RISK ASSESSMENT OF SELECTED WASTEWATER TREATMENT PLANT IN KLANG VALLEY

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ABSTRACT

Since the industrial revolution at 18th century, the industrial activities increased considerably and the wastewater is discharged to the nearby river without treatment, which lead to disease outbreak. People start aware on the need of wastewater treatment for the sake of environment and human health, and it became a compulsory to treat the wastewater before discharge to the environment. However, while operating the wastewater treatment plant, there will be risk associated in the operation, which categorized into 3 main types: physical, health and environmental risk. Therefore, risk assessment is used in order to understand the risk, and to develop control action in dealing with the risk. It is carried out in a selected premise in Klang Valley which including safety checklist, qualitative risk assessment, operators' survey and cleaner production assessment. According to the checklist, the manual handling and the waste management in the premise are poor which is high possible to cause risk to the operators and the environment. While from the qualitative risk assessment, the high risk hazards are identified which required extra attention to control the risk. From the operators' survey, it is found out that the operators are poor in competency / knowledge in safe operation, emergency preparation and response, and contribution to continual safety improvement. Risk control is required to minimize the risk identified and to improve the safety level in the premise by elimination, substitution, engineering control, administrative control and personal protective equipment (PPE). Cleaner production assessment is carried out to assess the possibility to reduce the resource usage and the waste production hence lead to cost saving, from the assessment in the selected premise, the resource can be reduced by reuse treated water instead of paying bill for clean water usage, and use more energy saving electric starter: variable frequency drive (VFD). The dried sludge produced by the premise content rich in nutrient value to be resell as organic fertilizer to bring profit to the premise instead of direct disposal.

Keywords: *wastewater treatment plant, safety checklist, qualitative risk assessment, survey, cleaner production*

ABSTRAK

Sejak daripada abad 18 revolusi industri, penambahan aktiviti industri dan juga air kumbahan yang mengalir ke air sungai berdekatan dengan tidak melalui sebarang rawatan. Inilah yang melibatkan peletusan penyakit yang mengorbankan berjuta-juta nyawa. Oleh itu, bermulanya penyedarian tentang keperluan loji rawatan kumbahan untuk melindungi flora, fauna dan alam sekitar. Walau bagaimanapun, operasi loji rawatan kumbahan melibatkan risiko dalam segi: fizikal, kesihatan dan alam sekitar. Jadi, penilaian risiko telah dilakukan di satu loji rawatan di Klang Valley untuk mengetahui risiko dalam lebih lanjut dan mengemukakan cara-cara untuk meminimumkan risiko dalam loji operasi. Senarai semak keselamatan, penilaian risiko qualitative, dan kaji selidik telah dilakukan dalam projek ini. Senarai semak telah mengetahui bahawa operators lemah dalam pengendalian manual dan pengerusan sisa tosik, ini akan melibatkan risiko tinggi pada kesihatan operators. Dalam penilaian risiko qualitative, elemen yang berisiko tinggi telah diketahui, dan dalam kaji selidik, kecekapan operators telah dinilai. Selepas semua penilaian telah dijalankan, elemen berisiko tingi dan kelemahan operator telah diketahui. Cara-cara menimumkan risiko dalam loji rawatan akan dicadangkan dengan menggunakan kaedah kaedah berikut: penghapusan risiko, pengantian risiko yang lebih rendah, pengubahsuaian dari segi kejuruteraan dan pentadbiran dan pengemukaan personal protective equipment (PPE). Penilaian cleaner production juga telah dilakukan untuk mengurangkan kegunaan sumber-sumber dalam loji dan mengurangkan kos beroperasi. Sumber air boleh dikurangkan dengan mengunakan air kumbahan yang telah dirawat, sumber elektrik boleh dikurangkan dengan mengunakan variable frequency drive (VFD). Enapcemar yang sudah dikeringkan dan sedia untuk dibuang bolehlah diguna sebagai baja organik dan jual untuk mendapat rezeki.

Keywords: *loji rawatan kumbahan, senarai semak keselamatan, penilaian risiko qualitative, kasi selidik, cleaner production*

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	:	Alternating Current
AGT	:	Authorized Gas Tester
BOD	:	Biochemical Oxygen Demand
CIDB	:	Construction Industry Development Board
COD	:	Chemical Oxygen Demand
COHNS	:	Carbon, Oxygen, Hydrogen, Nitrogen, Sulfur
DC	:	Direct Current
DO	:	Dissolved Oxygen
DOE	:	Department of Environmental
EA	:	Extended Aeration
EQA	:	Environmental Quality Act
H2S	:	Hydrogen Sulfite
HAZOP	:	Hazard and Operability Study
MBBR	:	Moving Bed Bioreactor
MBR	:	Membrane Bioreactor
MSIG	:	Malaysia Sewerage Industry Guideline
N	:	Nitrogen
NH4	:	Ammonia
NO2	:	Nitrite
NO3	:	Nitrate
O&G	:	Oil and Grease
OP	:	Oxidation Pond
P	:	Phosphorus
PAOs	:	Phosphorus Accumulating Organisms
PPE	:	Personal Protective Equipment
PWM	:	Pulse Width Modulation

RAS	:	Returned Activated Sludge
SAS	:	Surplus Activated Sludge
SBR	:	Sequencing Batch Reactor
SDS	:	Safety Data Sheet
SHE	:	Safety, Health and Environmental
SOP	:	Standard Operating Procedure
SWIFT	:	Structured “What If” Technique
UV	:	Ultraviolet
VFD	:	Variable Frequency Drive

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CHAPTER 1: INTRODUCTION

1.1 Background

The very beginning of existence of wastewater treatment has started from 4,500 BC, where the urbanization begins, basically there are two methods to clean the waste: buried in the ground or flush to the sewer/river. Then, moving forward to 18^{th} century, where industrial revolution begins. Number of inhabitants in the cities increase considerably, as well as a lot of industrial activities has been constructed and operated. Almost all waste water has been discharged to the nearby river and most of the drinking water pumps are located nearby to the discharged point, where problems arises. Chlorella and typhoid outbreak were the major incidents that occurred which causes more than 100,000 dead in 19^{th} century in the European country such as London, Germany and Hamburg. Besides, it has been recorded that 70% of the China's lake and rivers are polluted with industrial wastes, more than 300 million people have been affected. Furthermore, the environment pollution, which only been concerned in the past 50 years, is believed has been polluted for centuries, billions of trillions of flora and fauna has been affected from the wastewater pollution (*Cooper,2001*).

Along the centuries of development, a lot of incidents had been occurred that damaged the environment and sacrificed millions of lives. According to *Nasrin (2017),* from each of every incident, lesson has been learnt, and also paradigm shift to the action taken to environment problems occurred as below (*Nasrin, 2017*):

1. Frontier economics – the very premitive behavior that treat the nature as unlimited source and sink, development without taking care of the environment
2. Deep ecology – promote the non-anthropocentric behavior in order to maintain harmony relationship between human and nature by offering low technology.

3. Environmental protection – Regulatory approach behavior to control the pollution to the environment by setting the limit of pollution level. However, it does not work well as it indirectly gives the permit to the polluter to pollute by paying the pollution fee.
4. Resource management – management behavior of the resource available, all types of capital, productivity, policy, and resource available are incorporated into the planning.
5. Eco-development – latest directional behavior for development, taking care of environment as development grows. Focus on co-development of human and nature.

From the above incidents, people start aware on the need of the waste water treatment before discharging to the environment, for the sake of environment and human health. Sewer system begins to be constructed for new housing development for centralized treatment. Plenty of researches had been carried out in 20^{th} century for treatment system, from the very beginning physical and chemical treatment to the more efficient biological treatment (activated sludge process) with sequential treatment process. Besides, after years of effort of symposium, conference, meeting, Clean Water Act 1972 is the very first Act enforced to improve environmental protection.

In Malaysia, Environmental Quality Act (EQA) 1974 has been enforced to ensure the protection to the environment. One of the content in the EQA is all water discharged to the environment should qualify the following standard as shown in Table 1.1:

Table 1.1: Acceptable sewage discharge in EQA Regulations 2009

Parameter	**Unit**	**Standard**	
		A	**B**
Temperature	^oC	40	40
pH value	-	6.0-9.0	5.5-9.0
BOD at 20^oC	mg/L	20	50
COD	mg/L	120	200
Suspended solids	mg/L	50	100
Oil and Grease	mg/L	5.0	10.0
Ammonical Nitrogen (enclosed water body)	mg/L	5.0	5.0
Ammonical Nitrogen (river)	mg/L	10.0	20.0
Nitrate-Nitrogen (river)	mg/L	20.0	50.0
Nitrate-Nitrogen (enclosed water body)	mg/L	10.0	10.0
Phosphorus (enclosed water body)	mg/L	5.0	10.0

*Standard A is applicable to discharge to any inland waters within catchment area, whereas Standard B is applicable to any other inland wasters or Malaysian waters.

Since that, Suruhanjaya Perungurusan Air Malaysia (SPAN) had come out with a guideline– Malaysia Sewage Industry Guideline (MSIG) which is used as common language nationwide in designing the wastewater treatment plant in order to comply the effluent quality with the Environmental Quality Act. Most of the municipal wastewater treatment plants are operated by Indah Water Konsortium Sdn Bhd while industry areas have self-owned wastewater treatment plant within the premise to treat the chemical waste before discharging the effluent to the environment. Every development must comply to MSIG which is one of the criteria to obtain the Certificate of Fitness for the respective development.

1.2 Problem Statement

The hazard associated to wastewater treatment plant does bring great impact to people and environment. The rapid growth of development has created greater demand for housing and industry development, which leads to more wastewater treatment plant has been built to treat the waste water before it had been discharged to the environment. Thus, controlling the treatment effectiveness wastewater treatment plant become more important to minimize the impact to the people and environment. The important treatment facility should require special attention from design stage, to construction stage until operational and maintenance stage as to ensure the people and environment nearby are being protected.

There are many researches have been conducted in the area of process safety including risk assessment on major hazard industries such as nuclear plant, refinery plant, oil platform, power plant, chemical plant, and construction. However, the risk assessment study in wastewater treatment plant is found very rare, especially in the high altitude wastewater treatment plant in Malaysia.

Thus, an effective risk assessment framework should be developed to investigate the risk associated in the wastewater treatment plant which will bring impact to the operator, and the treatment effectiveness so recommendation can be done in order to minimize the risk and the impact.

1.3 Objectives

The objectives of this study are as below:

1. To identify the hazard associated in the operation and maintenance of wastewater treatment plant.
2. To evaluate the risk qualitatively and to give recommendation in minimizing the risk.
3. To assess the cleaner production aspect that can be carried out in the wastewater treatment plant.

1.4 Scope of Study

This study will cover the whole operation and maintenance of the wastewater treatment plant which includes pre-treatment, primary treatment, secondary treatment and their supporting facilities. Besides, cleaner production study is also carried out as environmental protection initiative to determine what can be done in order to reduce waste disposed to the environment. The selected wastewater treatment plant in this study is located at one of the high altitude treatment plants in Klang Valley, which is approximately 1500m above sea level.

1.5 Significant of Study

This research will generate a risk assessment framework which can be a guide for risk assessment in other wastewater treatment plant. It helps to save a lot of time from designing the risk assessment framework. Although there are varies of risk assessment framework that had been done, however, they are mostly related to major hazard industries such as nuclear plant, oil and gas industry, chemical industry and power plant. Hence, a more related and applicable risk assessment framework in wastewater treatment plant is developed so the occupier can easily evaluate the risk associated in the plant, the probability of occurrence and severity of impact, to support the decision of risk control procedure to minimize the risk and impact.

CHAPTER 2: LITERATURE REVIEW

2.1 Wastewater Treatment – The Process

The wastewater treatment is broken down into 3 stages: primary, secondary and tertiary. Primary treatment is mainly to filter out the incoming coarse solids, scope up oil and grease. Secondary treatment is the biological treatment which contribute the most in removing the biological content in the wastewater. Tertiary treatment is the final cleaning process to further improve the effluent quality before it is discharged. The schematic diagram of the wastewater treatment in shown in Figure 2.1 (*Meriam, 2015*):

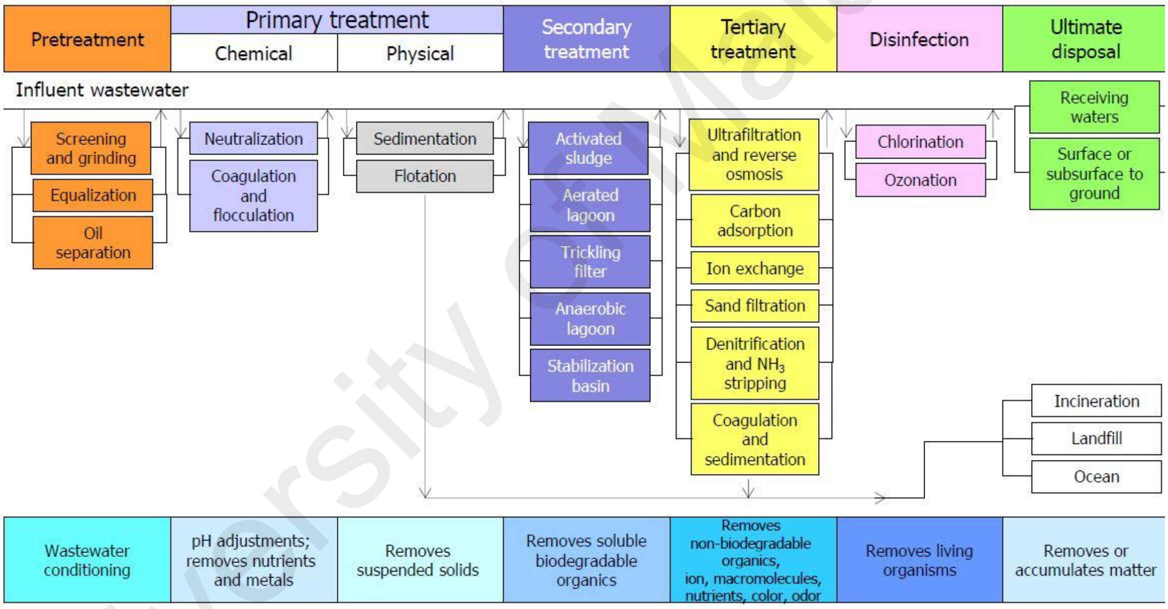

Figure 2.1: Wastewater treatment process

The wastewater will first enter the primary treatment, where there is screening device to trap and remove the debris from the flow. In some plants, equalization tank is used to ensure consistent flowrate by retaining high flow fluctuation. Then, grit, oil and grease will be removed by grit classifier and oil separation system. After physical removal process, chemical treatment will be carried out for chemical removal and pH adjustment by neutralization and coagulation with adding appropriate chemical into the flow. The coagulated and flocculated particles eventually grow bigger and heavier and settle down in the primary sedimentation tank and being removed from the flow. Next, the secondary treatment, where biological treatment is taking place. This treatment is mainly to remove the excess Chemical Oxygen Demand (COD), nitrogen (N) content and phosphorus (P) content by series of process environment: anaerobic (absence of nitrates and oxygen), anoxic (presence of nitrate, absence of oxygen), and aerobic (presence of sufficient oxygen). The biological treatment has to be carried out after physical and chemical treatment due to the debris and chemical that will affect the biological activity of the bacteria. "Activated Sludge", which made up of bacteria and protozoa play the main role in biological treatment. They are fed by the organic contaminants in the wastewater for growth. Biological flocs are formed as they grow and eventually settled down in the bottom of sedimentation tank, leaving a relatively clear liquid with very low quantity of organic material and suspended solids as effluent to be discharged to the environment. Aerobic tank is supplied with oxygen via aeration. Aeration playing 2 important role: supply oxygen to the microorganism for growth and provide better mixing between the microorganism and the organic substances. In aeration tank, there are two main biological processes occur, aerobic respiration and nitrification. The main difference between the two processes is the biological substance that is used to undergo oxidation, aerobic respiration uses organic matter (COHNS) present in the wastewater whereas nitrification process involve ammonia (NH4) that oxidize to nitrite (NO2) then to nitrate (NO3). Besides, phosphorus accumulating organisms (PAOs) will gain energy from the oxidation of storage product in form of polyphosphate, which it will be used up in the anaerobic tank. In anoxic tank, the major process occur is denitrification. There is no aeration for the tank and the system is lack of dissolved oxygen, nitrite that feed from the aerobic tank is used as electron acceptor instead of oxygen and reduce to nitrogen gas so complete oxidation reduction reaction is achieved. Anaerobic tank is designed mainly for phosphorus removal, it contains no dissolve oxygen in the system so anaerobic respiration (fermentation) will occur. PAOs will assimilate the fermentation products into storage products and the polyphosphate is converted to phosphorus and remove from the system as a result of sludge wasting. The settled activated sludge in the sedimentation tank will be recycled to mix with the incoming water in the process tank to enhance the treatment efficiency (*Metcalf & Eddy, 2003*).

The last stage of treatment, tertiary treatment, is the final process that help to improve the effluent quality before it is discharged. The treatment removes non-biodegradable organic, inorganic compound, excess nutrients, heavy metals, odor, color, bacteria and parasite. The processes involve in this system are: ultrafiltration, reverse osmosis, carbon absorption, ion exchange, sand filtration, denitrification, chlorination, and ozonation. Tertiary treatment system is designed based on the nature of the wastewater quality and it may not a necessity for all treatment plants.

Part of the settled sludge will be recycled to the biological process, whereas the rest will undergo dewatering process to dry the sludge and reduce the sludge volume. The dried sludge will be transported out from premise for disposal, landfill or incineration. However, according to the research, the dried sludge contains high nutrients value and suitable to become the fertilizer which is very useful to agriculture industry.

2.2 Type of Common Sewage Treatment Plant in Malaysia

In the wastewater treatment plant, pre-treatment and primary treatment are mandatory and the process involved are simple and direct. So the design associated is fixed. Tertiary treatment is subject to requirement, it might not be necessary if the effluent quality has met the regulation. However, there are variety of designs in the secondary treatment due to its complication of biological reaction. The common type of secondary treatment designed in Malaysia are summarized in Table 2.1 (*Metcalf & Eddy, 2003*):

1. Oxidation pond (OP) – the very beginning design of the wastewater treatment plant, use surface aeration to maintain the biological treatment
2. Sequencing batch reactor (SBR) – 4 process reaction: fill in the wastewater, oxidation reaction, sludge settlement, decant the sludge
3. Extended aeration (EA) – continuous aeration to keep the system biological active, mainly to remove BOD and COD, normally anoxic zone (non-aeration) is placed before the aeration for nitrogen removal
4. Membrane bioreactor (MBR) – combination of membrane process (ultrafiltration or microfiltration) with biological wastewater treatment process to enhance the treatment
5. Moving bed bioreactor (MBBR) – incorporate carrier into the treatment process where a biofilm can grow and enhance the good contact between the substrate (waste that need to be treated) and the biomass.

Table 2.1: Comparison of different type of secondary treatment in Malaysia

	OP	**SBR**	**EA**	**MBR**	**MBBR**
Aesthetic	Non-Aesthetic	Compact footprint	Foaming problem	Compact footprint	Compart footprint
Odor	Yes	No issue	No issue	No issue	No issue
Footprint	Large land required	30% smaller compact footprint compare to EA	Reduced footprint compare to oxidation pond	30% to 50% smaller compact footprint compare to EA	More than 50% smaller compact footprint compare to EA
Capital Expenses	Low	High	High	High	High
Operating Expenses	Low	Medium	Medium	High due to membrane replacement	High due to media replacement
Biological Nutrient Removal Capability (BNR)	Nil	Built-in	Built-in with additional ammonia removal	High BNR capability	High BNR capability
Process Efficiency	Low	High BOD, COD and nitrogen removal	High BOD and COD removal	Very high	High
Process Flexibility	No manpower required, simple design	Flexible, consistent effluent quality	Not flexible, effluent quality varies with loading	Flexible for future expansion	Flexible in treating high strength wastewater

2.3 Risk in Wastewater Treatment Plant

When operating the wastewater treatment plant, the operation routine will never be repeated because there will be uncertainties lied in the operation, these uncertainties are defined as risk. Risk is defined as the likelihood that a harmful consequence will occur as the result of an action or condition. It involves the combined evaluation of hazards and exposure. The risk usually written as (*Jamil & Wahab, 2016*):

$$RISK = PROBABILITY \times SEVERITY$$

In wastewater treatment plant, the risks that are associated in the operation are categorized into 3 main types: physical risk, health risk and environmental risk.

2.3.1 Physical Risk

Physical risk is the incidents that bring harm to the body without necessary touching it. In the wastewater treatment plant, the general examples of physical risk are listed in Table 2.2:

Table 2.2: Example of physical risk in wastewater treatment plant

Key Hazard	Contributing Factors
Physical injury	Slippery surface
	Carelessness
	Lack of technical knowledge
	Lack of safety awareness
Electrical shocked	Equipment breakdown
	Miss operation and maintenance
	Lack of technical knowledge
Ergonomic injury	Incorrect working posture
	Excessive work force

2.3.2 Health Risk

Health risk cause adverse effect to the body health upon exposure. The consequences may range from body minor illness to fatality. In the wastewater treatment plant, the general examples of health risk are listed in Table 2.3:

Table 2.3: Example of health risk in wastewater treatment plant

Key Hazard	Contributing Factors
Bacterial infection	Exposure to biological hazard
	Insufficient or impropriate PPE
	Lack of safety knowledge
Excessive inhalation of chemical	Pro-longed work time
	Poor ventilation system
	Insufficient or impropriate PPE
Suffocation in confine space	Poor ventilation system
	Inappropriate planning of work in confine space
	Lack of safety / emergency equipment
	Poor safety knowledge

2.3.3 Environmental Risk

Environmental risk is the incidents that will cause adverse effect to the environment. In the wastewater treatment plant, the environmental risk associated is pollution to the river, which will cause harm to the aquatic life, and the public health. The general examples of environmental risk are listed in Table 2.4:

Table 2.4: Example of environmental risk in wastewater plant

Key Hazard	**Contributing Factors**
River pollution	Treatment system failure
	Poor operational control
	Equipment breakdown due to poor maintenance

Risk is closely related to the cost, if any risk occurs, it may cause adverse impact to the operator, public, equipment and the environment. Extra cost is needed to be paid for medical, work time lost, repair or replace the equipment, and penalties by authorities due to non-compliance. Hence, the detailed assessment is required and develop and implement risk control measure in order to minimize the risk and the cost impact associated. Risk assessment enable affirmative action that will lead to safe working environment, optimization of treatment process, minimize the operational cost and ultimately achieve sustainable wastewater management (*Kohler et. al., 2017).*

2.4 Risk Assessment in Wastewater Treatment Plant

Within the great political, technological and social transformation that was pioneered by British Industrial Revolution in 18th century, the understanding of risk changed substantially from fate of nature which is unavoidable to something that can be managed. Risk can be accountable in all actions which help to support decision making under a condition of apparent uncertainty. Risk nowadays become a theoretical focus designed to be scientific, mathematically approached toward uncertainty, which create a lot of job opportunities, especially in financial and engineering safety segments (*Mtshali et. al., 2014*). Risk assessment has been used in wide range of engineering industries such as petroleum offshore and refinery, manufacturing, mining, construction, agriculture, power plant, water supply and waste treatment, and also non-engineering industries such as economics, medical, and security. The outcomes of risk assessment are:

1. Better understanding of process system
2. Estimation of the likelihood and the impact of the unwelcome circumstances
3. Management action in dealing with the risk and the monitoring program for the action implied
4. Review and modify of the existing risk control actions if necessary.

The risk is assessed in order to make decision on preventive or corrective action. Risk assessment is mainly answering 4 questions:

1. What can go wrong?
2. How likely it goes wrong?
3. What is the consequence of the event?
4. How to minimize it?

In engineering safety, according to *Steven(2003),* generally the risk assessment steps are:

1. Risk identification

   Risk identification is the crucial steps in the development of risk framework and subsequent risk assessment. Risk associated in the operation is identified, which may cause by equipment error and human error. The identification of hazards are the most significant in relation to wastewater treatment allowed the focus of risk assessment to be directed towards correct pathway (*Steven et. al., 2003*). The hazards are generally composed of two categories, human factor and technical factor:

   A. Human factor

      Human factor can be further divided into the followings:

      i. Carelessness
      ii. Poor working attitude
      iii. Lack of awareness towards workplace safety
      iv. Not following the standard operating procedure
      v. Inadequate technical skill and knowledge
      vi. Inability to obey work instructions
      vii. Unable to obey disciplinary rules and regulations
      viii. Lack of training

   B. Technical factor

      Technical factor can be further divided into the followings:

      i. Power failure
      ii. Equipment failure
      iii. Instrument failure
      iv. Operational error
      v. Lightning strike

2. Risk assessment

   From the risk that has been identified, determine the probability of failure and the impact of the consequences. It can be done qualitatively and quantitatively and they are further broken down into tens of unique risk assessment techniques which are shown in table 2.5 below *(David & Miroslav, 2009)*. Generally, qualitative risk assessment is performed prior to quantitative risk assessment to get the general picture of the risk level before a more detailed quantitative risk assessment is conducted.

3. Risk control

   Development of suitable management program in order to mitigate the risks identified. The hierarchy of risk control is shown below:

   A. Elimination – physically removed the hazards
   B. Substitution – replace the hazard to less hazardous one
   C. Engineering control – alter the operation design to minimize the risk
   D. Administrative control – change the way of people work to reduce the exposure to hazard below the exposure limit.
   E. Personal protective equipment – last line of defense, protect the operator expose to the hazard.

4. Monitoring and review

   The continual monitoring and review process are part of risk management process that allow a means of assessing whether the risk framework and management process are effective in providing suitable risk prevention, mitigation and control. Appropriate data collection is practiced regularly for review purpose and further refining the defined risk areas.

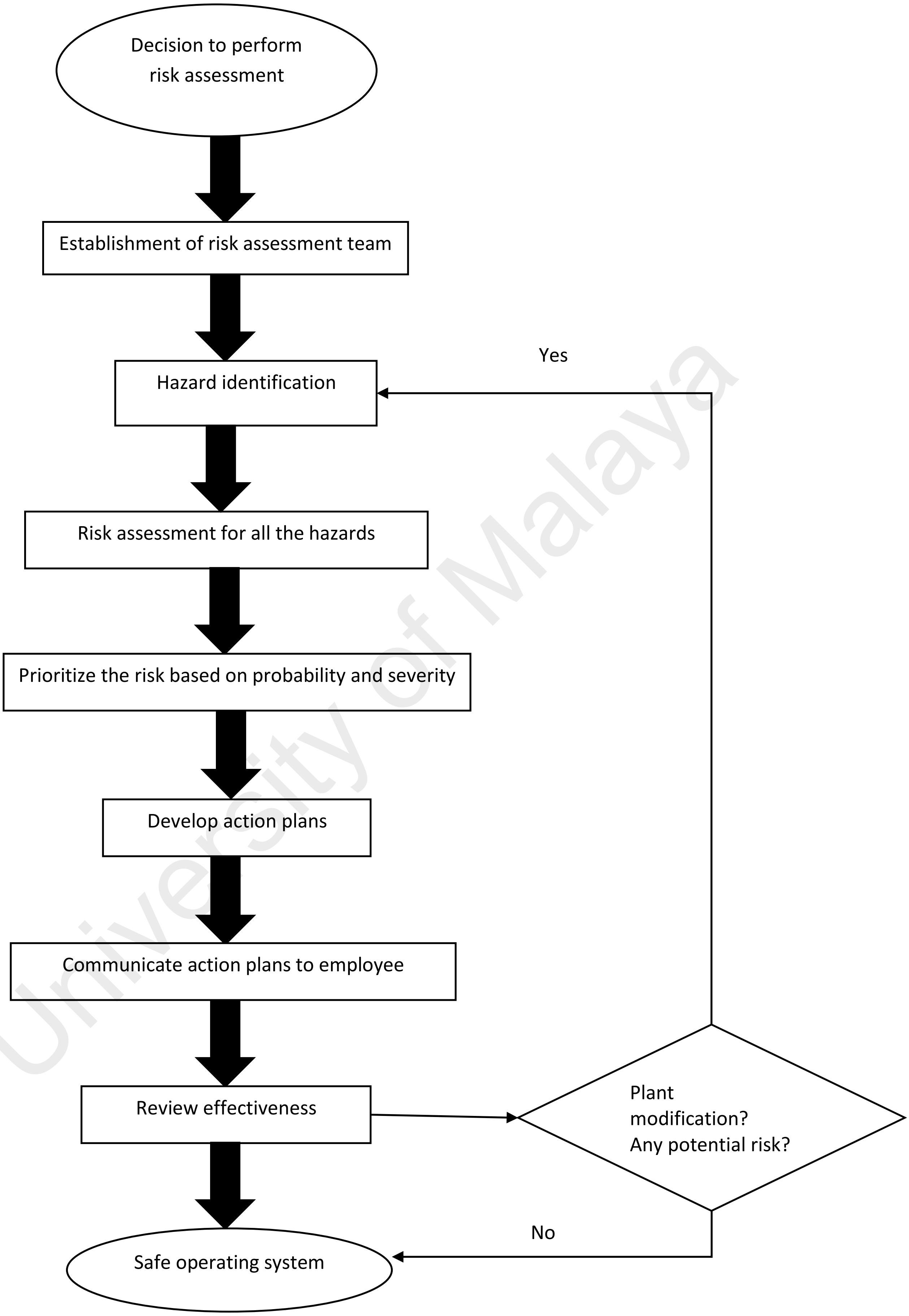

Figure 2.2: Risk assessment procedure

Table 2.5: Risk assessment technique

Type	**Description**
Brainstorming	Conversation and discussion among group of knowledgeable people to identify the risk and plan for risk treatment
Delphi technique	Procedure of obtaining reliable consensus of opinion from experts about the risk and risk management.
Safety checklist	List of hazard, risk and control failure that is developed based on past experience which help to check the existence of potential risk
Preliminary hazard analysis	Preliminary step to identify hazard at the project early development as a precursor to further study the risk and impact.
Hazard and operability study (HAZOP)	Structured and systematic examination to identify risk to people, equipment and environment.
Toxicity assessment	Risk assessment to animal, plant and mankind on exposure to chemical and biological hazard. Mainly focus on exposure, pathway, and identify treatment
Structured "what if" technique (SWIFT)	Simpler alternative to HAZOP, use "what if" phrase to investigate the operation system deviations from normal operation.
Scenario analysis	Identification of risk of possible future development or changes and the potential consequences and hence develop resilience needed to adapt to the changes.
Business impact analysis	Identification of key business process, and analyze how key disruption risk affect the operation of the whole organization.

Root cause analysis	Mainly concerned determination of root causes which contributed to major financial loss. Immediate action required to be taken to prevent the occurrence.
Failure modes and effect analysis	Identification of potential failure modes of the system, the cause of failure, the effect of failure, and to develop the plans to avoid the failure.
Fault tree analysis	Top down risk assessment method to identify the factors that contribute to the specific undesired event. This method can be use quantitatively to calculate the probability of the top event from the given probability of each bottom event.
Event tree analysis	Graphical technique for representing the mutually exclusive sequences of events following an initiating event according to the functioning or non-functioning of the system designed to mitigate its consequences.
Cause-consequence analysis	Combination of fault tree analysis and event tree analysis. Starting from top event and analyze the consequences using YES/NO logic gates, to show the consequence that may occur failure of the system designated to mitigate the consequences.
Cause-and-effect analysis	Identification of possible causes of the undesirable event. The assessment is normally organized in a Fishbone or tree diagram to display the causes of specific event.

Layers of protection analysis	Semi-quantitative method estimating the risk of undesired event and review the effectiveness control measure that has been used to prevent or control the risk.
Decision tree analysis	Analysis of the possible risk or consequences that may occurred as the outcome of decision that has been taken.
Human reliability assessment	Method to determine the impact of the consequences that human error can brought to.

2.4.1 Qualitative Risk Assessment

Qualitative risk assessment uses descriptive or relative scale to measure the probability of occurrence and the magnitude of potential consequences of an event. It is more applicable to a broader scope of circumstances and it will be relatively easy and simple to perform due to no complicated calculation steps involved. From the scale that put in the magnitude and consequences, the risk matrix is generated to determine the severity of a particular risk (*Paul & John, 2003*) as shown in Table 2.6.

Table 2.6: Risk matrix

Severity / Probability	**Negligible (1)**	**Minor (2)**	**Moderate (3)**	**Significant (4)**	**Severe (5)**
Very unlikely (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Very likely (5)	5	10	15	20	25

By rating the hazard probability and the severity of its consequences respectively with the scale of 1 to 5, the risk level can be known by the multiplication probability and severity scale. From the table above, the higher the risk level scale, the more dangerous the hazard is in terms of high probability of occurrence or high severity or both. Extra care is required to control the risk to ensure the probability and severity will be reduced so that it won't cause any harm to the people and the environment.

2.4.2 Quantitative Risk Assessment

Risk assessment that describes the outputs of risk in numerical form. The risk is analyzed in more detailed means compared to qualitative risk assessment. The number represent the probability of an event occurring during a specific time frame and also the impact of the consequences. These numerical data can give a more objective planning and review the effectiveness for risk control. However, the drawback of quantitative risk assessment is that it involves complicated calculation formula and some of the parameter's value is difficult to be obtained. If there is no data available, then there will be no comparison can be made to determine the likelihood of the risk and the severity of the impact (*Yu et. al., 2017*).

2.5 Risk Control - Cleaner Production Approached

Nowadays, cleaner production has been prioritized and practiced in all industries which focus on reducing environmental input (consumption of resource and energy) and output (waste & emission). According to, *Peter (2017)*, this approach can be implemented into the risk control for the wastewater treatment plant. The 4 elements of cleaner production includes: precautionary approach, preventive approach, democratic control and integrated and holistic approach. From these elements, cleaner production promotes pollution prevention, waste minimization, enhanced efficiency, resource conservation and also risk reduction that will promote safe environment in the workplace. Ultimately, these elements will relate to the cost, which will minimize the operation cost. The wastewater treatment plant receive incoming wastewater, undergo a series of operation, and discharged the treated effluent to the environment, some of the sludge will undergo dewatering process and the dried sludge will be disposed to the environment. Without proper operation and control, more resources have been used and yield poor quality effluent and more dried sludge dispose to the environment which will cause higher risk in environmental pollution, hence cleaner production approached should be practiced by (*Peter & Cookey, 2017*):

1. Risk elimination

   Risk elimination is the top hierarchy in the risk control pyramid. In the wastewater treatment plant, physical risk can be eliminated by proper maintenance schedule, regular housekeeping to maintain clean safe environment, training to increase operator technical and safety knowledge and safety checklist for the operation. These can prevent the unnecessary incident that may happen in the premise. With the competent operator and the standard operating procedure, the environment risk can also be eliminated since the treatment can be assured treated properly before discharged.

2. Risk substitution and transfer

   If risk not possible to eliminate, the next option will be risk substitution and risk transfer to reduce the risk impact. The chemical used in the wastewater treatment process can be substituted by less hazardous one, hence, the impact to the health will be reduced.

3. Better treatment efficiency control

   By having good engineering and administrative control action, the operation equipment and instrument can be modified with additional safety parameter and the operator will be ensured minimum exposure by the aid of administrative arrangement. Training can also be provided to the operator to ensure the competency in operation and hence treatment efficiency control will be assured.

4. Provide standard operating procedure and operational checklist

   SOP and operational checklist play very important role for operator to do things right. Each of operation steps is followed accordingly to ensure optimum treatment efficiency. Besides, carelessness and miss-operation can be prevented and hence unnecessary incidents will not occur.

5. Monitoring and review

   After the risk assessment and the implementation of risk control actions, regular monitoring and review are mandatory to ensure the risk control actions are well-performed. Modification of risk control is required if some other new risks are found or the known risk control action not able to reduce the risk and impact.

Besides, greater attention had put in sewage sludge generated from wastewater treatment plants by researches nowadays on the potential of improving soil properties and facilitating cell growth. (*Mtshali et. al., 2014*). Sewage sludge is known to be rich of nutrients, organic matter and trace elements that are beneficial for plant growth and better yield. It can be used as a fertilizer. However, the potential risk of heavy metal toxicity is a threat. Hence, characterization of sewage sludge is required before application of sewage sludge to soil for agricultural purpose to ensure it is suitable to facilitate cell growth and content less or no heavy metal which will cause soil pollution. According to *Mtshali (2014)*, low toxicity will be found in the public wastewater treatment plant due to food consumption by human contain less toxicity (controlled by Food Act 1983) and the industrial wastewater is compulsory to undergo in-house treatment to remove toxic chemical before discharging for further treatment, hence, the wastewater received by the treatment plant will be only contained rich of nutrients.

CHAPTER 3: METHODOLOGY

To complete this project, a strong fundamental in risk assessment and wastewater treatment plant process operation and maintenance are mandatory. Start from literature review on risk assessment, type of risk assessment and its details. Then, a detailed literature review is done on the wastewater treatment plant to study the full operation and maintenance of the plant in detail, including pre-treatment, primary treatment, secondary treatment, and supplementary facilities. On top of this, a site visit to the selected plant is held prior to the assessment to get better understanding on the process and operation in the plant. Risk assessment form, survey form and checklist are prepared.

3.1 Hazard Identification

Site visit is conducted to one selected wastewater treatment plant which situated at 1500m above sea level. This wastewater source flowing into the plant is mainly from the hotel and food & beverage industry. The purpose of visit is to inspect the process, operation and maintenance of the plant. This includes the observation of layout plan, manual operation, loading and unloading of material, maintenance routine, skills of operation, troubleshooting, and sampling. Potential hazards are identified and the probability of occurrence and its severity are studied in the risk assessment.

3.2 Checklist

A modified safety checklist which covers general safety and health hazard which applicable in the wastewater treatment plant is used during the site visit. This checklist helps to investigate the risk associated with the operation and maintenance and fulfilled the checklist requirement in order to minimize the risk. The checklist is subdivided into eleven categories and is attached in the Appendix A:

1. General management
2. Site perimeter
3. Manual handling
4. Hazardous gas exposure and management
5. Personal protective equipment (PPE)
6. Electricity
7. Fire safety
8. Waste management
9. Safety, health and environment communication
10. House keeping
11. Machinery and equipment

3.3 Qualitative Risk Assessment

Qualitative risk assessment is carried out in the premise to investigate the probability and the severity of the risk in the premise. Qualitative risk assessment is selected due to the simplicity of the assessment, and it can be easily usable in wastewater treatment plant. Physical risk, health risk and the environment risk are included into this assessment. In every hazard that has been identified, score from 1 to 5 will be given for its probability and severity respectively based on how frequent the hazard will occur and the impact of its consequences. Risk level will be determined from the multiplication of hazard likelihood and consequences:

$$R = P \times S$$

Where: R = Risk Level

P = Probability

S = Severity

The risk is low when the risk level is ranged from 1 to 4, it goes to medium risk when the risk level is ranged from 5 to 9, and high risk when the risk level is ranged from 10 to 14 and ultimately very high risk when risk level is ranged from 15 to 25. The high risk level hazard which cause by high probability of occurrence or high severity or both will be highlighted. Recommendations will be given to each hazard in order to reduce the probability and severity of the hazards.

3.4 Operators Survey

A survey form is developed and distributed to the operators in the selected premise, the survey form is broken down into 5 main themes which determine the quality of operators in terms of:

1. Competency / knowledge in safe operation
2. Compliance to safe work procedure
3. Emergency preparation & response
4. Stress level and health condition
5. Contribution to continual safety improvement

This questionnaire is based on 4-point likert type scale (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree). There are 5 questions in each theme, and weightage from 1 (least important) to 3 (very important) is given in each question respectively to differentiate how importance of the particular question to the theme. An average value will be calculated based using the formula below:

$$\frac{\sum_{i=1}^{n} P_i \times W_i}{\sum_{i=1}^{n} W_i}$$

Where P = Scale selected by interviewee

W = Weightage

i = Question number

n = Amount of question in each theme = 5

The survey form is attached in the Appendix B.

3.5 Cleaner Production Assessment

In this assessment, every single detail in the wastewater treatment process, from resource usage to the waste disposal are assessed to determine the potential cleaner production which can be practiced in the premise. This approach helps to reduce the resource usage and waste production and eventually leads to cost saving. For example, from the literature review, the dried sludge which is the waste from the sludge treatment, consist full of nutrient which can be used as organic fertilizer. Hence, a dry sludge sample is taken to the certified lab to determine the suitability of turning into fertilizer instead of disposal. The result of the analysis will be attached in Appendix C. Other possible cleaner production practice will be recommended upon detailed study of the site layout and site inspection.

3.6 Data Compilation and Analysis

After all the data is collected and compiled. A detailed analysis is carried out to determine the risk level which will affect the people and environment nearby the selected plant. The deficiency of the site parameter and operator performance, which will probably cause risk to occur, will be highlighted. Then, recommendations on risk control will be proposed to reduce the likelihood or severity of the risk, and ultimately to achieve zero risk in the premise.

The flow diagram of this project is shown in figure 3.1 below:

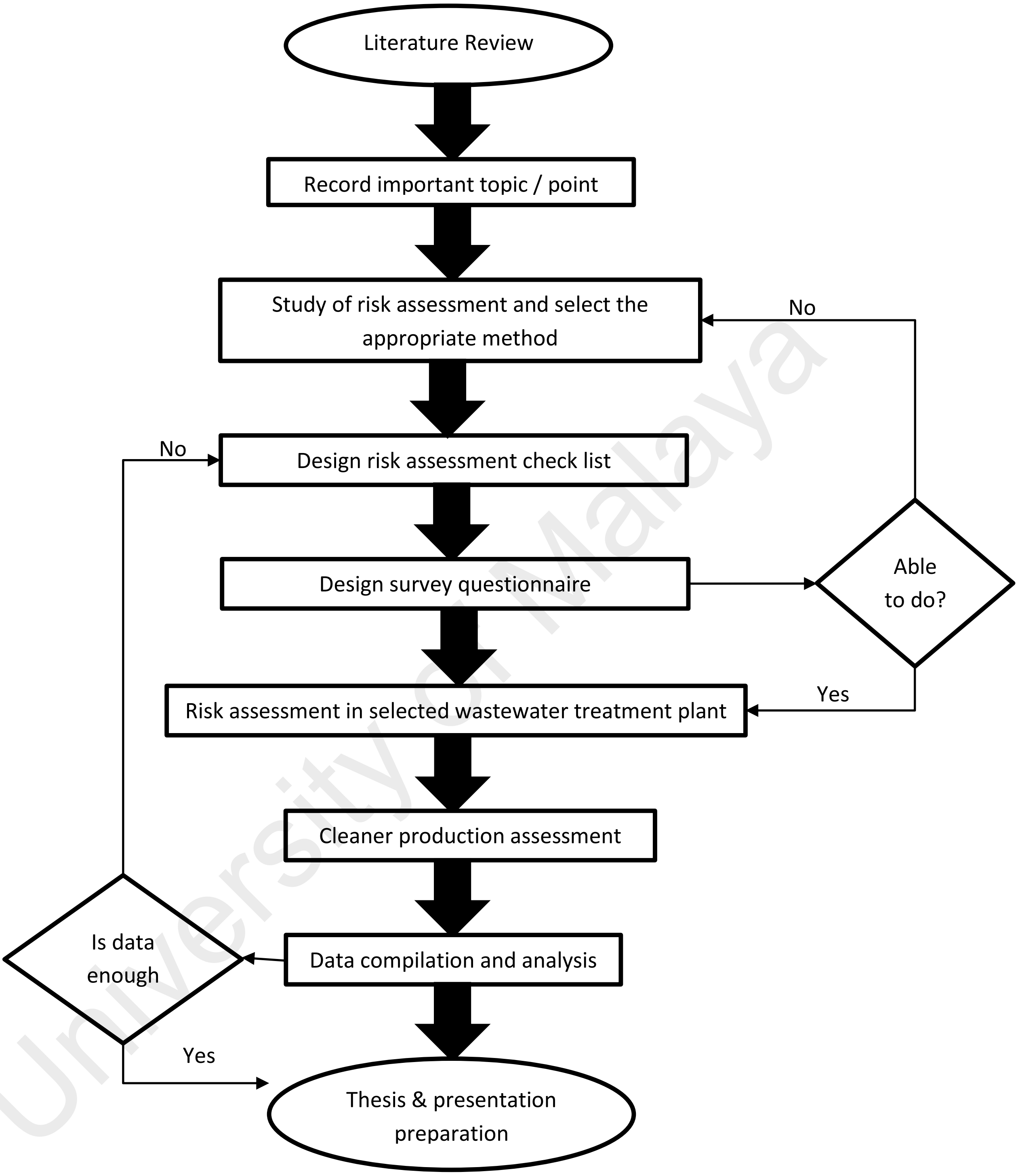

Figure 3.1: Flow diagram of the research project

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Process Description

Raw sewage will be the firstly enter the premise through preliminary treatment which comprise of trash screen, fine screens, grit and oil and grease removal. Large garbage will be trapped in the trash screen whereas smaller suspended solid including the toilet paper, fibers, hairs, woods, leaves will further screen by fine screen. The suspended solid larger than 6mm will be trapped on the screen and removed automatically after the trigger of the screen. The screenings will be conveyed upwards and dropped to the screening compactor by the conveying system. The screening compactor will dewater the debris by screwing/compaction. In grit chamber, air is introduced to create the circular or toroidal flow pattern which cause the grit settle as well as the lighter organic material suspended on the top. The grit will be drawn from the slope bottom from time to time using grit pump and then conveyed out from the stream. The flow will then go to two O&G removal chamber after the grit chambers. The O&G removal chamber will be similar to the aerated grit chamber which a grease skimmer/scraper is additionally equipped to remove the grease suspended and floating on the top water level. Air will be introduced to enhance the suspension of the light organic matter or grease to stick together for better separation. The separated supernatant (i.e. light organic matter or O&G) will be transferred to the sludge treatment.

The pre-treated wastewater will join the Returned Activated Sludge (RAS) and enter the anoxic selector which is a small tank with no aeration for the growth of the non-filamentous bacteria which can increase the settleability of the sludge and minimize the possibility of sludge bulking. Then, the flow will enter to the aeration zone via underflow channel. In aeration tank, the wastewater will be aerated to remove the carbonaceous and nitrogenous pollutants. It will be converted to sludge, carbon dioxide, nitrite and nitrate. The aeration rate will be controlled by the dissolved oxygen in the system that is measured using the DO sensor. After aeration and pollutants removal, flow from all tanks will be diverted to the final sedimentation tank. The final sedimentation tank is designed to separate the solid and liquid in which the sludge will be settled. The settled sludge will be returned to EA tanks via distribution channel or wasted as Surplus Activated Sludge (SAS) for sludge wastage. The supernatant, which is the treated effluent will be discharged out from the premise.

The surplus sludge will be fed to sludge holding tank for temporary storage when the mixed liquor suspended solid in the system is more than 3000mg/L. The sludge will be welled mix the sludge and prevent the solid from settling. Then, the sludge will be pumped from the sludge holding tank to a rotary drum thickener for thickening. Polymer from the polymer preparation tank will be mixed with the sludge to coagulate and facilitate the thickening process. The liquid will be separated from sludge and solid content of the sludge will increase to about 5%. After the thickening, the thickened sludge will be pumped to the centrifuge decanter. Polymer will be dosed to the sludge line feed to the centrifuge decanter as the same way as the rotary drum thickener. The centrifuge decanter will be able to dewater the sludge to achieve 20%DS of the sludge cake by centrifugal force. The sludge cake eventually will be delivered off-site disposal.

Other than the process treatment system, deodorization unit is designed to remove the odorous gas generated from the treatment process. Effective odor management is required to ensure safe working environment for the operator on-site and minimize the odor nuisance to surrounding. Hydrogen sulfide (H2S) and ammonia (NH3) are the major odorous gases generated from the wastewater. When wastewater is kept under anaerobic condition for a period, which is sufficient long for anaerobic micro-organisms to breakdown the organics, the gas including H2S will be generated. The anaerobic condition generally occurs within the sewer networks. While for ammonia, it is arisen from human urine and breakdown of organic matters. Sources of odor in the premise are identified including the primary treatment and sludge treatment area. The identified odor sources areas will be covered or housed and the odorous gas at these areas will be extracted by extraction fans. The extracted foul air will pass through deodorization unit for removal of odorous gas. Bio-trickling filter is recommended to be the deodorization technology. Through bio-trickling filter, the major odorous gas, H2S, will be biologically degraded, H2S is oxidized by bacteria and thus, the odor is removed before discharging to the atmosphere.

4.2 Safety Checklist

Site visit is carried out in a selected wastewater treatment plant to have better understanding of the operation and maintenance routine in the premise. It helps to facilitate the process of hazard identification with the aids of safety checklist. There are eleven safety categories in the checklist and each category further break down into 7 to 13 questions which represent the element to fulfill the safety category. The evaluation is made with "yes" for the existence of each element and "no" for the absence of the element. Safety score of 1 is given to each "yes" and 0 is given to each "no". The overall safety score in each category is calculated using formula below and the score is rated as shown in table 4.1 (*Gunduz & Laitenen 2018*):

$$Overall\ Safety\ Score: \frac{Total\ safety\ score}{Total\ number\ of\ questions} \times 100\%$$

Table 4.1: Rating of safety score

Score	**Rating**
0%-50%	Very poor
51%-69%	Poor
70%-84%	Good
85%-100%	Excellent

If the safety core is less than 50%, it is rated as very poor, which indicates high risks and hazards are present in the category, followed by poor rating which the score is range from 51% to 69%, good and excellent rating is given to safety score at the range of 70% to 84% and 85% to 100% respectively, which indicate low risks and hazards are present in the category. More attention is required at the category with the low rating to minimize the risk and hazard so that it won't cause harm to safety and health of the employee in the premise. The table 4.2 below shows the summary of safety score and rating of all the categories in the checklist.

Table 4.2: Summary of safety score for all the categories in the checklist

Category	Score	Rating
General Management	89%	Excellent
Site Perimeter	64%	Poor
Manual Handling	43%	Very Poor
Hazardous Chemical Management	70%	Good
PPE	86%	Excellent
Electrical Safety	90%	Excellent
Fire Safety	82%	Good
Waste Management	40%	Very Poor
Safety, Health & Environment (SHE) Communication	69%	Poor
Housekeeping	89%	Excellent
Machinery and Equipment	83%	Good
Average	**73%**	**Good**

From the table 4.2, the safety scores are given in each category with the lowest 40% (very poor) to highest 90% (excellent). The differences might due to ignorance and lack of awareness from the management or the employees. Very poor ratings are given to manual handling and waste management which may lead to ergonomic injury and biohazards to the operators. The next potential hazard issues are the site perimeter (64%) and SHE communication (69%), which are rated poor. The potential hazards the may cause by site perimeter are physical and health injury to the employee which range from minor slipping down to major fatality whereas SHE communication will affect the continual safety monitoring and improvement. Good rating is given to hazardous chemical management (70%), fire safety (82%) and housekeeping (83%) where their potential to cause hazards are lesser compare to those poor and very poor categories. However, improvements are still required to be done on these categories so that its potential to cause hazards can be further minimized. General management (89%), PPE

(86%), electrical safety (90%) and housekeeping (89%) entitled for excellent rating due to their fulfilled more than 85% of the elements the respective category, they bring least potential hazards to the operator and environment since the necessary actions or precautions as per in the checklist have been implemented.

The average safety score in this premise is 73% which it is still rated as a good score. However, attentions and actions are required on the non-fulfilled checklist elements which may cause potential hazards to the operators and the environment. The summary of the non-fulfilled checklist elements and its importance are shown in the table 4.3:

Table 4.3: Elements that are not been fulfilled in the premise and its importance

Categories	Non-fulfilled Elements	Importance
General Management	No safety promotion program (motivation, rewards)	Attractive offer to motivate operators to comply safety requirement
Site Perimeter	Safety signage not clearly shown	Awareness to the operator or visitors about the hazardous area so that precautions is done before the entrance
	Workplace not ergonomically designed	Will cause long term ergonomic injury
	Potential wet area not using anti-slip floor	Potential to cause slipping injury
	First aid kid is not sufficient in the workplace	Reduce risk of infection and the severity of the injury before getting worse immediately when injury occurred
Manual Handling	Tools and equipment not sufficiently provided	Operator tend to misuse the tools since the appropriate tools are not provided.

	Operators do not aware the maximum lifting weight limit (man 25kg, woman 16kg close to body)	Will cause long term ergonomic injury
	Operators are found awkward posture when performed manual work	Will cause long term ergonomic injury
	Ergonomic injury is not recorded	The record is important to identify the severity of the injury caused by the premise and to implement corrective actions.
Hazardous Chemical Management	Insufficient of gas detector is found in the premise and poor maintained	Concentration of hazardous gas can be detected before work to avoid health hazards
	Permit to work system is not practiced in the premise	Permit system helps to check and ensure all safety criteria are fulfilled before work.
	No training program for hazardous gas and chemical management is provided	Enhance the competency of operator and hence the hazardous substance can be handled with care without impose risk to the operator.
PPE	PPE issuance and inventory record is not available in the premise	Control the PPE issuance and the cost, ensure restock has been done before the PPE run out of stock
Electrical Safety	No full time or standby charge man in the premise	Charge man able to troubleshoot power failure immediately so it won't interrupt the treatment process
Fire Safety	Insufficient "KELUAR" sign available in the exit	Helps to guide people to the exit during fire

	No emergency shut down system available when fire alarm is triggered	Prevent secondary hazards or fire caused by the running equipment
Waste Management	Wastes are not properly labelled with the hazard sign	Aware the operator so that appropriate actions shall be done before handle the waste.
	Waste generation and storage are not recorded	Proper record will facilitate the arrangement of sending the waste out from the premise regularly before the premise storage is full
	Employees are found not properly handling the waste	The wastes produced by the premise are biohazard, properly waste handling will avoid health hazard
	Operators' knowledge about the waste management are insufficient	The operator competency in waste management will cause them exposed to hazard.
	No waste reduction plan is found in the premise	Waste reduction plan is helpful in reducing the operating cost
	Waste reduction plans are not reviewed and updated	Continual improvement in waste reduction plan will further reduce the operating cost.
Safety, Health & Environment (SHE) Communication	No full time or part time environmental officer in the premise	Environmental officer gives advice to management about the compliance of environmental regulation.
	No registered medical panel	Medical panel help to record the operators health

		condition and aware if the potential health hazard exist in the premise
	Employees health condition are not recorded	Health condition records help to determine the health hazard and to check whether it had been eliminated
	No emergency respond plan available in the premise	Fast actions can be taken during emergency with the emergency respond plan
Housekeeping	Some work place is found with some surface water	Potential to cause slipped injury
Machinery and Equipment	Some operators are found incompetent in the operation	Competency in the operation do correct action to ensure the treatment process is in optimum condition without imposed risk to himself or others.
	Some wear and tear spare parts are found not available in the premise	The spare parts can be changed immediately when found out of service, so that it will not affect the treatment process.

4.3 Qualitative Risk Analysis

From the above process description and the site visit, a qualitative risk assessment had been done based on the every single job steps that had been performed in the operation to assess the possible hazards that might be occurred during the job step and what will be the consequences of the incident. Then, the risk is evaluated based on the probability of occurrence and its severity, the higher the score indicate that the risk is at higher possibility to occur or higher severity of the risk. The risk level is calculated based on the multiplication of probability and severity score. Recommendations are given for each of the risks in order to reduce the risk occurrence probability and the risk severity. The result of the qualitative risk assessment is recorded in Table 4.4.

Table 4.4: Qualitative risk analysis

Severity / Probability	Negligible (1)	Minor (2)	Moderate (3)	Significant (4)	Severe (5)
Very unlikely (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Very likely (5)	5	10	15	20	25

TYPES OF ACTIVITY	***OPERATION OF WASTEWATER TREATMENT PLANT***					**DATE:**	*25/4/2018*
LOCATION:	*KLANG VALLEY*		**DEPARTMENT:**	*ENGINEERING*		**OFFICE:**	*K.L.*
BASIC JOB STEPS	**HAZARD IDENTIFICATION**		**EVALUATION OF RISK**			**RISK CONTROL**	
	HAZARD	**EFFECTS**	**PROBABILITY**	**SEVERITY**	**RISK LEVEL**	**ACTIONS RECOMMENDED**	**ACTION BY**
Primary treatment process	Hard solid break or trapped the equipment	Damage to equipment	2	4	8	Install trip sensor to stop the equipment when hard solid is detected.	Operation
	Misalignment of the scrapping	Unfiltered material may	2	4	8	Provide training to enhance the operator	Operation

	equipment	break down the subsequent equipment				competency	
Secondary treatment process	Blower break down	Biological treatment fail, polluted effluent	2	5	10	Standby blower Regular checking and maintenance schedule	Design Operation
	Diffuser pipe break	Uneven aeration, low treatment efficiency	2	5	10	Ensure the primary treatment in operation Do not allow hard solid fall in the aeration tank	Operation
	Incoming flow higher than designed flow	Inefficient treatment, polluted effluent	2	5	10	Prepare emergency treatment procedure for over capacity Upgrade the plant	Management Design
	Uncontrolled aeration process	Runaway reaction, floating sludge will formed, polluted effluent	3	4	12	Provide more training to increase operation competency.	Management

	Excessive activated sludge	Unclear supernatant effluent	4	4	16	Desludging. Regular checking the MLSS of the aeration tank	Operation
	Sensor (dissolved oxygen or mixed liquor suspended solid) calibration date due or breakdown	Wastewater not treated, or runaway reaction, non-optimum treatment	3	2	6	Regular checking and maintenance. Blower control switch to manual operation if the sensor is broken	Operation
Waste sludge dewatering	Slippery work area	Slipped down, physical injury	4	2	8	Regular housekeeping. Anti-slip floor	Operation Design
	High noise level from the equipment	Hearing impairment	5	4	20	PPE (hearing) when work around the equipment	Operation
	Low dryness sludge	More transportation required to take out the sludge	2	1	2	Upgrade the competency of the operator, adjust the centrifuge speed and polymer feed to obtain high dryness sludge	Management Operation

Odor control system process	Ventilation fan break down	Unpleasant smell in the premise, toxic gas, health hazard	1	3	3	Regular checking and maintenance. Reserve spare parts in the premise and speedy repair if break down	Operation Management
	Pipe leaking	Insufficient odor treatment, unpleasant air release to the environment	1	3	3	Regular checking and maintenance Patch the leaking pipe once leak is found.	Operation
Switch on the main switch board	Inappropriate start up method	Panel break down, explosion, injury	1	5	5	MSB startup by competent charge-man. Prepare checklist prior startup	Electrical Management
Start the power of the equipment	Inappropriate start up method	Equipment and breakdown, short circuit, physical injury	3	3	9	Equipment startup by competent person Prepare checklist prior startup	Electrical Management

	Reserve rotation (phase changed)	Equipment breakdown	3	4	12	Check the rotation during first start-up	Operation
	Air locked (for pump only)	No flow, pump damaged	5	4	20	Open the air release valve to release all air before start-up	Operation
	Submersible mixer or pump not fully submerged	Overhead, equipment breakdown	4	4	16	Check the water level before start-up Equipment start-up interlocked by level sensor	Operation Design
Manually skimming rubbish from manual screen	Biohazard	Sick	4	3	12	Automated process Equipped PPE when perform the job Ensure odor removal system in operation	Design Operation
Pack rubbish collected from primary treatment	Biohazard	Sick	4	3	12	Equipped PPE when perform the job Ensure odor removal system in operation	Operation

	Direct contact to the rubbish	Skin irritation	4	3	12	Equipped PPE when perform the job	Operation
Store or prepare the chemical	Direct contact or inhaling chemical	Skin or airway inflammation	4	5	20	Handle the chemical with extra care Equipped PPE when perform the job	Operation
	Chemical spillage	Eye injury, slippery ground surface, wastage	1	2	2	Quickly clean the chemical Prepare emergency eyewash and shower nearby the chemical storage area	Operation Design
Transporting the waste sludge out from the premise	Improper disposal	Environmental pollution	3	4	12	Provide training to enhance the awareness of environmental protection	Management
Wastewater sampling	Direct contact with wastewater	Health hazard	1	3	3	Automated sample collection Equipped PPE when perform the job	Design

	Chemical spillage	Health hazard	1	2	2	Handle the lab tester with care Prepare emergency eyewash and shower nearby the lab	Operation Design
Confined space services	Trapped in toxidic atmosphere	Health hazard, fatality	3	5	15	Gas check before entry Standby person at the entry Permit to work in the confine space	Authorized Gas Tester (AGT) Management
Release air locked in the pump	Inhaling toxic gas of wastewater	Health hazard	4	4	16	Automated valve to release the air Equipped PPE when performed job	Design Operation
	Air not fully release	Damage to pump	2	4	8	Double check the running amp during start-up Enhance competency of operator	Operation Management

Lifting up equipment using overhead crane or chain hoist	Lifting over capacity	Equipment will fall down, injury to operator	2	4	8	Use crane with sensor which will not perform lifting over capacity	Design
	Improper lifting procedure	Equipment will fall down, injury to operator	1	4	4	Enhance competency and awareness of operation	Management
Checking the functionality of equipment and instrument	Equipment or instrument power not turned off	Short circuit, physical injury	1	5	5	Ensure no direct contact to equipment or cable when checking Enhance the competency of operation	Electrical Operation Management
Replace wear and tear spare parts of the equipment	Improper replace procedure	Equipment or spare parts life span reduce	2	4	8	Request the equipment supplier to perform the replacement Prepare checklist and illustration for replacing spare parts	Management

	Power not turned off	Short circuit, physical injury	1	5	5	Enhance the competency of the operator	Management
Replace broken diffuser	Direct contact with activated sludge	Health hazard	5	3	15	Equipped PPE when performed the job Pump out the sludge before perform the job	Operation
	Diffuser do not tighten well	Uneven aeration, low treatment efficiency	3	3	9	Double check the pipe condition before filling in the wastewater	Operation
Add / replace gear oil to the mechanical equipment	Replace different grade of oil	Damage to equipment	1	4	4	Check the oil grade requirement Enhance the operator competency	Operation Management
	Putting too much oil	Oil overflow and spill out, slippery floor, risk of slip	4	2	8	Check the oil mark, fill the oil with care Enhance the competency of the operation	Operation Management

Replace electrical accessories (relay, e-stop, starter, isolator)	Power not shut down completely	Short circuit, severe injury	2	3	6	Prepare checklist before parts replacement	Management
	Wrong cable installation	Equipment may not start, damage to other accessories and the equipment	3	3	9	Mark the cable properly Parts replacement done by competent person (chargeman)	Electrical
Replace damaged cable	Power not shut down completely	Short circuit, severe injury	1	4	4	Double check the electricity of the cable before perform work	Electrical
	Replace smaller size of cable	Cable overheat, shorten life span	2	4	8	Check the cable size of the old cable before purchase the new cable	Electrical
	Cable terminate in reverse orientation	Damage to equipment	4	4	16	Double check the motor rotation during the startup	Operation

Based on the qualitative risk assessment table, 43 risks had been identified that possible to occur during the operation job steps. The risks level are categorized into 4 based on the score that had been determined: low risk (1-4), medium risk (5-9), high risk (10-14) and very high risk (15 to 25). 9 low risks, high risks and very high risks are found respectively, and the medium risks are found the most which is 16. Generally, the risks in the wastewater treatment plant will caused harm to the operator, equipment and the surrounding environment, which had been labelled in each of the effect of the risk.

The hazard is in low risk when the probability and its impact is low, however, when the probability or the severity score getting higher, the risk level will increase from low to high and very high when the risk has high score in both probability and severity. More attention is required to look on those high and very high risk, due to higher probability of occurrence and the dispersed severe consequences to operator, operation, and surrounding. In the selected wastewater treatment plant, the high risk level that required attention are summarized in the table 4.5:

Table 4.5: High risk job analysis in the selected wastewater treatment plant

Type of Hazards	Description
Physical Hazard	Entering high noise level area without proper PPE
	Submersible equipment overheat due to not fully submerged
	Pump air locked and cause breakdown
	Wrong electrical termination cause damage to equipment
Environmental Hazard	Process equipment breakdown that will leads to treatment failure, especially aeration equipment
Health Hazard	Handling chemical which is hazardous

	Handling biological sludge which is biohazard
	Entering confine space which has dangerous atmosphere
	Releasing air locked in the pump that contain hydrogen sulfide

In every industry, “risks are closely related with the cost”, this phrase can be explained as when any risk had been occurred in the premise, it will caused extra direct and indirect cost associated with the risk consequences. For example, if equipment breakdown, it caused extra cost for repair or buy a brand new unit. Besides, the failure of the major treatment equipment will also cause the wastewater treatment failure, and the nearby river will polluted by the uncompleted treated wastewater. As the consequence, a higher cost is paid to the authority to clean the polluted environment and also there will be potential penalty up to RM 500,000 given by Department of Environment Malaysia (DOE) for causing pollution to the river. Dealing with the chemical and biological substance will cause harm to operator health, if the necessary precaution action has not been done appropriately prior to the handling, the effect will be range from minor operator injury to major fatality. Extra cost is required to pay for operator medication, work time lost, operator substitution and many other indirect cost and consequences that cost even more than direct cost such as reputation lost, retrain the competency of the replacement operator, investigation cost and potential penalty by authority. Thus, once the risk had been identified from the qualitative risk assessment above, appropriate risk control actions should be implement to reduce the probability or severity of the risk or both.

4.4 Operators Survey

The operator survey had been carried out to determine the quality of operators in terms of competency / knowledge in safe operation, compliance to safe work procedure, emergency preparation and response, stress level and health condition and contribution to continual safety improvement. These are 5 important themes to ensure that the wastewater treatment plant is operate in optimum condition and safe working environment. Total of 40 survey sheets had been distributed to the selected premise and 37 respondents are responded to the survey. The summary of general information of the respondent (age group, gender, working experience and hierarchy in the organization) is shown in the figures below:

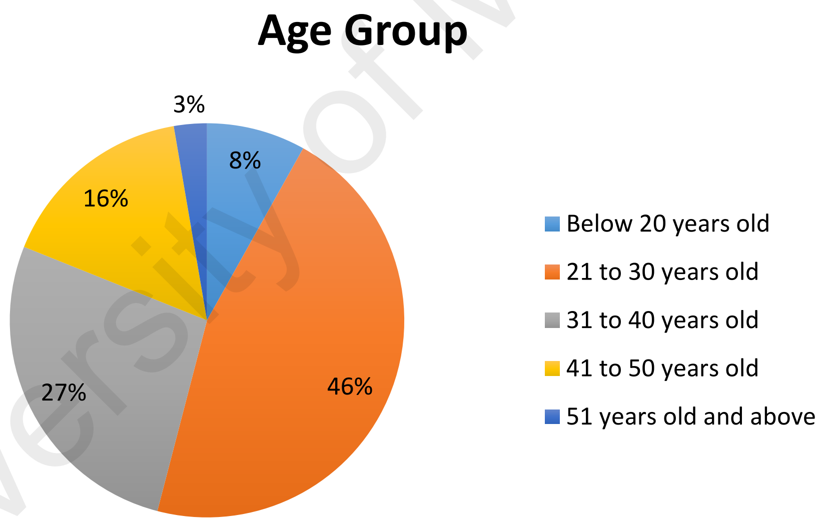

Figure 4.1: Summary of age group of the respondents

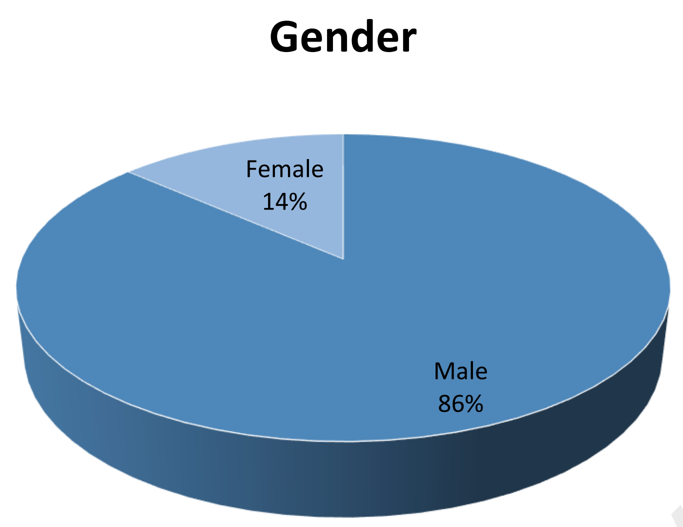

Figure 4.2: Summary of gender of the respondents

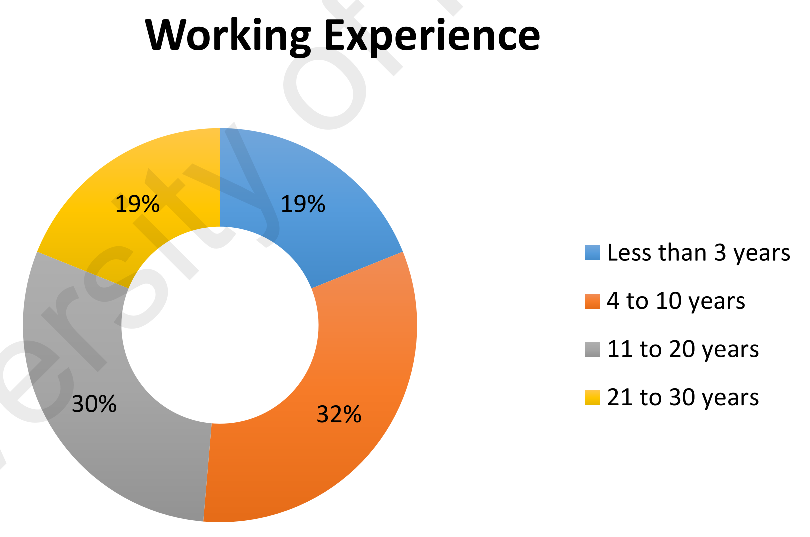

Figure 4.3: Summary of working experience of the respondents

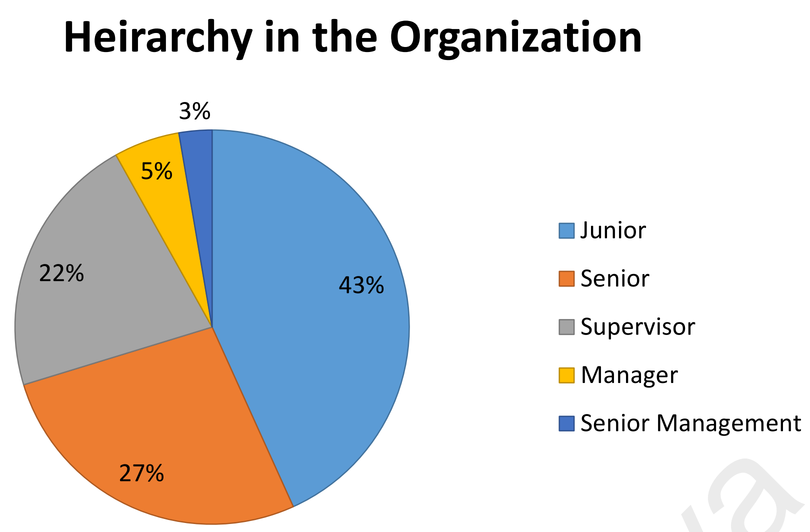

Figure 4.4: Summary of hierarchy in the organization of the respondents

From the figures above, majority of the respondents are in the age of 21 to 30 years old (46%), followed by 31 to 40 years old (27%), 41 to 50 years old (16%), below 20 years (8%) and only 3% of the respondents are in the age to 51 and above. The male respondents are 6 times more than female respondents, 86% and 14% respectively. This might be due to female do not prefer to work in the treatment plant as it is sound hazardous and dirty. From figure 4.3 and 4.4, it is shown that the working experience in the premise is closely related to the hierarchy in the organization. 19% and 32% of respondents have working experience less than 3 years and 4 to 10 years respectively, and they are majority junior (43%) and minority senior (27%) position in the organization. 30% of respondents that have working experience 11 to 20 years are in the hierarchy of senior (27%) and some of them may be in supervisor (22%) position. There are 19% of respondents have working experience 21 to 30 years which holding position of supervisor (22%), manager (5%) and senior management (3%) in the organization.

There are total of 25 questions that are required to response, which break down into 5 sections, 5 questions in respective section. Each question has its own weightage with the range of 1 to 3 which represent how important the question contribute to the theme. The average marks of each section will be calculated to rate the quality of operator in each theme as shown in table 4.6:

Table 4.6: Rating of the operator quality based on the average score

Average Score	Rating
1.00 to 2.00	Very Poor
2.01 to 3.00	Poor
3.01 to 3.50	Good
3.51 to 4.00	Excellent

The summary of the respondents are tabulated in the table below:

4.4.1 Competency / Knowledge in Safe Operation

Table 4.7: Summary of respondents to competency / knowledge in safe operation

	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	Weightage	Total
Q1	0%	19%	51%	30%	1	3.11
Q2	11%	27%	43%	19%	1	2.70
Q3	11%	27%	43%	19%	3	8.11
Q4	8%	38%	38%	16%	3	7.86
Q5	16%	46%	30%	8%	2	4.59
Total					10	26.38
					Average Score	**2.64**

The table above shows summary of respondents' answer to questions pertaining to the competency or knowledge in safe operation. A total of 81% of the respondents do aware the characteristics and the SDS of the hazardous substances they dealt with in the premise with only 19% disagree that they aware of this particular matter, which they are potentially unaware they are exposed to hazard when handling hazardous substance.

Total of 62% of respondents with 43% agree and 19% strongly agree that they understand why the treatment plant is needed and the consequences of treatment failure to the environment, and the same amount of respondent are confident at his competency in the process operation and control, however, 11% and 27% respondents are strongly disagree and disagree respectively, this will be a potential threat to environmental pollution as they are likely to make mistake on the process operation without aware that the severity of consequences of their act to the environment. There are quite a number of respondents, 46% and 62% are not confident at their competency in safety, health and environment (SHE) knowledge and maintenance & troubleshooting works (mechanical and electrical) respectively. Poor SHE knowledge will easily exposed to hazard inadvertently whereas poor maintenance & troubleshooting works will cause the process equipment break down more frequently and takes longer time for troubleshooting and repair. Competency in process operation control, SHE and maintenance & troubleshooting works are constitute a great weightage since they are important to ensure safe operation in the premise. The average score in this section is only 2.64 which is a poor rating, enhancement in the competency is necessary in order to achieve excellent safe operation.

4.4.2 Compliance to Safe Work Procedure

Table 4.8: Summary of respondents to compliance to safe work procedure

	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	Weightage	Total
Q1	0%	0%	46%	54%	1	3.54
Q2	0%	5%	27%	68%	3	10.86
Q3	0%	0%	24%	76%	2	7.51
Q4	0%	8%	38%	54%	3	10.38
Q5	0%	11%	43%	46%	3	10.05
Total					12	42.35
					Average Score	**3.53**

The table above shows the summary of respondents' answer pertaining to the compliance to safe work procedure. The rating of this section is excellent with the average score of 3.53. Generally, most of the respondent are agree and strongly agree to the all questions in the section with 0% strongly disagree, 100% of respondents aware the safety policy in the premise and hold valid CIDB green card. There are only 5% are disagree that he aware and complied to SOP in the premise, 8% disagree that he aware regular checking and maintenance of all equipment in the premise, and 11% disagree that they are confident to properly equip all PPE. Although there are only a small portion of respondent disagree, but action is still required to be taken in order to ensure all operators are aware to comply SOP, regular checking and maintenance and properly equipped PPE as they contribute higher weightage in this section.

4.4.3 Emergency Preparation and Response

Table 4.9: Summary of respondents to emergency preparation and response

	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	Weightage	Total
Q1	19%	62%	11%	8%	3	6.24
Q2	8%	57%	24%	11%	3	7.14
Q3	5%	46%	35%	14%	2	5.14
Q4	5%	22%	46%	27%	1	2.95
Q5	5%	70%	14%	11%	2	4.59
Total					11	26.05
					Average Score	**2.37**

Table above shows the summary of respondents to the questions in the emergency preparation and response. There are only 11% respondents agree and 8% respondents strongly agree that there is emergency response plan in the premise. Besides, 57% respondents disagree and 8% respondents strongly disagree that they confident to take appropriate actions during the emergency. A total of 51% of respondents do not regularly check on emergency equipment and ensure they are function properly and total of 75% respondents are not confident to proper use all emergency equipment in the premise. These indicate that most operators are not been told, trained and educated about emergency response plan which may lead them probably fail to react during the emergency. Furthermore, only 46% and 27% agree and strongly agree that they aware the emergency pathway to assembly point, which another 27% of the operators possibly trapped in the premise and exposed to hazard during emergency. The average score calculated is only 2.37 which is rated as poor, emergency training are required to be carried out to enhance their reaction to emergency so that they are able to protect themselves during emergency and able to control the accident from getting worsen.

4.4.4 Stress Level and Health condition

Table 4.10: Summary of respondents to stress level and health condition

	Strongly Disagree (1)	**Disagree (2)**	**Agree (3)**	**Strongly Agree (4)**	**Weightage**	**Total**
Q1	0%	0%	57%	43%	2	6.86
Q2	0%	19%	59%	22%	3	9.08
Q3	0%	16%	62%	22%	1	3.05
Q4	0%	0%	14%	86%	3	11.59
Q5	24%	51%	14%	11%	2	4.22
Total					11	34.81
					Average Score	**3.16**

The table above shows the summary of respondents' answer pertaining to the operator stress level and health condition. The rating of this section is good with the average score of 3.16. By looking the tables in detailed, 100% of respondents are comfortable with the working environment and happy with their job. There are 19% of respondents disagree that they do not fall in sick more frequently after enroll in the job, this indicates they are highly possible exposed to hazard in the work unintentionally. 16% of respondents are not satisfied to the utilities service in the premise, utilities cleaning and upgrade is required in order to enhance the working environment. There are total of 75% respondents do not carry out medical checkup every year, the management should look into this issue seriously and take appropriate action, such as to provide free medical checkup once a year, to ensure that the operators are in good health condition and not exposed to long term chronic hazard.

4.4.5 Contribution to Continual Safety Improvement

Table 4.11: Summary of respondents to contribution to continual safety improvement

	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)	Weightage	Total
Q1	11%	43%	30%	16%	1	2.51
Q2	8%	46%	32%	14%	1	2.51
Q3	19%	27%	46%	8%	2	4.86
Q4	11%	32%	41%	16%	3	7.86
Q5	16%	46%	27%	11%	3	6.97
Total					10	24.73
					Average Score	**2.47**

Table above shows the summary of respondents' on the questions in the contribution to continual safety improvement. There are 30% and 16% of respondents agree and strongly agree that they aware on the potential hazard of their job and will prevent the dangerous occurrence, however, the 54% of respondents that do not aware of it and they may easily exposed to hazards. Approximately half of the respondents are passive in contribution to safety enhancement as there are total of 54% respondents are not contribute in safety audit, 47% of respondents are not actively involved in safety related program, 43% of respondents are not give feedback to improve the workplace safety and 62% of respondents do not regularly attend training to improve competency. These had contributed the average score of 2.47, a poor rate. The contribution of the operators towards safety improvement is important to minimize the risk in the workplace as they are the first person standing at the front line of operation and deal with the hazard associated in the operation, they may see the hazard that the management had overlooked. Thus, actions shall be taken by the top management to encourage operators to actively commit in the continual safety improvement.

4.5 Cleaner Production Assessment

After the detailed study on the premise layout plan and the site visit, there are a few cleaner production approaches can be done at the site in terms of resource and waste reduction

1. Reuse treated water
2. Use more energy saving electric starter: Variable Frequency Drive
3. Reuse the waste dried sludge as fertilizer

4.5.1 Reuse Treated Water

The wastewater, flowing into the wastewater treatment plant, will go through series of treatment, and will enter to the clarifier for separation between suspended sludge particles and the supernatant treated water. The treated water which the quality had complied to the Environmental Quality Act 1974 then will discharge to the environment. This free resource shouldn't be wasted and spend extra money to source for clean water. Instead of paying bill for clean water usage that coming from water treatment plant, a simple water treatment plant can be built to further treat the water so that the water can be reuse in the premise as shown in Figure 4.5.

The water tank is provided to store the water from clarifier while the excessive one will be discharge from the premise. 3 steps of treatment will be carried out to produce the better quality water to use in the premise. Firstly, the water will enter to the sand filter to further remove the smaller size suspended matter as well as floating particles. The influent flow vertically through the sand bed in the middle of the filter, and the particles are removed by absorption. The main advantage of the sand filter is it can produce high quality water without adding any chemicals, and the simplicity of this system leads to low operation and maintenance cost.

Then, suitable dose of sodium hypochloride is added to further enhance the water quality by removing odor and pathogenic microorganism. The last stage of the water treatment process is the UV disinfection system. The water will flow into a reactor chamber where UV light is activated to sterilize the water and to suppress the growth and reproduction of the microorganism. Finally, the treated clean water is ready to be used for the purpose of operation, maintenance, cleaning and washing.

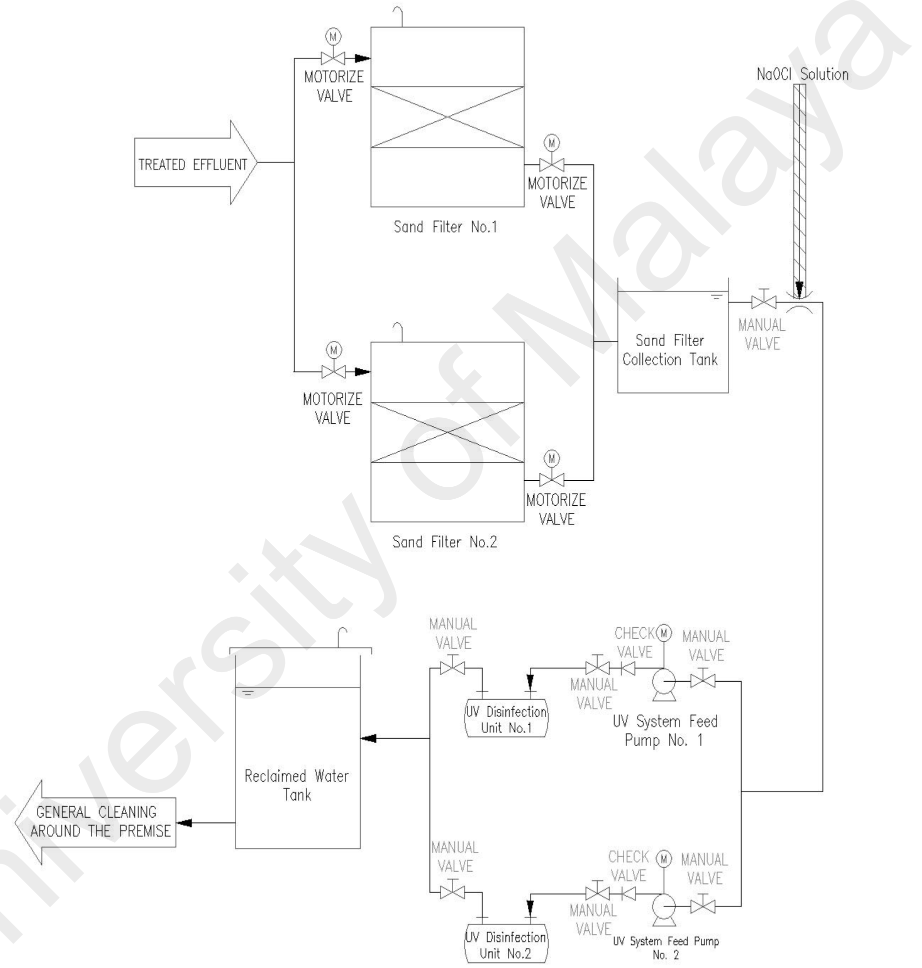

Figure 4.5: Schematic diagram of simple water treatment plant

4.5.2 Variable Frequency Driver

All of the equipment used in the treatment system is electrical powered. Typically, these 3 phase equipment are start-up using direct-on-line, start-delta, auto-transformer or soft starter, depending on the equipment power requirement. More than 60% of money is spent in the electric consumption, and this can be reduce by using the variable frequency driver (VFD) or inverter. Unlike other motor start, VFD smoothen the equipment startup by providing sufficient torque required during startup without drawing excessive electric power compare to other starter. When the equipment startup, electric power first go into the VFD, the rectifier will convert the AC to DC power. DC bus and filter smoothen the rectified DC power and to provide clean, low ripple power and then invert to AC output and resemble AC power sine wave by using pulse width modulation technique (PWM) (*Amit et. al., 2017*). The smoother power supply via VFD also helps to reduce the noise and vibration level of the equipment and hence enhance the equipment lifespan.

Besides, the VFD also able to control the speed of electrical motor during the run cycle by varying the frequency of the input power to the motor. This is very advantage to the equipment that do not require to run in full speed or run in vary speed controlled by some of the parameter in the treatment system. For example, the aeration blower running capacity is controlled by the dissolved oxygen in the system, it runs at higher speed when the dissolved oxygen is low and lower speed when dissolved oxygen is high. Hence, the electricity cost can be reduced.

Although high capital cost is the main factor that the premise do not install VFD for every electric equipment starter, however, according to *Amit (2017)*, the return of investment of the VFD will be in within 2 years from the electricity cost saving and the average lifespan of the VFD with proper maintenance is approximately 8 years. Hence, VFD is highly recommended to be use as a starter of all equipment in the premise.

4.5.3 Conversion of Dried Sludge as Fertilizer

In the wastewater treatment plant, the activated sludge in the secondary treatment growth by consuming the organic nutrient in the wastewater as a treatment process. The sludge mass eventually will growth to the extent that destroy the treatment system. In order to maintain the cell mass of activated sludge, excessive sludge will be removed from the treatment system. These excessive sludge will enter dewatering system to remove the moisture for the ease of transportation for disposal. However, the dried sludge, which full of organic content, poses potential commercial value to resell as organic fertilizer instead of disposal.

A dried sludge sample is taken back from the site visit and sent to the lab for analysis and the full report is attached in Appendix C. The selected results of analysis are shown in the table 4.12 and table 4.13:

Table 4.12: General parameters of the dried sludge sample

No.	Parameter	Unit	Result
1	Total Organic Matter	%	85.3
2	Total Organic Carbon, C	%	49.5
3	Total Nitrogen, N	%	6.06
4	Phosphorus, P	%	1.74
5	Carbon : Nitrogen Ratio	-	8:1
6	pH	-	3.67

Table 4.13: Heavy metal content analysis of the dried sludge sample

No.	Parameter	Unit	Result
1	Lead, Pb	mg/kg	17.1
2	Cadmium, Cd	mg/kg	0.51
3	Barium, Ba	mg/kg	98.5
4	Manganese, Mn	mg/kg	225
5	Copper, Cu	mg/kg	388
6	Selenium, Se	mg/kg	2.27
7	Chromium, Cr	mg/kg	12.9
8	Boron, B	mg/kg	25.3
9	Nickel, Ni	mg/kg	13.7
10	Sodium, Na	mg/kg	344
11	Molybdenum, Mo	mg/kg	6.13
12	Mercury, Hg	mg/kg	0.28
13	Iron, Fe	%	0.61
14	Zinc, Zn	%	0.14
15	Aluminum, Al	%	0.52
16	Calcium, Ca	%	0.49
17	Magnesium, Mg	%	0.11
18	Potassium, K	%	0.15

From the table above, the total organic matter were found in very high concentration (85.3%) which able to facilitate plant growth. The total organic carbon which were found nearly 50% in the dried sludge sample. Organic carbon is an important parameter for soil fertility, it releases nutrient to promote structure and enhance the physical health of the crops. Nitrogen and phosphorus are also found in the sludge sample, which play important role for cell growth. Nitrogen is an important element in the chlorophyll which convert the sunlight, carbon dioxide and water to energy, whereas phosphorus helps to complete the plant cell production cycle. Although the nitrogen is found smaller quantity compare to organic carbon, however, the high carbon to nitrogen ratio (8:1), limits the mobilization of nitrogen and incorporate into cell mass, so nitrogen is make available when it is needed for growth. The pH of the dried sludge sample is found too acidic for plant growth. According to *Mtshali (2014)*, the optimum pH for agriculture crops grow is between 6 and 7, however, water can be added to neutralize this acidic sludge so that the pH can be increase to the optimum range.

Beside the organic content and pH analysis, the heavy metal analysis was also carried out to identify the potential toxicity in the dried sludge sample. It is known that lead, selenium, molybdenum, cadmium and mercury carry high level of toxicity to humans and animals while nickel, copper and zinc are toxic to plants in high concentration (*El-Sayed, 2015*). However, they are found in relatively low concentration. The macronutrient for plant growth such as potassium, calcium and magnesium are found in relatively high quantity. Furthermore, plant micronutrient, such as boron, copper, manganese, molybdenum, zinc, nickel, are found in low concentration, which are beneficial to plant growth and do not carry toxicity to the cell growth. Iron and aluminum, which are not macronutrient for plant growth, present in almost similar concentration as macronutrient, however, the concentration is less likely to cause toxicity to the crops (*Teresa, 2001*). Thus, the results of this dried sludge analysis shows that it has great potential to be organic fertilizer by providing essential nutrient for plant growth and gives low risk of heavy metal toxicity.

4.6 Recommendation for Safety Improvement

After the site inspection, qualitative risk assessment, safety checklist and operators survey that had been done in this research, potential risk had been identified such as: wastewater treatment failure due to equipment or instrument breakdown by various reasons, handling hazardous chemical or sludge, entering confine space, high noise level and ergonomic injury. Those risks will bring severe consequences to the employee and the environment, and are likely to occur due to lack of safety awareness and enhancement. From the safety checklist, it is found that the manual handling skill and the waste management in the premise are poor. The poor quality of site perimeter, SHE communication and supervision may be the cause of the accident. Besides, the operators' survey found out that the operators are inadequate in operation and safety competency, emergency preparation and response and the contribution to the continual safety improvement. These are the causes that contribute to unsafe environment in the premise. Hence, control actions are required to correct all the deficient elements in the premise in order to minimize the risk.

By applying the hierarchy of risk control, risk elimination is in the top priority which totally remove the risk from the premise. This can be done by provide sufficient tools and regularly maintained to avoid risk caused by misuse of tools that is not fit for purpose. Besides, review and upgrade of workstation with ergonomic design factor is required enhance the comfort of workplace and avoid the long-term ergonomic injury caused by poor workstation. Other than that, by complying all the elements in the safety checklist, all means of hazards can also be eliminated or at least reduce to minimum.

The hierarchy in the risk control is the risk substitution, by assessing the hazard characteristics of chemical that been used in the premise, the hazard chemical can be substituted by less hazardous one which can perform the same function. Although the less hazardous chemical is usually more expensive, but considering the direct and indirect cost that caused by the cheaper, more hazardous chemical, such as sick pay, work time lost, purchase better PPE and emergency equipment, expensive cleaning agent and provide training to operators, the total cost associated will be more expensive.

In engineering control, the risk can be reduced by upgrading the safety equipment in the premise, such as ventilation system for better air circulation to reduce the concentration of hazardous gas. The gas detector also should be installed in the potential hazardous area to measure the concentration of hazardous gas and give alarm when the value exceeded threshold limit value in 8 hour time weight average. Furthermore, plant upgrade to more automated process operation and control is recommended to reduce the human intervention in the operation. This will highly reduce the human factor risk such as carelessness, lack of awareness, poor working attitude, not complying standard operating procedure, and incompetency in process operation. Besides, the upgrade also will enhance the treatment efficiency and thus reduce the resource consumption. However, training is still required to enhance the operator capability to detect the error and troubleshooting during the operation failure alarm is raised and before the problem get worsen.

Administrative control helps to protect the operator exposed to risk, it involves standard operating procedure (SOP), operation and maintenance checklist and schedule, working shift, job rotation and enhance operator attitude and knowledge. The top management team is highly responsible to initiate safety enhancement in the premise, they are the role model to initiate and enforce the safety. They shall ensure all operators are comply to all safety requirements. Besides, rewards system can be practiced to motivate the employee to build up a safe working environment and culture. The connection and bond between management and operators is also an important factor to keep 2 way communication so that operators will not hesitate to comments on potential unsafe element that the management may not aware at. Close supervision is also required to ensure that the standard operating procedure and scheduled maintenance had been complied, so that the accident caused by incompliance will be eliminated. Apart from that, continual training and education program in safety, environmental, health, operation and maintenance to enhance their competency and awareness, are also one of the key factor to reduce the risk. Competent operator perform correct work method, able to detect and troubleshoot error before it get worse and ensure the safety of himself and others in the premise.

Personal protective equipment (PPE), the last line of defense to the operator, are essential to ensure the operator are fully protected from the hazard if the hazard are not able to remove completely by elimination, substitution, engineering and administrative control. The PPE issuance and inventory record must be make available and regularly updated to ensure all operators are distributed with sufficient PPE and aware to restock before it running out of stock. Besides, the training on how to use the PPE properly should be provided at least once per year to ensure the operators are competent in equipped with the PPE so that they are fully protected by the PPE without exposed to any hazard.

Continual monitoring and review for risk control are also necessary to ensure the risk control implementation is effective in minimize the risk. The SOP, operational and maintenance schedule and checklist, risk assessment and control shall be reviewed once per year to determine whether it is effective to prevent or minimize all the risks in the premise. Update is necessary when the existing risk control is found not fully covered all risks or when new risk is found in the premise.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Wastewater treatment plant is not categorized as major hazard industry, however the threat of the risk is significant to the employee health and to environment. The gas release by the wastewater is hazardous and may threaten the operator life. The treatment failure may polluted the environment and caused long chain link consequences such as aquatic life lost, land contamination which reduce agriculture crop yield and affect the flora and fauna habitat. Furthermore, human will get toxic as the result of consume those contaminated food.

This research is carried out to identify the hazard associated in the operation and maintenance of wastewater treatment plant via study of process description and the site visit to the premise with the aids of safety checklist and operators surveys. Potential hazards such as physical, health and environment hazards are identified due to the operators are poor in manual handling, waste management, competency in safe operation, emergency preparation and response and majority of them are inactive in the involvement of continual safety improvement.

The qualitative risk analysis are carried out to identify the potential risks that may occurred during the process operation and maintenance and to evaluate the risk level of the particular risk. High risk level indicate that it has high probability of occurrence or high severity or both. From the risk analysis, the high risks underlying in the operation and maintenance are: equipment breakdown due to air locked or wrong wiring termination or overhead, treatment failure due to major equipment breakdown, working in high noise level area, and biohazard when dealing with chemical or waste material. In order to eliminate and minimize the risks in the premise, the hierarchy of risk control is recommended: risk elimination, substitution, engineering control, administration control, and personal protective equipment. The management should provide sufficient tools and equipment for the operators to perform work, and upgrade the plant to enhance the safety level. Besides, training, 2-way communication and management commitment to safety enhancement are important in order improve the operators' safety competency and awareness which will help to reduce the risk occurrence. By implementing necessary risk control actions, continual monitoring and review is required to ensure the effectiveness of the control actions to risk minimization.

Furthermore, cleaner production assessment is carried out to assess the possibility of reduce the resource usage and waste production. It found out the possibility of reduce the resource usage by reuse the treated effluent to reduce water usage, a simple water treatment plant is recommended to further improve the quality of the water for the purpose of operation, maintenance, cleaning and washing. The use variable frequency driver able to reduce the electricity usage by smoothen the power supply. The waste production in the premise can be reduced by reuse the dried sludge as organic fertilizer instead of direct disposal. From the lab test result, the dried sludge contain sufficient macro and micro nutrients to facilitate the plant growth. The cleaner production approach help to reduce the cost of resources (water and electricity) and also will bring profit to the premise by selling the dried sludge to agriculture industry.

5.1 Recommendation for Future Studies

1. In this research, qualitative risk assessment is used to assess the risk associated in the wastewater treatment plant. It is the simplest and most direct method to identify and assess the risk. A more complicated and detailed quantitative risk assessment will usually be done after qualitative risk assessment to express the risk outcome numerically. However, it is not done in this research due to lack of numerical data of the risk outcome in the wastewater treatment plant. Most of the quantitative risk assessment numerical data are only available in major hazardous industries such as oil and gas and chemical plant. Hence, future studies about the numerical data of the risk outcome in the wastewater treatment plant are recommended so that quantitative risk assessment can be done in this industries.
2. Besides, the dried sludge sample from the premise had been analyzed and the result shown that it contain varies of nutrient that essential for plant growth with very low heavy metals. This shows economic potential of the dried sludge to use as organic fertilizer to increase the crop yield instead of direct disposal which bring no revenue to the premise. However, more detailed experiment is recommended to be done to plant different types of crops by using the dried sludge as fertilizer to study the effectiveness and potential harm of the dried sludge to the different agriculture crop yield.

CHAPTER 6: REFERENCE

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