OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM FOR UNIVERSITI TEKNOLOGI PETRONAS SEWAGE TREATMENT PLANT

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CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JUNE 2010

Occupational Safety and Health Management System for Universiti Teknologi PETRONAS Sewage Treatment Plant

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JUNE 2010

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Program
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
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(CIVIL ENGINEERING)

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June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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SITI DHAMINA BT MUHAMAD FADZIL

ABSTRACT

OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM (OSHMS) FOR UNIVERSITI TEKNOLOGI PETRONAS (UTP) SEWAGE TREATMENT PLANT (STP)

Wastewater treatment plant operators are facing a variety of accidents and near-misses resulting from exposure to a wide range of hazards related to plant design and processes. Among all, exposure to excessive noise levels, skin irritation and slips and falls are the most noticeable hazards in UTP STP. The aims of this study is first to identify these hazards at STP particularly in UTP, then, based on likelihood and severity the most risky hazards in the area of study were assessed by literature research, questionnaire surveys, interviews and observation at the workplace. According to produced list of hazards, proper management system via hierarchy of control (Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, and Personal Protective Equipment) is implemented. The research founded 26 hazards available in STP which covers 38.46% biological hazards, 34.62% physical hazards and 26.92% chemical hazards. Mitigation strategies proposed for excessive noise are installing sound absorber, using silencer, enforcing work rotation and providing ear plugs. While for skin irritation, solution proposed are installing auto cleaner, self-cleaning bar screen and scraper blades, providing trainings and safety gloves. Removing decant fluid, cordoning off the cleaning areas, providing ramps, delivering trainings and distributing slip resistant footwear are the mitigating strategies proposed for slips and falls hazard. An experiment to reduce the noise was conducted resulting the sound level decrease from no mitigation (93.71 dBA) to 93.16 dBA with carpet mitigation and 92.08 dBA for cardboard mitigation which consequently comply with the NIOSH requirement for the permitted time exposure (5, 6 and 7 hours respectively).

ACKNOWLEDGEMENTS

In the name of Allah the Most Gracious and the Most Merciful

Praise to Him the Almighty that in His will and given strength, had I managed to complete this two semesters Final Year Project titled Occupational Safety and Health Management System for Universiti Teknologi PETRONAS Sewage Treatment Plant.

A lot has transpired during this period of time and I am indebt to so many who had made this project an illuminating and enriching venture. My deepest gratitude goes to both of my supervisors, Dr. Amirhossein Malakahmad and Dr. Alan Giffin Downe, whose continuous support, enlightening supervision and countless hours spent in sharing their insightful understanding, profound knowledge and valuable experiences throughout the project accomplishment.

Greatest appreciation goes to the Final Year Project committee, UTP Civil Engineering Department lecturers and laboratory technicians, UTP HSE Department officers and UTP STP operators whom I used to work with, for their help and kind support. Many thanks also go to experts in Indah Water Consultant and NIOSH Malaysia whom I've communicated to for their kind sharing and cooperation.

Special thanks conveyed to beloved parents, Muhamad Fadzil Ab. Rahman and Khalidah Mohamad, and other family members for their eternal love, additional support, encouragement and sincere prayers. My sincere and heartfelt thanks to fellow friends, particularly Umi Najua, Nuramalina, Farhana, Izzah, Izaidah, Ammira, Zulfa as well as other individuals whom their names are not written here for their earnest contributions, directly or indirectly.

Last but not least, a special recognition to the oral presentation panel examiners, for their affirmative critics and kind evaluation on the assessment of the project. May the Almighty bless them all.

Siti Dhamina bt Muhamad Fadzil

May 2010

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ABBREVIATIONS AND NOMENCLATURES

OSHMS	Occupational Safety and Health Management System
UTP	Universiti Teknologi PETRONAS
STP	Sewage Treatment Plant
FWR	Foundation for Water Research
P.E.	Population equivalent
USM	Universiti Sains Malaysia
PMT	Pakar Management Technology
KLCCB	KLCC Berhad
DGSS	Design and Installation Guidelines for Sewerage Systems
OHSAS	Occupational Health and Safety Assessment Series
ILO-OSH	The International Labour Organization Guidelines on Occupational Safety and Health Management Systems
NIOSH	National Institute of Occupational Safety and Health
CSDS	Chemical Safety Data Sheet
MSDS	Material Safety Data Sheet
HSE	Health, Safety and Environmental
PPE	Personal protective equipment

CHAPTER 1

INTRODUCTION

1.1 Background

The concept of an Occupational Safety and Health Management System (OSHMS) has become common over the past 20 years. A variety of OSHMS-based standards, guidelines, and audits have been developed within the public, private and not-for-profit sectors and many have been adopted by workplaces. Some countries, including Canada, are in the process of developing management standards for occupational safety and health [1].

OSHMS promotes a safe and health practices and methods within the work environment and these are frameworks based on regulations and legal obligations. This provides any organization to identify and control risks that relate to health and safety resulting in reduction of potential for accidents [2].

For many years, wastewater treatment plants have been regarded as severely dangerous work environments. This field is considered somewhat less hazardous today, but treatment plant workers still do experience health problems and deaths. Accidents and near-misses result from worker exposure to a wide range of hazards related to plant design and processes [3].

For that reason, civil engineers and safety professionals need to carry out safety risk assessment and implement effective solutions to the problems. Thus, this paper attempts to elaborate the implementation of OSHMS at wastewater treatment field and particularly in Universiti Teknologi PETRONAS (UTP) Sewage Treatment Plant (STP).

1.2 Problem Statement

Wastewater treatment plant operator is a skilled worker who is responsible for the day-to-day operation, maintenance, trouble-shooting and handling of special problems of municipal, industrial, and other wastewater treatment plants [4]. They use mechanical equipment, treatment tanks, and chemicals to clean the water. Those activities can expose them to a mixture of hazards.

An analysis by the International Occupational Safety and Health Information Centre in Geneva found that wastewater treatment operators encounter no fewer than 15 accident hazards, three physical hazards, four chemical hazards, three biological hazards, and three ergonomic and psychosocial hazards in the course of their daily duties. The injury rate for workers in the wastewater treatment industry in 2006 was 5.2 injuries per 100 workers, according to the U.S. Bureau of Labor Statistics. That is 15% higher than the national average of 4.4 per 100 workers. Significant operation and maintenance activities occur at the headwork, so it is fitting to address safety concerns specific to this area [5].

Because of the unique nature of the work in the treatment process, slips and falls are the main hazards for wastewater treatment workers [6]. In a study conducted in Taiwan, falls accounted for 13.9% of all occupational injuries. Among the reported falling cases, 76.6% were falls on the same level, which accounted for 10.6% of all occupational injuries. Statistics showed that the majority of falls in the United States of America and European countries also occurred on the same level [7].

Particularly in the United States, the annual direct cost of occupational injuries due to slips, trips, and falls is estimated to be in excess of USD 6 billion. In total direct workers' compensation for occupational injuries due to slips and falls, falls on the same level accounted for 65% of claim cases and, consequently, 53% of claim costs [8].

Meanwhile, in the year 1995 until 1996, the United Kingdom Health and Safety Commission figures reported that slips, trips and falls from a same level constituted 20% of over 3-day-absence injuries and 35% of all major injuries. The figures reported by the Austrian Workers Compensation Board are even more impressive, slips and falls representing 27% of over 164,469 occupational or commuting-to-work accidents and 41% of compensation costs in 1994 [9].

Besides slips and falls, water borne disease is another concern for wastewater workers [10]. Wastewater treatment can be considered as potential sources of airborne pathogenic and non-pathogenic microorganisms where the facilities represent an exposure hazard to workers and people living in their immediate surroundings [11].

Based on a study conducted in Hanoi, contact with wastewater is a strong risk factor for skin ailments. People who exposed with wastewater had the higher risk of skin problems than those who were not exposed. The condition was similar to the findings in Phnom Penh where people who exposed to the wastewater had a higher prevalence of skin diseases than the one who does not exposed which is 22% versus 1% [12].

In addition, hearing loss is another common workplace injury that is often ignored. It was common in the past for workers to accept partial hearing loss as a cost of working in a noisy workplace, including a wastewater treatment plant [13].

Foundation for Water Research (FWR), an independent charity body in United Kingdom said that if uncontrolled, the noise generated within the works in sewage treatment plant may be sufficient to damage workers hearing [14].

Operators in Universiti Teknologi PETRONAS Sewage Treatment Plant also cannot escape from facing the hazards that are available at their workplace. Because of the unique nature of the job, they are exposed to slips and falls hazards and irritation due to contact with wastewater. Besides that, they are also facing the problem of excessive noise levels from mechanical equipments such as aerator, pumps etc. [15].

1.3 Objectives

This study attempts to implement the OSHMS at UTP STP. The main objectives of the paper are:

(i) To identify and assess the existing occupational hazards at STP in UTP.

(ii) To properly manage the identified hazards at STP in UTP based on OSHMS.

1.4 Scope of Study

This report attempts to present an overview of Universiti Teknologi PETRONAS Sewage Treatment Plant operation. Besides that, it will also elaborate the hazards that are available in UTP STP. Explanation on Occupational Safety and Health Management System also be included as one of the scope of study for this project

CHAPTER 2

LITERATURE REVIEW

2.1 Universiti Teknologi PETRONAS Sewage Treatment Plant

The UTP STP was designed based on a total population equivalent (P.E.) of 23,000 persons and was constructed in two parallel modules in which each module catered for a P.E. of 11,500 persons. Shamsul Rahman and Siti Hasna (2007) found that the treated effluent quality is supposed to comply with Effluent Standard A as stipulated by the Environmental Quality Regulations 1979, i.e BOD_5 and TSS of 20 mg/l, respectively (Appendix I) [16]. The design parameters for the STP are as shown in Table 2.1.

Table 2.1: UTP STP current parameter and design criteria.

Parameter	Design criteria
Influent BOD_5	250 mg/l
Influent TSS	300 mg/l
Effluent BOD_5	10 mg/l
Effluent TSS	20 mg/l
Peak flow	3.33 dry weather flow (d.w.f)
Total flow rate	5175 m^3/day
P.E.	23,000 persons

(Source: Monitoring the Removal of TSS, MLSS and MLVSS in UTP Sewage Treatment Plant, Siti Hasna Malinda Halimansyah, 2007)

The existing sewage treatment facility treats sewage discharge from the existing Universiti Sains Malaysia (USM) and UTP campuses as shown in Appendix II. Prior to this, the system consists of two numbers of oxidation ponds and one Imhoff tank [16].

From Pakar Management Technology (PMT), according to UTP development planning scheme prepared by KLCC Berhad (KLCCB), three phases of development parcels would be constructed. Phase 1 development parcel involves the development of the new sewerage system inclusive of the construction of new STP and a pumping station. Once the new STP and shifting of the existing USM campus has completed, the existing oxidation pond No. 1 will be closed [16].

Pakar Management Technology also said that Phase 1 covers only the areas outside the existing USM campus such as the academic and administrative complex, mosque and most of the student accommodation facilities. The new STP was designed to cater for the ultimate development of UTP and shall be completed by modules in stage [16].

According to the project proposal, the STP was designed to cater for Phase 1 and Phase 2 modules to facilitate a capacity of about 23,000 P.E.. To ensure the compliance of absolute effluent standards, the STP was designed based on the recommended guidelines from Design and Installation Guidelines for Sewerage Systems (DGSS), including the population equivalent estimate (Appendix III).

2.2 Hazards at Sewage Treatment Plant

As consequences from the development project of the UTP STP, the workers will be more exposed to the occupational hazards. It increases the likelihood and severity of a worker in facing certain hazards because there are more areas they need to cover in daily working activities.

In general, the workers are exposed to a wide variety of hazardous chemicals, deadly confined spaces, explosions, infectious diseases, extremes of heat, along with sprains, cuts and bruises [4].

Because there is so much water involved in the treatment process, slips and falls are the main hazards for UTP STP workers. Confined spaces are another concern at sewage treatment facilities [17]. Exposures to a low oxygen environment or high levels of hydrogen sulfide, methane gas, or ammonia can cause serious illness or death [18].

Engulfment and/or drowning in treatment tanks are categorized as one of the hazards at treatment plants. Pumps and valves which are used for moving water and another moving parts such as screens, belt presses, and conveyors can cause caught or crush hazards if the worker place a hand, arm, or foot too near that moving part [18].

Some chemically-related health complaints are acute in nature, involving short-term exposures and complaints such as irritations of the eyes, nose or throat. Other problems are chronic in which repeated exposures, sometimes over several years, have caused effects upon internal organs or have involved occupationally-related allergies [3].

Studies have shown that wastewater treatment may generate aerosols containing microbiological and chemical constituents. In fact, the primary route of exposure for workers is probably inhalation. The physical layouts of UTP STP involve open tanks and basins; which typically not designed to prevent aerial dispersion of wastewater during the treatment process. Volatile organics in wastewater may be vaporized or airstripped during treatment. Many of the compounds are carcinogens and/or mutagens, so the workers may be at increased risk of cancer or adverse birth outcomes [3].

Infections from exposure to waterborne disease organisms may be subclinical or may appear as actual disease in wastewater workers. Treatment personnel have reported nausea, vomiting, indigestion, diarrhea, and flu-like complaints. Studies of antibodies in the blood of many sewage workers have documented that disease exposures have occurred [3].

An enormous range of chemicals may be present in the influent and sludge. The presence of toxic chemicals and organisms in sewage, in sludge, and in the air at specific sites in sewage plants has raised suspicion regarding their possible effects on the health of the workers in this plant [3].

2.3 Occupational Safety and Health Management System

As OSHMS promotes a safe and health practices and methods within the work environment, it can be the solution for the problems faced by the workers. The standard on Occupational Health and Safety Assessment Series (OHSAS) 18001:1999 and The International Labour Organization Guidelines on Occupational Safety and Health Management Systems (ILO-OSH 2001) offers a good framework for this project [19].

Basically, OSHMS provides a framework to reduce disruption due to accidents, reduce workers compensation claims and assist any organization in complying with regulatory requirements. Besides that, OSHMS also contribute to the morale and high level and esteem, assist promoting and maintaining organization image, expedite the safe and successful induction of personnel. In addition, it also assists in the induction of new personnel or cross functional training and adds requirements to contractors thus reducing hazards which will contribute to risks [2].

OSHMS requirements, while fulfilling ILO-OSH follow a structure similar to OHSAS 18001:1999 / 2002 and Loss Prevention including; Occupational Safety and Health requirements clauses, general requirements, policy, planning, implementation and operations, verification and acting, management review and continual improvement [2].

The OHSAS 18001 specifies requirements for an organization to control its occupational safety and health (OSH) risks to improve its performance. As stated in Occupational Health and Safety Management System (1999), it should be noted that the Occupational Health and Safety Assessment Series (OHSAS) 18001 does not set out specific OSH performance criteria, nor provide detailed specifications to design management systems. It does only mention that it is important that organizations should:

(i) establish OSH management systems to minimize risks to its employees and other interested parties;

(ii) implement, maintain, and continuously improve OSH management systems;

(iii) assure itself of its conformance with its stated OSH policy;

(iv) demonstrate these conformances;

(v) seek certifications/registrations of its OSH management systems by an external organization; and

(vi) make self-determination and declaration of conformance within specifications.

CHAPTER 3

METHODOLOGY

The present work deals with methods that have been adopted in OSHMS-related studies which are applicable in the field of sewage treatment plants. Based on NIOSH, hazards are commonly identified by conducting review of documents and publications, inspection and observation at the workplace and questionnaire surveys [19]. On the other hand, British Journal of Industrial Medicine has adopted structured interviews with selected interviewees in order to collect data for their study [20].

Thus, the author has combined and selects a set of methodology in order to complete the study. They are:

- Literature research
- Questionnaires
- Interviews
- Inspection and observation at the workplace
- Risk assessment
- Applying control measures

3.1 Literature research

For hazards identification by literature research, reports of accidents, accident investigations and published journals were reviewed. This assisted in the identification of hazards which have previously identified. These reports can be obtained from the sewage treatment plant operators. From publication, information gained is trusted as the journals are downloaded from the online resource websites (e.g. ScienceDirect, Springerlink, ASCE etc.).

In addition, regulations and codes of practice can provide information on a known hazardous conditions, materials or practice. While if there is any statistics found, information on common accidents to watch out for can be obtained. Handbooks give practical information, whereas Chemical Safety Data Sheet (CSDS) and Material Safety Data Sheet (MSDS) provide information on hazardous materials, control measures first-aided and emergency response [19].

3.2 Questionnaires

A set of questionnaire was designed with various questions addressing hazards likelihood and severity. The questionnaire was drafted based on a series of hazards finding through journals reading, internet searching and books reading. Once the questionnaire was drafted, it was evaluated by a team that includes wastewater lecturers, safety officer and a Health, Safety and Environmental (HSE) specialist.

Based on the evaluation, changes were made; the questionnaire was adjusted to avoid bias. Subsequently, the questionnaire was again adjusted and finalized. A complete set of questionnaire is available in Appendix IV. It was then administered to various respondents including STP personnel, lecturers and safety officers.

3.3 Interviews

Based on the results gained from the questionnaires, a structured interview session with selected interviewees then constructed. Main purpose of the interview session is to validate the data gained from the questionnaires. At the end of the session, there are some general discussions in order to gain more data and information regarding the papers' topic.

In addition of validating data from the questionnaire, the interview also were carried out for the purpose of gaining details and supporting data and information on applying control measures for the selected hazards to be managed.

3.4 Inspection and observation at the workplace

Identifying hazards by inspection and observation can be divided into four types which are: statutory inspection, periodic inspection, formal and informal inspection. Before conducting the inspection or observation, some documentation needs to be prepared, i.e. a set of checklist [19].

Site visits to the STP at UTP were conducted to observe hazards identified from the questionnaire and interviews. Activities during the inspections involved measuring ambient noise, assessing flooring aggregates and observing procedures when cleaning the treatment tanks.

3.5 Risk assessment

Using preliminary data and onsite observation, risk associated with each hazard was calculated using a formula proposed by NIOSH Malaysia (Equation 3.5.1). Questions like how many people are exposed to each hazard and for how long are figured out. This is done to predict the frequency of an accident occur and the consequence of that accident. That information then used to assess the likelihood and severity of each hazard and a qualitative risk table is produced.

$$\text{Risk} = \text{Likelihood} \times \text{Severity} \quad \ldots\ldots\ldots \quad (3.5.1)$$

According to NIOSH, how likely is that a hazardous event will occur is ranked as [19]:

1. Highly unlikely – Yearly
2. Unlikely – Monthly
3. Likely – Weekly
4. Very likely – Daily

While the severity of a hazard is being ranked as:

1. Negligible injuries – First aid and near misses
2. Minor injuries – Less than or 4 days MC
3. Major injuries – More than 4 days MC
4. Fatality – Fatality or permanent disability

Risk assessment was prepared using a matrix table with one table for each hazard identified. This approach is very good for visualization and understanding. Table 3.1 illustrates an example of a risk assessment form [19].

Table 3.1: Qualitative Risk Table

HAZARD NO.	**HAZARD**	**LIKELIHOOD (a)**	**SEVERITY (b)**	**RISK (a) x (b)**
1	A	4	4	16
2	B	1	2	2
3	C	4	2	8
4	D	1	4	4

3.6 Applying control measures

Based on the level of risk, the hierarchy of control measures (Figure 3.1) was used to identify the mitigating strategies. The topmost hierarchy is eliminating the hazards followed by substitution and isolation. It is then followed by applying engineering control, administrative control and providing personal protective equipment as the last resort solution.

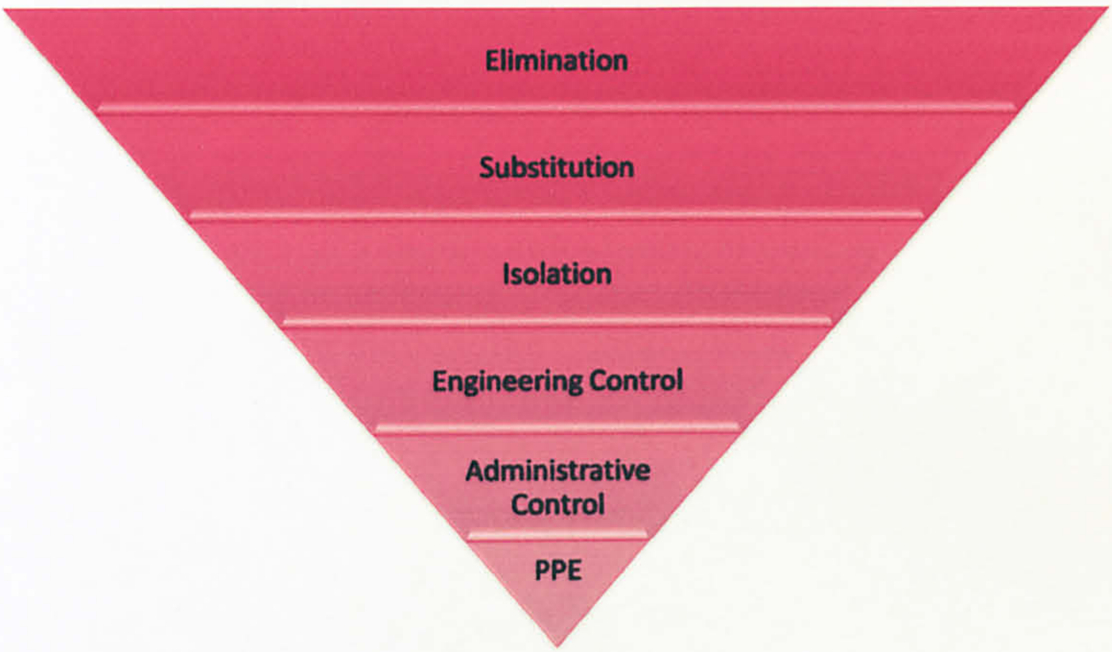

Figure 3.1: Hierarchy of control measures

Below are the descriptions for each element in the hierarchy:

1. **Elimination** – removing the hazard or hazardous work practice from the workplace. This is the most effective control measure.

2. **Substitution** – substituting or replacing a hazard or hazardous work practice with a less hazardous one.

3. **Isolation** – isolating or separating the hazard or hazardous work practice from people not involved in the work or the general areas.

4. **Engineering control** – this may include modifications to tools or equipment, providing guarding to machinery or equipment.

5. **Administrative control** – includes introducing work practices that reduce the risk.

6. **Personal protective equipment (PPE)** – should be considered only when other control measures are not practicable or to increase protection and as last resort measure.

For designers, engineers, operations personnel responsibility for safety and safety practitioners, a hierarchy of controls sets forth a way of thinking about taking actions in a feasible order of effectiveness to reduce risks. Achieving an understanding of the significance and the rationale for the order in which the elements in a hierarchy of controls are placed is an important step in the continuing evolution of the practice of safety [21].

3.7 Experimental procedure for sound mitigation

Based on interviews with the STP operators and results from risk assessment, excessive noise hazard was selected as the most noticeable hazard in STP at UTP. Hence, an experiment to reduce the noise was conducted on site.

Noise level near the blower room was measured with an AEMC Instruments Sound Level Meter CA832. The measurement time for one measurement was one minute, and 30 measurements were done. Frequency band ''A'' and time response ''fast'' were used. The range of 80 – 130 dBA was selected during the measurement.

Two mitigation methods were used in order to compare the sound level with no mitigation applied. Those methods are carpet mitigation and cardboard mitigation. Materials selection was done by experts' advice and internet sourcing.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Identification of hazards at sewage treatment plant

Based on previous semester's research, the author received a response rate of 8.54% out of one hundred seventeen (117) questionnaires from sewage treatment plant contractors and PETRONAS' subsidiaries staffs. Nine (9) interview sessions involving sewage treatment plant workers, wastewater and environmental lecturers contributes to the hazards ranking below. Besides that, seven (7) site visits for hazard inspection and observation at STP in UTP and journals evaluation had given points to the rank of the hazards.

In order to increase the response rate, reminders were sent for two times to the respective receiver. Other contacts such as telephone calls can be done to increase the response rate. The response rate for this survey was low, which is 8.54%. Some of the questionnaires were bounced back because the email address of the respondents might not update, or some had been moved or the company has closed down. The other reason of low response rate is probably due to the worry of being audited.

Although the response rate was low (below 50%), it was similar to a response rate reported by another questionnaire survey distributed to small and medium enterprises in Thailand regarding OSHMS which is 22.44% for small size enterprises and 14.06% for medium size enterprises [22].

The hazards then were categorized into three major groups which are biological hazards, chemical hazards and physical hazards. Pie chart in Figure 4.1 shows the fraction for each category of hazard which are biological hazards (38.46%), physical hazards (34.62%) and chemical hazards (26.92%).

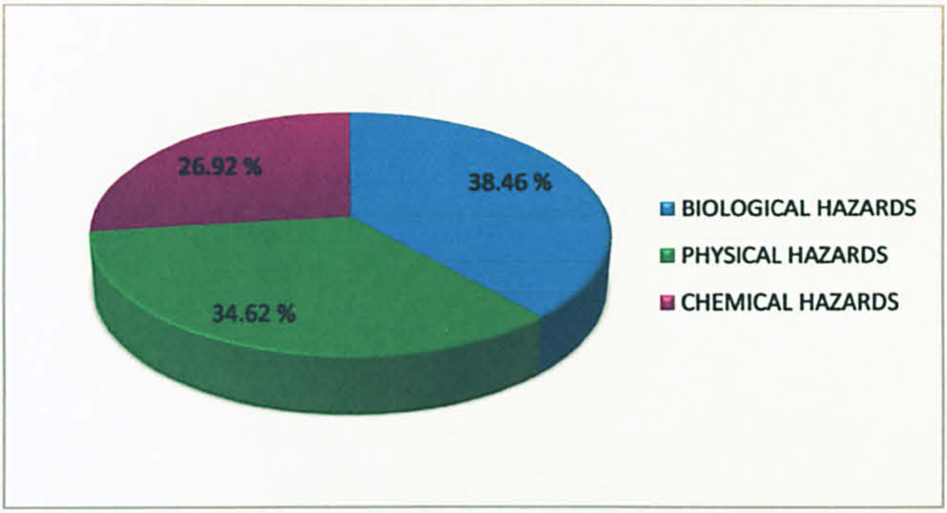

Figure 4.1: Hazards classification fraction

Meanwhile Table 4.1 lists the hazards in each category. Biological hazards comprises of UV radiation, extreme weather, dermatoses, irritation, latex allergy, diseases caused by infectious agents, diseases caused by contact with the toxins released by the infectious agents, diseases caused by insects or rodents, musculoskeletal injuries discomfort and psychological problems. The hazards that fall into chemical category are; vigorous chemical reactions, entry into confined spaces, acute poisoning caused by various chemicals, acute intoxication caused by erroneous drinking of untreated wastewater, poisoning by phosgene, chemical burns by corrosive liquids and eye damages caused by liquid splashes. Meanwhile slips and falls, blows and contusions, excessive noise, falls into treatment tanks, burns, electric shock, cuts and pricks, eye injuries, fire and explosions fall into physical hazards category.

Table 4.1: List of hazards classification

No.	Hazard class	Hazard
1	Biological	Exposure to UV radiation.
2		Exposure to adverse weather (low or high temperature, rain, snow, storms, etc.)
3		Dermatoses caused by exposure of the skin to waste waters, cleaning formulations, acid and alkaline solutions, etc.
4		Irritation of mucous membranes (in particular of the respiratory tract) by acid or alkaline vapors or aerosols, by hydrogen sulfide, and other substances.
5		Latex allergy caused by the use of latex gloves.
6		Diseases caused by infectious agents (bacteria, viruses, protozoa, helminths and fungi) present in the raw domestic wastewater (mainly from human origin) and in agricultural wastes.
7		Diseases caused by contact with the toxins released by the infectious agents.
8		Diseases caused by insects or rodents proliferating in the sludge drying beds.
9		Musculoskeletal injuries caused by overexertion while handling heavy loads, such as containers of chemicals, or by awkward working postures (including frequent bending), etc.
10		Discomfort and psychological problems related to prolonged wear of protective clothing (including heavy boots, aprons and other impermeable pieces), to the bad smells of the wastes, to the feeling of working with "soiled" liquids in a "dirty" and not too "respectable" occupation, and to the apprehensions caused by awareness of the dangers of the workplace.
11	Chemical	Vigorous chemical reactions caused by uncontrolled mixing of chemicals (e.g., if water is mixed with concentrated sulfuric

		acid) during the preparation of reagents for wastewater treatment.
12		Hazards related to entry into confined spaces - suffocation due to oxygen deficiency, poisoning (e.g. by hydrogen sulfide), etc.
13		Acute poisoning caused by various chemicals present in the wastes, used as reagents (e.g., gaseous chlorine), or released during the treatment; a particular hazard is caused by the possible release of a number of poisonous gases, e.g., hydrogen-cyanide (from metal plating or heat treatment wastes upon acidification), hydrogen-sulfide, etc.
14		Acute intoxication caused by erroneous drinking of untreated wastewater.
15		Poisoning by phosgene, which may be formed if a worker smokes in the presence of chlorinated-solvent vapors, or if welding or other flames or arcs are used.
16		Chemical burns by corrosive liquids such as mercury etc.
17		Damage to eyes by splashes of irritating or corrosive liquids such as chlorine etc.
18	Physical	Slips and falls on floors made slippery by water, aqueous solutions or solvents.
19		Blows and contusions caused by falling heavy articles, including containers of chemical reagents, e.g., from overhead conveyers, or by contact with moving machinery or vehicles.
20		Exposure to excessive noise levels from mechanical equipment.
21		Falls into ponds, pits, clarifiers or tanks causing injuries or drowning.
22		Burns, by steam or hot vapors, by splashes of hot plating baths, solvents and other liquids, by contact with hot surfaces (e.g., annealing ovens), etc.
23		Electric shock caused by contact with faulty electrical

		equipment, cables, etc.
24		Cuts and pricks by sharp tools or sharp edges of articles to be plated sharp deposits on jigs, etc.
25		Injuries (especially of eyes) caused by flying particles, in particular from rotating brush cleaning or wheel grinding.
26		Fire and explosions due to the formation and release of flammable gases during processing (e.g., methane, hydrogen).

From both Figure 4.1 and Table 4.1, we can see that biological hazards made up the biggest fraction, which is 38.46% (10 hazards). It is then followed by physical hazards, which is 34.62% (9 hazards) and the least is chemical hazard which comprises of 26.92% (7 hazards).

This combination seems almost the same for each category of hazard. This is most probably because of the plant design and the nature of the job in sewage treatment area. Facilities in STP at UTP as shown in Appendix II can pose the workers to the various mixtures of hazards as listed above.

Out of twenty six hazards identified, Table 4.2 below lists the top ten most risky hazards at sewage treatment plants. The highest is hazards related to entry into confined spaces which is 9.36 followed by musculoskeletal injuries, electric shock, falls into treatment tanks, chemical poisoning, fire and explosions, slips and falls, excessive noise, blows and contusions and the tenth highest hazard is eye damages due to liquid splashes.

Table 4.2: Hazards Rank

No.	Hazard	Average Risk score
1	Hazards related to entry into confined spaces - suffocation due to oxygen deficiency, poisoning (e.g. by hydrogen sulfide), etc.	9.36
2	Musculoskeletal injuries caused by overexertion while handling heavy loads, such as containers of chemicals, or by awkward working postures (including frequent bending), etc.	7.00
3	Electric shock caused by contact with faulty electrical equipment, cables, etc.	6.90
4	Falls into ponds, pits, clarifiers or tanks causing injuries or drowning.	6.50
5	Acute poisoning caused by various chemicals present in the wastes, used as reagents (e.g., gaseous chlorine), or released during the treatment; a particular hazard is caused by the possible release of a number of poisonous gases, e.g., hydrogen-cyanide (from metal plating or heat treatment wastes upon acidification), hydrogen-sulfide, etc.	5.73
6	Fire and explosions due to the formation and release of flammable gases during processing (e.g., methane, hydrogen).	5.40
7	Slips and falls on floors made slippery by water, aqueous solutions or solvents.	5.27
8	Exposure to excessive noise levels from mechanical equipment.	5.00
9	Blows and contusions caused by falling heavy articles, including containers of chemical reagents, e.g., from overhead conveyers, or by contact with moving machinery or vehicles.	4.90
10	Damage to eyes by splashes of irritating or corrosive liquids such as chlorine etc.	4.89

Figure 4.2 below shows the simplified graphical view of the hazards rank. It illustrates the result from the risk calculation which is the outcome of multiplication of likelihood and severity. Four hazards ranked above 6, three hazards between 5 to 6 and below 5 comprises of three hazards.

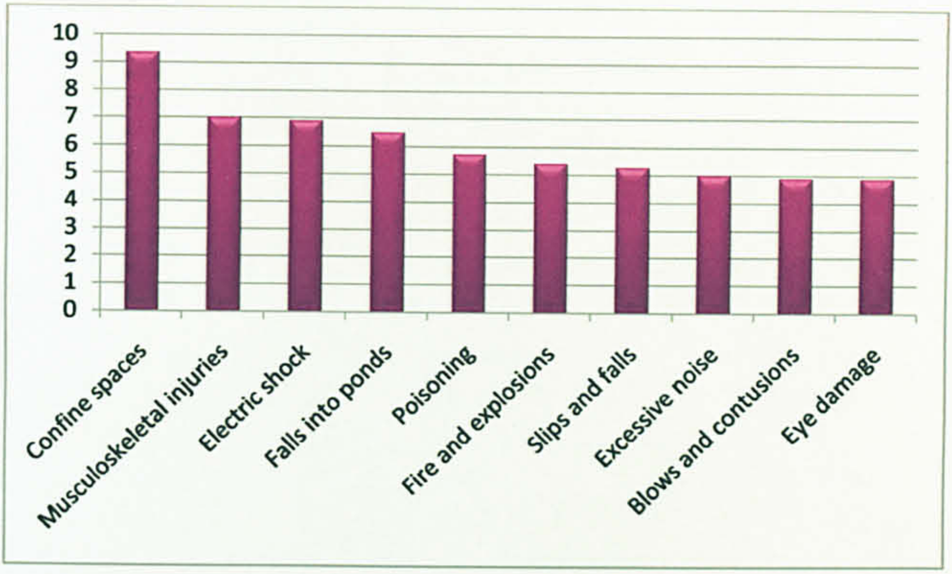

Figure 4.2: Hazards risk

From all of the listed hazards and based on the interviews with UTP operators as well as their supervisor from Tenaga Kini Sdn. Bhd., the author has select three hazards which has significant existance at STP in UTP and among the topmost risky hazards [15], [23] and [24]. Those hazards are:

i. Exposure to excessive noise levels from mechanical equipment
ii. Irritation caused by exposure of the skin to waste waters
iii. Slips and falls on floors

4.1.1 Exposure to excessive noise levels from mechanical equipment

The noise in UTP STP is mainly caused by the aerator which provides air to the aeration tank [25]. The ambient noise level measured at the blower house was 93.7 dBA, which exceeds the permissible limit by NIOSH (Appendix V).

Noise level was measured according to NIOSH standard with an AEMC Instruments Sound Level Meter CA832. The measurement time for one measurement was 2 minutes, and 5 measurements were done at selected points around the blower house. Frequency band ''A'' and time response ''fast'' were used. The range of 80 – 130 dBA was selected during the measurement.

4.1.2 Irritation caused by exposure of the skin to waste waters

The workers at STP in UTP also experience skin irritation. The reason is mainly because of the characteristic of the wastewater which contains heavy metals and microbiological matters. Since their main routine at the plant deals with the wastewater, the possibility of contact between the skin and wastewater is high [15], [23] and [24].

Domestic wastewater contains organic and inorganic matter in suspended, colloidal and dissolved forms. The concentration in the wastewater depends on the original concentration in the water supply and the uses to which water has been put. The climate, wealth and habits of the people have a marked effect on the wastewater characteristics [26]. Raw domestic wastewater characteristics are shown in Appendix VI. The range of values given is typical for municipal wastewaters, which predominantly domestic in character. The wastes are mainly organic in nature, containing nutrients like carbon, nitrogen and phosphorus, among others with relatively high concentrations of microorganisms [26].

4.1.3 Slips and falls on floors

According to the workers at STP in UTP, they are prone to have slips and falls hazard at workplace mainly due to the nature of the job. Their daily job which are cleaning the grit chamber and bar screen at the primary section and clearing the clarifier from solid waste pose them to the falling hazard. Besides that, the weekly routine which is taking effluent sample also can lead to the slips and falls hazard [15], [23] and [24].

K. W. Li et al found that slips and falls are among serious safety problem in the workplace. It is generally assumed that slips are more likely to occur on slippery floors. Since STP operates and deals with a lot of liquids, the chance for the workers to have this hazard is high [7].

4.2 Applicable control measures for each hazard

For each selected hazard, steps in control hierarchy are then followed in order to manage those hazards and reduce the risk to the workers. Proper referencing from published journals and trusted books were done to ensure the quality of the work.

The findings for control measure are as below:

4.2.1 Exposure to excessive noise levels from mechanical equipment

Elimination	This hazard cannot be eliminated. It is proofed that for any wastewater treatment, this kind of aeration has many advantages compared to others such as low capital cost, easy operation, low odor and produce non explosive gas like CO_2 & NH_3 [27]. Thus, the blower

	cannot be eliminated due to its' advantages compared to others.
Substitution	As per original design calculation by PMT (Appendix VII), the blower specification already suits the usage of STP in UTP. Hence, any idea of substitution will need modification in the design criterion and it requires high cost.
Isolation	Isolation of the blower also cannot be implemented because the blower house situated just beside the administration and control room, the room where most of the time the workers be in. It is only divided by a concrete wall which still not effective in reducing the noise generated by the blower.
Engineering control	<u>Installation of Unit Sound Absorbing Panels</u> Functional (unit) Sound Absorbing Panels can be installed on the ceilings and walls for that particular blower room. In a study carried by Institute of Noise Control Engineering, installation of these absorbing panels can reduce the noise level in the blower room to 82 dBA bringing the room into OSHA compliance, and reducing reverberation to levels that did not interfere with communication between workers [28]. <u>Provision of aerators' exhaust fan with silencer</u> The strategy is adopted from West Country Treatment Plant Noise and Odour Control Project. It is proven that, by providing the silencer, noise emissions are reduced by 10 – 14 dBA [29].
Administrative control	<u>Enforcement of work rotation</u> Generally, this strategy has limited use because the contactor seldom permits shifting from one job to

	another [30]. Moreover, the practice of rotating workers between quiet and noisy jobs, although it may reduce the risk of substantial hearing loss in a few workers, may actually increase the risk of small hearing losses in many workers. Provision of quiet areas where employees can gain relief from workplace noise The areas will be used for work-breaks and lunch rooms should be located away from noise. Since the control room, which the place where the workers always stay at is just next to the blower house, the room should be acoustically treated to minimize background noise levels.
Personal protective equipment	Distribution of ear plugs to the workers Unless great care is taken in establishing a hearing protector program, workers will often receive very little benefit from these devices. Each worker can react differently to the use of ear plugs. They must take responsibility for being fully informed about the need for hearing protection, wearing their hearing protectors correctly at all times and seeking replacements as necessary.

4.2.2 Irritation caused by exposure of the skin to waste waters

Elimination	Since the cause of connection between the worker and the wastewater comes from activity of sampling and cleaning treatment tanks [31], we can eliminate the

	contact by changing the procedure of carrying out their tasks. This will be explained further in engineering control section.
Substitution	There are options to substitute the existing procedure of collecting samples and cleaning the tanks. Those options will be explained further in engineering control section.
Isolation	The contact of wastewater can be isolated from the unauthorized personnel by limiting the access into the area only for workers with appropriate safety measures.
Engineering control	<u>Installation of Auto-Cleaner at clarifier</u> The cleaner is employed on radial tanks and is mounted on the rotating half-bridge. On the cleaning cycle, the vacuum head is lowered below the water line to be close to the upper surface of the screens, the pump is activated and solids wastes are sucked up through both layers of mesh. The tank remains in operation during cleaning. The image in Appendix VIII shows the clarifier screens installed as an annulus complete with a new inner baffle board. The existing scraper leg assembly is modified as necessary. <u>Installation of Self Cleaning Bar Screen Unit at bar screen</u> This self-contained unit acts as a screen to prohibit debris from entering the wastewater treatment plant. Bar Screen Unit comes with a steel tubular frame, evenly spaced bars, metal rakes and conveyor chains. It also needs only simple adjustments for pump pressures and flows. Chain speed and tension are field adjustable for maximum field operation. Image of this unit can be

	viewed at Appendix VIII. <u>Installation of Scraper Blades at grit chamber</u> The blades of the scraper collect the grit settled on the floor of the grit chamber. The grit so collected is elevated to the ground level by several mechanisms such as bucket elevators, jet pump and air lift. The grit washing mechanisms are also of several designs most of which are agitation devices using either water or air to produce washing action.
Administrative control	<u>Delivery of trainings for workers regarding standard hygiene practices</u> OSHA recommends that employers require employees to use proper personal hygiene practices, including giving them proper trainings regarding to this matter. Good personal hygiene practices to limit exposure to wastewater include the following: • Prohibiting eating, drinking or using tobacco products in plant areas; • Washing hands and face before eating, drinking, smoking, or applying cosmetics; • Showering before leaving the worksite; • Changing into clean clothing before leaving the worksite; and • Parking cars where they will not be contaminated with the wastewater.
Personal protective equipment	<u>Distribution of gloves to the worker</u> The nature of the hazard and the operation involved in the plant will affect the selection of gloves. The variety of potential occupational hand injuries and skin irritation makes selecting the right pair of gloves

	challenging. It is essential that employees use gloves specifically designed for the hazards and tasks found in the workplace because gloves designed for one function may not protect against a different function even though they may appear to be an appropriate protective device.

4.2.3 Slips and falls on floors

Elimination	In order to eliminate the slipping and falling hazards, it is necessary to remove all of the decant fluid on the walkways.
Substitution	From the inspection done at the STP in UTP, it is found that the flooring materials are still in good condition. Hence, there is no need to substitute the materials with the new one.
Isolation	Cordoning off areas while cleaning is in progress This strategy can be implemented while cleaning activities are in progress. Unauthorized personnel are prohibited from accessing the area except safety measures are already in place.
Engineering control	Provision of ramps at cleaning area points around the clarifier From the interview with the workers in STP at UTP, they claimed that, cleaning activities especially cleaning the clarifier will pose them to the hazard of falling into the treatment tanks. It is suggested that the management to provide ramps around the clarifier so that the slipping and falling hazard at that point can be eliminated.
Administrative control	Delivery of trainings on good housekeeping Good safety housekeeping can significantly reduce

	accidents and injuries in the plant. By developing good safety habits, and by being aware of the work environment and any hazards associated with it, workers can help to create a much safer workplace. OSHA's General Requirements for Housekeeping related to Walking-Working Surfaces, CFR 1910.22 stated that all places of employment, passageways, storerooms, and service rooms shall be kept clean and orderly and in a sanitary condition. Thus, it is the employer's responsibilities to provide this training to the workers.
Personal protective equipment	Distribution of slip-resistant footwear to the workers Using slip-resistant footwear when performing wet or greasy tasks can help reducing the hazard. Non-slip shoe provide safe footwear for a minimal cost.

4.3 Experimental results

Based on the interviews with the STP operators, an experiment to reduce the sound from the blower was conducted. Three different conditions were set up in order to measure the sound level produced by the blower. Those conditions are:

i. No mitigation
ii. Carpet mitigation
iii. Cardboard mitigation

Figure 4.3 shows the bar chart of frequency of occurrence of the sound levels where for no mitigation, the highest occurrence is 93.6 dBA which is 23.33% occurrence. Figure 4.4 shows the result for carpet mitigation, where the highest occurrence is 93.2 dBA which is 43.33% occurrence and Figure 4.5 illustrates the result for cardboard mitigation which shows that 92.2 dBA as the highest frequency which is 33.33% occurrence.

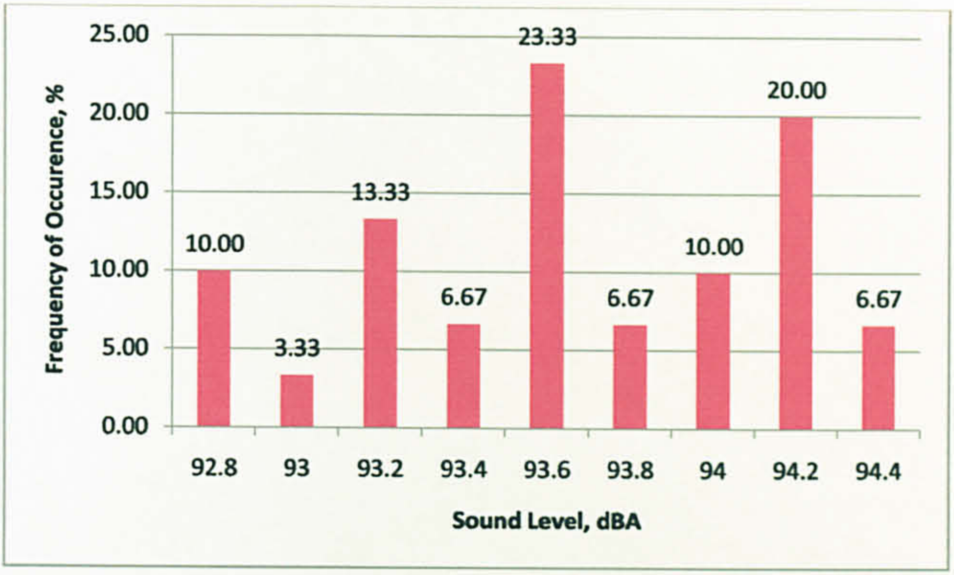

Figure 4.3: Frequency of occurrence of sound level for no mitigation

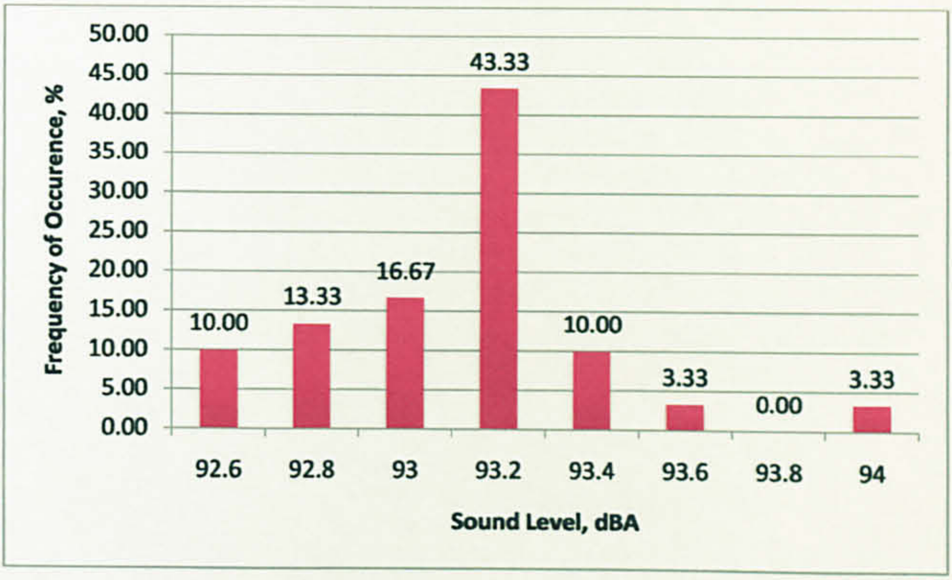

Figure 4.4: Frequency of occurrence of sound level for carpet mitigation

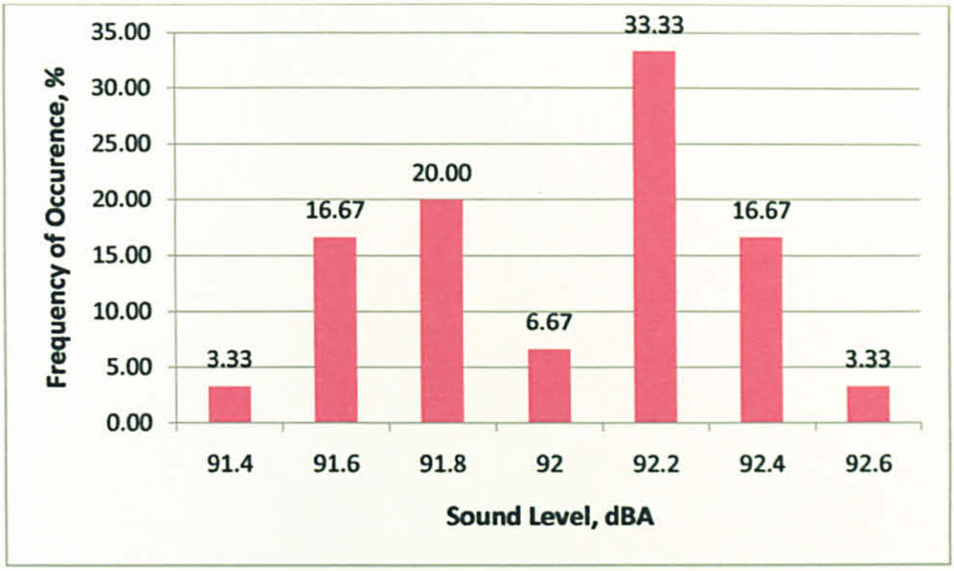

Figure 4.5: Frequency of occurrence of sound level for cardboard mitigation

Corresponding to the results gained above, NIOSH has recommended that occupational noise exposure be controlled so that no worker is exposed in excess of the limits defined by line B. In addition, NIOSH recommends that new installations be designed to hold noise exposure below the limits defined by line A [32]. Hence, Figure 4.6, 4.7 and 4.8 illustrates the permitted duration for each level of sound emitted.

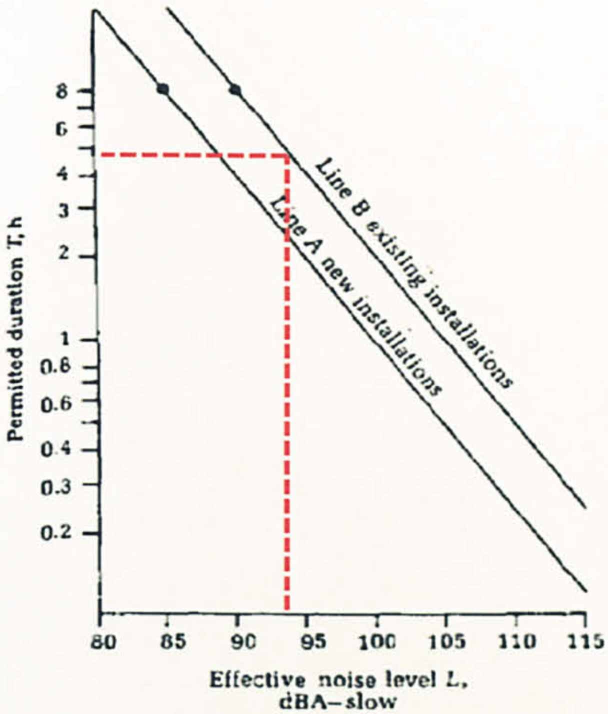

Figure 4.6: Permitted duration for sound level from no mitigation

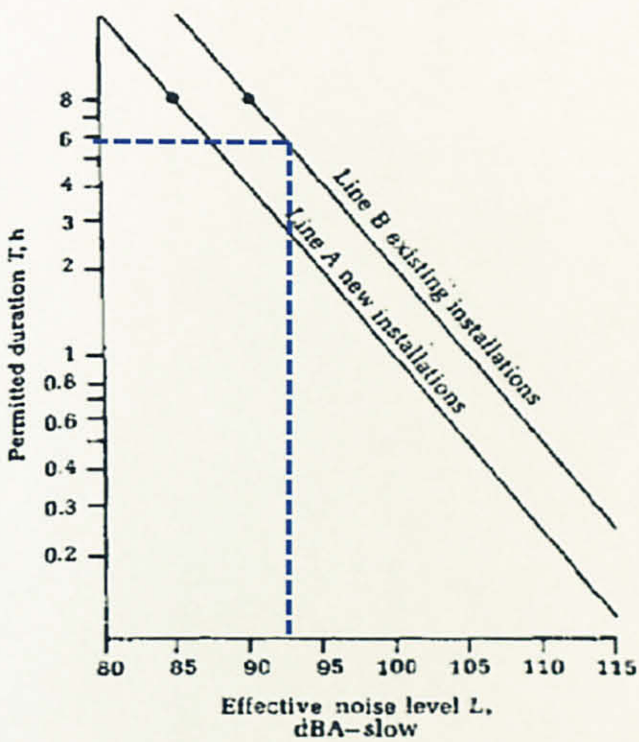

Figure 4.7: Permitted duration for sound level from carpet mitigation

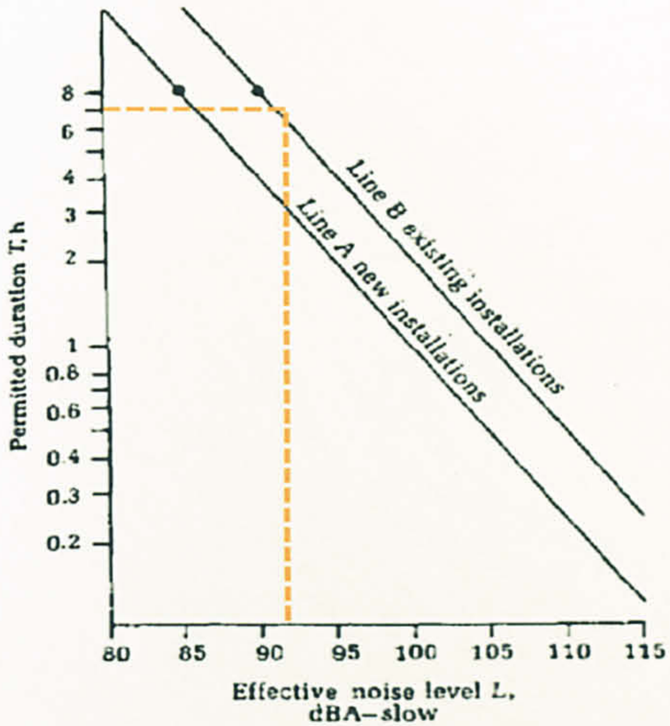

Figure 4.8: Permitted duration for sound level from cardboard mitigation

Figure 4.9 below shows the overall comparison for the sound absorbance experiments. The figure shows that cardboard mitigation is the most effective mitigating strategy in reducing excessive noise in the STP. It shows that for no mitigation, the workers can only exposed to the sound for approximately five hours. By installing carpet mitigation, the worker can exposed until approximately six hours. For cardboard mitigation, the permitted duration for the workers' exposure increased to seven hours.

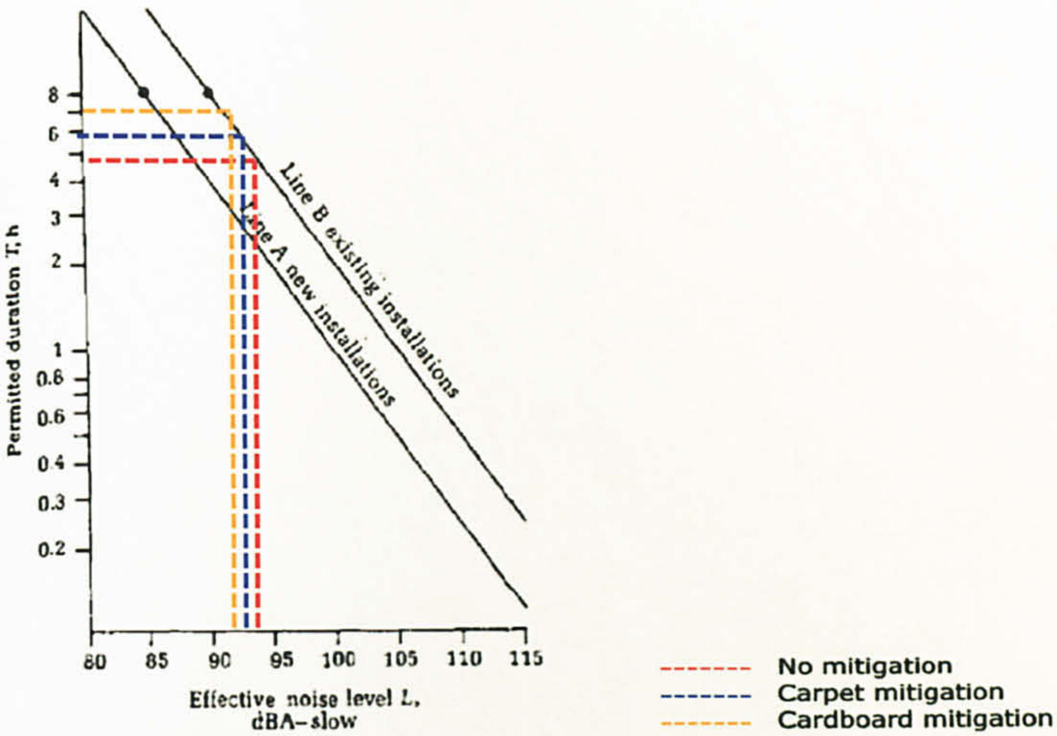

Figure 4.9: Sound absorbance overall comparison

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Hazards at Universiti Teknologi PETRONAS Sewage Treatment Plant had been identified through four means which are literature research, questionnaire surveys, interviews and observation at the workplace. There are 26 hazards found comprising of ten biological hazards (38.46%), nine physical hazards (34.62%) and seven chemical hazards (26.92%).

Using preliminary data from those methodologies, the hazards were ranked based on the most risky until the least risky using a formula proposed by NIOSH Malaysia (RISK = LIKELIHOOD x SEVERITY). Ten most risky hazards are entry into confined spaces (9.36), musculoskeletal injuries (7.00), electric shock (6.90), falls into treatment tanks (6.50), chemical poisoning (5.73), fire and explosions (5.40), slips and falls (5.27), excessive noise (5.00), blows and contusions (4.90) and eye damages due to liquid splashes (4.89).

Considering the level of risk and experiences of workers at STP in UTP, the hierarchy of control measures was used to identify mitigating strategies for three chosen hazards (Exposure to excessive noise levels from mechanical equipment, Irritation caused by exposure of the skin to waste waters and Slips and falls on floors). The hierarchy begins from elimination followed by substitution, isolation, engineering control, administrative control and personal protective equipment.

In order to get more effective solution for all of the listed hazards, it is recommended that future study for selecting the correct mitigating strategies can be carried out. The strategies can be either grouped for the quite similar hazards (i.e. injuries especially of eyes caused by flying particles and damage to eyes by splashes of irritating or corrosive liquids) or break the hazard down to provide more detailed investigation (i.e. hazards of entry into confined spaces can be branched into hazard related to gases, falling hazard, animal bites etc.)

In addition, it is recommended that future researcher to put in place experimental procedures in order to support the mitigating strategies that have been proposed. The data collected from the experiment also can be used to measure the effectiveness of the strategies and its' impact on the workers in the STP.

As a conclusion, it can be said that a systematic approach is an effective and efficient way of improving dangerous work environments, not only within sewage treatment facilities but in other industrial settings as well. Future research is necessary to enhance safety systems and develop industry standards.

CHAPTER 6

ECONOMIC BENEFITS

As the popular quote says – "Health is Wealth," this project has its own beneficial value in terms of economic side. Figure 4.9 explains this well, whereby by decreasing the sound level, it will increase the permitted duration for the workers to be exposed to that effective noise level. This situation will profit the employer, because the worker can work longer in a day in the sewage treatment plant.

In addition, as stated in the problem statement which is the annual direct cost of occupational injuries due to slips, trips, and falls in United States is estimated to be in excess of USD 6 billion. In total direct workers' compensation for occupational injuries due to slips and falls, falls on the same level accounted for 65% of claim cases and, consequently, 53% of claim costs [8].

By adopting OSHMS in place, it can guarantee a safer workplace to the workers. This condition will eventually reduce the amount of claims from the workers. It also can reduce the frequency of absenteeism, which then will benefit the employer.

In a meanwhile, although delivering trainings to the workers will impose some amount of money to the employer, it is actually a profitable investment. This is because; trained workers will carry out their jobs in the correct manner. This in return will reduce the indirect cost in the future.

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APPENDIX I

Standard A and B

THIRD SCHEDULE

ENVIRONMENTAL QUALITY ACT 1974 (ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS))

REGULATIONS 1978

[Regulation 8 (1), 8 (2), 8 (3)]

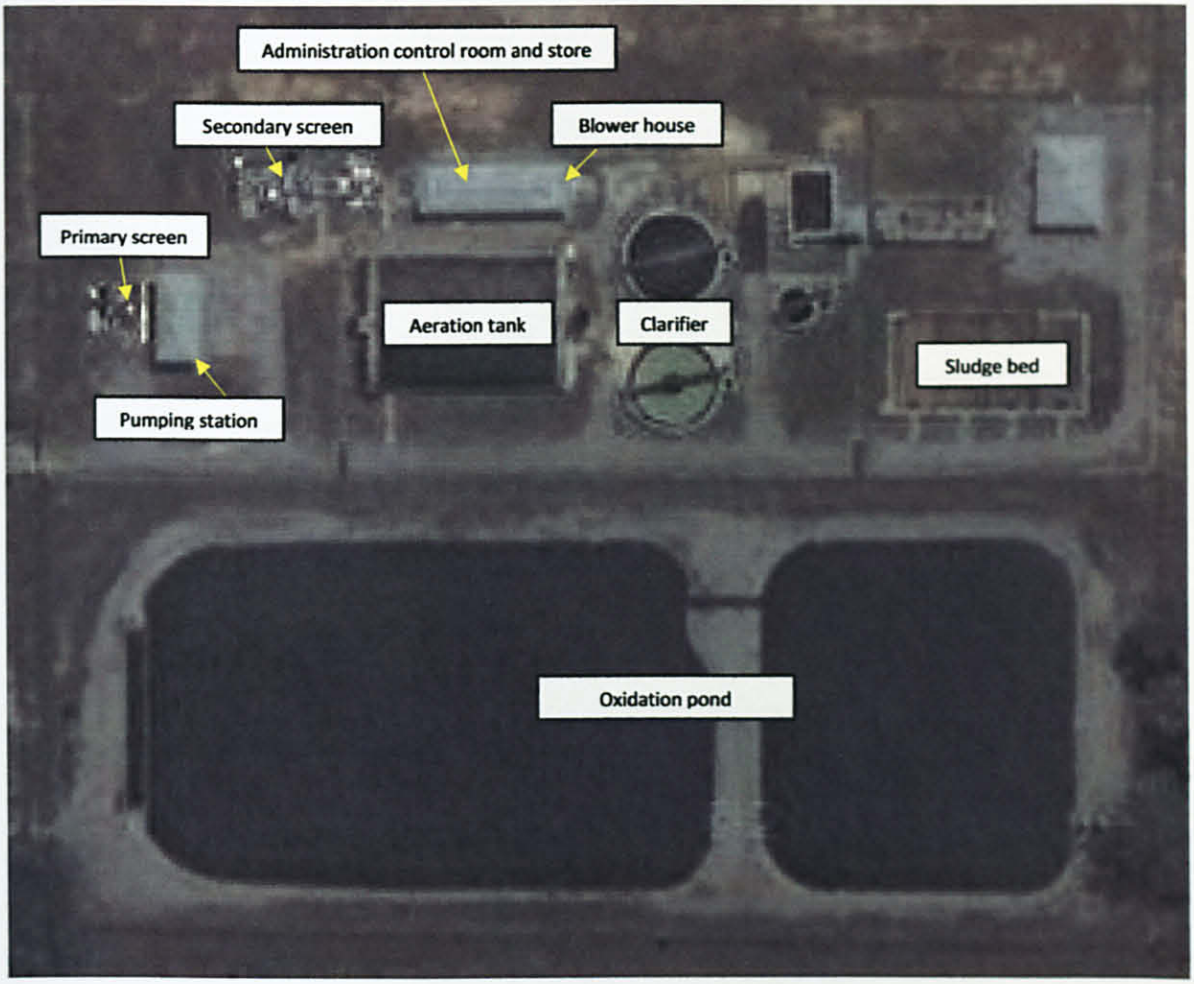
Table A-I: Parameter Limits of Effluent of Standards A and B

Parameter	Unit	Standard	
		A	B
Temperature	°C	40	40
pH value		6.0 – 9.0	5.5 – 9.0
BODs at 20 °C	mg/L	20	50
COD	mg/L	50	100
Suspended solids	mg/L	50	100
Mercury	mg/L	0.005	0.005
Cadmium	mg/L	0.01	0.02
Chromium, Hexavaient	mg/L	0.05	0.05
Arsenic	mg/L	0.05	0.10

Cyanide	mg/L	0.05	0.10
Lead	mg/L	0.10	0.50
Chromium, Trivalent	mg/L	0.20	1.00
Copper	mg/L	0.20	1.00
Manganese	mg/L	0.20	1.00
Nickel	mg/L	0.20	1.00
Tin	mg/L	0.20	1.00
Zinc	mg/L	1.00	1.00
Borom	mg/L	1.00	4.00
Iron (Fe)	mg/L	1.00	5.00
Phenol	mg/L	0.001	1.000
Free chlorine	mg/L	1.00	2.00
Sulphide	mg/L	0.50	0.50
Oil and grease	mg/L	Not detectable	10.00

APPENDIX II

Facilities in UTP STP



APPENDIX III

Population Equivalent Estimation Guidelines

Type of premises / Establishment	Population Equivalent (Recommended)
Residential	5.0 per house
Commercial: Includes offices, shopping complex, entertainment/recreational centers, restaurants, cafeterias, theatres	3.0 per 100 m^2 gross area
Schools/Educational Institutions: - Day schools/Institutions - Fully residential - Partial residential	 0.2 per student 1.0 per student 0.2 per non-residential student 1.0 per residential student
Hospitals	4.0 per bed
Hotels with dining and laundry facilities	4.0 per room
Factories, excluding process water	0.3 per staff
Market (wet type)	3.0 per stall
Market (dry type)	1.0 per stall
Petrol kiosks/Service stations	15 per toilet
Bus terminal	4.0 per bus bay
Taxi terminal	4.0 per taxi bay
Mosque	0.2 per person
Church/Temple	0.2 per person
Stadium	0.2 per person
Swimming pool/Sport complex	0.5 per person
Public toilet	15 per toilet
Airport	0.2 per passenger bay 0.3 per employee
Laundry	10 per machine
Prison	1.0 per person
Golf course	20 per hole

APPENDIX IV

Questionnaire

SEWAGE TREATMENT PLANT
OCCUPATIONAL SAFETY, HEALTH AND HAZARD ASSESSMENT QUESTIONNAIRE

The information on this form will be kept strictly confidential and is used to aid risk assessment for the workers at Sewage Treatment Plant. The form is treated as Hazard Analysis at Sewage Treatment Plant and remains the property of the Universiti Teknologi PETRONAS.

Your name and affiliation will be acknowledged in any report or publication produced from this study. A copy of any publication will be sent to your e-mail.

Based on the completed Occupational Health and Hazard Assessment Questionnaire, the researchers in Universiti Teknologi PETRONAS will rank the hazard according to each risk.

PART A – POSITION DETAILS

Position Title:

Department/Division:

Brief description of responsibilities:

Name:

Email address:

Telephone no.:

PART B – OCCUPATIONAL HAZARDS TO BE EVALUATED

Hazards listed below might be different ranking in likelihood and severity.

Please rank from 1 - 4 in the corresponding column that best represents your opinion of each of the following hazards.

How likely is it that a hazardous event or situation will occur?

5. Highly unlikely – Yearly
6. Unlikely – Monthly
7. Likely – Weekly
8. Very likely – Daily

How severe the hazard is?

5. Negligible injuries (First aid and near misses)
6. Minor injuries (Less than or 4 days MC)
7. Major injuries (More than 4 days MC)
8. Fatality (Fatality or permanent disability)

NO.	HAZARD	LIKELIHOOD (a)	SEVERITY (b)
1	Slips and falls on floors made slippery by water, aqueous solutions or solvents		
2	Blows and contusions caused by falling heavy articles, including containers of chemical reagents, e.g., from overhead conveyers, or by contact with moving machinery or vehicles		
3	Falls into ponds, pits, clarifiers or tanks causing injuries or drowning		
4	Hazards related to entry into confined spaces - suffocation due to oxygen deficiency, poisoning (e.g. by hydrogen sulfide), etc		

5	Burns, by steam or hot vapors, by splashes of hot plating baths, solvents and other liquids, by contact with hot surfaces (e.g., annealing ovens), etc.		
6	Electric shock caused by contact with faulty electrical equipment, cables, etc.		
7	Cuts and pricks by sharp tools sharp edges of articles to be plated sharp deposits on jigs, etc.		
8	Injuries (especially of eyes) caused by flying particles, in particular from rotating brush cleaning or wheel grinding		
9	Fire and explosions due to the formation and release of flammable gases during processing (e.g., methane, hydrogen)		
10	Vigorous chemical reactions caused by uncontrolled mixing of chemicals (e.g., if water is mixed with concentrated sulfuric acid) during the preparation of reagents for wastewater treatment		
11	Acute poisoning caused by various chemicals present in the wastes, used as reagents (e.g., gaseous chlorine), or released during the treatment; a particular hazard is caused by the possible release of a number of poisonous gases, e.g., hydrogen-cyanide (from metal plating or heat treatment wastes upon acidification), hydrogen-sulfide, etc.		
12	Acute intoxication caused by erroneous drinking of untreated wastewater		
13	Poisoning by phosgene, which may be formed if a worker smokes in the presence of chlorinated-solvent vapors, or if welding or other flames or arcs are used		

14	Chemical burns by corrosive liquids such as mercury etc.		
15	Damage to eyes by splashes of irritating or corrosive liquids such as chlorine etc.		
16	Exposure to excessive noise levels from mechanical equipment		
17	Exposure to UV radiation		
18	Exposure to adverse weather (low or high temperature, rain, snow, storms, etc.)		
19	Chronic poisoning by inhalation or ingestion of many of the chemicals used in waste- water treatment		
20	Dermatoses caused by exposure of the skin to waste waters, cleaning formulations, acid and alkaline solutions, etc.		
21	Irritation of mucous membranes (in particular of the respiratory tract) by acid or alkaline vapors or aerosols, by hydrogen sulfide, and other substances		
22	Latex allergy caused by the use of latex gloves		
23	Diseases caused by infectious agents (bacteria, viruses, protozoa, helminths and fungi - see appendix) present in the raw domestic wastewater (mainly from human origin) and in agricultural wastes		
24	Diseases caused by contact with the toxins released by the infectious agents		
25	Diseases caused by insects or rodents proliferating in the sludge drying beds		
26	Musculoskeletal injuries caused by overexertion while handling heavy loads, such as containers of chemicals, or by		

	awkward working postures (including frequent bending), etc.		
27	Discomfort and psychological problems related to prolonged wear of protective clothing (including heavy boots, aprons and other impermeable pieces), to the bad smells of the wastes, to the feeling of working with "soiled" liquids in a "dirty" and not too "respectable" occupation, and to the apprehensions caused by awareness of the dangers of the workplace		

PART C – PERSONAL EXPERIENCES

Have you ever experience any near misses, incident or accident at sewage treatment plant? (If so, please identify)

Any other comments:

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THANK YOU FOR YOUR COOPERATION

APPENDIX V

Combinations of noise exposure levels and maximum duration time

Exposure level, *L* (dBA)	Duration, *T*			Exposure level, *L* (dBA)	Duration, *T*		
	Hours	Minutes	Seconds		Hours	Minutes	Seconds
80	25	24	—	106	—	3	45
81	20	10	—	107	—	2	59
82	16	—	—	108	—	2	22
83	12	42	—	109	—	1	53
84	10	5	—	110	—	1	29
85	8	—	—	111	—	1	11
86	6	21	—	112	—	—	56
87	5	2	—	113	—	—	45
88	4	—	—	114	—	—	35
89	3	10	—	115	—	—	28
90	2	31	—	116	—	—	22
91	2	—	—	117	—	—	18
92	1	35	—	118	—	—	14
93	1	16	—	119	—	—	11
94	1	—	—	120	—	—	9
95	—	47	37	121	—	—	7
96	—	37	48	122	—	—	6
97	—	30	—	123	—	—	4
98	—	23	49	124	—	—	3
99	—	18	59	125	—	—	3
100	—	15	—	126	—	—	2
101	—	11	54	127	—	—	1
102	—	9	27	128	—	—	1
103	—	7	30	129	—	—	1
104	—	5	57	130–140	—	—	<1
105	—	4	43	—	—	—	—

Source: http://www.cdc.gov/niosh/docs/98-126/chap1.html

APPENDIX VI

Domestic wastewater characteristics

Items	Range of values contributed in wastes (g/capita per day)
Biochemical oxygen demand, 5 days, 20°C (BOD_5)	46 - 54
Chemical oxygen demand	1.6 – 1.9 x BOD_5
Total organic carbon	0.6 – 1.0 x BOD_5
Total solids	170 – 220
Suspended solids	70 – 145
Grit (inorganic, 0.2 mm and above)	5 – 15
Grease	10 – 30
Alkalinity (as Calcium Carbonate, $CaCO_3$)	20 – 30
Chlorides	4 – 8
Total Nitrogen, N	6 – 12
Organic nitrogen	~ 0.4 x total N
Free ammonia	~ 0.6 x total N
Nitrite	-
Nitrate	0.0 – 0.5 x total N
Total phosphorus, P	0.6 – 4.5
Organic phosphorus	~ 0.3 x total P
Inorganic (ortho- and polyphsosphates)	~ 0.7 x total P
Potassium (as potassium oxide, K_2O)	2.0 – 6.0
Microorganisms present in water • Total bacteria • Coliforms • Faecal Streptococci • Salmonella typhosa • Protozoan cysts • Helminthic eggs • Virus (plaque from units)	(per 100 ml wastewater) $10^9 – 10^{10}$ $10^9 – 10^{10}$ $10^5 – 10^6$ $10^1 – 10^4$ Up to 10^3 Up to 10^3 $10^2 – 10^4$

Source: Wastewater Treatment for Pollution Control and Reuse, Arceivala and Asolekar (2007)

APPENDIX VII

Design Calculation

AIR BLOWER DESIGN

Air Volume required	=	1857.27	m^3/hr
	=	30.95	m^3/min
Type of diffuser provided	=	Uniflex	
Air flow per unit diffuser	=	**0.05**	m^3/min
Thus, unit of diffuser require	=	Air volume required / Air flow per diffuser	
	=	(30.95) / (0.05) units	
	=	619.10	units
No. of units of diffuser provided	=	**620**	units
Thus, air volume provide	=	No. of diffuser provided x air flow per diffuser	
	=	620 x 0.05	m^3/min
	=	**31.00**	m^3/min

To check Mixing Power Provided by Blower

Mixing power by diffused air	=	1000 m^3 volume required 20 to 40 W/m^3	
Volume of aeration tank	=	3888	m^3
Volume of air provided	=	31.00	m^3/min
Thus, mixing power provide	=	Power of blower / volume of aeration tank	
	=	(31.00 m^3/min) / (3888 $m^3/1000$)	
	=	**7.97**	m^3/min per 1000 m^3 volume

APPENDIX VIII

Pictures

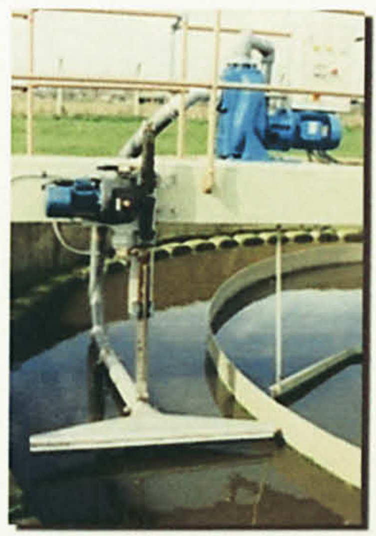

Figure A-I: Auto cleaner for clarifier

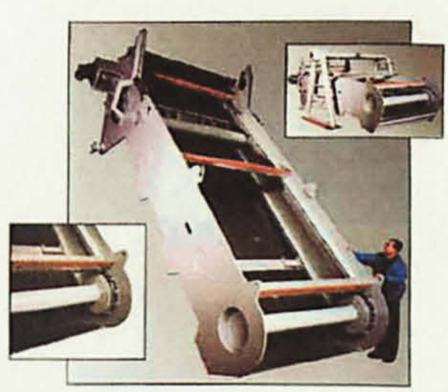

Figure A-II: Self Cleaning Bar Screen Unit for bar screen

APPENDIX IX

Experimental Data

Table A-II: Sound level for no mitigation

Minutes	Sound level (dBA)					
	1	2	3	4	5	Average
5	93.3	92.8	93	92.8	92.9	92.96
10	93.3	93.2	94.1	93.8	94.1	93.7
15	94.3	93.7	93.7	94.3	94.2	94.04
20	93.4	93.6	93.3	93.6	94.4	93.66
25	93.6	94.3	93.7	94.2	93.7	93.9
30	94.2	94.4	93.5	93.9	94	94
						93.71

Table A-III: Sound level for carpet mitigation

Minutes	Sound level (dBA)					
	1	2	3	4	5	Average
5	93.7	94.1	92.8	93.2	93.2	93.4
10	93.3	93.2	93.3	92.7	93.1	93.12
15	92.6	93.2	93.3	93.4	93.2	93.14
20	93	93.3	93.3	93.4	92.8	93.16
25	93.2	93.2	92.9	93.4	93.1	93.16
30	93.1	93.2	92.9	92.7	93.1	93
						93.16

Table A-IV: Sound level for cardboard mitigation

Minutes	Sound level (dBA)					
	1	2	3	4	5	Average
5	92.3	92.5	92.3	91.9	91.4	92.08
10	91.7	92.2	91.9	91.7	91.8	91.86
15	91.8	91.7	92.1	91.9	91.6	91.82
20	91.9	91.6	92.7	92.2	92.1	92.1
25	92.2	92.2	92.4	92.5	92.2	92.3
30	92.2	92.4	92.4	92.3	92.3	92.32
						92.08