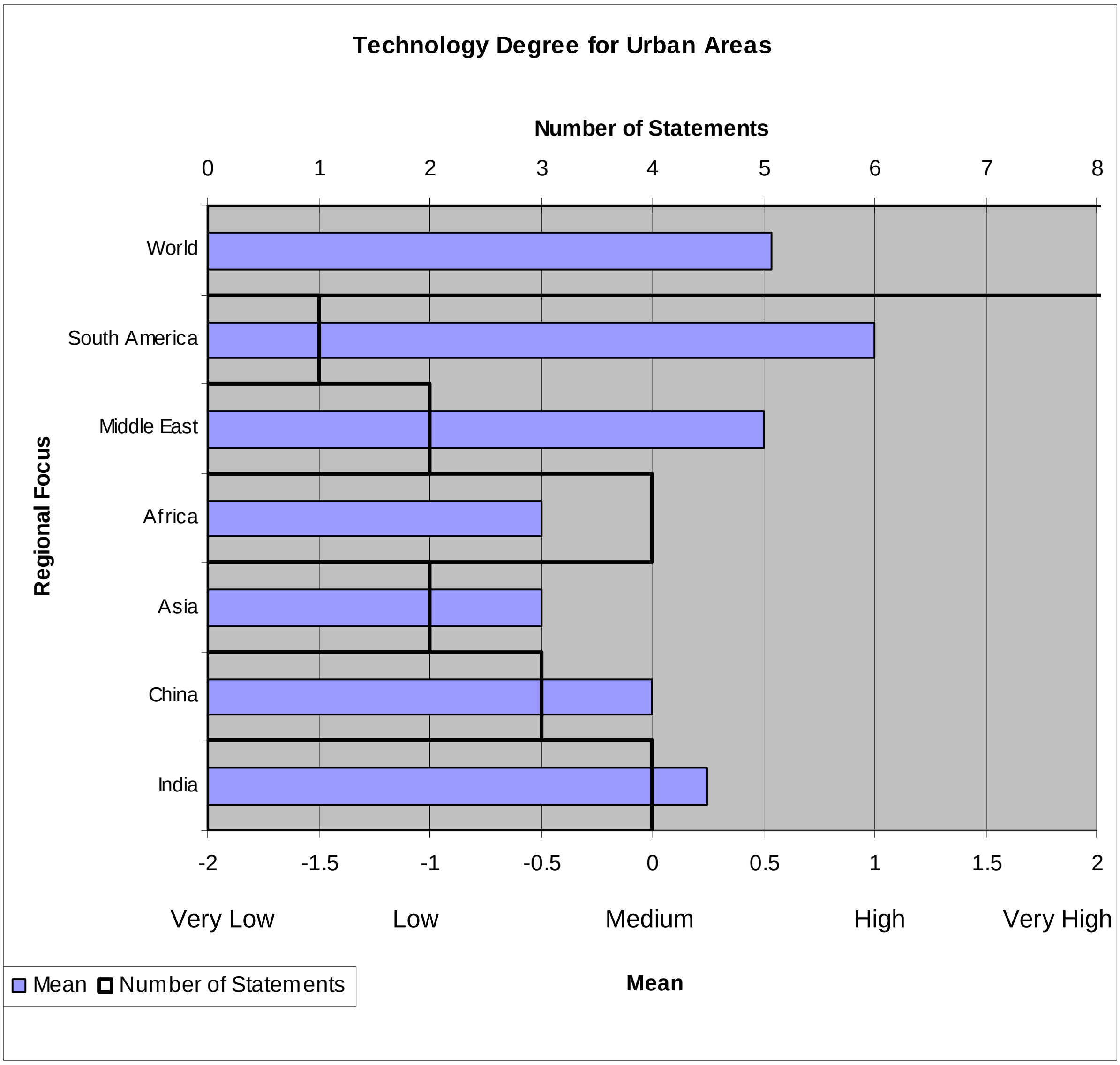


FIGURE 187: GERMAN/WESTERN POSITIONS ON TECHNOLOGY DEGREE FOR URBAN AREAS

For rural areas, interviewed western experts favour simple and natural systems. Decentralisation is mentioned by some experts.

„I think decentralised wastewater treatment plants would be the first help, the best help that can be effective, because it is a beginning, doesn't need big administration, that doesn't need big effort" (Manufacturer – Expert Interview Germany No. 3).

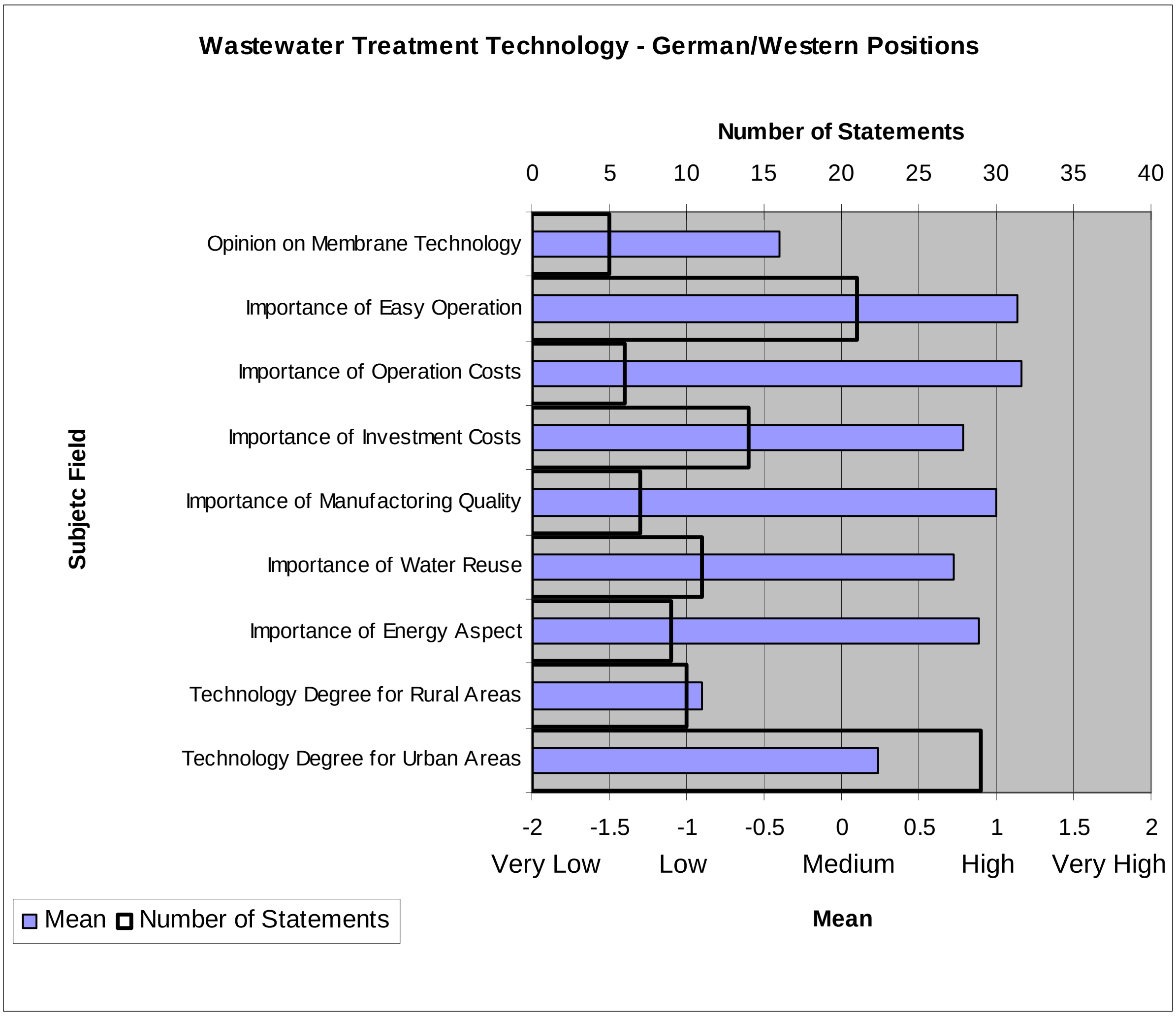


FIGURE 188: WASTEWATER TREATMENT TECHNOLOGY – GERMAN/WESTERN POSITIONS

Like interviewed Indian and Chinese experts, western experts see a need for high manufacturing quality of treatment technology (index value 1.0). The relative comparison of the technology criteria in figure 188 indicates that operation costs are more relevant than investment costs for western experts.

The interviewed western experts see a strong need for easy operation (index value 1.14). The Indian test persons see this aspect less important (index value 0.22 resp. 0.73). The following statement of a German manufacturer of treatment plant equipment expresses the need for easy operation very typically:

„The only thing is, you have to use robust processes, you have to use processes where only few actions are prescribed, that are normally very simple and then it will work. The experience over the last 15-20years is that if such a simple process exists, it functions also after 10years, whereas complicated controlled plants… the plants degenerate when the (initial) trained staff has left the plant" (Manufacturer – Expert Interview Germany No. 3).

Economic Aspects of Technology and Knowledge Transfer

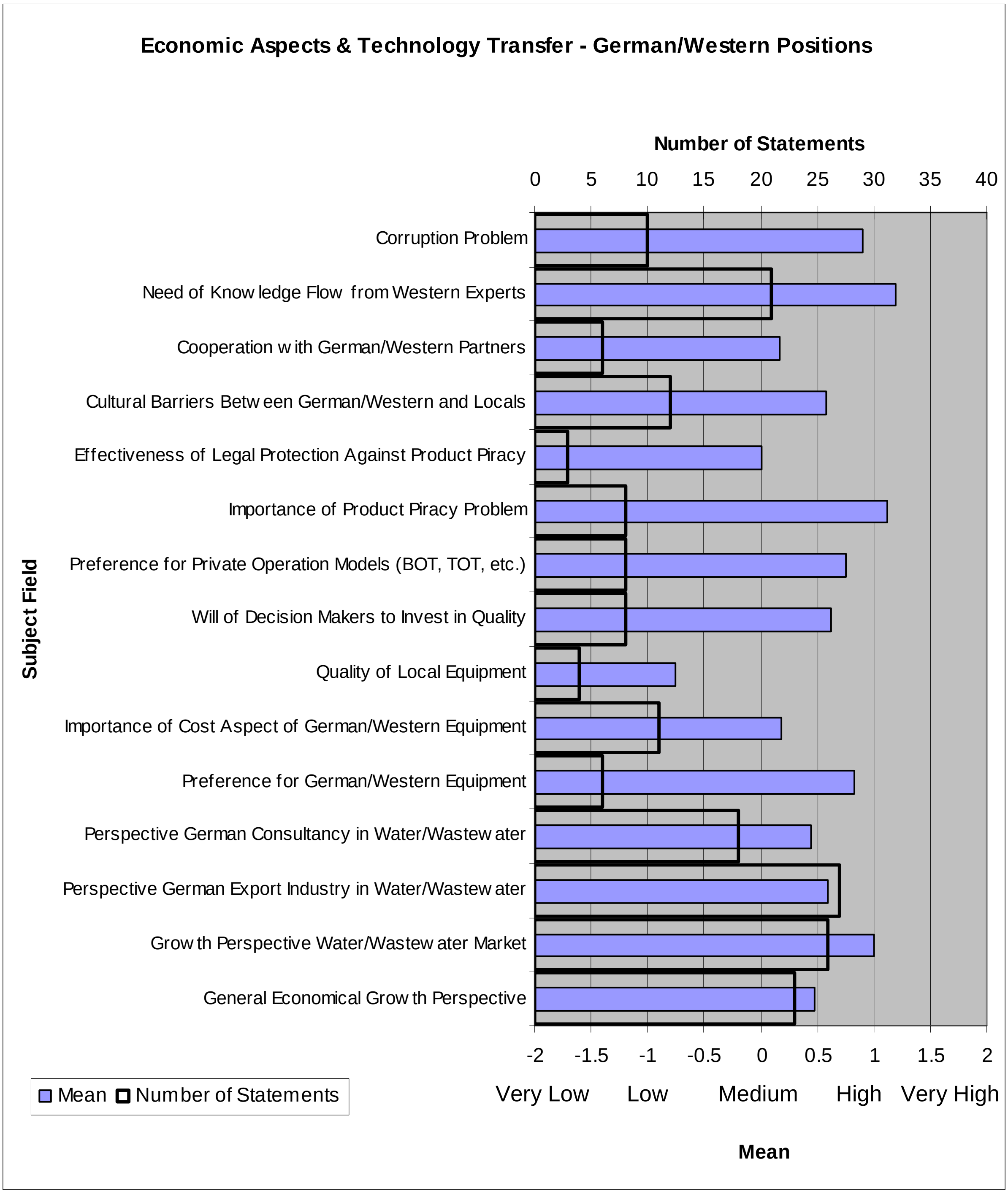


FIGURE 189: ECONOMIC ASPECTS AND TECHNOLOGY TRANSFER – GERMAN/WESTERN POSITIONS

Regarding the economic possibilities of the German export industry in the water and wastewater sector for developing and newly industrialising countries, the interviewed experts are moderately optimistic (index value 0.59).

The reasons are seen, both in financial limitations of many countries – especially African nations – and the competition with other western export countries. Especially the last point is seen critical by many interviewed experts. German companies would have disadvantage both because of lack of political support and the fact that many companies are medium sized and don't unite to focus on similar targets. A statement from a French business expert with focus on China shows these basic problems.

"The problem of Germany is that there are a lot of small medium sized companies and the problem is marketing. If you see what the Americans are doing at the moment, they are a lot more active than German companies, although Germany is a pioneer in environmental technologies…. They have to do lobbying" (Business Expert – Expert Interview Germany No.17).

For India remarkably better market chances are expected, than for China. An important factor named by the interviewed experts is the strong competition situation in China.

For the economic relations with developing and newly industrialising countries, cultural aspects play an important role. For that reason a look on cultural barriers is interesting. Relations to foreign specialists and partners are described moderately positive (index value 0.58) by the interviewed western experts. A strong need of knowledge flow from the west is expressed by the interviewed western experts (index value 1.19), whereas this aspect is seen much less relevant by the interviewed Indian experts (index value 0.4). For Chinese experts, an index value of 1.0 was determined. Local experts in developing and newly industrialising countries are very often not considered as sufficiently skilled, as the following example illustrates:

"Wherever I see such things, I approach the people and ask them:"Hey guys, are you not clear about what you are doing here?!" I see total incomprehension. And the strange thing is that this incomprehension doesn't exist only among the simple people in the village – even among the engineers that should work on the local level in the administration in India, they don't know the relation either" (Scientist – Expert Interview Germany No. 30).

In the interviews, some western experts speak in a "we – they" mode, which is a sign for low understanding for the local conditions, even among western experts who have intensive contacts to these countries since many years. The statement of an interviewed sales manager of a European equipment manufacturer about China shows a critical "superior" position of some western experts.

“The reason I think is that they are a developing country, they are developing, that means that they don’t have the knowledge. They don’t have a proper system, they don’t have the people that have the knowledge” (Manufacturer – Expert Interview Germany No.27).

Corruption and extreme bureaucracy are seen as big problems in many developing and newly industrialising countries (see figure 189). The following statement shows the position of a German scientist regarding this topic.

“In India you can buy everything on each corner, if you pay accordingly. Almost everything, time delays and so. I leave Himalaya and Kashimr out, yes. And why doesn’t it function in the water field? Because there are huge institutions. That is completely nationalised and corrupt in the sense that the interests are misdirected” (Scientist – Expert Interview Germany No.31).

Awareness & Professional Education

In the following, the detailed consideration of aspects of awareness, education and motivation is carried out. Figure 190 gives an outlook on the determined positions and estimations of western experts. Very interesting is the opinion of the western experts regarding the awareness among the population in developing and newly industrialising countries concerning environmental and hygienic issues. Interviewed experts describe the awareness of the upper population level moderate (index value -0.19) and very critical on the lower population level (index value -0.77). Interviewed Indian and Chinese experts see the situation much more positive in their countries (see figures 87, chapter 7.1.3 and figure 142, chapter 7.2.3). An interviewed expert of the German development cooperation describes the situation as follows:

“You have to differentiate. I think in almost all countries, there are groups who are aware of this. But these are normally very small groups. These are not necessarily those groups who have the power, normally not. The broad population is not so aware. The political class is aware of this, but has other priorities” (Expert German Development Cooperation – Expert Interview Germany No. 14).

The existing qualification of treatment plant staff is seen on a low level in most developing and newly industrialising countries (index value -0.5). The interviewed Indian experts see the workers qualification similarly critical (index value -0.62, see figure 87, chapter 7.1.3), also Chinese experts (index value -0.5, see figure 142, chapter 7.2.3). Also the qualification systems both for workers and engineers are seen very critical by the interviewed western experts (see figure 190). Deficits are seen in the engineer education due to lack of practical references in many countries.

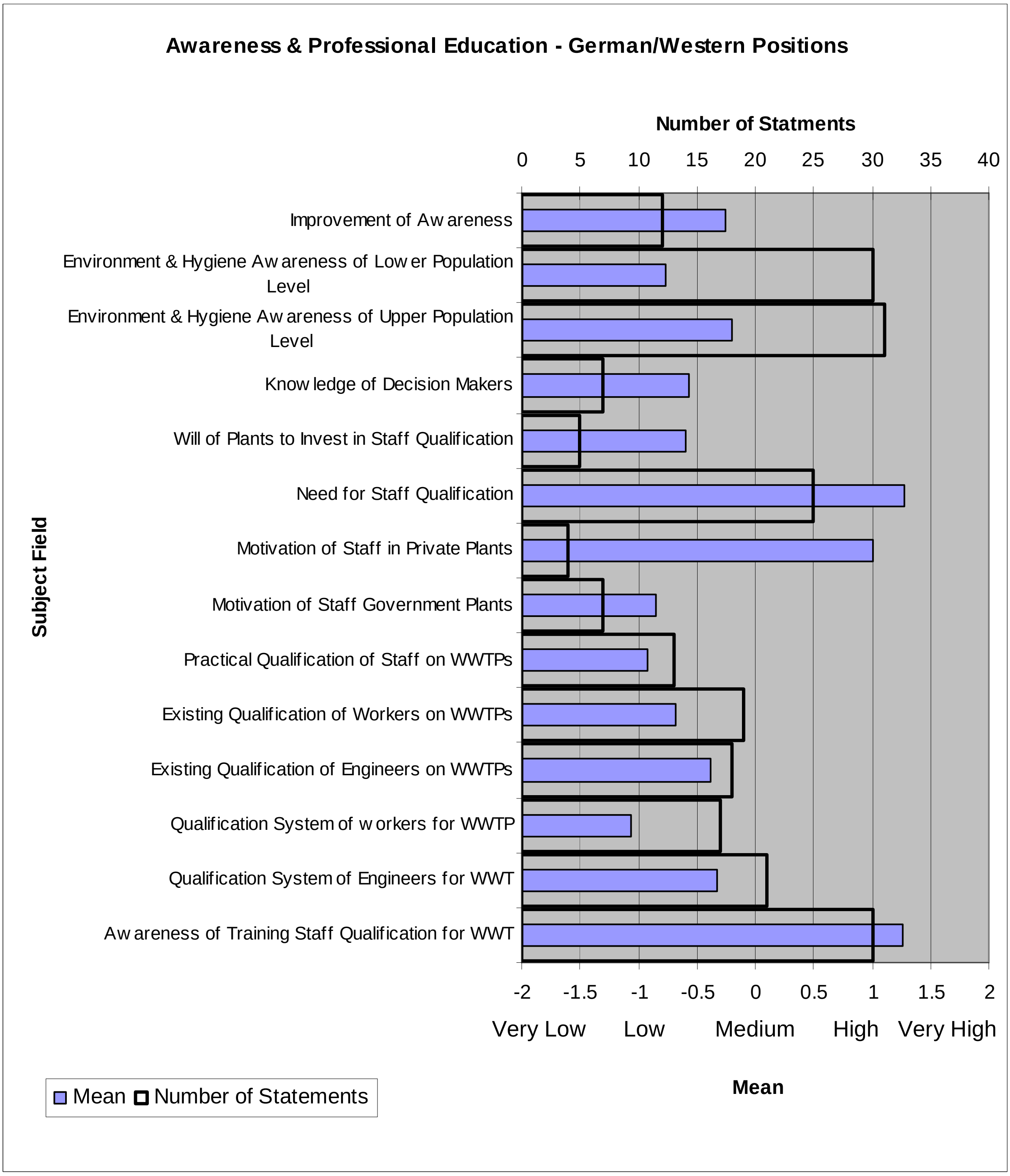


FIGURE 190: AWARENESS AND PROFESSIONAL EDUCATION – GERMAN/WESTERN POSITIONS

For almost all regions, western experts see a high need for staff qualification (index value 1.28), whereas in India and China this need is seen much less (index value 0.85 resp. 0.38). For business relations and treatment plant operation this indicates that staff training and running in of technical equipment can lead to discussions as the western and local partner can have potentially very different opinions on the importance of training. Western experts see a very moderate intension in developing and newly industrialising countries to invest in staff qualification (index value -0.6).

Very interesting is the great difference in the estimation of the motivation on government plants and private plants (see figure 190). Motivation in the private sector is considered to be much higher than in the public sector.

The knowledge of decision makers in developing and newly industrialising countries is considered to be relatively low.

7.3.4 Summary & Discussion

Treatment Plant Efficiency & Processes

For the inspected STPs in this study, an average treatment efficiency of 95% for COD could be stated. For ammonia, an treatment efficiency of 97% and for total phosphorous an average efficiency of about 85% could be determined. The average values of the main discharge parameters are comparable to the nationwide average in Germany. The average treatment efficiency of German STPs for BOD is 98%, for COD the efficiency is 94%. For total nitrogen, a treatment efficiency of 81%, for total phosphorous, a treatment efficiency of 90% is achieved in average (UBA 2007).

As mentioned in chapter 7.3.1, 12 of 13 that were included in this study are activated sludge plants, 1 plant is a RID-plant.

Technology Status

As shown in chapter 7.3.1, almost all equipment used on German wastewater treatment plants is of German origin. The detailed considerations of structural, machinery and control equipment showed a relatively high technology level. A strong focus on a high efficiency and long durability of the equipment can be stated, although this means high investment costs. High quality materials like stainless steel of different qualities, high manufacturing quality, high corrosion resistance, high durability and a high grade of automation are characteristic for treatment plant equipment in Germany. The detailed analysis of the equipment on the inspected plants in this study showed that more than 40% of the machinery and control equipment is more than 10 years old (see figures 159 and 168, chapter 7.3.1).

Considering this fact and the relatively positive picture regarding corrosion freeness, cleanliness and function ability, beside a high product quality, a high level of maintenance can be stated. This also show the expert interviews with the management of the inspected treatment plants. Smaller treatment plants mainly use professional paper schedules where the major preventive maintenance works are noted in calendar shape or they conclude a maintenance agreement with suppliers or service contractors for the whole plant or for key components. Maintenance planning is on a high level. Larger plants use very often software for preventive maintenance planning (see figure 175, chapter 7.3.1). Characteristic for German plants is the assurance of high function ability and high safety standards for the protection of the discharge water bodies.

Manpower Status

The general knowledge of the questioned staff is very strong in the relevant fields for wastewater treatment, like mechanics, electrics and biology/chemistry (see figure 180, chapter 7.3.2). Technicians from the mechanical and electrical disciplines could answer almost all answers from their field to a very high degree correctly. Compared to India and China, the questioned German treatment plant staff knows very well about the purpose of various treatment plant steps and equipment (see figures 181 and 182, chapter 7.3.2), although certain technologies like SBR or SBBR are less known.

Compared to India and China, a high work satisfaction can be stated (see figure 184, chapter 7.3.2). The results of the question regarding wishes and priorities shows that training is only slightly more important than more staff, higher salaries and better plant equipment (see figure 183, chapter 7.3.2). The questionings showed that most technicians and workers have sufficient access to training and knowledge share (see also wastewater treatment plant neighbourhood, chapter 5.2.3).

Economic & Market Perspective Developing & Newly Industrialising Countries

The market situation in the wastewater field is seen positive for most developing countries (see chapter 7.3.3). Especially for the Indian market, the interviewed experts see a high potential in the water and wastewater sector, whereas for China the optimism is not too strong. The positive market perspective for India corresponds to the results of a branch study on the Indian water sector by the German Office for

Foreign Trade (bfai). Yearly growth rates of 10-15% are expected in the water sector. Specifically for the field of wastewater treatment and reuse, a market growth rate of 15-20% is expected, due to the increasing water scarcity especially in areas of high population density (Alex 2007). A study on the environmental scenario carried out by the Indo German Chamber of Commerce mentions a growth rate of 10-12% for the environmental sectors and an expected market potential of about 22.3 billion US$ for wastewater and sludge treatment. German financial analysts describe water as “megatrend”, considering that China will invest about 125 billion US$ in water infrastructure until 2010 (Bangert 2007).

Although very few interviewed western expert gave a statement on the quality of local equipment in developing and newly industrialising countries, local equipment is considered to be of low quality in tendency (see figure 189, chapter 7.3.3). Interviewed Indian experts describe Indian technology moderately positive (see figure 86, chapter 7.1.3).

Other than experts in India and China, many western experts are hesitant regarding the implementation of modern technical equipment, both in rural and urban areas of developing and newly industrialising countries. Aspects of easy operation are very important for western experts (see figure 188, chapter 7.3.3). A medium technology level is considered to be suitable for urban areas. As main reason, a problematic manpower situation was mentioned by many experts. For western experts, operational and maintenance considerations are very important, which is expressed also in the relatively strong emphasis of manpower development and training aspects (see figure 190, chapter 7.3.3). Severe deficits are seen regarding the qualification of treatment plant staff in many countries. A high need for qualification and knowledge flow from western nations was expressed by many interviewed western experts in this study (see figure 189 and 190, chapter 7.3.3). This corresponds to the strong emphasis of these aspects in the German development cooperation (see chapter 3.3).

7.4 Comparison of Special Aspects

In the following paragraphs, detailed comparisons of special aspects are presented.

Comparison of Technology Levels

Figure 191 shows a comparison of the technology level that was determined based on the plant inspections in this study. Four equipment groups are compared:

- Indian equipment used in India
- Chinese equipment used in China
- German equipment used in China
- German equipment used in Germany

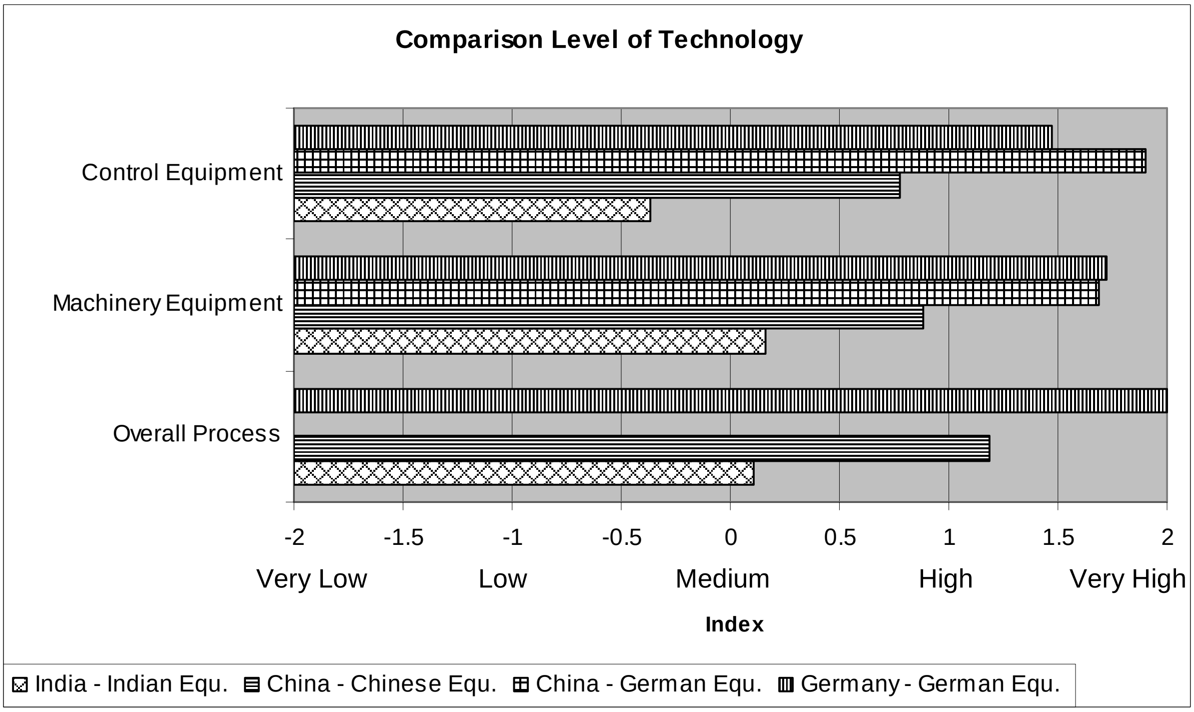


FIGURE 191: COUNTRY COMPARISON LEVEL OF TECHNOLOGY

German control equipment on the inspected Chinese plants is very modern on the plants that were built in Sino-German cooperation in the last 10 years (see chapter 7.2.1). Indian control equipment is on a relatively low technical level. Very similar is the situation for machinery equipment. The comparison of the overall processes shows that the processes in India are far behind treatment processes used in China and Germany. Indian wastewater treatment is focussing on BOD-removal, whereas in China the focus is more on nitrification and denitrification (see chapter 7.1.1 and chapter 7.2.1).

Detail Comparison of Machinery Equipment

As the results of the equipment status determination in India, China and Germany show significant differences between the three countries, a detailed consideration is carried out on the example of screening systems (coarse and fine screens). In figure 192, the following equipment groups are compared:

- Indian screens operated in India
- Chinese screens operated in China
- German screens operated in China
- German screens operated in Germany

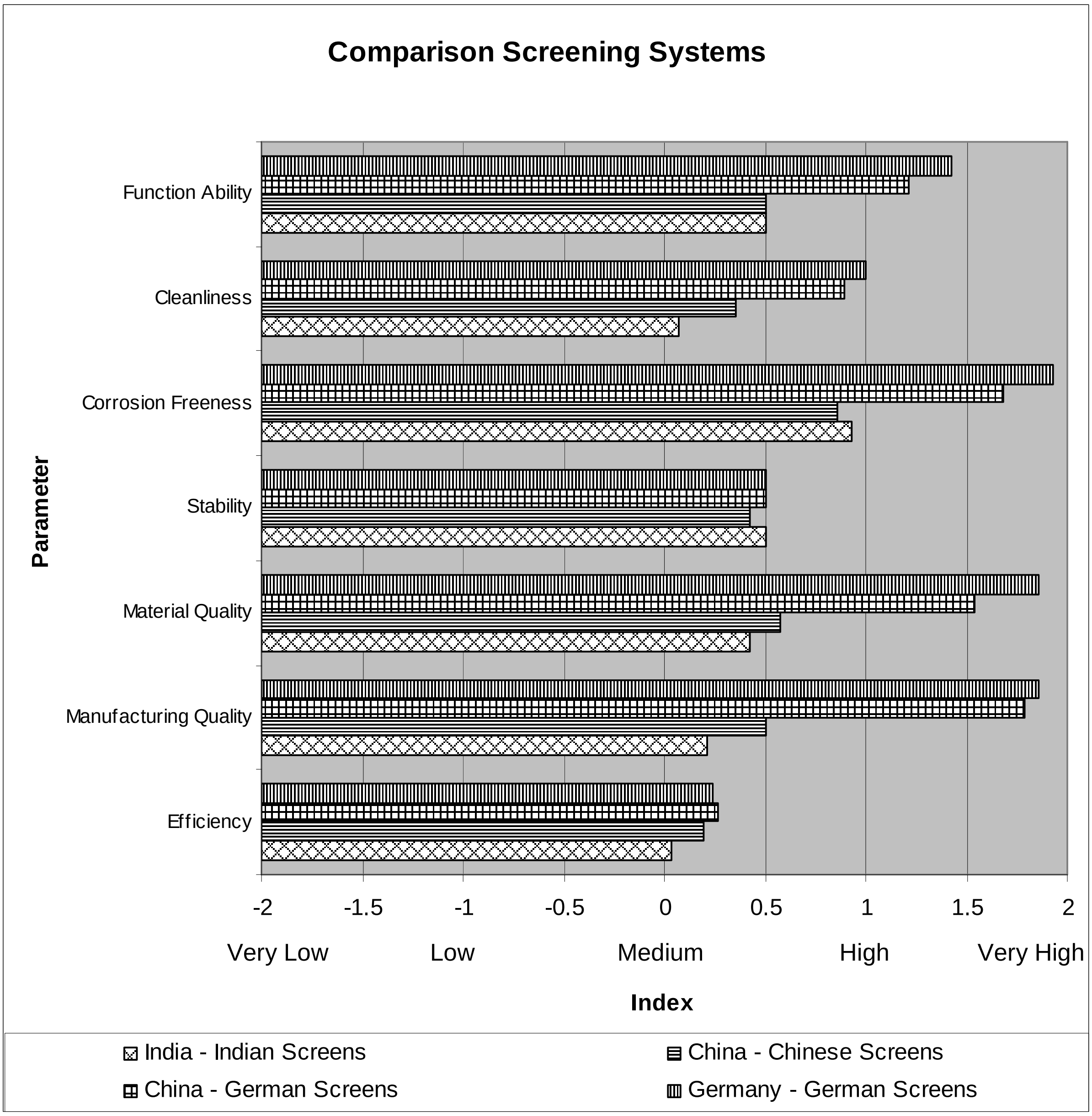


FIGURE 192: COUNTRY COMPARISON COARSE AND FINE SCREENS

FIGURE 193: INDIAN SCREEN (LEFT) AND CHINESE SCREENS (RIGHT)

FIGURE 194: GERMAN SCREEN IN CHINA (LEFT) AND GERMAN SCREEN IN GERMANY (RIGHT)

The technology and manufacturing aspects “material quality” and “manufacturing quality” of Indian and Chinese screens are significantly on lower level than of German screens (see figure 192). Regarding efficiency, the values are very similar for German and Chinese screens, as this parameter also incorporates price, beside the technology level. The results show that Chinese screens are characterised by a slightly better material quality, manufacturing quality and efficiency than Indian screens.

Regarding the parameters “function ability”, “cleanliness” and “corrosion freeness”, also Indian and Chinese screens are on much lower level than German screens. Figure 192 shows that these parameters are on a lower level for German screens operated in China than German screens operated in Germany. The average age of both screen groups is very similar. About 20% of the inspected Chinese screens are less than 5years old and about 80% are between 5 and 10 years old. Of the inspected German screens, about 70% are less than 5years old and about 30% are between 15 and 20years old.

Technology – Control & Automation

Figure 195 and 196 show the comparison of the technology level of control equipment in India, China and Germany based on the results of the plant inspections (see chapter 7.1.1, 7.2.1 and 7.3.1).

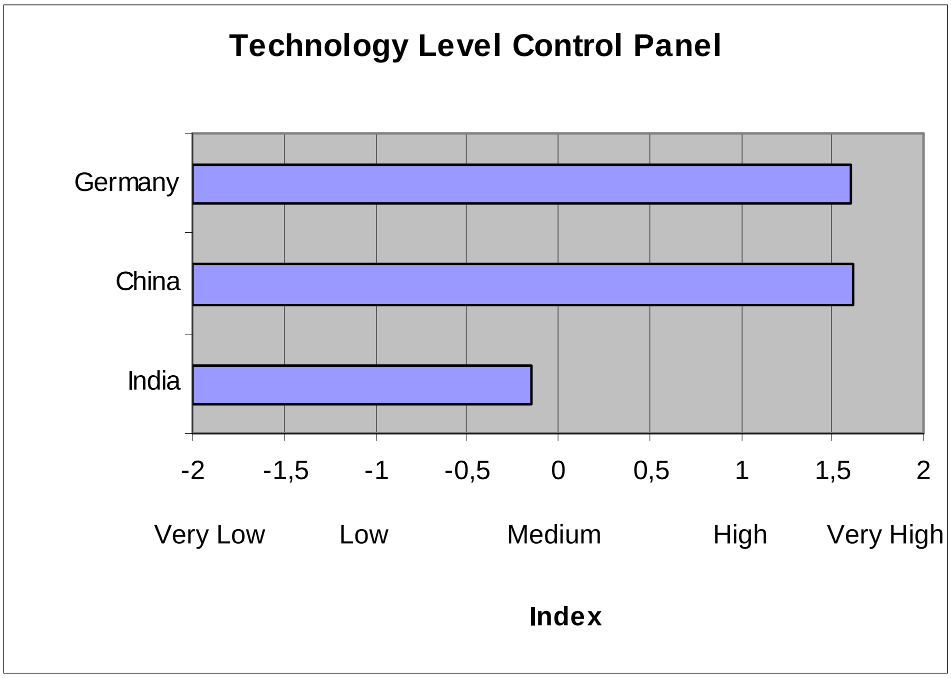


FIGURE 195: COMPARISON TECHNOLOGY DEGREE CONTROL PANEL

FIGURE 196: CONTROL ROOMS IN GERMANY (LEFT), CHINA (MIDDLE) AND INDIA (RIGHT)

As visible in figure 195 and 196, control panels and automation in China and Germany are about on the same level for the inspected plants, whereas for Indian plants simple and manual control elements, as well as a low automation degree are characteristic. The vast gap is of major importance, considering the skills of the operation and maintenance staff, as well as the contents of ITI syllabi. The analysis of the ITI syllabus for electricians shows that modern control technologies, like PLC and SCADA, are not covered. For China, the high automation degree on the inspected plants poses a problem due to lack of automation specialists, as the interview with a plant manager in China showed.

7.5 Pilot Training in India

Results

Key Information on the Questioned Test Persons

In total, 12 participants of the pilot trainings were questioned with a questionnaire before and after the pilot trainings (see appendix D). The average age of these test persons is 37years. In average the test persons are in their actual professional position since about 10years. Regarding the education degree, 4 test persons passed 9th class, 3 persons passed secondary school level, 3 persons visited a technical course in an Industrial Training Institute (ITI), 1 person visited a polytechnic and another one has a bachelor degree in commerce. Ten persons are working as skilled workers, two persons are helpers. Five persons are mechanics, three are electricians and four persons are operators. Only one out of twelve test persons did ever take part in training on wastewater treatment.

Asked about their interest field the wish for understanding of the general treatment process and special information on electrical and mechanical details are equally important for the participants. Two test persons specifically mentioned that maintenance should be covered in the training.

Knowledge & Awareness

In order to get information on the knowledge gain of the pilot training participants, the test persons should describe a series of processes as detailed as possible The same questions were asked before and after the training (see question 10 pre-test and question 7 final test, appendix D). For the analysis, both correctness and detail degree of the answers were considered. Similarly to the analysis of the guided expert interviews in this study, answer categories between -2 and +2 were set and the answers classified according to correctness and detail degree.

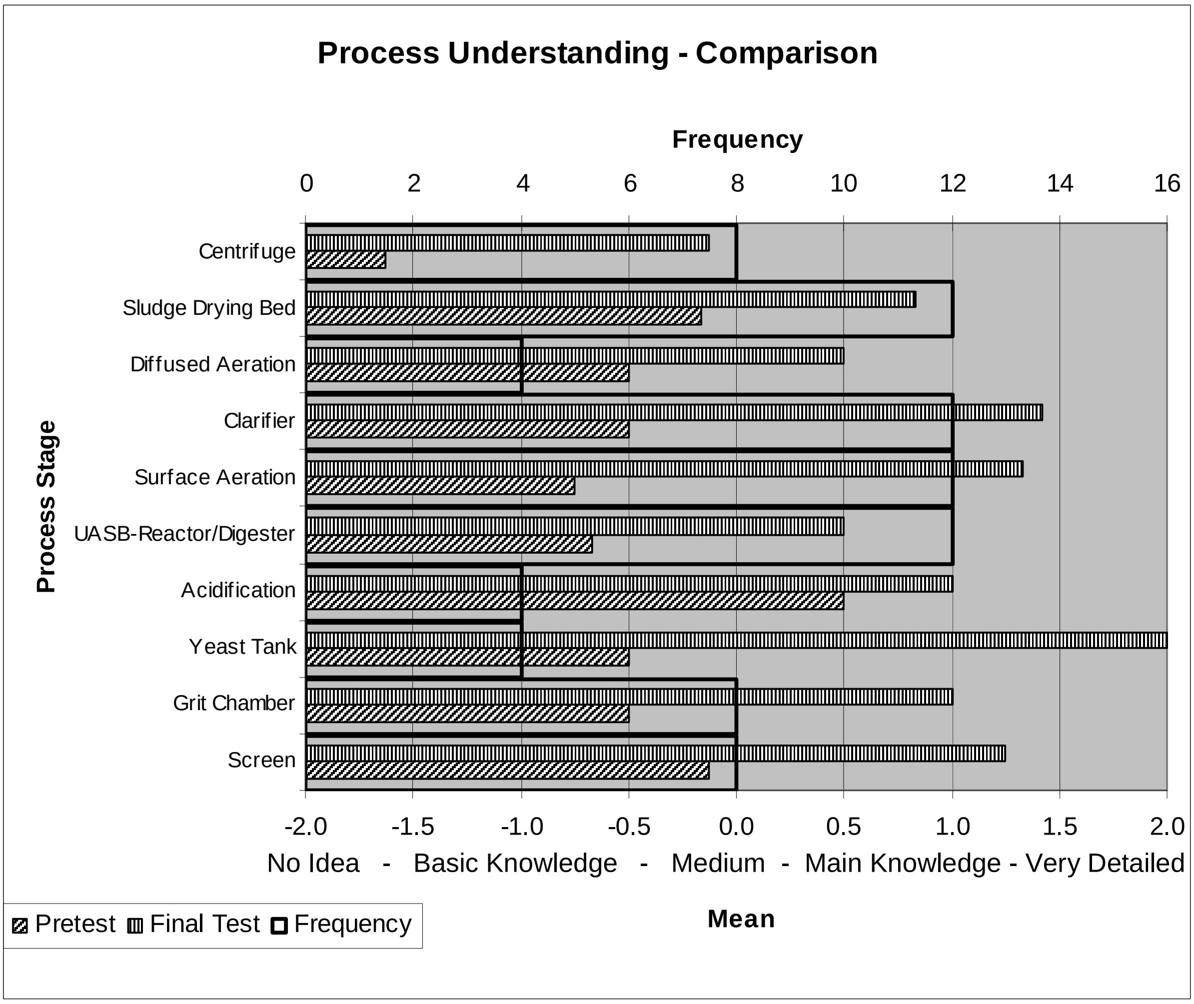


FIGURE 197: PILOT TRAINING – RESULTS PROCESS UNDERSTANDING

In total, the comparison of the answers before and after the training indicates an increase of the knowledge in most covered fields. In the tests before the training, an index value of -0.48 could be determined for the answers quality, that means the workers had a knowledge on the asked processes between “basic” and “medium”. After the training, an index value of 0.82 could be determined, that means “main knowledge” could be detected for the asked processes in average. However, strong differences can be seen between the different processes. The highest knowledge gains could be detected in the topics “yeast tank”, “surface aeration” “clarifier” and “centrifuge”. Although existing in many plants, the function principles of the activated sludge process were not known to many test persons before the training. After the training, most tested staff members had understood the principles and the relations between aeration tank and clarifier. Regarding the yeast tank, most test persons knew only the phenomenon that pipes are clogged, if the yeast is not separated out. In the training, the settling mechanisms, as well as the influence of the particular organic matter on the whole process were covered. After the training, the tested staff could describe the processes of the yeast separation very detailed. Regarding decanter centrifuges, a very low knowledge on the purpose and the function principle could be stated. In this field, the strongest need for training could be seen. After the training, a medium knowledge level could be detected, although a poster, sketches and photos were used to support the basic explanations. A moderate initial knowledge level could be determined for anaerobic digester/UASB-reactor and acidification tank. After the training, the main knowledge about the function principle existed among the tested participants as the results of the questionnaires show.

Beside the knowledge about different processes, the understanding for the consequences of certain behaviours was tested before and after the training (see question 11 pre-test and question 8 final test, appendix D). Figure 198 shows the results.

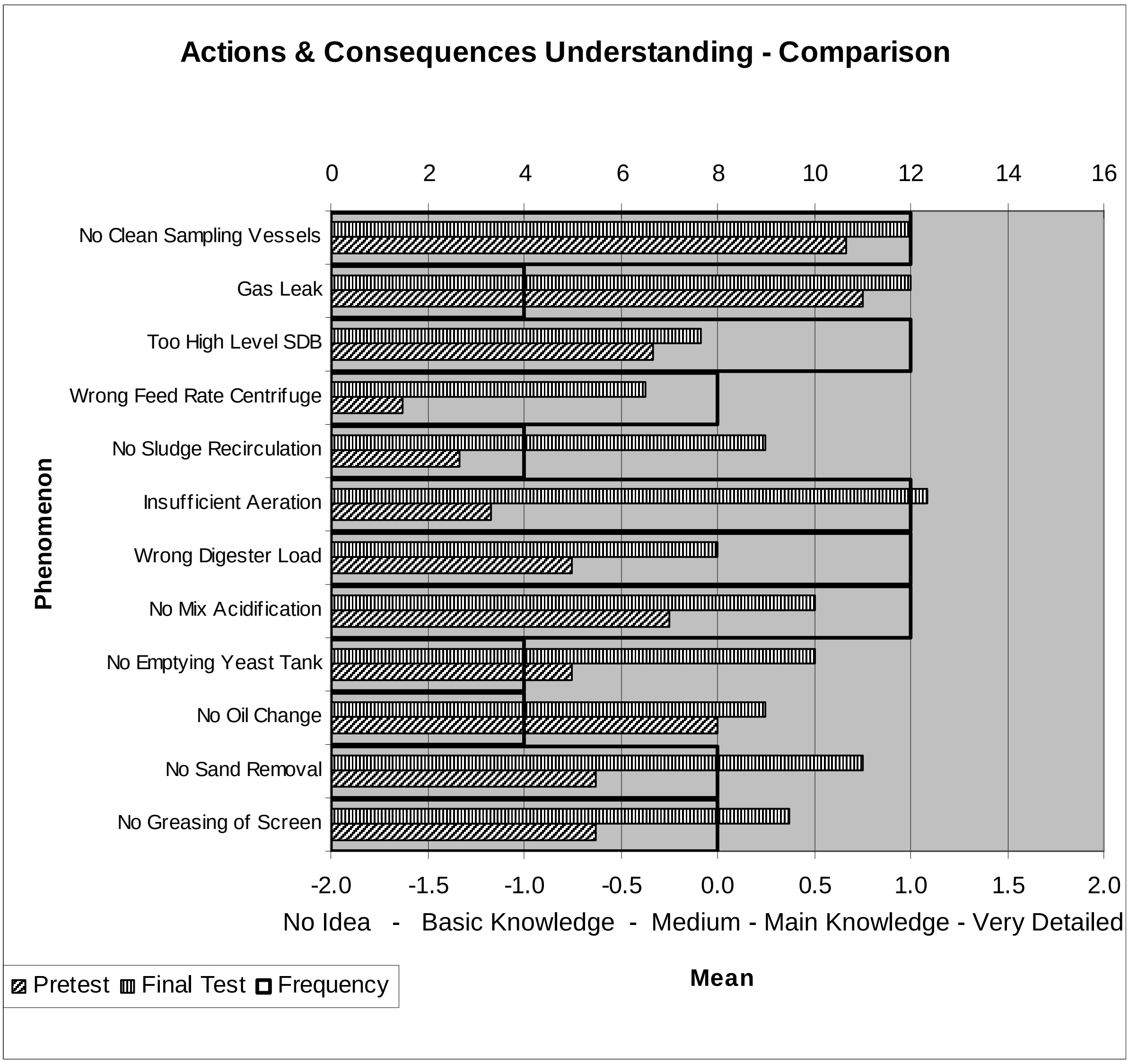


FIGURE 198: PILOT TRAINING – RESULTS ACTIONS AND CONSEQUENCES UNDERSTANDING

In total, the results indicate an increase of the knowledge depth. In the tests before the training, an average value of -0.50 could be determined for the answers quality, that means the worker had a knowledge on the asked processes between “basic” and “medium”. After the training, a value of 0.44 could be determined, that means a result between “medium” and “main knowledge” could be detected. Similarly to the results regarding the process knowledge, the highest increase of understanding could be stated at the topic “activated sludge system”, including sludge recirculation and aeration. Understanding and detail degree of explanation of the negative consequences, if the yeast settling tank is not emptied, were much higher after the training – a rise from -0.75 to 0.50 could be detected. Also remarkable positive changes could be detected for the topics “no sand removal”, ”no greasing of screen” and “wrong feed rate centrifuge”. In the other topics, little changes were found. In the pilot test, also information on the environmental awareness and the possibilities to change it by training should be gained. Therefore the test persons should describe why they are doing their job. Unexpectedly a trend from personal/financial and work place reasons towards environmental and social reasons could be stated. However, the influence of social desirability due to the foreign questioning leader can not be determined in detail.

Feedback

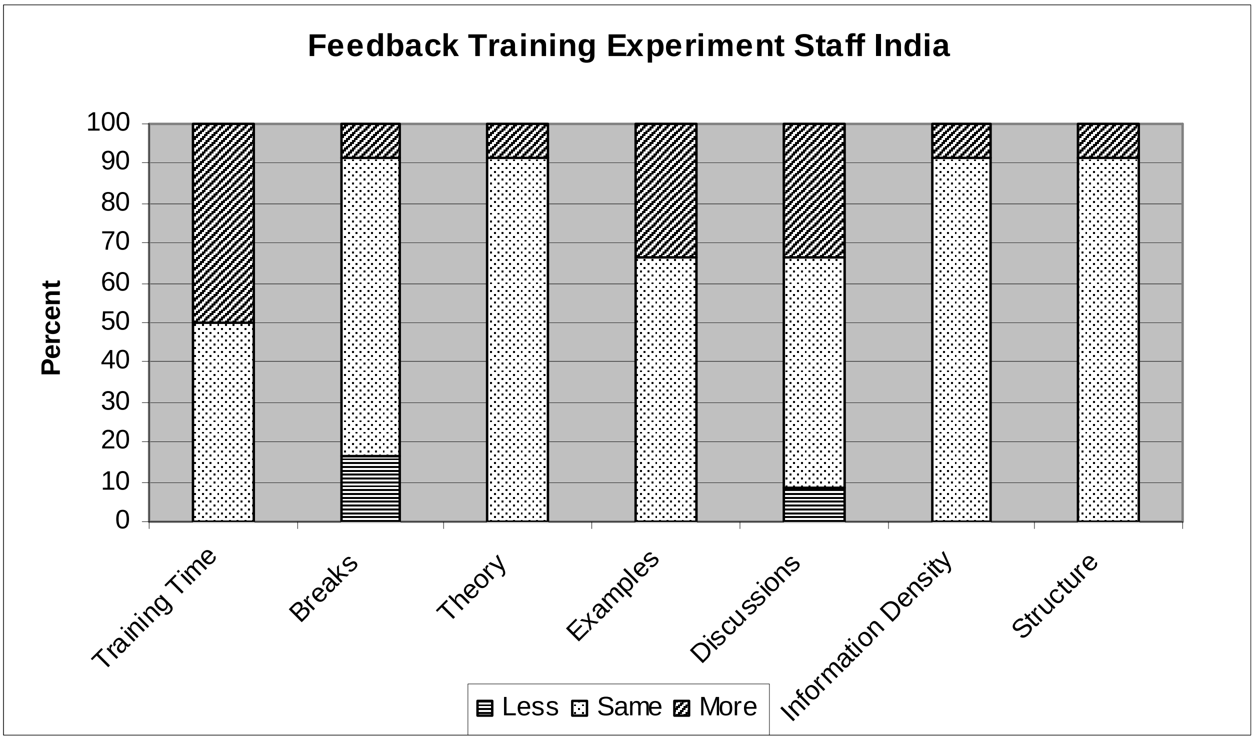


FIGURE 199: PILOT TRAINING - FEEDBACK

Other important information from the pilot trainings is the feedback of the participants. For that reason, the tested persons were asked whether different parameters of the training should be emphasised “more”, “same” or “less” in their opinion (see question 4 final test, appendix D). The results of the feedback show that the participants wanted to learn more – 50% prefer more training time. The distribution and length of breaks, was considered to be okay by most tested persons. Regarding the theoretical contents and illustrating examples a wish for more examples can be detected, although most participants are satisfied with the quantity of theoretical contents. Very interesting is the wish for more discussions, considering the education tradition in India (see chapter 5.2.1). Information density and structure were accepted by the participants.

Almost all test persons described the training positive, ranging from “it was good” to “I feel better” (see question 1 final test, appendix D). Also almost all test persons felt comfortable and think that other workers should also get this type of training (see question 2 final test, appendix D). Problematic is the language. Many workers speak only a little or no English. In the pilot trainings a strong emphasis was set on illustrations, photos and drawings. As already mentioned, translations were carried out by present English speaking staff.

Discussion & Conclusions

The results of the pilot trainings show several important aspects that will be discussed in the following passages.

Fact Knowledge & Motivation

The results of the questionnaire based questionings, as well as the observations of the training group during the pilot trainings show that the existing knowledge is mainly based on observations. The workers know what happens from observations, but very often not why it happens and what consequences this can have for other plant stages. This can be seen on various answers in the tests that were carried out prior to the training and the comparison of the answers on the process questions with the answers on the consequences questions (see figures 197 and 198). Considering the fact that in average the tested persons are in their job since about 10years, this has to be seen critical. Complex machinery equipment like centrifuges was obviously hardly understood - basic biological and chemical processes were also widely unknown before the training. By the training, at least short term improvements could be reached (see figures 197 and 198). Considering the fact that none of the test persons from the training experiment ever received any training on wastewater treatment and that only 4 out of 12 tested persons of the training experiments passed a technical course of an ITI or a polytechnic, the relatively low knowledge base doesn’t surprise. Similarly to the results of the staff questionings (see chapter 7.1.2), a very low awareness and information status about aspects of hygiene and work safety could be confirmed in the pilot trainings. Most workers are not aware about the health risks that are related to the work with activated sludge.

Method & Teacher-Participant Relation

Very interesting is the high motivation of the participants during the trainings, though they were not used to long theoretical work. High concentration was required from the participants also because of the fact that the trainings were carried out in English language with the help of a translator. Initially it was necessary to animate the workers to ask questions, if they don’t understand. This obvious hestitation to ask decreased to certain extend during those trainings, where no engineers were present. In the training where engineers – means superiors – were present, the engineers dominated the conversations. Few workers asked questions. Obviously, nobody wanted to disgrace himself, although the training was kept very vivid with discussions, examples, sketches etc. Confidential talks with workers after the training showed that the practical staff on plant C was very much under pressure from the academic level. Very problematic is obviously the fact that the superior engineers have a relatively low understanding about important plant processes. This showed the questions of the engineers in the training, as well as discussion on the plant operations and the reason for existing problems. Basically, the relatively low knowledge of the academics does not surprise, considering that they were shifted to the STP from other municipal departments. As already mentioned in chapter 5.2.1, Indian society is characterised by strong hierarchies also in the education system. In the workplace the hierarchies are expressed in obedience and respect towards seniors and superiors. Because of the legitimate authority, “…those of lower rank submit willingly to those of higher rank” (Seng and Lim 2004). In that sense, it is not astonishing that the workers initially hesitated to ask questions to the seminar leader, especially if he is from a European university. Once a certain trust was created mainly by using simple and figurative examples, the participants also asked questions. The group size also seems to have an influence on the active participation. In the test training with 22 participants, the activity of several workers was very low, compared to high activity in smaller “trustful” groups.

Media & Material

The visual based concept like the modular poster based concept used for the pilot training tests can basically be seen as a suitable basis for the training of workers in India. The use of attracting colours, pictograms and key words in combination with real photographs are very important for the poster design. The feedback of the workers, as well as the observations during the trainings, shows that the concept is basically well accepted as discussion base. Problematic regarding the material design in general has to be seen the dilemma between structure, comprehensibility and content. A training manual as training guideline and knowledge source parallel to the poster wall would be important. This shows again, that is it very difficult to find the right demand level, so that the training participants are neither over- nor underloaded. However, a complete set, where poster contents and manual contents are well adjusted to each other, has to be seen as a promising solution. As visual information transfer is very important, chart paper, blackboard, overhead slides or Laptop plus beamer are important. In any case, flexible sketches have to be possible. Flexibility is essential for the training of workers. As the observation during the trainings and also the feedback from the tested staff showed (see figure 199), a stronger emphasis on illustrating examples is required. The use of demonstration models would be very useful, although for practical reasons the use of such illustrating material appears only realistic in central training facilities like ITIs for example.

The trainings were carried out in rooms on site of the treatment plants. The training material was installed in paper form on the wall (see figure 39, chapter 6.2.3). After the training, the poster set should remain on the wall and should serve as a reminder. Modern presentation equipment like beamer was not used and would also not have been suitable under the conditions on the plants where the pilot trainings were carried out. The fact that relatively simple means were used as discussion base – posters, sketches, photos - seems to contribute to a relaxing influence on the working staff. Obviously, it gives the signal of an approach to the simple workers level rather than expecting the staff to approach to the academic level. It can be assumed that perfect technical equipment might create a too formal atmosphere. In the feedback tests, no sign could be detected that the participants would have preferred more structure, although this aspect was explicitly asked.

On several inspected STPs and ETPs the need for adequate treatment plant manuals was expressed by the management or staff. Currently, no suitable training manuals are available in India for the workers level. Those very few existing operation manuals are technical sum-ups and target mainly on the engineer level. Western manuals are based on the pre-qualification of western staff, as well as common western plant equipment and processes, which are on a much higher level. This counts also for the training material used within the German wastewater treatment plant neighbourhoods. The results of this study in the previous chapters showed the great differences between India and Germany, both regarding technologies and qualification.

A basic problem is that most of the practical staff doesn’t speak English. Unless the staff is taught at least basic knowledge in English language, effective qualification will be difficult, under the assumption that more and more equipment will also be imported from the world market in future. Summarising above considerations the conclusion has to be drawn that if a basic qualification is not introduced prior to STP specific training, special training material has to be developed with a very strong focus on existing processes and plant equipment in India, using a well developed pedagogical approach.

8 Conclusions

Based on the results and discussions shown in previous chapters, several main aspects can be determined that have a strong influence on the proven operation and maintenance deficits, both in India and China that are shown in the following figure:

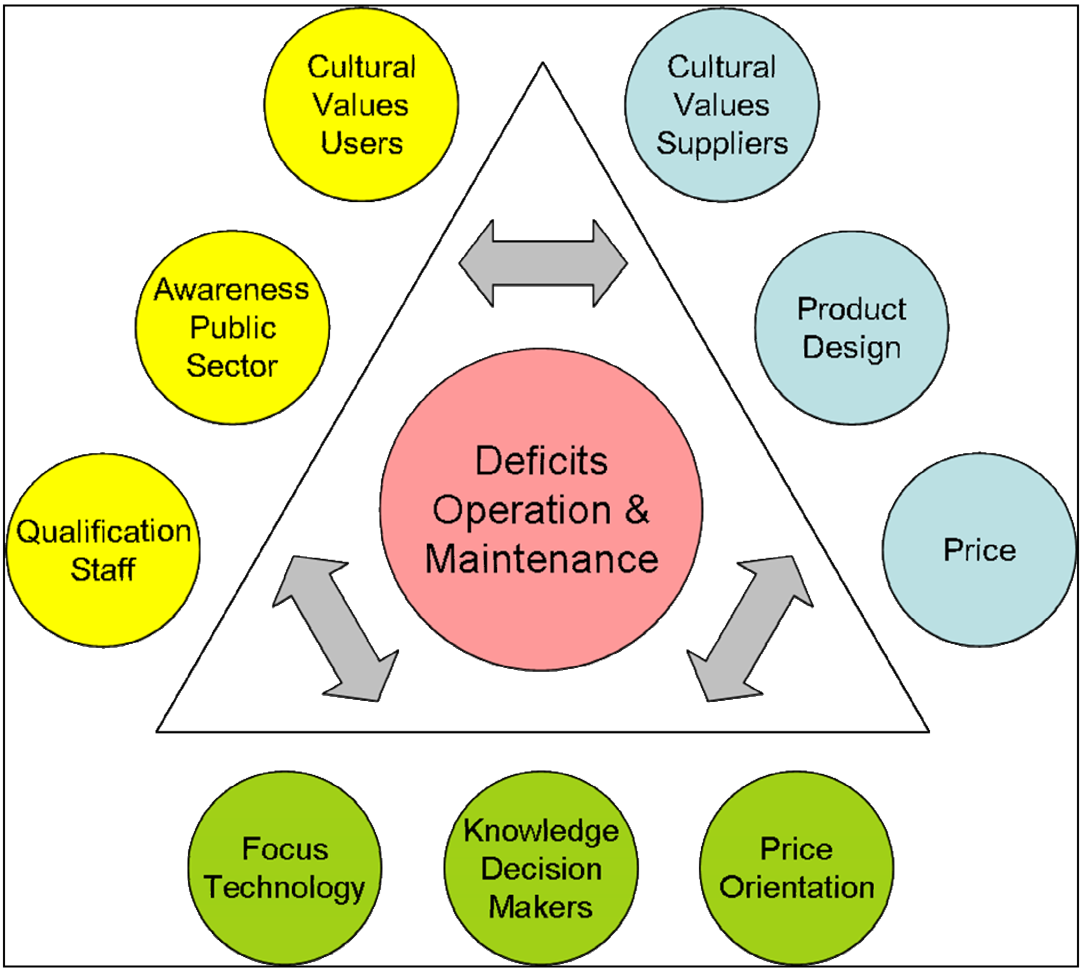


FIGURE 200: IDENTIFIED INFLUENCE FACTORS ON OPERATION AND MAINTENANCE

Gaps were identified between the following three sides that contribute to the problem field:

- Aspects of staff qualification & local culture
- Aspects of technology choice & knowledge on decision making level
- Aspects of product development & culture on supplier side

In the following, the different identified gaps will be presented more in detail and conclusions will be drawn.

8.1 Staff Situation & Technology Choice

8.1.1 India

Based on the results of treatment plant inspections, expert interviews and staff questionings in India, the following conclusions can be drawn that are illustrated in figure 201:

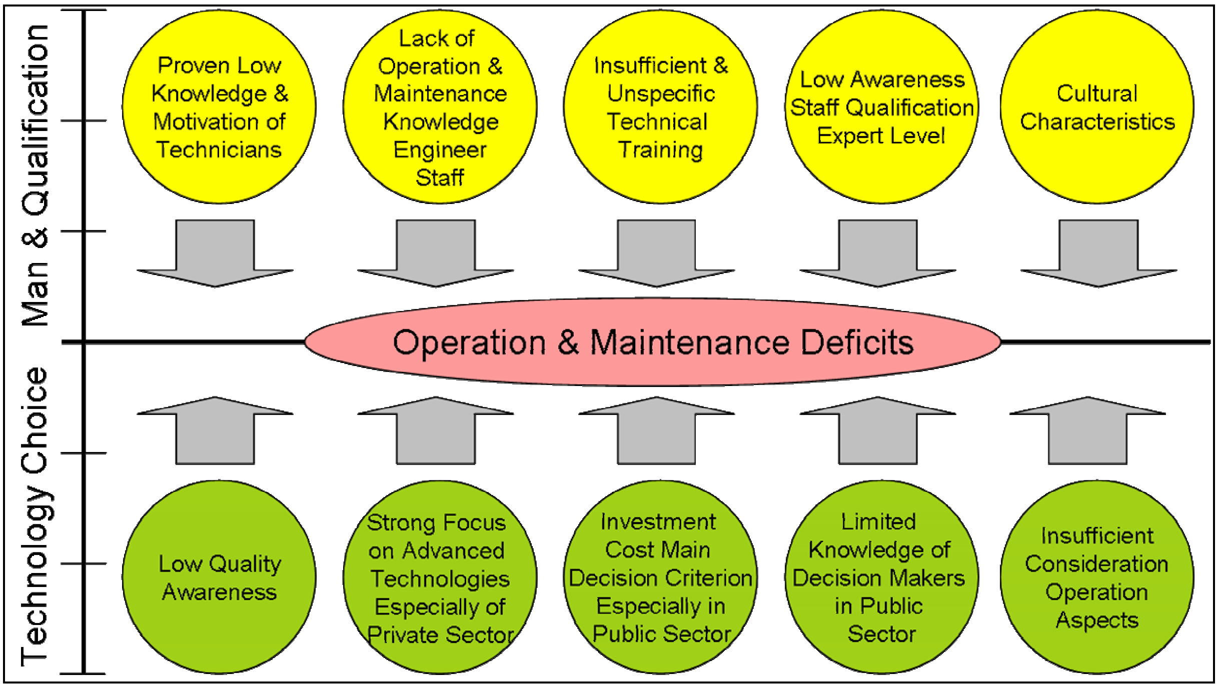


FIGURE 201: DISCREPANCIES BETWEEN TECHNOLOGY PREFERENCES AND MANPOWER IN INDIA

As visible in figure 201, several critical points in Indian wastewater treatment can be identified.

The expert interviews among Indian experts show a strong preference for advanced and innovative technical solutions especially for urban areas (see figure 85, chapter 7.1.3). Activated sludge process is considered by most Indian experts as suitable technology for urban areas in India. Especially the private sector is a driving force for more advanced technologies. Regarding membrane technology, the picture is mixed, whereas the technical advantages are appreciated, especially in the private sector (see figure 88, chapter 7.1.3). Due to several reasons, the conclusion has to be drawn that quality awareness is relatively low. In average, investment costs are of higher importance for Indian experts than manufacturing quality, as the expert interviews show (see also figure 85, chapter 7.1.3). Interviewed experts state a moderate will of decision makers to invest in quality (see figure 86, chapter 7.1.3). The fact that the interviewed experts express a relatively low preference for German equipment and the very high relevance of the high costs (see figure 86, chapter 7.1.3) leads also to the conclusion that product quality is a minor decision criterion in India. Also the conclusion has to be drawn that long term cost calculations play a minor role compared to investment costs that are by far the most important decision criterion (see figure 85, chapter 7.1.3).

The results of the plant inspections presented in chapter 7.1.1 and the staff questionings, presented in chapter 7.1.2, show deficits in maintenance, staff qualification and motivation. As visible in figures 77, 78 and 79 (chapter 7.1.2), the existing qualification is very low, especially compared to the situation in Germany (see chapter 7.3.2). Critical has to be seen the fact that in average, more than 46% of the practical staff on Indian STPs is unskilled workers (see also figure 73, chapter 7.1.2). Considering that even skilled mechanics or electricians (mainly ITI trained) don’t know about very basic subjects of their field (see analysis chapter 7.1.2), the conclusion can be drawn that the knowledge transmitted in the existing vocational training system is far behind German standard. This shows also a look into the syllabus of relevant ITI courses, as well as the training equipment in ITIs. Staff questionings and expert interviews show that no training opportunities exist for practical plant staff specifically for wastewater treatment.

Several reasons lead to the conclusion that awareness and motivation are very low on Indian STPs. From the results of staff questionings (see chapter 7.1.2) and the expert interviews with plant managers, as well as estimations of experts from science, administration and private sector (see figure 87, chapter 7.1.2) the conclusion has to be drawn that motivation and awareness are very low, especially in STPs of the public sector. Not uncommon seems to be the practice in municipalities to “punish” employees by shifting them to the STP. As corrosion freeness and cleanliness are indicators for maintenance works, the relatively low index values of Indian equipment compared to German equipment at these parameters (see figures 44 and 53, chapter 7.1.1, figures 151 and 160, chapter 7.3.1 and figure 192, chapter 7.4), also leads to the conclusion of low awareness on Indian STPs. Another important reason for the low staff motivation has to be seen in extremely bad work conditions, low image and very low salaries (see chapter 7.1.2). In average, the interviewed experts also state a relatively low to very low motivation of the staff on STPs (see figure 87, chapter 7.1.3).

Based on the results of the expert interviews, the conclusion can be drawn that decision makers in the public sector are hardly aware of manpower qualification, whereas scientists and consultants are much more aware of the existing qualification deficits (see figure 88, chapter 7.1.3). Interviewed experts from science and the private sector consider the qualification of practical staff to be relatively low and see a high need for staff qualification. Easy operation is of relatively low importance compared to other aspects, like costs, or manufacturing quality, which leads to the conclusion that operational aspects play a very minor role also in decision processes pro or con technical solutions (see also figure 85, chapter 7.1.3).

A limited knowledge of decision makers about technical processes can be assumed based on the estimations of interviewed experts from science and the private sector, as well as discussions with administration staff (see also figure 88, chapter 7.1.3).

Figure 202 shows the conclusions that can be drawn from the results of technology analysis (chapter 7.1.1), staff analysis (chapter 7.1.2) and expert interviews (chapter 7.1.3) regarding technology degree and treatment plant staff.

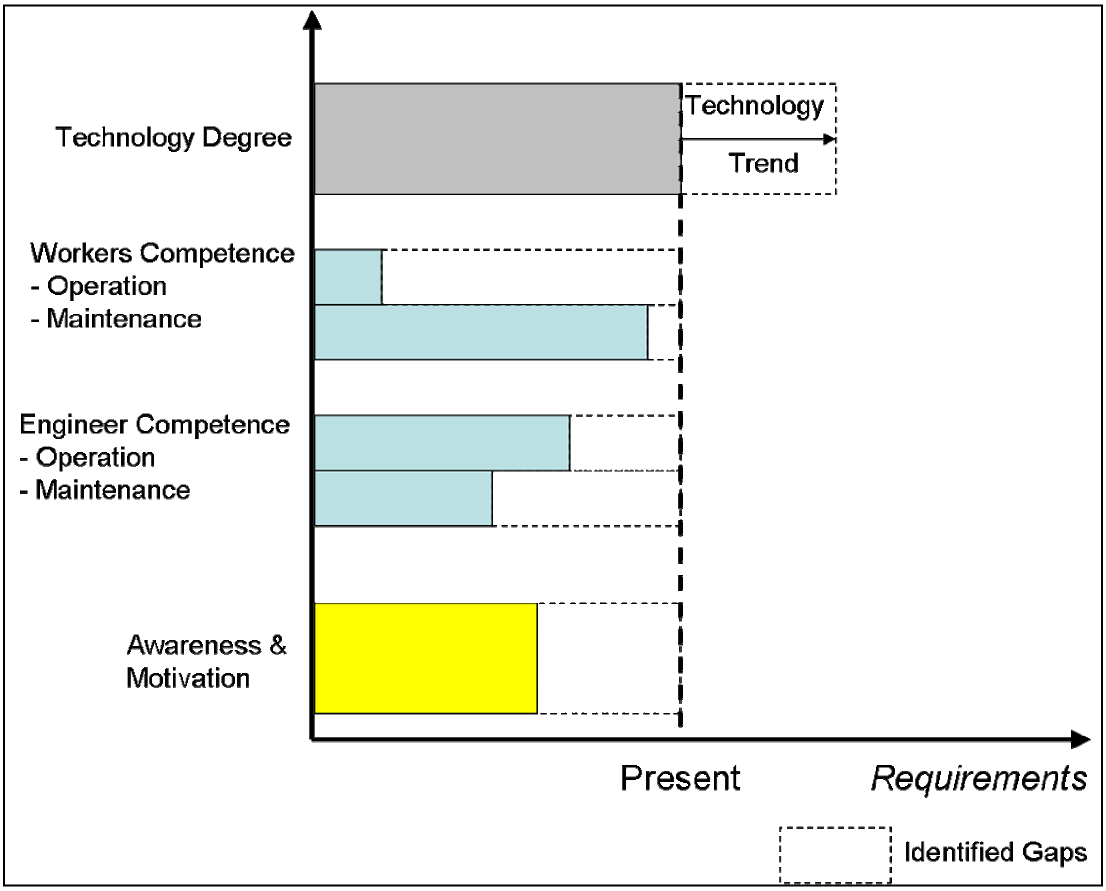


FIGURE 202: RELATIVE COMPARISON TECHNOLOGY DEGREE, QUALIFICATION AND AWARENESS IN INDIA

The analysis of the existing treatment technology on Indian STPs shows a relatively low technology degree compared to China and Germany (see chapter 7.1.1 and 7.3.1). Indian equipment is characterised by simple and stable mechanical constructions and a very low degree of automation compared to Germany. Considering the results of the staff questionings regarding education background and professional knowledge in chapter 7.1.2, as well as observations of repairs on STPs, it can be assumed that for most maintenance works of Indian standard equipment, the existing skills of technicians and workers are sufficient. This also indicates the fact that hardly any severely damaged Indian equipment that was obviously out of service for a longer period of time was found in more than 30 inspected treatment plants. Most repairs can be carried by the staff due to the low complexity of most Indian standard equipment.

Regarding operation specific knowledge, very low knowledge was detected, both in the staff questionings (see chapter 7.1.2) and the pilot training (see chapter 7.5). Although working for many years in an activated sludge or an extended aeration plant, many staff members don't know very basics of the process. Even elemental parameters, like BOD are hardly known (see figure 79, chapter 7.1.2). Important and obvious elements, like weir edges of clarifiers, are extremely dirty in some cases (see figure 45, chapter 7.1.1) and short cut streams due to concrete flaking of weirs are obviously not recognised. The fact that maintenance schedules exist in only about half of the inspected plants (see figure 70, chapter 7.1.1) and that for maintenance large differences exist regarding the time intervals (see table 30, chapter 7.1.1), leads to the conclusion that knowledge deficits on maintenance exist on engineer and management level.

It can be concluded that the hierarchical work structure on STPs is a major factor for the identified problem fields. Figure 203 illustrates basic relations that were identified.

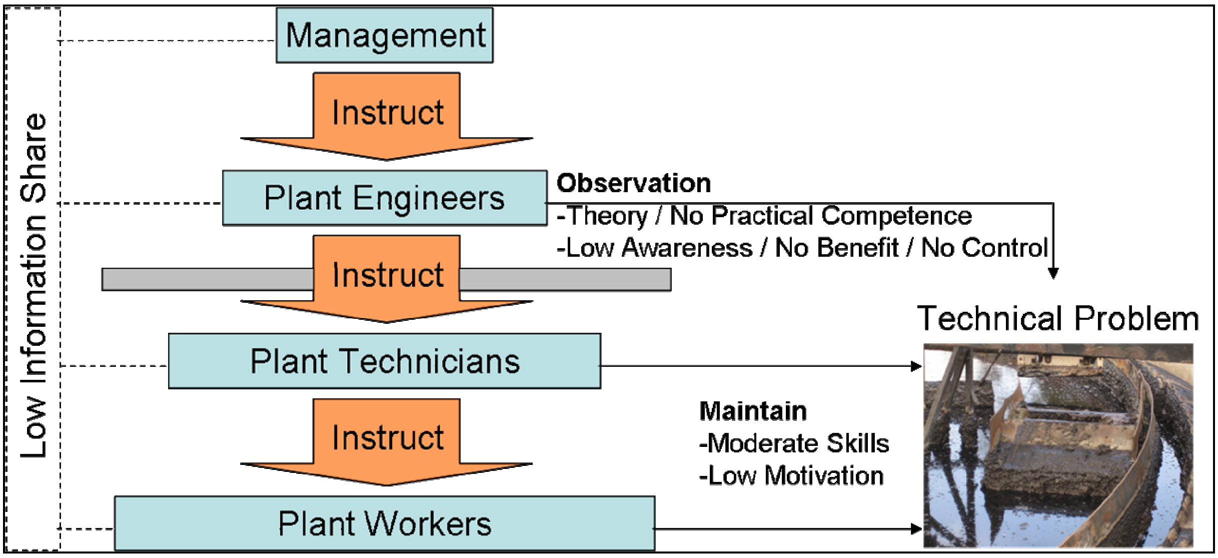


FIGURE 203: HIERARCHICAL WORK STRUCTURE ON STPS IN INDIA

The results of the expert interviews with the plant management, as well as the experience from the pilot trainings show very strong hierarchies – up to seven hierarchy levels were detected in big STPs. Especially in bigger plants, operation control is carried out by engineers who give order to the forman and technicians. In many cases, plant operations are directed to foreman during absence of engineer staff. Very definite functions and responsibility fields are characteristic for the work on Indian STPs. The own function is fulfilled, but not exceeded. Responsibility fields of others are not entered and if possible, responsibilities are handed over to the superior. The reasons have to be seen in the Indian cast system (see chapter 5.2.1). Other than in German vocational training system, decision making competence is hardly transmitted in the Indian vocational education system. This explains the relatively low degree of self initiative of practical plant staff.

The denial of practical work of engineers has to be seen as a major reason for the very low awareness of engineers about maintenance aspects. Discussions with practical staff in the pilot training, as well as the fact that during the trainings where academic superiors were present, the participation of the practical staff was very low (see chapter 7.5), show this vast gap. This corresponds to other studies in literature that state a denial of practical work of the academic level and a strong focus on theoretical qualification (see chapter 5.2.1).

The following conclusions can be drawn:

1) Although qualification deficits of the practical staff exist in technical fields that are relevant for maintenance, the main reason for the proven maintenance deficits has to be seen in low awareness and knowledge about practical technical problems on the engineer level.

2) The reason for operational problems has to be seen, both in extremely low operation knowledge of practical staff and limited operation knowledge of plant engineers.

3) A major problem, both regarding operation and maintenance, is an extremely low work motivation. Main reasons have to be seen in the low public image of wastewater treatment, very bad work conditions, very low salaries and lack of incentives.

4) For repair and maintenance of modern Indian or imported equipment on German level, the existing skills of practical staff are by far not sufficient.

5) With the existing trend and need for more technical solutions, severe operation and maintenance problems are unavoidable, if no action is taken, both in the education of engineers and practical staff.

6) Measures of an improvement of the maintenance situation primarily have to target on awareness creation of the engineer staff and in second line on the practical staff.

7) A change towards increased knowledge share and information flows between all staff groups, like in German STPs should be initiated, but appears very difficult in practice. Even if introduced from external side, the strong barrier between the staff groups will be a strong obstacle.

8) Due to the education tradition (see chapter 5.2.1) and above mentioned hierarchies, an extension of the competence field of practical staff towards more decision making competence, like it is the target of German vocational education (see chapter 5.2.3), appears very difficult, especially in the public sector.

9) The implementation of an alternative qualification platform, like the German concept of “wastewater treatment plant neighbourhoods” can be successful for an increase of operation and maintenance knowledge on engineer level, but most probably not on practical staff level.

8.1.2 China

For the situation in China, the following conclusions can be drawn, based on the plant inspections, staff questioning and expert interviews in China.

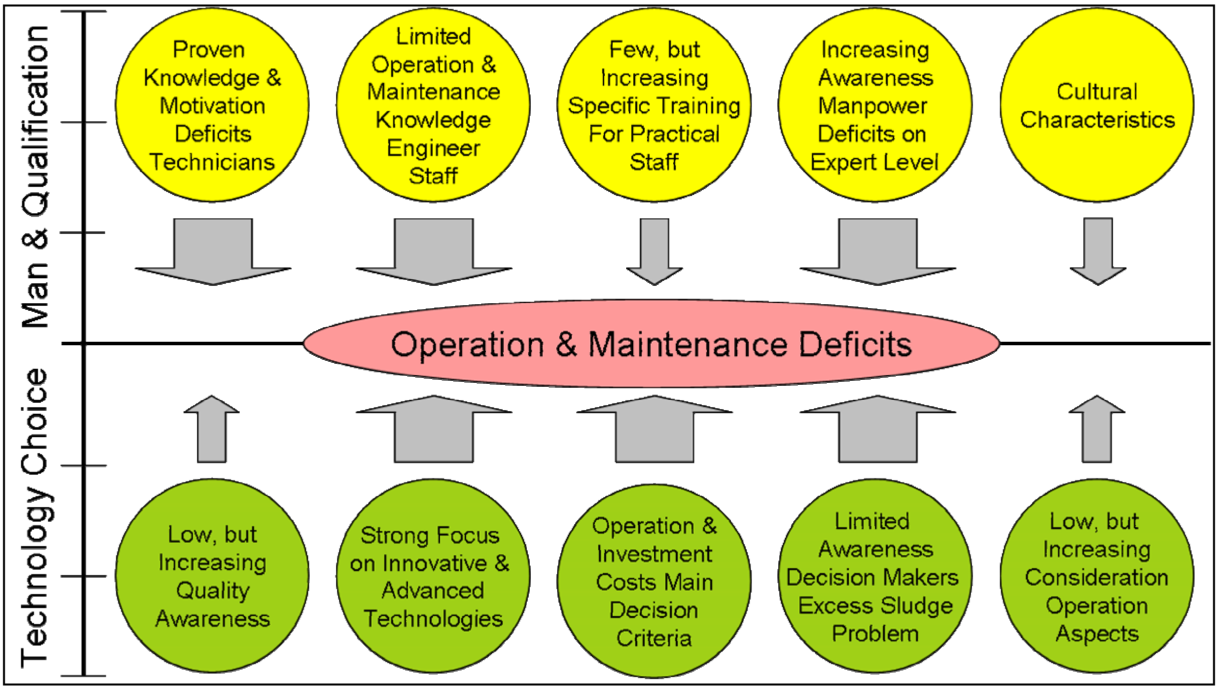


FIGURE 204: DISCREPANCIES BETWEEN TECHNOLOGY PREFERENCES AND MANPOWER IN CHINA

Similar to India, a focus on innovation and advanced technical solutions for urban areas has to be stated, as the analysis of the expert interviews shows (see figure 140, chapter 7.2.3). Although innovation is emphasised even more by Chinese experts, a slightly lower preference for high-tech can be concluded (see also figure 85, chapter 7.1.3).

Due to the results of several question fields in the expert interviews, the conclusion can be drawn that a higher quality awareness exists among Chinese experts than among Indian experts. As visible in figure 141, chapter 7.2.3, Chinese experts have a higher preference for German products than Indian experts (see figure 86, chapter 7.1.3), whereas the quality of Chinese equipment is seen critically. Expert interviews with plant managers and other Chinese experts lead to the conclusion, that manufacturing quality is a more important factor than in India (see figure 140, chapter 7.2.3). Though, operation and investment costs are important decision criteria.

The analysis of the plant inspections (chapter 7.2.1) showed that maintenance deficits exist and that very often imported equipment can't be repaired by the technical staff. Cleanliness of technical machinery equipment is on a much lower level than on German plants (see figure 107, chapter 7.2.1 and figure 192, chapter 7.4). Problematic is that especially important details of machinery equipment are not properly maintained – dirt is accumulating, which is increasing the failure risk (see figure 108, chapter 7.2.1). Also corrosion protection measures of normal steel surfaces are insufficient (see figure 109, chapter 7.2.1). Repair works are carried out in an improvised way or the problem is "surrounded". In above considerations, the fact has to be considered that more than 60% of the inspected machinery equipment is German equipment (see figure 105, chapter 7.2.1). Based on above considerations, the conclusion has to be drawn that both awareness for maintenance works, as well as the technical skills are not sufficient for modern treatment plant equipment. Also observations of damaged and removed German equipment, repair situations and discussions with Chinese plant managers and German Service technicians lead to this conclusion. The comparison of the results of the staff questionings in China and Germany contributes to this conclusion, too (see chapter 7.2.2 and 7.3.2). An important reason has to be seen in unsuitable maintenance manuals of western equipment in English language that most technicians can't read.

From the results of the expert interviews the conclusion can be drawn that on expert level, operation and maintenance problems, as well as the deficits in the staff qualification are more understood than in India. Several aspects lead to this conclusion: First of all, Chinese experts see a high need of knowledge flow from western experts (see figure 141, chapter 7.2.3). Both existing qualification and qualification system for treatment plant staff are seen very critical (see figure 142, chapter 7.2.3). The results of the expert interviews indicate that operational considerations are of higher relevance than in India (see chapter 7.2.3).

Other than in India, first steps to reduce the existing deficits on the manpower side can be observed in China. In Qingdao, a training centre was developed, where treatment plant staff of plants that were co-financed by KFW bank was trained from 2001 until 2006, financed by KFW bank (see also chapter 7.2.4). In 2007, a Sino-German training centre for treatment plant staff was founded in Beijing with participation of public education institutions and a control authority (more information will be given in chapter 9.1).

Figure 205 shows the conclusions that can be drawn from the results of technology analysis (chapter 7.2.1), staff analysis (chapter 7.2.2) and expert interviews (chapter 7.2.3) with respect to technology degree and treatment plant staff.

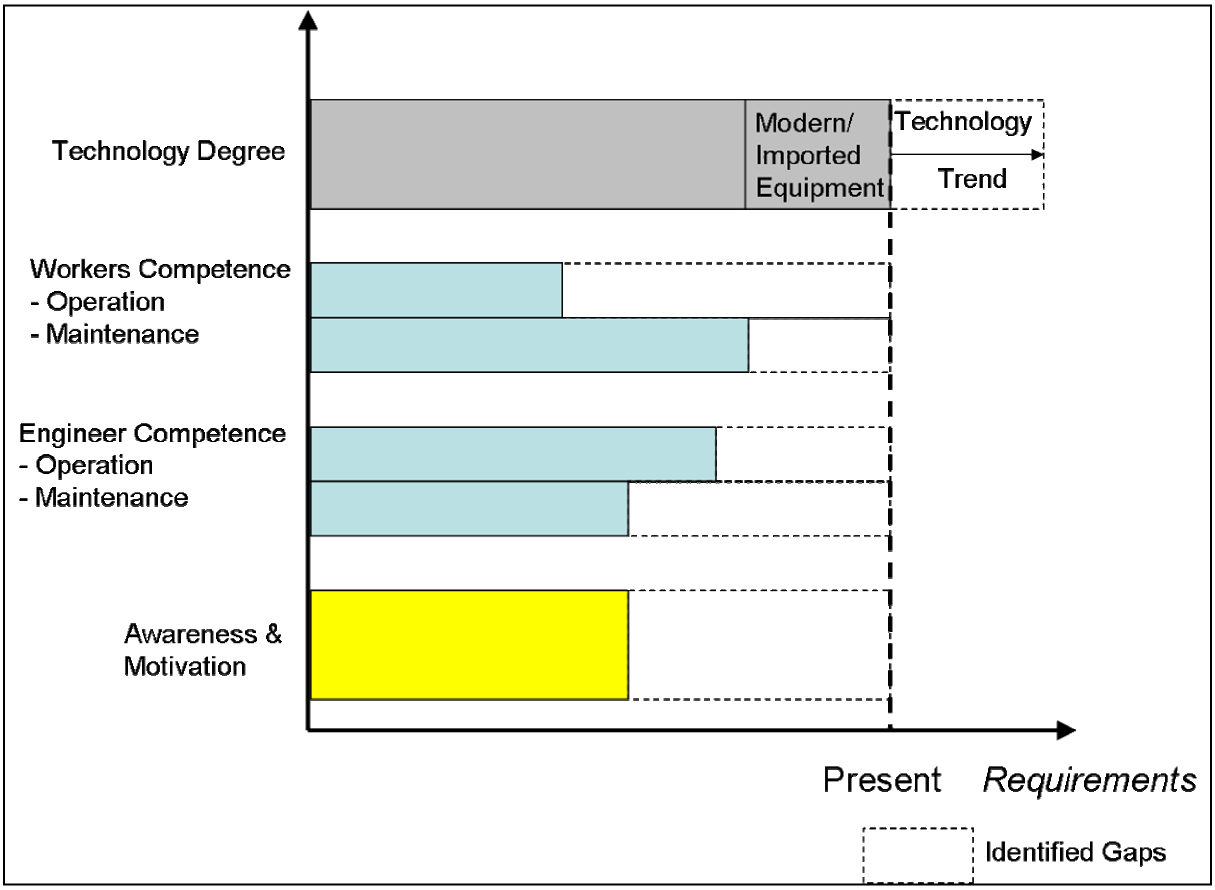


FIGURE 205: RELATIVE COMPARISON TECHNOLOGY DEGREE, QUALIFICATION AND AWARENESS IN CHINA

As already mentioned, a high proportion of European equipment could be found on the inspected plants (see figure 105, chapter 7.2.1), which leads to a relatively high technology degree in average (see figure 113, chapter 7.2.1), compared to India. Also in plants that were not co-financed by KFW-bank, many European components are used. The status of structural, machinery and control equipment in China was shown in detail in chapter 7.2.1.

The results of the staff questionings show that basic operational understanding exists among the practical staff that is on a higher level than in India, but still lower than in Germany (see figure 133, chapter 7.2.2, figure 79, chapter 7.1.2 and figure 182, chapter 7.3.2). The results of the staff questionings indicate that also the knowledge in the electrical and mechanical field is on a much higher level than in India (see figure 77, chapter 7.1.2 and figure 131, chapter 7.2.2). As observed damaged equipment on inspected Chinese plants was mainly imported equipment from Europe, the conclusion can be drawn that skills demand of Chinese equipment and existing qualification of technicians are on a similar level. Also the questioned treatment plant staff reported about problems with foreign equipment (see figure 126, chapter 7.2.1).

Although the operational skills of the academic staff were not tested in this study, expert interviews with Chinese plant managers and estimations of representatives of the German development cooperation lead to the conclusion of a lack of work relevant operational skills on engineer level. Also a report of SEPA about operational problems of treatment plants indicates a lack of competence for treatment plant operation on the engineer level (see chapter 7.2.4). The fact that in several inspected plants, no proper maintenance planning exist (see figure 125, chapter 7.2.1), also leads to the conclusion of limited awareness about maintenance aspects on the engineer level.

Discussions with plant managers and German service technicians in China show a relatively low motivation of the practical staff, whereas the high proportion of degree holders in practical positions also has to be seen as one reason (see also figure 130, chapter 7.2.2). The results of the staff questionings also indicate a lower work motivation than on German STPs (see figure 135, chapter 7.2.2 and figure 184, chapter 7.3.2).

Similarly like in India, interviews with plant management and staff questionings show that Chinese employees in treatment plants have a very definite field of responsibility. Responsibility fields of other colleagues are not entered. Although also in Chinese society, traditionally strong hierarchies and a low image of practical work exists (see chapter 5.2.2), a higher sense of community, as well as less hierarchy levels than in India could be stated on the inspected plants. Therefore, the conclusion can be drawn, that improvements of the staff qualification and awareness can be achieved easier than in India.

Based on above considerations, the following conclusions can be drawn:

1) Insufficient knowledge about plant operation, both on engineer and technician level is a main reason for operational problems.

2) The reasons for maintenance problems have to be seen, both in qualification deficits on technician level, compared to the requirements of imported equipment, and qualification deficits of the engineer staff regarding maintenance planning.

3) Staff qualification measures for technicians have to concentrate on skills for maintenance of high automated equipment.

4) Low motivation, as well as low awareness, are main reasons for existing operation and maintenance problems.

5) Alternative qualification measures, like the development of “wastewater treatment plant neighbourhoods” similarly like in Germany, (see chapter 5.2.3) is strongly recommended. Other than in India, the successful introduction of the concept, both for the engineer and technician level is realistic.

8.2 Technology Suppliers & Local Technology Choice

Figure 206 shows different aspects that contribute to problems in the realisation of projects, as well as operation & maintenance deficicts, both from supplier and local decision maker side. The results of this study show very similar critical aspects that lead to difficulties, both in project realisation and operation & maintenance in India and China.

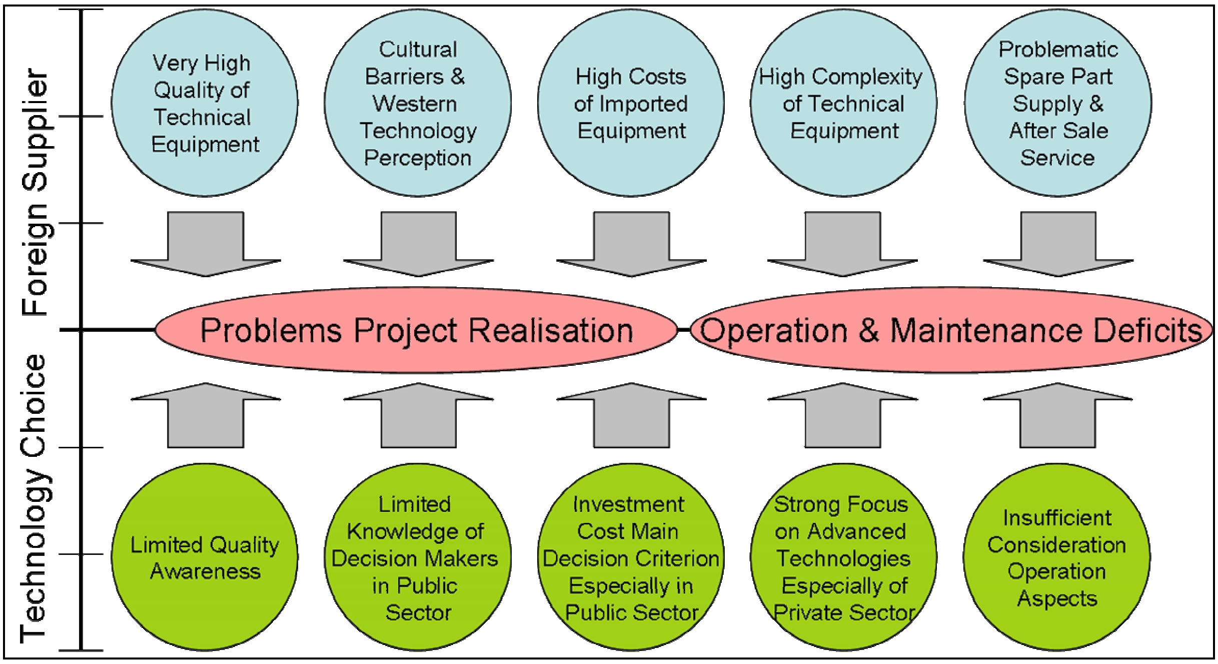


FIGURE 206: DISCREPANCIES BETWEEN LOCAL TECHNOLOGY PREFERENCES AND EQUIPMENT SUPPLY

India

Although currently very few imported treatment plant equipment from Germany exists in India, the conclusion has to be drawn that the high complexity of German equipment can be problematic, considering the existing education level that was determined based on the results of staff questionings and pilot trainings in this study (see chapter 7.1.2 and 7.5). It can be assumed that especially for equipment with a high automation degree, maintenance and repair works will be very difficult for normal ITI trained electricians (see also figures 195 and 196, chapter 7.4). For the repair of modern mechanical or electromechanical equipment on western standard, also severe doubts are indicated, whether the existing skills of STP staff will be sufficient, if the demand for the repair goes beyond common standard practices in India.

It can be assumed that normal mechanics will not be able to repair a modern decanter centrifuge, as the results of the pilot trainings indicate (see chapter 7.5). It can be assumed that above deficits can be compensated to a certain extent by well developed operation and maintenance manuals. Problematic is the fact that in many cases, manuals are designed on the assumption of western staff skills. The pilot trainings, as well as the staff questionings carried out in this study show, that due to lack of English skills also among electricians and mechanics, western manuals have to focus very strong on visualisation – both in India and China.

Currently, spare part supply is not seen as a problem on Indian plants (see figure 71, chapter 7.1.1 and figure 80, chapter 7.1.2) due to almost exclusive use of Indian equipment (see figures 51 and 62, chapter 7.1.1). Due to the trend for more technical and innovative solutions (see figure 85, chapter 7.1.3) and the good market perspective also for German equipment suppliers, spare part supply and after sale service will become an important topic. From reports with plant engineers, as well as reports about damaged imported equipment, the conclusion has to be drawn that the importance of technical support and spare part supply at reasonable conditions is not yet understood by many western suppliers.

Although the brand “Germany” is well appreciated, the high costs of German equipment stand in very strong opposition to the extreme focus on investment costs in India. The conclusion has to be drawn, that compromises on quality and costs on the supplier side are unavoidable. Based on the results of the expert interviews with Indian experts a limited knowledge among Indian decision makers has to be concluded (see also figure 88, chapter 7.1.3). Also discussions with consultants indicate that the decision making level very often has difficulties to evaluate aspects of quality and efficiency.

From the results of the western expert interviews in this study (see chapter 7.3.3), as well as the considerations on intercultural aspects (see chapter 5.3), the conclusion can be drawn that cultural barriers exist in minor dimension on engineer and academic level in general. At the western side, superior positions could be detected in some interviews, whereas the Indian side considers relations with German partners mainly positive (see also figure 86, chapter 7.1.3).

China

The comparison of German machinery equipment operated in Germany and German machinery equipment operated in China (see figure 192, chapter 7.4), as well as observations about damaged and un-repaired German equipment on Chinese plants show, that equipment complexity and available skills don't match (see also figure 205). Based on expert interviews with plant managers and staff, the conclusion has to be drawn that a major reason for the difficulties has to be seen both in unsuitable maintenance manuals and poor after sale service (see also chapter 7.2.4). As the staff questionings showed, hardly any technical staff speaks English. On the management or engineer level, English language skills are on a very low level, if existing. Therefore, common English manuals of western equipment can't fulfil their purpose. The fact that a German company engages successfully in the market field "spare part supply for foreign equipment" shows the dimension of the problem Chinese plant managers are facing with spare parts supply.

Similar to India, the high costs of German equipment are a major problem, as also Chinese experts focus very strongly on costs. Other than in India, operation costs and manufacturing quality are more relevant in China, which can be concluded from the results of the expert interviews (see figure 140, chapter 7.2.3). Interviewed plant managers prefer German equipment for important equipment like double-piston blowers, as interviews on treatment plants showed. For standard mechanical or electromechanical equipment, like screening systems, for example, the quality of Chinese equipment is considered to be sufficient in most cases. An increasing quality of Chinese machinery equipment is reported by several plant managers. Interviewed Chinese experts from the private sector consider local equipment to be only of moderate quality (see figures 141 and 143, chapter 7.2.3), whereas the fact has to be considered that the test person are working in Chinese subsidiaries of German companies. Based on above considerations, an increasing awareness for quality aspects and more long-term considerations can be concluded in China, compared to India.

Excess sludge has to be seen as a very big problem in China. The topic "excess sludge" was discussed in detail in chapter 7.2.4 (see also figures 137 and 139, chapter 7.2.1). The conclusion has to be drawn that, both among interviewed experts and decision makers, the awareness about dimension and solutions for the excess sludge problem, is still low, but increasing. Potential suppliers of suitable solutions are well advised not to miss this upcoming market field.

8.3 Technology Design Principles

As the results of the expert interviews show, very different positions exist among experts from India, China and Germany regarding preferences for treatment technologies. A major difference is that western experts consider mainly medium level technology to be suitable for urban areas in developing and newly industrialising countries, whereas local experts in India and China favour mainly more technical solutions (see figure 85, chapter 7.1.3, figure 140, chapter 7.2.3 and figure 188, chapter 7.3.3).

In the following, major conclusions for the technology choice are drawn. It is obvious that the weight of the different aspects depends on the respective application case in the respective countries.

Innovative Technologies, but no High-Tech

Based on the results of the data analysis of the data gained in India and China, it can be concluded that wastewater treatment technology for urban areas should be **innovative, but sensitive equipment should be avoided.**

With increasing urbanisation, lack of space and increasing water scarcity, solutions are required that are characterised by small footprint and the potential reuse of treated water. Especially in India, aspects of reuse are very important, as also interviewed experts in India state. Also the expert positions in India and China show this very clearly (see figure 85, chapter 7.1.3 and figure 140, chapter 7.2.3). However, high-tech solutions are only recommended for very special applications in industry, if highly skilled maintenance staff is available. Comparing the status of machinery equipment in India (figure 53, chapter 7.1.1) with the status of German machinery equipment (figure 160, chapter 7.3.1), cleanliness of Indian machinery equipment is much lower than on German plants, which is a sign for much less maintenance works. Therefore, an increased risk of technical problems for sensitive high-tech equipment exists. Similar is the situation of Chinese machinery equipment. Although the technical level of the machinery equipment is much higher than in India, especially detail cleanliness is a problematic point (see figures 107 and 108, chapter

7.2.1), which is also a sign for maintenance deficits. The comparison of German screening systems operated in China and German screening systems operated in Germany shows this, too (see figure 192, chapter 7.4). As already mentioned, repairs are very often carried out in a very improvised way, which is very problematic, in case of electrical aggregates (see figure109, chapter 7.2.1). Due to the fact that most mechanical equipment on Indian plants is installed outside, without roofing, dust and dirt can easily enter connection points of moving parts. Windows and doors of control rooms are normally open. Via ventilators, fine dust particles are distributed everywhere in the room, which can be problematic for sensitive control equipment.

High Stability & Corrosion Resistance

Mainly due to the above mentioned reasons, it can be concluded that treatment plant equipment has to be **very stable**, as well as **very corrosion resistant,** also due to extreme climatic conditions, like high temperatures and high humidity.

As visible in table 30 (chapter 7.1.1), maintenance intervals vary in a great range for certain equipment types on Indian plants. A typical example is oil change of gear boxes and pumps, where the information regarding the intervals given by the plant management range between “2-4months”, “2.000work hours” and “never”. Preventive maintenance is the biggest problem – bearings are changed in intervals between 2.5years and never (see table 30, chapter 7.1.1). In less than 50% of the inspected plants in India maintenance schedules are used for maintenance planning (see figure 70, chapter 7.1.1). As shown in figure 125 (chapter 7.2.1), also in China only 50% of the plants use schedules for maintenance planning. It is therefore strongly recommended to install leakage detection sensors, warning signals and other safety instruments, in order to avoid unforeseen total equipment damages due to improper maintenance works.

As the analysis of the machinery equipment in chapter 7.1.1 on Indian plants showed, corrosion freeness is less than in Germany with great variations from plant to plant (see figures 54, 55, 57 and 58, chapter 7.1.1). This shows that also maintenance of metal surfaces is basically problematic, so that stainless steel equipment is strongly recommended. Problematic is that stainless steel means significantly higher investment costs, especially if equipment is constructed very stable with higher material thicknesses. The increasing proportion of stainless steel equipment – both imported and locally manufactured - on Chinese plants indicates that the long-term advantages are more and more recognised. In India, a similar trend can be seen, at least for screening systems. Machinery equipment that is characterised by high robustness and high corrosion resistance can compensate to a certain extent maintenance deficits.

Easy Operation & Maintenance

Based on the results of the staff questionings the conclusion has to be drawn that **easy operation and maintenance** are equally important for the design of treatment plant equipment in India.

The basic problem of lack of awareness on the engineer level that was shown in chapter 8.1.1 is another reason, why simplicity has to be a major design principle. Considering the low knowledge of practical staff about the principles of activated sludge process that could be stated especially in the pilot trainings (see chapter 7.5), and the fact that even the meaning of a basic parameter, like “BOD”, is hardly known, (see figure 79, chapter 7.1.3), it has to be concluded that automated treatment systems that are common in Europe hardly can be operated by the existing staff on STPs in India. Although operation problems can be reduced to great extent by automation, solutions have to be found, how repairs and maintenance are assured.

As the direct comparison of the technology level of control panels shows (see figure 195 and 196, chapter 7.4), Indian control equipment is far behind China and Germany. The pilot trainings have shown that many technicians don’t even know the function principle of a decanter centrifuge, and if, then the information background is extremely low (see figures 197 and 198, chapter 7.5). Considering the results of the staff questionings regarding the electrical and mechanical field (see also figure 77, chapter 7.1.2) and the expert estimations both from Indian and western experts regarding the qualification of practical staff (see figures 87, chapter 7.1.3 and figure 190, chapter 7.3.3) it has to be concluded that it is very doubtful, how modern mechanical and control equipment, like it is used on western plants, should be maintained by the existing staff on Indian STPs (see also figure 202, chapter 8.1.1).

Although the qualification of Chinese plant staff is on a higher level compared to India, highly automated equipment should be avoided outside major development centres in China. Qualified automation experts are rare in China as they get better opportunities in industry (information of interviewed plant manager).

Low Spare Parts Requirements & Simple Components

The results of the interviews especially with plant managers, discussions with service technicians and plant inspections in China, lead to the conclusion that imported technical equipment has to require **as less spare parts as possible**. Although this should be a task for any kind of technical equipment, it is of special importance for foreign equipment.

As shown in figure 105 (chapter 7.2.1), almost 70% of the inspected machinery equipment on Chinese plants is from Europe or the US. In the plant inspections it was found that very few spare parts of foreign equipment are kept in stock on site long-term. As shown in chapter 7.2.1 important wearing parts for foreign equipment are very often not replaced or just removed. Both Indian, as well as Chinese plant managers reported about bad experiences with spare part supply of foreign equipment, whereas high costs and long delivery times were seen very critical. Too complex and too costly spare parts are a major reason why foreign treatment equipment is not operated long-term. Problematic after-sale service is currently an important argument against foreign equipment for plant managers in China (see chapter 7.2.4), as more and more equipment of acceptable quality is made in China - with Chinese after-sale service and Chinese manuals.

Although very few European equipment is in use on Indian STPs, minimisation of spare parts requirements and simplicity are even more important in India, due to the more severe manpower situation in India.

Moderate Energy Demand & High Electrical Protection

Due to instable power supply and power cuts in many Indian cities, aggregates and control equipment should be protected accordingly with motor protection switches, fuses etc. Also treatment processes have to be able to cope with power cuts of several hours. Undoubtedly, energy efficiency is an important aspect for technical equipment as it has a strong influence on the running costs. The results from the expert interviews indicate that Indian experts consider energy efficiency as an important aspect (see figure 85, chapter 7.1.3). The fact is that about 26% of the treated sewage of Class I cities is treated by UASB process (see table 32, chapter 7.1.4). Also the fact that new STPs are built based on UASB technology, although operational problems were reported by several interviewed experts and plant managers, stresses the conclusion that basically energy efficient solutions are required in India. Considering existing treatment processes for sewage treatment in China, as well as the results of the expert interviews, the conclusion can be drawn that energy aspects play a role regarding the operation costs, but less because of power shortages.

Technical & Clear Appearance

The direct comparison of the technology parameters determined for coarse and fine screen equipment from India, China and Germany (see figure 192, chapter 7.4) shows that great differences exist between the three countries. In almost all parameters, German screens reach the highest values. Very interesting is the observation that both corrosion freeness and cleanliness of German screens operated in China are higher than for Chinese screens. Also for other machinery equipment this could be observed. Undoubtedly, the extremely high corrosion resistance of stainless steel equipment has to be seen as the major reason for the high corrosion freeness, as basically no maintenance for corrosion protection is required.

The observation that also cleanliness of imported equipment is higher than of local equipment leads to the conclusion that the “high-tech appearance” of many machines - also due to the use of stainless steel - has a positive influence on the motivation to keep that equipment in good shape.

What does that mean for the concrete technology choice? Undoubtedly, the “ideal” solution is determined by the respective application situation, treatment targets, capacity, etc., whereas hardly any technical system can fulfill all above criteria, especially when it comes to cost considerations. However, **high process stability, low automation, simplicity, but high material quality** are of major importance – with the brand Germany. Not least the example of the international success of a German supplier of compact STPs who considers above principles proves this. Basic recommendations will be given in chapter 9.2.

German Equipment

Comparing above conclusions for the design of treatment plant equipment for the use in countries like India and China, with existing treatment plant equipment that is supplied from Germany, the conclusion has to be drawn, that German suppliers can offer suitable products, but that in many cases not the right product is chosen for a special application. Lack of understanding for the right weighing of above mentioned criteria in the respective application case, both on decision making level and at the sales staff of the supplier has to be seen as a major reason. The conclusion has to be drawn that education and more communication on both sides is required.

The results of the technology analysis show that especially regarding robustness and corrosion resistance, German manufacturers can offer best and innovative products for developing and newly industrialising countries, also compared to other European suppliers. In some product categories, complexity and automation are too high, both for applications in China and especially in India, so that specially trained staff or external service is recommended for maintenance. For some equipment, like screw conveyors, required wearing parts should be avoided or modified in way that they can be sourced locally.

Weak points of many German suppliers are marketing and after sale service, which could be stated also in the expert interviews (see chapter 7.3.3). Marketing and education of decision makers about the innovative solutions that German suppliers can offer requires the will and the ability to take the perspective of the foreign partner.

9 Recommendations

9.1 Manpower & Education

The following recommendations focus mainly on India. As per the situation in China, results from expert interviews, plant inspections and recent development in the establishment of training institutions show, that promising steps for improvement of the critical aspects are being undertaken in China.

Development of Legal Frame Conditions

An important step that is strongly recommended is that the control authorities should focus not only on the outlet values, but also on efficiencies of plant stages, so that major problem points can be identified. Minimum reduction rates for the major wastewater parameters should be set for the main plant stages. Exceeding should be sanctioned – undershooting should lead to financial benefits.

The implementation of legal guidelines for minimum manpower qualification in the wastewater sector is strongly recommended for the existing situation in India. Based on the results of the expert interviews and the considerations in chapter 8.1.1, the conclusion can be drawn that in the public sector an improvement of the situation is very difficult, if municipalities are not forced to train, both engineer and technical staff. Although increasing pressure of control authorities is essential pre-condition, it will lead to efficient use of treatment plant equipment and efficient processes only to a certain extent, as it doesn't solve the basic know-how problem regarding practical plant operation. The dramatic results of a CPCB report on the performance of CETPs also show that the implementation of minimum qualification standards is essential (see chapter 7.1.4).

The implementation of strict legal standards and controls regarding work safety and work hygiene on STPs, is strongly recommended, as the observations during plants inspections, staff questionings and pilot training showed dramatically low awareness of the staff about these aspects. The provision of the staff with basic protection equipment and safety clothes has to be controlled effectively by local authorities.

In China, due to the increasing awareness on manpower questions on STPs, as well as the establishment of training institutions, the conclusion can be drawn that the implementation of legal guidelines for minimum staff qualification is not as important as in India. Of major importance is the implementation of an effective control institution. Currently, control authorities can’t fulfil their control function, as they are on the same level like water supply and drainage departments in the local administration structure in China.

Development of Incentive Systems

The results of this study, as well as performance reports of the CPCB show that solutions have to be found, towards capacity building and knowledge upgradation of engineer staff about treatment plant operation, as well as the awareness for operation and maintenance aspects. As already mentioned in previous chapters, the almost exclusive focus on theory, rather than incorporation of relevant qualification for the work practice is characteristic for academic education in India. The reasons, like the denial of practical work, are routed in the education tradition and the cultural background, as shown in chapter 5.2.1, so the expected change can only be a long term reality (see also chapter 8.1.1).

For engineer and practical staff, the implementation of incentive systems has to be seen as a very promising way to improve both motivation and awareness. Engineers, technicians and operators have to be responsible for defined plant stages. Efficiency values and failure rates of equipment have to be linked to bonus salaries, extra holidays or other incentives. Suitable incentives that strengthen the image of the respective employee as specialist – various possibilities can be perceived to be developed in detail. Via incentive systems, also the awareness for qualified practical staff on the engineer level could be increased, so that the barrier between academic level and practical staff level (see figure 203, chapter 8.1.1) could be compensated to a certain extent and a more intense information flow in form of meetings etc. could be achieved.

On plant management level, awards should be set out by municipalities and control authorities for best performing STPs and rankings should be published, so that also on management level, more motivation for better plant performance and plant shape is created. For the introduction of incentive systems, external advisors are recommended.

Improvement of the Work Conditions

From plant inspections and staff questionings the conclusion has to be drawn, that the extremely bad work conditions of the practical staff especially compared to Germany, are an important reason for the low staff motivation, beside low salaries (see figure 75, chapter 7.1.2) in India. Therefore, the following items are strongly recommended:

- Regular work safety inspections of all plant stages by local authorities
- Provision of proper protection equipment and work clothes
- Regular awareness training of staff about health risks and work safety
    - Strict separation of work areas and staff areas
    - No food storage or intake at the work place
- Provision of proper staff rooms, bathrooms and showers
- Establishment of canteens and food supply for bigger plants

Plant inspections and staff questionings in China showed that the work conditions are on a very high level compared to India. Work safety equipment, protection clothes, overalls etc., as well as staff rooms, showers and canteens exist in almost all bigger plants.

Image Improvement of Wastewater Treatment

Due to the bad image of wastewater treatment, measures for an image improvement are strongly recommended. Although a relatively high awareness exists especially in the upper population level (see figure 87, chapter 7.1.3), the contribution of STPs to environmental protection is hardly known and hardly appreciated in public. Measures have to target on enlightenment of the public about the contribution of STPs to the health of the population and clean environment. Via the creation of a better image of wastewater treatment in public, also positive effects on the work motivation of the plant staff can be expected. Recommended measures are:

- Arrangement of guided tours for school classes and other interested groups for more awareness creation in the public

- Integration of wastewater treatment plants in other environmental campaigns
- Initialisation of regular reports in newspapers and other media

With increasing trend and a need for the reuse of treated wastewater (see figure 85, chapter 7.1.3) an improvement can be expected, as the plant discharge turns from waste to a product that is or can be used.

Operation Organisation

As the consideration in chapter 8.1.1 show, lack of motivation and awareness are major problems on STPs that are operated by municipal staff. Low and fixed salaries, as well as the strong job safety of municipal staff are frame conditions that make changes very difficult. Under economical aspects, plant operation by the public sector is doubtful.

The outsourcing of plant operation to private contractors, which is already very common in many cities in India, as also the plant inspections in this study showed (see figure 69, chapter 7.1.1) has the advantage of improvement in staff qualification. Expert talks with private contractors show an interest to train their technical and operation staff. Another advantage is that incentive systems can be implemented more easily. Due to the economic pressure, staff is used more efficiently. Important is that discharge values and treatment efficiencies are adequately controlled and exceedings are sanctioned by the respective State Pollution Control Boards. Problematic regarding maintenance is the relatively short running time of most operation agreements of only 2years, as repairs and maintenance works are carried out only with a short term focus.

Long-term operation of treatment plants by the private sector, like on BOT or TOT basis has to be considered as the most promising way how improvements of plant operations can be achieved. The results of the expert interviews show that the private sector is much more aware of manpower questions than the public sector (see figure 88, chapter 7.1.3). More efficient operation and long-term focus regarding the plant equipment are essential advantages, with supposition that efficiencies and discharge standards are adequately controlled by the client and the control authorities. As the increasing compliance of large scale industries due to strict controls by control authorities showed (see figure 89, chapter 7.1.4), control measures are in practice by far more effective in the private sector than in the public sector. Variable salaries and incentive systems based on treatment results or failure frequency of plant stages can be introduced more easily than in the public sector. An important aspect that has to be considered is an adequate salary of the staff with increasing qualification. The problem arises, when the staff that has been trained, very often changes the work due to higher salary offers in other companies, which also shows the demand for skilled staff in the private sector. Another problem that has to be considered is that knowledge means status and that trained practical staff rises in the work hierarchy so that again repairs are carried out by unskilled staff. Under adequate control pressure by control authorities and client, manpower and salaries are automatically regulated in the private sector.

Possible Solutions for Qualification & Training Realisation

Whereas in China, increasing awareness is recently leading to demand and development of qualification institutions, no signs for such a trend can be seen in India. The considerations in chapter 8.1.1 showed that operation and maintenance deficits can mainly be traced back to motivation and awareness deficits of the treatment plant staff. However, with the trend for more complex technical solutions, an adaptation of the staff skills is unavoidable. Several ways seem to be possible, how an improvement could be reached.

One solution could be the introduction of a training course in Industrial Training Institutes (IITs) or in Polytechnics. However, the acceptance of such courses is doubtful. As the analysis regarding work satisfaction and work situation has shown, the work on a wastewater treatment plant in India is currently not attractive. The fact that even a post-diploma course in environmental engineering doesn't get enough applicants, because other disciplines are more attractive in the fast growing industrial sector makes clear that parallel to the development of formal courses, an image improvement, as well as an improvement of the work conditions is required, including higher salaries. As a pilot study, such an ITI-course could be designed and tested in one IIT in Delhi for example, considering that 17 STPs exist in Delhi. Already working plant staff could participate part time in such an ITI-course.

The extension of special mechanical or electrical IIT courses by wastewater treatment specific course contents can be seen as a promising way, as no extra course has to be formed. The German job profile of "specialist for wastewater treatment" (see chapter 5.2.3) is very broad – too broad for many large plants that require specialists who are managed by an experienced foreman or engineer.

The formation of “mobile training squads” has to be seen as a very promising possibility for the realisation of practical and theoretical trainings, both for engineers and technicians. Discussions with operation contractors, as well as expert estimations indicate that mobile training units would be ideal from the point of view of plant managers – no off times for the staff, training parallel to plant operation and plant specific training. From the organisational point of view, a maximum of practice-orientation without central training location would be possible. Unclear is the finance of such training squads. Further analysis would be required to determine to what extent STPs and ETPs are willing to invest in training, though a demand is expressed by many plant managers. Interviewed Indian experts see a moderate will of decision makers to invest in staff qualification (see figure 87, chapter 7.1.3). Ideal would be, if the mobile training groups would be at least subsidised by the government as part of the vocational training system.

As already mentioned in chapter 8.1.1, the German STP-neighbourhood concept is an interesting alternative way of staff qualification on the engineer level (see also chapter 5.2.3). Considering the informal nature of the German STP-neighbourhood concept and the proven advantages gained in 40years, the concept could be adapted to the situation in India and in China, too. Both costs and organisation demand are relatively low, considering the positive effects, as the experience in Germany has shown. Very important is an organising institution, like the Indian Water Works Association (IWWA). Meetings and knowledge share can be organised also on town or regional level by the respective drainage departments. Important is the transfer of theoretical and practical knowledge into the neighbourhood. This could be achieved by experienced consultants or scientists in combination with experienced plant engineers. Training sessions by equipment suppliers are recommended in order to create awareness for maintenance aspects of modern treatment plant equipment. Important is the adaptation of the meetings on the demand of the participants. It can be assumed that the neighbourhood system contributes also to the development of a more positive job image and group feeling.

Regarding the choice of pedagogical methods and materials, the pilot training carried in this study gave interesting first information that can serve as a basis for the development of training material, as well as further studies (see chapter 7.5).

Staff Qualification in China

As already mentioned in chapter 7.2.4, an increasing awareness for aspects of manpower qualification can be stated in China. In Mai 2007, the „Sino-German

Training Centre for Water and Environment Ltd.“, situated in Beijing was founded as a cooperation between Kocks Consult GmbH, Emscher Gesellschaft für Wassertechnik mbH, InterTraining Institut für Training & Consulting International GmbH and the German Association for Water, Wastewater and Waste (DWA). Chinese partners are the China Urban Water Association (CUWA), Water Pollution Control Committee of China Environmental Protection Industry (CWPCC), SEPA Shandong, one environmental school and one vocational school. Also in the private sector a demand for manpower training can be stated. Expert talks with plant managers showed that the first Sino-German training centre in Qingdao was well accepted and considered to be very suitable for the training of plant technicians and operators. Questioned plant managers are willing to send new staff to training institutions for initial training. It can be assumed that also the new founded training centre will be well accepted and meet the requirements. In addition, the development of “wastewater treatment plant neighbourhoods” similarly, as in Germany, is recommended (see also chapter 5.2.3), where both engineers and practical staff should be incorporated.

Qualification & Service Outsourcing

The considerations regarding the manpower situation India in chapter 8.1.1 show that the realisation of measures for an improvement of operation and maintenance is not an easy task. The situation analysis on Chinese treatment plants showed gaps between manpower and modern wastewater technology (see also figure 205, chapter 8.1.2). As further increase of the qualification requirements about operations and equipment maintenance seems to be unavoidable especially in urban areas, the question has to be asked, if, how and to what extent operation and maintenance works can be outsourced.

The much too expensive, but unfortunately common form of such an outsourcing is a repair or maintenance work carried out by a service technician of the respective supplier, which means extremely high costs in case of a foreign supplier without qualified local technical service staff. Maintenance and repair agreements between treatment plants and a specialised local service contractor for maintenance works has to be seen as a promising alternative, especially for foreign or high-tech equipment. Various forms of agreements are possible, ranging from exchange only of special wearing parts, to complete operation and maintenance of whole plant steps. The success of a small German service company, which is active in that field in China, shows, both the high demand on the side of the treatment plants and the business potential for private companies. That way, also highly efficient technical solutions can be applicated in developing and newly industrialising countries, in cases where no adequately skilled maintenance staff is available, or where the development of high skilled staff is economically not interesting or not possible.

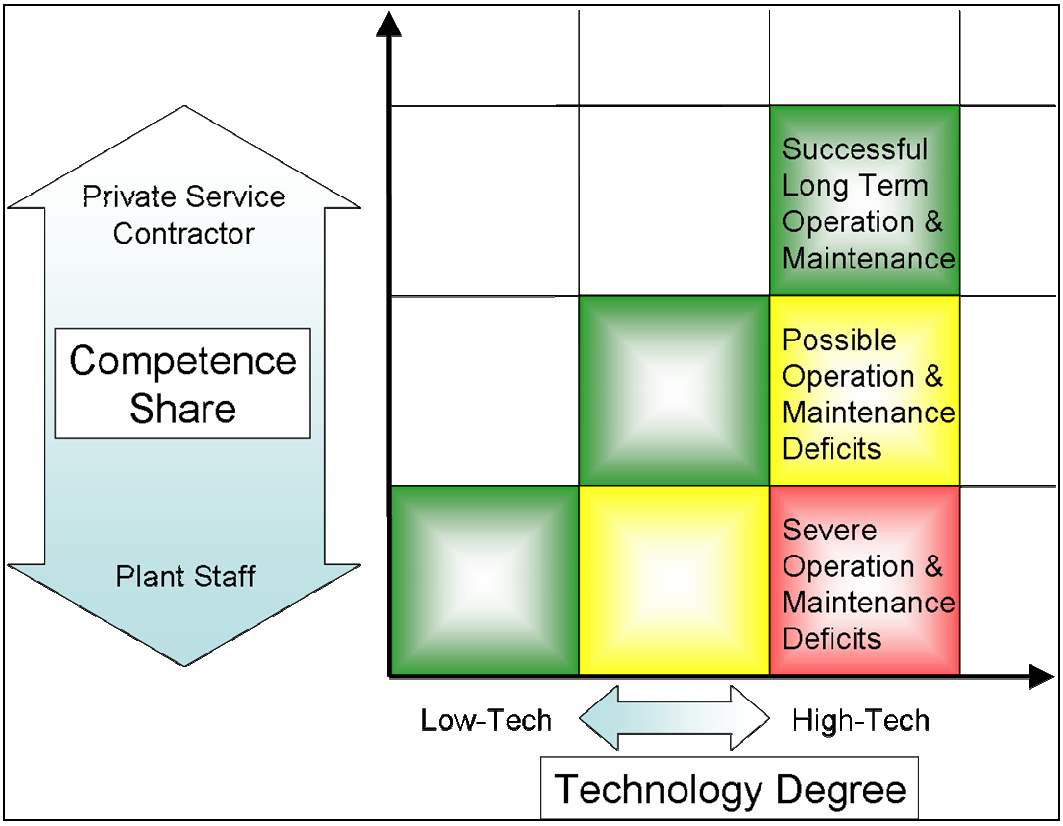


FIGURE 207: SERVICE OUTSOURCING AND COMPETENCE SHARE

9.2 Equipment Choice & Design

Process Selection

The considerations in chapter 8.3 show that especially stability, simplicity and easy operation are major design principles that should be followed, independently from efficiency parameters and effluent quality.

Based on the conclusion drawn from the results of the manpower considerations and technology analysis, the following basic recommendations can be given for qualification requirements of certain technologies in India.

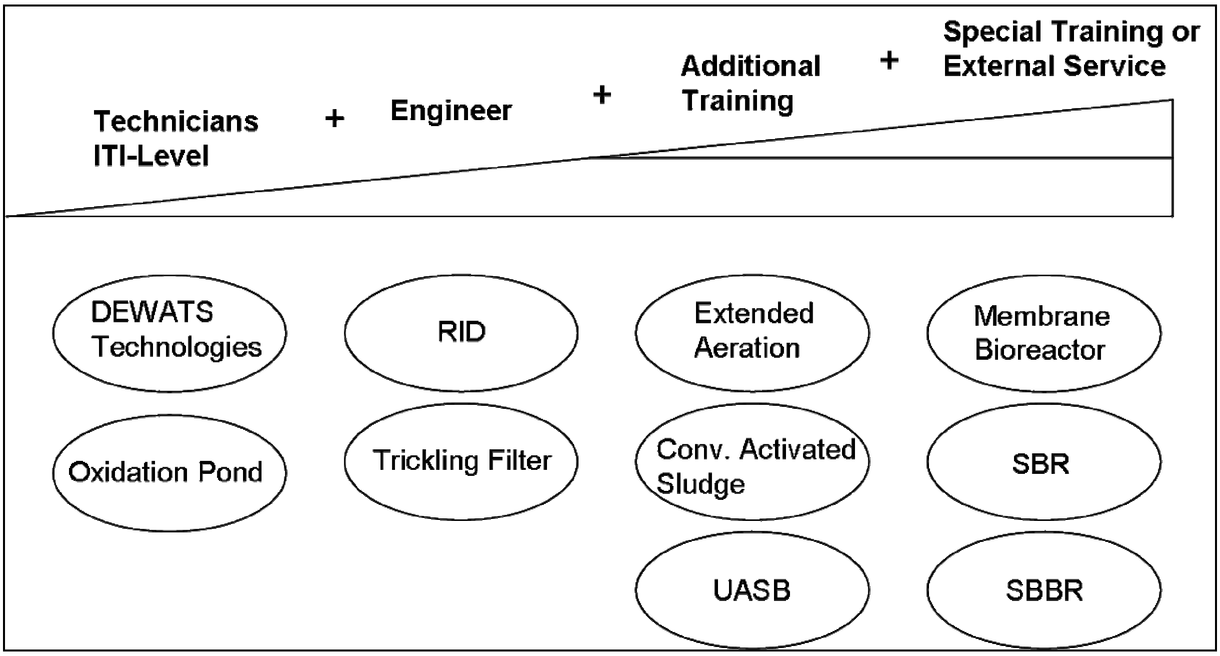


FIGURE 208: RECOMMENDED BASIC MANPOWER QUALIFICATION AND TREATMENT PROCESSES FOR INDIA

Decentralised Wastewater Treatment Systems (DEWATS), as well as oxidation ponds require hardly any operation skills. The very basic maintenance works can be carried out by unskilled workers. Pumping systems can be maintained and repaired by ITI-technicians. Due to the large space demand, the application of these technologies is not recommended for densely populated urban areas. Rotating Immersion Disks (RID) are suitable for plant capacities up to about 1.000m³/d. For maintenance and repair works of Rotating Immersion Disks (RID) and Trickling Filters, the existing skills of ITI-technicians are basically sufficient, engineer staff is recommended for control and adaptation of the treatment process, if the plants exceed a certain capacity. Other reasons, why these systems are recommended, are the high process stability (fixed film systems) and the relatively low energy demand.

The results of this study, as well as performance reports of CPCB show that operation problems exist on many activated sludge plants, extended aeration plants and UASB plants (see chapter 7.1.4) that can be traced back to lack of operation skills of plant engineers. It is therefore strongly recommended to introduce additional training measures (see also chapter 9.1).

Special training by equipment suppliers or external service contracts are strongly recommended for technologies like membrane bioreactors (MBR), sequence batch reactors and sequence batch biofilm reactors (SBBR). Due to the high automation degree, special emphasis should be given to profound training of electricians. Engineers should be trained very detailed about essential operation and maintenance processes. The two main advantages of MBR technology – highest compactness and best reuse quality of the treated wastewater – compensate the relatively high costs and qualification demand in India in special applications, like in the hotel sector (top end), special industries and extremely densely populated and sensitive areas. For these applications, MBR technology is recommended.

For China, basically similar recommendations regarding manpower and treatment processes can be given. As the results of the staff questionings show, Chinese technicians have a relatively high knowledge about treatment processes compared to India (see chapter 7.1.2 and 7.2.2), so that it can be assumed that small and medium sized RID and trickling filters can be operated also by technicians.

For alternative treatment concepts that are summed up under ECOSAN and DESAR the respective way of technical realisation of the single components of the concepts has to be considered. Undoubtedly, the reuse of treated wastewater and nutrients in an overall solution for sanitation is strongly recommended. Based on the results of the expert interviews the conclusion can be drawn, that such alternative concepts to conventional end of pipe solutions are still hardly known and hardly considered on expert level. What can be stated is that current technical realisations of DESAR are on relatively high technology level, so that special training or external service for high-tech components appears unavoidable in developing and newly industrialising countries. Examples of the realisation of ECOSAN concept are characterised by a moderate technology degree, so that the concept is recommended both for India and China.

Basic Technical Design Recommendations

First of all, the technical solution has to fulfil the customer’s requirements in terms of efficiency, technical characteristics etc. A very basic, problematic phenomenon is too strict German standards for the choice and design of machinery equipment and treatment processes in developing or newly industrialising countries. More flexibility is required from German suppliers and designers. The considerations on the basic cultural differences (see chapter 5.3) have shown that uncertainty avoidance is very important in German culture – but not for Asian cultures. Beside the recognition of different local conditions, like regarding temperature, wastewater quantity and constituency etc., German suppliers should consider the respective local estimation on efficiency safety. This includes also the consideration of a high capacity utilisation already in the dimensioning and offer phase, in order to avoid inadequate safeties and overpricing.

Based on the results of the equipment inspections, the following recommendations can be given for the adaptation of German equipment in addition to the conclusions regarding the design principles mentioned in chapter 8.3.

Indian wastewater is characterised by a high content of plastic waste, especially plastic bags, and all kinds of solid waste. Screening systems and screw conveyors have to be designed or chosen accordingly, whereas robustness should have highest priority. Fine mechanical structures should be avoided. Instead, larger mechanical elements that can be repaired with simple means in damage case should be chosen. It has to be possible that all required repairs can be carried out with simple standard tools in India. Special elements that cannot be sourced in India should be avoided. The plant inspections showed that only very few spares are kept in stock on site – spares of foreign equipment hardly exists, after the initial spares are used. Equipment should be designed in a way that change intervals are minimum even if the costs of the spares are higher. Screens, conveyors and other equipment are installed normally outside without protection, so that in direct sunlight, equipment can heat up extremely, whereas in winter, temperatures can fall below zero, depending on the region. In addition, the equipment has to withstand extreme humidity and rain, depending on the installation location. Automatic oiling and greasing systems as well as warning systems for essential maintenance works are recommended. Cables and cable connections should be extremely stable and should withstand mechanical impacts and movements, as cabling is very often not properly fixed (see chapter 7.1.1). For China, basically the same recommendations can be given. Chinese sewage is also characterised by a high content of solid waste - even carpet pieces -, which means that high robustness is required for screening systems and screw conveyors. Drive systems and axis have to be extremely robust. Press zones also have to be extremely robust or at least adjustable.

For the technology choice, basically the following essential questions have to be asked:

1) Is the function ability of the equipment assured – at least with reduced efficiency - if essential parts are not cleaned according to the manuals?

2) Is the function ability of the equipment assured – at least with reduced efficiency - if required wearing parts, like brushes, are not changed or replaced?

3) Can repairs be carried out with local standard tools?

Technology design has to orient on the common electrical and mechanical skills in India, resp. China. In metro cities, specialised companies are available, so that more complex equipment can be repaired in case of damage, whereas for small and medium sized towns, high-tech shoud be avoided. Instead, a focus should be set on process stability and durability. Suppliers should be well aware of the operational risks with increasing process complexity, that in the end can lead to financial and image losses. The equipment studies, as well as the interviews with plant engineers have shown that spare parts supply is a very sensitive topic, both with respect to operation stability and long term business success. Special emphasis should be given on the development of suitable operation and maintenance manuals in the local language.

9.3 Equipment Supply

Intercultural Aspects

From expert interviews with plant managers and discussions with plant engineers the conclusion can be drawn that existing poor support of foreign suppliers has strong negative consequences on the long-term business success (see also chapter 7.2.4). Therefore the strong recommendation can be given to foreign suppliers to assure that competence and customer care activities of the local representatives correspond to the high quality of their products. Customers can expect competence that goes beyond the presentation of an offer from the mother company. In house trainings, as well as intercultural training in order to avoid communication obstacles are recommended. In head offices, competent and intercultural trained staff should give uncomplicated direct support to clients. International service help desks are recommended.

Although the results of the expert interviews in India and China basically don’t show severe cultural obstacles in average, cultural misunderstandings, as well as communication difficulties could be stated or were reported in some cases, which does not surprise, considering the very different cultural values in India, China and Germany (see chapter 5.3). Other studies show a more critical picture. In his study on technology transfer to the Russian, Arabic and Latin-American region Hermeking concludes: “Signs for the high conflict potential in the practice of technology transfer are the remarkably strong emotion of the German test persons during their description of the obvious neuralgic points of differing ways of interaction with transferred technology, as well as the alarming frequency of their ethnocentric, partially extremely negative judgements about the different culture” (Hermeking 2001). Sonnenborn (2001) describes the problematic self-perception of many Germans in Japan critically with the following words: „We don’t want to learn from a master, but we are the master”. The studies of Hermeking have shown that in the private sector, the importance of intercultural competence is still not recognised. Neither from the management side, nor from the technical staff a need for intercultural training and thus for investment in human capital in this respect is seen. A similar result is also revealed by a study on intercultural aspects of the relation between German staff and the Indian partner in the high-tech sector in Bangalore (India). One of the “hard” results of that study: „Engineers deny social competences and intercultural trainings as not exact, not technical and therefore senseless” (Mahadevan 2007).

Based on the results of this study and above considerations the conclusion can be drawn that an important task has to be the creation of the understanding on engineer and technician level that the own virtues, cultural characteristics and values, also regarding the use of technology (see also chapter 5.3) are not the benchmark for the rest of the world. In order to create more awareness of this matter in the private sector, the following major steps are recommended, which are also partly mentioned by Hermeking (2001):

1) Total cost comparison of offers and successful negotiations that led to order

2) Integration of intercultural aspects in the education of technical disciplines

3) Intercultural training of staff prior to work stays abroad

The Brand Germany

An important question is, if and to what extent adaptation of business processes and products to the respective foreign culture is recommended in the wastewater sector. The success of BMW in the Japanese market shows that being different and respecting the foreign culture is a successful strategy for German companies. The following citation of a former German manager of BMW in Tokyo brings it to the point:”Awareness for self-identity is expected and that can be absolutely coupled with sensitivity and openness for a foreign culture. It’s only an apparent contradiction. A key parameter for successful living and working in a far eastern country is the solution of this apparent contradiction" (Sonnenborn 2001). The growing market success of several German companies in the upper quality segment also in many developing and newly industrialising countries shows that above considerations count also for the wastewater sector.

FIGURE 209: GERMAN SUPPLIERS OF TREATMENT PLANT EQUIPMENT IN CHINA

10 Summary & Outlook

Summary

Based on inspections of treatment plants, staff questionings and interviews with plant managers, this work provides a detailed description of the state of the art of wastewater treatment equipment and technology in India and China (chapter 7). Great differences were observed between these two biggest Asian newly industrialising countries. These mainly concern treatment and quality targets, efficiencies, technology level, equipment characteristics and aspects of operation and maintenance.

A comparative evaluation of the technology level shows that wastewater treatment technologies in China are quickly approximating wastewater treatment standards in Germany. This can be seen in a high automation degree, as well as modern treatment processes and technologies that are approaching western standards.

In contrast, both treatment processes and equipment encountered on Indian plants were on a significantly lower technological level than in China and Germany. Indian quality targets are mainly focussing on BOD removal; plant equipment is characterised by a very low automation degree, significantly lower manufacturing quality and efficiency than equipment used on plants in China or Germany.

In an explorative approach, the most relevant cultural values, expert estimations as well as the staff situation on wastewater treatment plants in these different countries were analysed and compared in terms of the technology status. Although remarkable differences in the technical equipment were observed, similar phenomena can be stated in India and China regarding the use of technologies. In both countries, operation and maintenance deficits compared to the wastewater treatment standards in Germany were revealed.

From the presented observations it emerges that both in India and China, aspects of awareness and motivation have to be seen as major reasons for the present operation and maintenance situation. A lack of knowledge required for operation and maintenance of imported water treatment equipment, could be stated in different dimensions in both countries among the responsible personnel. Due to the use of very complex processes and treatment plant equipment in China, deficits of the qualification of technical staff are more relevant than in India. However, due to the trend towards more technical solutions also in India, there is an urgent need for strategies to raise the level of qualification of practical staff. In both countries, lack of basic knowledge for practical plant operation on engineer level is a frequent reason for operational problems. Measures for an improvement should therefore primarily target the engineer level primarily.

A large variety of potential applicational cases exists, as well as very different practical realisations of measures and very different manpower constellations. The evaluation of different aspects regarding technology design and technology choice mentioned in chapter 8.3 has to depend on the respective case. Technology choice and realisation will finally always depend on the intentions of the involved actors and the available financial means. The results of this study show that in China, aspects of equipment quality play a more important role than in India, where cost aspects are the predominant decision criterion. However, especially in India, first priority has to be assigned to high material quality and robustness, as well as simplicity and ease of operation. This is to assure that - independent from quality targets and efficiencies - successful long-term plant operation can be achieved.

Regarding the relevance of cultural characteristics in the wastewater sector, the results underline the importance that all involved parties need to recognize cultural aspects of the respective countries better when organizing technology transfer to India and China. Many problems, concerning both the technical realisation and business relations, could be avoided in this way. The results of this study show that many difficulties that superficially appear to represent technical problems calling for technical solutions, in practice result from a mismatch of provided technical solutions and the cultural environment. This is especially evident by the use of German equipment on Chinese STPs. Wastewater treatment is far from being a culturally neutral technical discipline, which is clearly revealed by positions of interviewed experts, and by the results of staff questionings in the different countries. Relevant aspects include environmental, technological, educational and economical issues.

Cultural values and positions that are portrayed in intercultural literature prove to be valid to a certain extent in the wastewater sector. The expert interviews carried out in this study indicate that from an Asian perspective, reliability and quality thinking are the most sought for characteristics of German partners, whereas a lack of flexibility is frequently criticised. From the interviews of the western experts, the position that the own standards and values represent benchmarks for the rest of the world was regularly apparent.

The results of this study should contribute to a better understanding of critical aspects concerning technology choice, manpower and technology supply in developing and newly industrialising countries on the example of India and China. Recommendations for an improvement of the situation in the two countries were worked out. Due to the very different cultural values predominating in countries like India and China as compared to Germany, certain differences in the use of technology will persist that can only be bridged to a certain extend. However, rather than being considered a “deficit”, this fact should be respected as a difference.

Outlook

The demand for wastewater treatment technologies both in India and China is expected to increase dramatically in the next years. This is indicated by the results of the expert interviews carried out in the two countries, as well as by the estimations of interviewed western experts (chapter 7 of this study). In India, currently only about 6 million m³/d out of 29 million m³/d of sewage from Class I and Class II cities are treated in sewage plants (CPCB 2005). Accordingly, 23 million m³/d, or about 80% of the wastewater are left untreated. In China, about 45 million m³/d out of 98 million m³/d of urban sewage is treated (Abele 2006), indicating that a lower value of about 54% (53 million m³/d) is disposed of without further treatment. China is considered to become the world’s largest market in water, wastewater, air and renewable energies, with investments of more than 80 billion US$ per year to meet international standards by 2030 (Kaiser 2007). Western suppliers have very good market chances in both India and China. However, the results of this study show that great differences exist between these countries that have to be considered.

The most important step is that one question is brought into the mind of all parties involved in water and wastewater projects: “What can we do together?”

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Appendix A: Interview Guidelines Plant Management

WWTP:

Contact Person:

Visitors:
Date of Visit:
Plant Type:
Design Capacity:
Actual Capacity:
Location:
Start-Up Date:
Construction Company:
Technologies:

Operation & Maintenance:

Spare Parts Availability:

Treatment Targets:

Inlet Values:

Actual Outlet Values:

Staff

Worktime:

Responsabilities:

Salary Structure:

Skills & Training:

Motivation of Staff:

Health of Staff:

Experience
Original Product <-> Copy:
(Only China)

Remarks:

Appendix B: Interview Guidelines Expert Interviews

India & China

1. What is your opinion on the environmental situation here in India/China at the moment? What are the reasons for this development?
    a. *Awareness of Situation*
    b. *Importance*
    c. *Reasons*
2. What do you think are the effects of the environmental situation on the people and the economy in India/China?
    a. *Relation Environment - People - Economy*
    b. *Awareness of Effects*
3. From your experience - are the different parts of the population aware of the environmental situation and hygiene? How do you see the general knowledge in these fields at the moment?
    a. *Awareness Relation Hygiene - Environment*
    b. *Education Level*
4. How do you see education and professional training especially in the field of water and wastewater?
    a. *Training Possibilities*
    b. *Organisation/Costs*
5. Different treatment technologies are available in India/China and the world market. How should India/China approach to the water pollution problem?
    a. *Suitable Technologies (Wastewater Treatment & Sludge Handling (only China))*
    b. *International Cooperation*
6. How do you see the phenomenon that many foreign brands are copied by local manufacturers in China (only asked in China)?
    a. *Product Quality, Lifetime, Costs*
    b. *Legal Issues*
    c. *Future Perspectives*
7. What will be the future for the people and the economy? How should it be controlled in our opinion?
    a. *Technology*
    b. *Politics*
    c. *Education*

Germany

1. What is your opinion on the environmental situation in developing and newly industrialising countries at the moment? What are the reasons for this development?
    a. *Awareness of Situation*
    b. *Importance*
    c. *Reasons*
2. What do you think are the effects of the environmental situation on the people and the economy in these countries?
    a. *Relation Environment - People - Economie*
    b. *Awareness of Effects*
3. From your experience with developing and newly industrialising countries - are the different parts of the population aware of the environmental situation and hygiene? How do you see the general knowledge in these fields at the moment?
    a. *Awareness Relation Hygiene - Environment*
    b. *Education Level*
4. How do you see education and professional training especially in the field of water and wastewater?
    a. *Education level/Training Possibilities*
    b. *Organisation/Costs*
5. Different treatment technologies are available in developing and newly industrialising countries, and the world market. How should the water pollution problem in these countries be solved?
    a. *Suitable Technologies (Wastewater Treatment & Sludge Handling (sludge only China))*
    b. *International Cooperation*
6. What will be the future for the people and the economy in developing and newly industrialising countries? How should it be controlled in our opinion?
    a. *Technology*
    b. *Politics*
    c. *Education*
7. How do you personally see the economic possibilities in the relations with developing and newly industrialising countries?
    a. *Export Orientation*
    b. *Chances & Risks*
    c. *Regional Focus*

Appendix C: Questionnaires Treatment Plant Staff

Questions Block A:

1) (WW1)

What do you think of, when you hear the word “water”? Give in a few words what you have in mind. *–open-*

____

____

____

2) (WW2)

Drinking water - where do you get drinking water from? *-insert numbers (0 = don't use this water; 1 = use this water sometimes; 2 = use this water regularly)-*

[ ] A	House Connection	[ ] D	Bottled Water	[ ] G	River
[ ] B	Public Tap	[ ] E	Water Well	[ ] H	Other: _______
[ ] C	Water Vendor	[ ] F	Tube Well		

3) (WW3)

Where do you get the water you use for bathing mainly from? *-insert numbers (0 = don't use this water; 1 = use this water sometimes; 2 = use this water regularly)-*

[ ] A	House Connection	[ ] D	Bottled Water	[ ] G	River
[ ] B	Public Tap	[ ] E	Water Well	[ ] H	Other: _______
[ ] C	Water Vendor	[ ] F	Tube Well		

4) (WW4)

Of course it is difficult to say in detail, but can you estimate roughly how much water you need in a day only for you? *-several answers can be given; please answer as precise as possible-*

[ ] A Drinking water is about____bottles of____litres, if I shall estimate the volume

[ ] B The water for bathing/showering/washing of clothes is about____buckets of____litres

[ ] C Following the water meter, the water consumption in my household is about_______m^3/year

5) (WW7)

Do you know whether the wastewater from the settlement where you live is treated? *–open-*

____

____

____

6) (WW8)

How much do you have to pay for water? *-choose one-*

[ ] a I have to pay about Rs_____ per _____

[ ] b My water is free – I don’t have o pay for it.

7) (GP12)

Do you try to save water? If yes, why and how, if no, why not? *–open-*

____

____

____

8) (ED1)

Which is your highest education level (that means which school level did you finish successfully)? *-choose one-*

[ ] a I couldn’t visit a school
[ ] b Elementary School
[ ] c High / Secondary School
[ ] d University / College - Bachelor
[ ] e University / College - Master
[ ] f Doctorate / Professor

9) (GP5)

As environment protection technology requires high investments, the finance can be difficult. With which position do you agree most? *-choose one-*

[ ] a In the current critical environmental situation, cities and companies should be forced to match the national pollution standards as soon as possible even if loans have to be taken.
[ ] b Companies and cities should have about 15-20 years to invest in adequate control technologies because the water and wastewater problem is not too extreme at the moment.

10) (GP6)

Would you use treated wastewater in your household for gardening and toilet flushing, if it is less expensive than normal tap water? *-choose one-*

[ ] a Of course I would
[ ] b No, because__________________

11) (GP8)

Worldwide, scientists are working hard. But the people have different opinions on this and not all people think that the scientific results are always good for them. To which position do you tend more? *-choose one-*

[ ] a Normally, the scientists and doctors are right. I try to do what they found out.
[ ] b The health of my family depends on the goodwill of the god – I’m sceptic about science.

12) (GP13)

Do you think, that technologies are available in India to solve the water pollution problem? *–open-*

____

____

____

13) (ED6)

Can you name any suitable technologies for water or wastewater treatment? *–open-*

____

____

____

14) (TP1)

Imagine the managing director would realise up to 3 wishes for you. What would you tell him? *-up to 3 items can be chosen-*

[ ] A	"Hire more workers!"	[ ] E	"Offer job training!"
[ ] B	"Pay higher salaries!"	[ ] F	"Buy better plant equipment!"
[ ] C	"Fire the superior!"	[ ] G	"Improve the work health care!"
[ ] D	"I am happy with my job!"	[ ] H	"It is too difficult to get spare parts!"

15) (TP2)

You are working on this wastewater treatment plant – which technologies are used?

-mark true answers with (T), mark false answers with (F), mark don't know with (D)- *Observer*

[ ] A	Screen or Sieve	[ ] G	Anaerobic Treatment	[ ]	[ ]
[ ] B	Conventional Activated Sludge System	[ ] H	Membrane Technology	[ ]	[ ]
[ ] C	Sequence Batch Reactor	[ ] I	Biol. Wastewater Composting	[ ]	[ ]
[ ] D	Sequence Batch Biofilm Reactor	[ ] J	Sand Filtration	[ ]	[ ]
[ ] E	Rotating Immersion Disks	[ ] K	Others: ________________	[ ]	[ ]
[ ] F	Trickling Filter	[ ] L	I am not sure	[ ]	[ ]

16) (TP3)

What happens on this wastewater treatment plant where you work?

-mark true answers with (T), mark false answers with (F), mark don't know with (D)- *Observer*

[ ] A	Solids are taken out of the raw wastewater.	[ ]
[ ] C	The dissolved pollutants are eaten by bacteria in this plant.	[ ]
[ ] D	The BOD of the wastewater is degraded.	[ ]
[ ] E	Filtration is an important treatment step on this plant.	[ ]
[ ] F	BOD is removed and ammonium is nitrified here.	[ ]
[ ] G	In this plant, there is an aeration step for BOD-removal.	[ ]
[ ] H	The internal sludge recirculation is not important here.	[ ]
[ ] I	The wastewater sludge of our plant cannot make anybody ill.	[ ]
[ ] J	Flocculation is an important step of the cleaning process here.	[ ]

17) (TP4) What kind of work do you do on this wastewater treatment plant? *–several items can be chosen-*

[ ] A	Office work	[ ] D	Go into Dirty Basins or Cleaning Works
[ ] B	Valve Operation	[ ] E	Delegate / Lead Persons
[ ] C	Switch Room Operation	[ ] F	General Repair Works

18) (TP8) Your job on this treatment plant - would you like to have additional job training? *-choose one-*

[ ] a The plant operation needs technical understanding, but we are all very experienced here.

[ ] b It is not easy to understand everything - additional training would be good for the workers.

19) (TP9)

Is the plant perfectly running or are there some problems (sometimes or regularly)? Which ones?

____

____

____

Questions Block B:

20) (WW6)

Now to the wastewater. What happens with the main wastewater stream from the household where you live? *-several items can be chosen-*

- [ ] A It enters the subsoil sewer system.
- [ ] B First, it enters a septic tank.
- [ ] C The wastewater is used for ______________________________
- [ ] D It flows on the ground.
- [ ] E It enters an open collection channel.

21) (ED2)

In what field would you say that you have special knowledge? *-several items can be given-*

- [ ] A Electronics
- [ ] B Mechanics
- [ ] C Chemistry / Biology
- [ ] D Economics
- [ ] E Civil Construction
- [ ] F Medicine
- [ ] G Politics
- [ ] H Other: _______ _______

22) (ED4)

What can you do to get good quality drinking water? *-mark true answers with (T), mark false answers with (F), mark don't know with (D)-*

- [ ] A Heat bad water to 50℃.
- [ ] B Drink water upstream any settlement.
- [ ] C Filter water with a piece of textile.
- [ ] D Drink bottl ed water.
- [ ] E Don't cover water wells – air should enter.
- [ ] F Drink river water 100m downstream a village.

23) (ED5)

Now please decide which of the following expressions are true and which are false. Some may appear difficult to you, which is absolutely natural – nobody can know everything. *-mark true answers with (T), mark false answers with (F), mark don't know with (D)-*

- [ ] A Manmohan Singh is prime minister since 2004. (India)
- [ ] A Hú Jintao is first chairman of the party since 2004. (China)
- [ ] A Angela Merkel is chancellor since 2005. (Germany)
- [ ] B The Lok Sabha has 540 seats. (India)
- [ ] B The Peoples Congress has 2.852 seats in 2007. (China)
- [ ] B German parliament has 595 seats.
- [ ] C Jaques Chirac is the president of Belgium. (India/China)
- [ ] C Pervez Musharraf is president of India. (Germany)
- [ ] D The stronger the EURO, the worse for European exporters to the US.
- [ ] E A letter of credit means bank costs both for the Indian and the foreign business partner.
- [ ] F Marketing means buying from the market.
- [ ] G Three-phase connection means a lower starting current than single-phase connection.
- [ ] H A Volt-Meter is used to increase or lower the current voltage.
- [ ] I A motor protection switch is protecting the operating person from electric shock.
- [ ] J A torque spanner is required for the controlled tightening of screws.
- [ ] K Spherical roller bearings allow axe bending within certain limits.
- [ ] L "M16" means metric standard thread with 16mm length.
- [ ] M Nitrogen is an extremely toxic gas even in very small amounts.
- [ ] N Humans have DNA – plants don't have DNA.
- [ ] O Chlorine is toxic for bacteria.

[ ] P If steel is well covered by concrete, it cannot corrode even in water.
[ ] Q Cement is less expensive than sand.
[ ] R In a typical concrete, about 40% is sand/gravel, 40% is cement and 20% is water.
[ ] S AIDS can be transmitted by shaking the hands of an infected person.
[ ] T A worm infection can be caused by drinking of polluted water.
[ ] U Hepatitis B is transmitted via blood contact.
[ ] V Indian Independence Day is on the 16th of August. (India)
[ ] V Chinese National Day is on the 2nd of October. (China)
[ ] V Day of German Reunion is on October 4th. (Germany)
[ ] W Goa is situated in the Bay of Bengal. (India)
[ ] W Fuzhou is situated in the bay of Bo Hai. (China)
[ ] W Rostock is situated on the North Sea. (Germany)
[ ] X Berlin is the capital of Germany. (India, China)
[ ] X New Delhi is the capital of India. (Germany)
[ ] Y Mozart was a famous author of short stories.
[ ] Z Charles Darwin was a famous mathematic.

24) (GP1)
Construction and maintenance of infrastructure is expensive and has to be financed by taxes of the citizens. How do you see the importance of the following infrastructure elements? *-in a ranking please prioritise by giving numbers from 1 - 6 for the urgency of each infrastructure element (1 = most urgent infrastructure element, 6 = already well developed)-*

[ ] A Streets/Railways
[ ] B Electricity Supply
[ ] C Drinking Water Supply
[ ] D Solid Waste Handling
[ ] E Wastewater Treatment/Reuse
[ ] F Air Pollution Control

25) (GP4)
Prioritise the decision criteria for your sanitation facility? *–give numbers from 1 – 4; 1 = not so important for me, 4 = very important for me-*

[ ] A Comfort [ ] B Hygiene [ ] C Water saving [ ] D Costs

26) (GP9)
In many cities, education and training possibilities are offered. What is your opinion on this with regard to your work?

____
____
____

27) (TP5)
What is the opinion in your family about your work?

____
____
____

28) (TP6)
When you think of the future and your work…….

____

____

____

29) (GP5)
Everywhere in the world, people have different habits – even concerning where they go to toilet. Which type of toilet do you use? *-insert numbers (0 = don't use; 1 = use sometimes; 2 = use regularly)-*

[ ] A European Type Water Flushing Toilet [ ] C Compost Toilet/Dry toilet
[ ] B Indian Style Water Flushing Toilet [ ] D I go into the fields

End Block A:

30) (GI1)
When you look at the children, the boys and girls around you, how they grow up and once become the leaders of this country when you are old, which advice would you give to them?

____

____

____

Finally, we would like to know some data on your person for the statistic analysis. As already mentioned, all given personal data will be handled absolutely confidential.

31) (GI2)
What is your age and your religion?

____

32) (GI3)
Your Gender:

[ ] a Male [ ] b Female

33) (GI4)
Are you married and how many children do you have? *–choose one-*

[ ] a Married I have____children [ ] b Not Married

34) (GI5)
In which town and township do you live?

Town: __________________________ Township: __________________________________

35) (GI6)
What is your residential status - where do you live? *-choose one-*

[ ] a Luxurious House
[ ] b Small and Nice House
[ ] c Well Equipped Flat
[ ] d Very Small Flat
[ ] e Simple Small Hut
[ ] f I sleep Where I find a place

36) (GI8)
What is your profession?

____

37) (GI11)
In what range is your monthly income? *-choose one-*

India

[ ] a > Rs 50.000
[ ] b > Rs 20.000 – Rs 50.000
[ ] c > Rs 5.000 – Rs 20.000
[ ] d > Rs 1.000 – Rs 5.000
[ ] e < Rs 1.000
[ ] f No Own Income

China

[ ] a > Yuan 10.000
[ ] b > Yuan 5.000 - Yuan 10.000
[ ] c > Yuan 2.000 - Yuan 5.000
[ ] d > Yuan 500 - Yuan 2.000
[ ] e < Yuan 500
[ ] f No Own Income

Germany

[ ] a > EUR 4.500
[ ] b > EUR 3.500 - EUR 4.500
[ ] c > EUR 2.500 - EUR 3.500
[ ] d > EUR 1.500 - EUR 2.500
[ ] e > EUR 500 - EUR 1.500
[ ] f < EUR 500

Plant data:
*Town:*____________________*Type(municipal/industry):*____________________________________
Technologies:
____
*Contact Person (Name, Email, Tel, Fax):*____
____

End Block B:

38) (GI7)
In which town and which company are you working?

Town: _________________________ Company: _______________________________

39) (GI9)

What is your professional position? *-choose one-*

[ ] a	Management	[ ] d	Skilled Worker	[ ] g	Student
[ ] b	Division Leader	[ ] e	Helper	[ ] h	Work in Household
[ ] c	Group Leader	[ ] f	Lecturer	[ ] i	Unemployed

40) (GI10)

How long are you in this position? *-choose one-*

____

Appendix D: Questionnaires Pilot Training in India

Pre-Test Questions

Plant Name:

1)

You will take part in a training programme for workers on STPs and ETPs. Did you ever take part in a training before? If yes, when and on what subjects? *–choose one-*

[ ] a Yes, in ______ I took part in a course on ______________ [ ] b No

2)

What should be discussed in the training in your opinion? *-open question-*

____

____

____

3)

What is your age and your religion?

____

4)

What kind of work do you do on this wastewater treatment plant? *–several items can be chosen-*

[ ] A Office Work
[ ] B Valve Operation
[ ] C Switch Room Operation
[ ] D Go into Dirty Basins or Cleaning Works
[ ] E Delegate / Lead Persons
[ ] F General Repair Works

5)

Which education institutions did you pass successfully? *–several can be chosen-*

[ ] A I couldn't visit a school
[ ] B Elementary School
[ ] C High / Secondary School
[ ] D Higher Education - Bachelor
[ ] E Higher Education - Master
[ ] F Industrial Training Institute (ITI)
[ ] G Polytechnic
[ ] H Other: ________________________

6)

In which field are you working on the plant? *–choose one-*

[ ] A Mechanic/Fitter
[ ] B Chemist
[ ] D Electrician
[ ] E Nothing Special
[ ] G Operator
[ ] Other: ____________

7)

What is your position in this plant? *-choose one-*

[ ] a Foreman
[ ] b Skilled Worker
[ ] c Helper
[ ] e Other : ________________________

8)
How long are you in this position?

____

9) (fin6)
How important is what you do in your job here? For whom or for what? Please explain… *-open question-*

____
____
____

10) (fin7)
In the following please explain, which processes happen in which plant stage.
–open question-

Training in Plant A

	Plant Stage		*Processes*
[ ] A	Yeast Tank	a	______________________________ ______________________________
[ ] B	Acidification Tank	b	______________________________ ______________________________
[ ] C	UASB Reactor	c	______________________________ ______________________________
[ ] D	Surface Aeration Tank	d	______________________________ ______________________________
[ ] E	Intermediate Clarifier	e	______________________________ ______________________________
[ ] F	Diffused Aeration Tank	f	______________________________ ______________________________
[ ] G	Final Clarifier	g	______________________________ ______________________________
[ ] H	Sludge Drying Beds	h	______________________________ ______________________________
[ ] I	Other:_________________________	i	______________________________

Training in Plant B/C

	Plant Stage		*Processes*
[ ] A	Inlet Screen	a	______________________________ ______________________________
[ ] B	Grit Chamber	b	______________________________ ______________________________
[ ] C	Aeration Tank	c	______________________________ ______________________________
[ ] D	Final Clarifier	d	______________________________ ______________________________
[ ] E	Centrifuge	e	______________________________ ______________________________

[ ] F Digester f ______________________________
____

[ ] G Sludge Drying Beds g ______________________________
____

[ ] H Other:____________________________ h ______________________________

11) (fin8)
Please explain what consequences can have the following phenomena or undone works.
–open question-

Training in Plant A

	Phenomenon/Undone Work		*Consequences*
[ ] A	No Oil Change of Gearbox	a	______________________________
[ ] B	No Change & Emptying of Yeast Tank	b	______________________________
[ ] C	No Mixing of Acidification Tank	c	______________________________
[ ] D	No Constant Load of UASB Reactor	d	______________________________
[ ] E	Insufficient Aeration in Aeration Tank	e	______________________________
[ ] F	Sludge is Not Recycled to Aeration Tank	f	______________________________
[ ] G	Too High Sludge Level in Sludge Drying Bed	g	______________________________
[ ] H	Gas leak	h	______________________________
[ ] I	No Use of Clean Vessels for Sampling	i	______________________________
[ ] J	Other:_________________________	j	______________________________

Training in Plant B/C

	Phenomenon/Undone Work		*Consequences*
[ ] A	No Correct Greasing Of Screening System	a	______________________________
[ ] B	No Sand Is Taken From Grit Chamber	b	______________________________
[ ] C	No Oil Change of Gearbox & Pumps	c	______________________________
[ ] D	Insufficient Aeration in Aeration Tank	d	______________________________
[ ] E	Sludge is Not Recycled to Aeration Tank	e	______________________________
[ ] F	Too High Load Rate of Digester	f	______________________________
[ ] G	Wrong Feeding Rate of Centrifuge	g	______________________________

[ ] H Too High Sludge Level in Sludge Drying Bed h ____________________

[ ] I No Use of Clean Vessels for Sampling i ____________________

[ ] J Other:____________________ j ____________________

12)
What are your wishes for the future?

____

Final Test Questions

1)
After taking part in the workers training, how would you describe it? *–open question-*

____

2)
Try to describe your feelings during the training. Did you feel comfortable, stressed or overloaded? *-open question-*

____

3)
Were the main subjects, that are interesting for you, covered in the training? Please explain. *–open question-*

____

4)
Suppose you and your colleagues would take in professional training again, what would you wish?
-choose one for each category-

A	Total Time	[ ] a	Less	[ ] b	Same	[ ] c	More
B	Breaks	[ ] a	Less	[ ] b	Same	[ ] c	More
C	Theory	[ ] a	Less	[ ] b	Same	[ ] c	More
D	Examples	[ ] a	Less	[ ] b	Same	[ ] c	More
E	Discussions	[ ] a	Less	[ ] b	Same	[ ] c	More
F	Information per Time	[ ] a	Less	[ ] b	Same	[ ] c	More
G	Structure	[ ] a	Less	[ ] b	Same	[ ] c	More

5)
In your opinion – should similar training be offered to workers in other plants, too? Please explain
–open question-

___
___
___

6) (pre9)
How important is what you do in your job here? For whom or for what? Please explain… *-open question-*

___
___
___

7) (pre10)
In the following please explain, which processes happen in which plant stage.
–open question-

Training in Plant A

	Plant Stage		*Processes*
[ ] A	Yeast Tank	a	___
[ ] B	Acidification Tank	b	___
[ ] C	UASB Reactor	c	___
[ ] D	Surface Aeration Tank	d	___
[ ] E	Intermediate Clarifier	e	___
[ ] F	Diffused Aeration Tank	f	___
[ ] G	Final Clarifier	g	___
[ ] H	Sludge Drying Beds	h	___
[ ] I	Other:___	i	___

Training in Plant B/C

	Plant Stage		*Processes*
[ ] A	Inlet Screen	a	___
[ ] B	Grit Chamber	b	___
[ ] C	Aeration Tank	c	___
[ ] D	Final Clarifier	d	___

[ ] E Centrifuge e ______________________

[ ] F Digester f ______________________

[ ] G Sludge Drying Beds g ______________________

[ ] H Other:______________________ h ______________________

8) (pre11)

Please explain what consequences can have the following phenomena or undone works.

–open question-

Training in Plant A

	Phenomenon/Undone Work		*Consequences*
[ ] A	No Oil Change of Gearbox	a	______________________
[ ] B	No Change & Emptying of Yeast Tank	b	______________________
[ ] C	No Mixing of Acidification Tank	c	______________________
[ ] D	No Constant Load of UASB Reactor	d	______________________
[ ] E	In sufficient Aeration in Aeration Tank	e	______________________
[ ] F	Sludge is Not Recycled to Aeration Tank	f	______________________
[ ] G	Too High Sludge Level in Sludge Drying Bed	g	______________________
[ ] H	Gas leak	h	______________________
[ ] I	No Use of Clean Vessels for Sampling	i	______________________
[ ] J	Other:______________________	j	______________________

Training in Plant B/C

	Phenomenon/Undone Work		*Consequences*
[ ] A	No Correct Greasing Of Screening System	a	______________________
[ ] B	No Sand Is Taken From Grit Chamber	b	______________________
[ ] C	No Oil Change of Gearbox & Pumps	c	______________________
[ ] D	Insufficient Aeration in Aeration Tank	d	______________________
[ ] E	Sludge is Not Recycled to Aeration Tank	e	______________________
[ ] F	Too High Load Rate of Digester	f	______________________

[ ] G	Wrong Feeding Rate of Centrifuge	g	____________________
[ ] H	Too High Sludge Level in Sludge Drying Bed	h	____________________
[ ] I	No Use of Clean Vessels for Sampling	i	____________________
[ ] J	Other:____________________	j	____________________

9)
What are your wishes for the future?

____

____

____

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