EFFECTS OF INDUSTRIAL WASTEWATER ON WATER AND SEDIMENT QUALITIES AND EFFECTIVENESS OF BIOREMEDIATION METHODS OF INDUSTRIAL WASTEWATER TREATMENT,GEBENG, PAHANG, MALAYSIA

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ABSTRACT

Gebeng is a very important industrial estate of Pahang, Malaysia. A study was conducted in Gebeng industrial area in order to obtain the current status of industrial wastewater, surface water and sediments. Results of industrial wastewater and surface water were compared to Malaysian and different standards limits. Moreover, the industrial wastewater and surface water classification and contamination intensity were calculated. Sediment quality guidelines were used to compare the results of sediments. Some of water quality parameters such as BOD, COD, TSS, Pb, Cd, Cr and Hg were higher compared to standard limits in studied wastewater. BOD, COD, ammoniacal nitrogen, total nitrogen, total phosphorous, nitrate, phosphate, As, Hg, Co, Pb, Ni, Cr, Cd and Cu were higher in surface water compared to standard threshold. For sediments, Co, Hg, As, Pb and Cu concentrations were higher than those of permissible levels. In addition, wastewater treatments were done by bio-remediation methods. It was performed first by *Pseudomonas aeruginosa* and secondly by Vetiver grass, Cattails and Water hyacinth. From the treatments of *Pseudomonas aeruginosa*, the expected pollutants removal efficiency was found. Because of lower pollutants tolerant features vetiver grass and water hyacinth did not survive in 100 % wastewater while cattails were adapted to 100 % wastewater due higher contaminants tolerant characteristics. The 75 % wastewater with N-P-K mixed fertilizer treatment was found as the best treatments among vetiver grass and water hyacinth treatments. In case of cattails, 100 % wastewater with mixed fertilizer treatment showed the best performance. Statistical software (SPSS) was used to compute data and results. Least significance difference, first order kinetics, correlation analysis, principal component analysis, pollution load index, contamination factors, geo accumulation index and surface water enrichment factors were used to test the significance, validity of data, groupings of parameters and interpretation. In this study, a novel two steps technique was used which proven to give higher efficiency compared to direct treatments with plants. From this study, it could be concluded that the study area is moderately contaminated by industrial wastewater. Furthermore, the surface waters are classified as polluted (DOE-WQI) and sediments are very strongly and strongly polluted by Co and Hg respectively while Pb, Cd and As are found unpolluted to moderately polluted. So, recycling of wastewater, wastewater treatments by bioremediation techniques, close monitoring and supervision in every industry have to be introduced.

ABSTRAK

Gebeng merupakan sebuah kawasan industri penting di Pahang. Satu kajian telah dijalankan di kawasan perindustrian Gebeng untuk mengenal pasti status terkini sisa air, permukaan air dan mendapan industri. Hasil kajian sisa air dan permukaan air industri dibandingkan antara had piawaian Malaysia dan had-had lain. Tambahan klasifikasi dan tahap pencemaran sisa air dan permukaan air industri dikira. Tatacara kualiti mendapan digunakan untuk membandingkan hasil-hasil kajian mendapan. Beberapa parameter kualiti air seperti BOD, COD, TSS, Pb, Cd, Cr dan Hg didapati tinggi dibandingkan dengan had-had piawaian dalam sisa air yang dikaji. BOD, COD, nitrogen daripada ammonia, jumlah nitrogen, jumlah fosforus, nitrat, fosfat, As, Hg, Co, Pb, Ni, Cr, Cd dan Cu adalah tinggi dalam permukaan air dibandingkan dengan piwaian ambang. Untuk mendapan, kepekatan Co, Hg, As, Pb dan Cu adalah lebih tinggi daripada tahap-tahap yang dibenarkan itu. Disamping itu, rawatan-rawatan sisa air dilakukan dengan menggunakan kaedah-kaedah rawatan-bio. Ia pertamanya dilaksanakan dengan menggunakan Pseudomonas aeruginosa dan keduanya dengan menggunakan rumput Vetiver, Cattail dan keladi. Daripada rawatan-rawatan menggunakan Pseudomonas aeruginosa, kecekapan penyingkiran bahan cemar yang dijangka ditemui. Disebabkan sifat toleransi terhadap bahan cemar yang rendah, rumput vetiver dan keladi tidak boleh hidup dalam 100% sisa air tetapi Cattail boleh hidup dalam medium berkenaan disebabkan sifat toleransinya yang tinggi. Sisa air 75% dengan rawatan baja campuran N-P-K didapati merupakan rawatan terbaik di antara rawatan menggunakan rumput vetiver dan keladi. Dalam kes Cattail, sisa air 100% dengan rawatan baja campuran menunjukkan pencapaian yang terbaik. Perisian statistik (SPSS) digunakan untuk mengira data dan hasil ujikaji. Beza ketara terkecil, kinetik tertib pertama, analisa korelasi, analisa komponen asas, indeks beban pencemaran udara, faktor pencemaran air, indeks penumpukan-geo dan faktor-faktor pengkayaan permukaan air digunakan untuk menguji tahap signifikan (ketermaknaan), penerimaan terhadap data, pengumpulan parameter-parameter dan penterjemahan. Dalam kajian ini, dua teknik baharu digunakan yang terbukti memberi kecekapan yang lebih tinggi dibandingkan dengan rawatan secara langsung dengan menggunakan tumbuh-tumbuhan. Daripada kajian ini, ia boleh dirumuskan bahawa kawasan kajian dicemari secara sederhana oleh sisa air industri. Malahan, permukaan air dikelaskan sebagai tercemar (DOE-WQI) dan mendapan adalah sangat kuat dan sangat dicemari masing-

masing oleh Co dan Hg sedangkan Pb, Cd, dan As ditemui tidak tercemar kepada tercemar sederhana. Oleh itu, kitar semula sisa air, rawatan-rawatan sisa air oleh teknik rawatan-bio, pemantauan dan penyeliaan yang ketat dalam setiap industri patut diperkenalkan.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

At the beginning of civilization, human interferences induced changes in nature and environment. The industrial revolution and its negative impact expedite the global environmental degradation. Large scale environmental changes are found in recent years. These alterations on temperature, water, soil, sediment, air and plants are enormous, creating adverse effects on ecosystem. The human footprints are touching the continents, oceans and even outer space. The increasing trend of anthropogenic activities like rapid industrialization is a great threat in this millennium and that could destroy the green planet (Dong et al., 2014; Bedewi, 2010).

In the present world, industrialization could fulfill all the socio-economic objectives such as to alleviate poverty, creating employment for generations, to promote gender equality, to get health care, shelter and education. Nevertheless, the industrial activities may contribute a substantial negative impact on the environment. It promotes climate changes, water, air, soil pollution and extinction of various indigenous species including flora and fauna. Therefore, the economic, socio-cultural welfare and the global environment are now very much of concern. In industrialized countries, although the new technologies and recycling of wastes minimize the environmental effects but it depletes the natural resources. On the other hand, in the developing countries, chemical pollution, air, water and sediment pollution, deforestation, soil degradation and greenhouse gas productions are the general plight by the industrial activities.

The environmental sustainability might be achieved through the initiation of green economy and eco-friendly products, services, technology, treatments methods and management phenomenon (UNEP, 2013). Today, the earth is facing natural disasters each and every year. The improper industrial development and industrialization is the main cause behind the environmental imbalance. The industrial wastewater disposal is a great problem in the world. It has been thrown mostly to the surrounding watersheds. The surface water is one of the most valuable resources in this earth but it is mostly affected by the industrial processes. Industrial practices have made a huge impact on surface water in the world. The industrial dumping causes a lot of harms for the adjacent areas and it is the drawbacks of sustainable industrialization (Changhao and Zhans, 2013).

Sediments are also being contaminated throughout the world by anthropogenic activities. Generally, sediments are being contaminated through industrial activities (EPA, 2014; Wang et al., 2012). The main problem behind sediment pollution is the entry of metals in food cycles. As they are chemically and biologically not degradable, they pose major pollution factors and ultimately make a great harm for animals (Singare et al., 2011). Malaysia is a rapidly growing industrial country and her economy is mainly dependent on the industrial sectors. Gebeng, one of the industrial clusters in Pahang, Malaysia consists of a large number of petrochemicals, chemicals, metal builders, polymer and other industries. It was found a higher percentage of industrial pollution in Malaysia by industries (Chan, 2012). Moreover, it is reported that the surface water and the sediments are being contaminated in the Gebeng industrial area by industrial dumping. It is well known that the chemical treatment methods and procedures have many adverse, lethal and permanent effects on environments. So the environmental friendly alternative treatment measures are needed to combat the challenges of environmental pollution. Use of bioreactor is an environmental friendly and cost effective procedure. At present, treatment through bioreactor is regarded as an advanced technology and significant in environmental protection (Latif et al., 2011). Bacteria play an important role in removing heavy metals as well as contaminants from wastewater (Kumaran et al., 2011).

Now a day, phytoremediation is being used for the industrial wastewater treatment and environmental cleansing. It has been regarded as the latest biotechnology and endeavor to decontaminate environment through phyto extraction of pollutants (Ziarati, 2014). Vetiver grass has large rooting systems and could grow rapidly as well as found potentiality to remove heavy metals (Roongtanakiat et al., 2014; Ho et al., 2013). The best species for the phytoremediation of industrial wastewater are the water hyacinth (*Eichhornia crassipe*s) and cattails (*Typha latifolia*) (Sukumaran, 2013). Industry discharges hot water, wastes, various organic, inorganic substances and heavy metals. So, surface and sub-surface water, soils, sediments, plants, fishes, flora and fauna as well as all lives are being contaminated by these types of industrial activities. Today, the planners and policy makers are thinking about recycling and sustainable management of the wastewater. Pollution free water, plant and sediment are indispensable for life. Congenial atmosphere is needed for the existence of human being. So, it is high time for taking measures to save the Gebeng industrial area as well as the surrounding environment.

1.2 PROBLEM STATEMENT

The United Nations estimates that 1.8 billion people will suffer from water scarcity over the world by 2025 (Shuster, 2012). In Malaysia, a severe water crisis happened in 1997-1998. Malaysians usually overuse water and has poor management of water resources. Owing to less rainfall and no rainfall in Putrajaya and some parts of the country in the last couple of years, water rationing has already started. The water demands are increasing many folds day by day in Malaysia (DOE, 2014). The real scenario is the rapid developments including the metal, wood processing, polymer, chemicals, petro-chemical industries that is deteriorating the environmental quality in the Gebeng industrial estate (Sujaul et al., 2012). In previous times, the study area was included into the reserve forest before industrial development. After forest cleaning, the industry started its journey. So, the surface water and studied catchment area is being contaminated due to industrialization. The surface water in the study area contains high BOD, COD, TSS and heavy metals.

CHAPTER 3

MATERIALS AND METHODS

3.1 INTRODUCTION

In this chapter, the location, geography, geology, the climatic conditions of the study area and the methodologies of wastewater, surface water, sediments and water quality index are described. Moreover, it also includes the methodologies of wastewater treatment by bioremediation. In addition, the selection of monitoring stations, parameters measured, planning of sampling methodology and sampling frequencies, methods of laboratory analysis, statistical analysis, contamination intensity, different procedures, formulas, guidelines to evaluate pollution and kinetics study also discussed.

3.2 STUDY AREA

3.2.1 Location and Geography

Gebeng industrial estate is the study area of this research. It is one of the potential industrial areas of Malaysia. The industrial park is situated between the coordinates of 03 º 59 ' 12 " N and 103 º 22 ' 32 " E. Gebeng town is about 20 km far from Kuantan city and near Kuantan port. The two rivers namely Bhalok and Tungguk are flowing through the industrial area which ended into the South China Sea (Sujaul et al., 2013). It prevailed that before industrialization Gebeng was a green valley included into Paya Tanah Merah forest. Now the forests are very much vulnerable and located in the coastal areas.

Industrial development in Gebeng area has been started since 1970s. Initially the small scale industries like wood processing, metal ducting, concrete ducting, pipe coating facility, detergent etc were the main industries. But since 1990s the medium and large scale industries started their journey those are petrochemicals, chemicals, metal builders, polymers, metal works factories, steel industries, air products, energy, oil and gas industries. The heavy industries are active in Gebeng area such as Lynas, MTBE-Petronas, Polyplastics Asia Pacific Sdn. Bhd, BP chemicals, Kaneka, Asturi metal buliders, Eastman chemicals, Kertih, Palm oil factories etc (Hossain et al. 2013).

3.2.2 Climatic Condition

Malaysia is located near the equator. So, its climate is equatorial as well as hot and humid around the year (Swee-Hock, 2007). As Gebeng industrial estate is located adjacent to coast, therefore it belongs to sunny climate (Marshall Cavendish Corporation, 2008). There are two seasons dry (summer) and wet (rainy); dry season extended from April to September, while the wet season extended from October to March. At summer season the high temperature is observed whereas the high rain fall found in wet season. Sometimes the high rainfall has been found that causes surface runoff and the surface soils are washed away and mixed with surrounding watersheds. The average temperature and precipitation of the study area are presented by (Appendix C).

3.2.3 Geology of Gebeng Industrial Estate (GIE)

The soil of GIE is formed with the Quaternary alluvium and peat. Granites are found in bed rock formation in some areas, basalts also found in south west Balok area. Furthermore, sedimentary rocks are reported in Bukit Balok area. In accordance with Quaternary Geological Map the GIE is formed by the alluvium, peat and silts of Beruas and Simpang Formation. The upper parts of the soils are comprised of gravels, clayey sandy gravel, clayey sandy, organic clay and peat. It is reported that the upper alluvium posses very soft and medium plasticity (Lynas, 2008).

3.3 SELECTION OF MONITORING STATIONS

3.3.1 Industrial Wastewater Sampling Stations

The studied wastewater was collected from the point sources. A survey was conducted to select the monitoring stations for industrial wastewater sampling. It was made on the basis of point and non-point sources, location of the industries, type of industries, channel of wastewater discharging and by using GPS. To cover the whole industrial area, the six technical points were selected for wastewater sampling (Figure3.1).

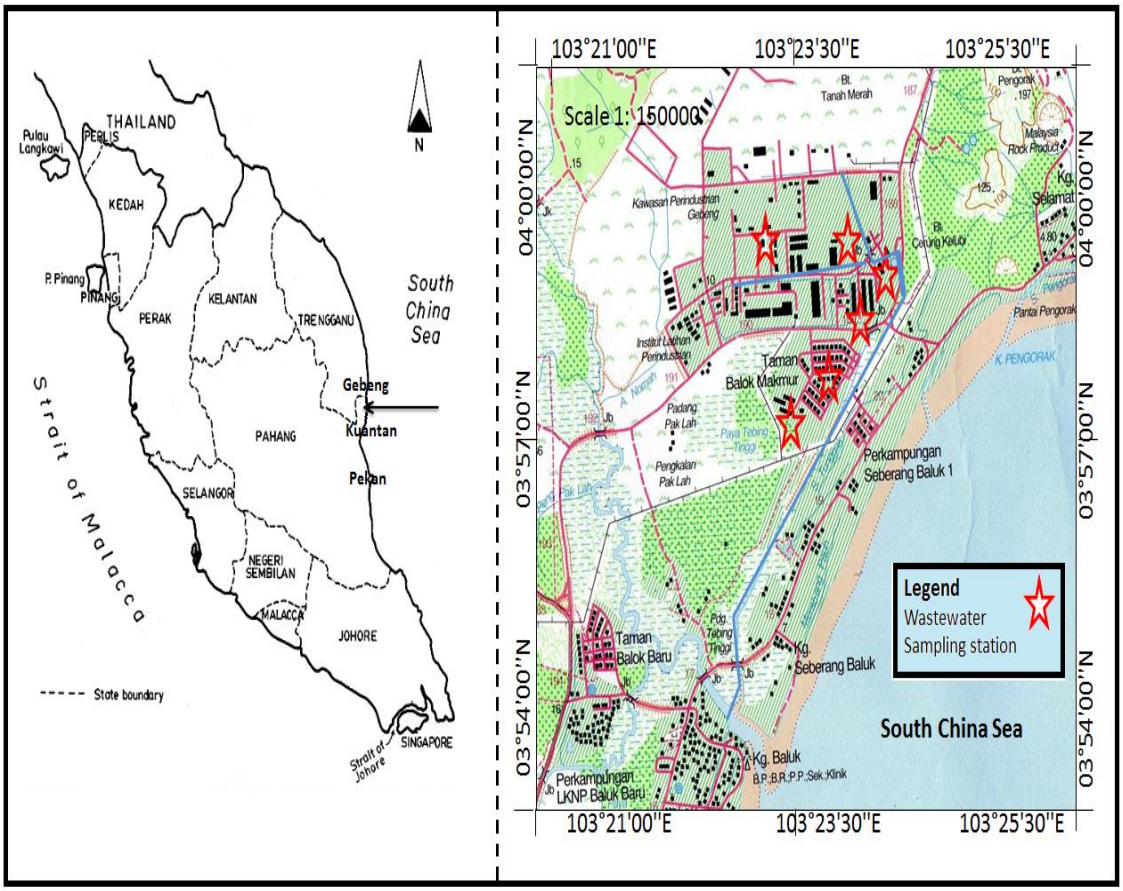

Figure 3.1: Map of the study area showing industrial wastewater sampling stations