The Use of Effective Microorganisms (EM) for Pretreatment of Wet Market Wastewater

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Abstract

Nature based solutions have received considerable attention for water and land quality restoration and potential for sustainability management. The use of naturally occurring permaculture of non-pathogenic microorganisms known as Effective Microorganisms (EM) have gain reputation in the past few years in the South East Asia due to its environmental friendly nature. The technology is not new and has been used in agriculture, restoration and rehabilitation of water resources, and animal housekeeping and husbandry for years in countries like Japan and Thailand. The use of chemicals for water treatment has been costly and detrimental to the environment. In this report, we present the results from the use of EM which we developed in our laboratory for the pretreatment of wastewater from Selayang wetmarket in Selangor. We examined the effects of EM use on the water quality based on the parameters of pH, DO, BOD_5, COD, TSS and NH_3-N. Improvements of the water quality before and after treatment were observed and quantified. It was proven that application of EM, the wastewater quality were reduced to its acceptable standards. Pretreatment with EM reduces expenditure and operational stress of the treatment plant. We also proposed a new design of EM treatment plant with detail specifications for the treatment to optimize the efficiency of EM in treating the wastewater from a wet market.

Keywords: Effective microorganisms; wastewater; wet market; sustainability; nature based solution

1. INTRODUCTION

Wet market is a public market where the locals get their supplies of fresh vegetables, fruits, dairy, fishes and meat. The wastewater from wet market contains higher organic matter and solids compared to domestic wastewater (Santos & Robbins, 2011). Discharged of untreated wastewater contaminates the nearby rivers and streams with harmful bacteria and organic pollutants. Therefore, the municipal authority is required to minimize the pollutant load impact to the river to reduce the detrimental effect on the population's living quality, health, and environment. Increasing knowledge and research in the reduction of pollutants in the wastewater using bioremediation approach have led to the design of efficient and cost-effective methodology.

Management strategies in sustainable water management system are aimed at reducing pollutant at source point in general. Nature based solution for sustainable water management such as the use of Effective Microorganisms (EM) has received a lot of attention for its low operational cost and synergistic effects to the environment. The technology was developed by Teruo Higa from Okinawa, Japan and has been described as inoculum of 80 coexisting non-pathogenic beneficial microorganisms. EM technology is not new and widely applied in many countries for wastewater reuse treatment method (Sangakkara, 2002). It has been proposed that EM preparation acts as antioxidant and able to inhibit harmful bacteria substances and enhance the proliferation of beneficial microorganisms and fungi to restore the balance in the natural system.

Untreated wastewater discharged from Selayang wet market has been identified as one of the major problem affecting the water quality of Sungai Batu. Currently, many wastewaters are treated using dispersant and chemical that are toxic to the environment such as alum, lime and ferric chloride which can be more harmful to the environment when reacted with biological diversity (Kurihara, 1990).

2. METHODOLOGY

A. Identification of area and collection of samples

Selayang wet market is located at Bandar Baru Selayang, Batu Caves, Selangor at N 3°14'34" and E 101°39'56" which is at the intersection of the most critical sources of untreated effluent from two rivers, namely Sungai Batu and Sungai Jinjang.

The basis of the selection for the timing of the sample taken was done by the temporal monitoring. Temporal monitoring is a method of observing and recording the effluent that has been discharged in term of time, where the determination of the maximum loading can be done by the discharged effluent for both markets. The wastewater samples were collected on 5-hour basis with one hour interval starting from 7.00 a.m. till 12.00 pm. For Selayang market, the opening hours is from 3.00 a.m. till 12.00 pm daily.

The wastewater samples were collected by using 2 L clean plastic sampling bottles and preserved by adding sulphuric acid (H_2SO_4) to reduce the pH to 2 or less. The samples were stored at 4oC or lower and kept no longer than 28 days. Prior conducting any test, we warm the preserved samples to room temperature and neutralized the samples with sodium hydroxide solution (NaOH). Except for BOD test and treatment with EM, H_2SO_4 was not added into the sample as it affect the viability of the samples.

B. Float method

The approximate velocity of flow in a stream and discharge can be determined by the use of floats. The float can be any buoyant object. In this experiment, table tennis ball was being used as the float. A reach of drain, straight and uniform in cross section and with a minimum of surface waves, will be chosen for this method. This experiment should be attempted on windless days to avoid wind-caused deflection of the floats. A length of 2 meter will be measured off along the bank of a straight section of the stream. The distance from the upstream to the downstream site were located far enough apart so the time interval required for the float to travel can be accurately measured. A rope will be string across each end of the 2 meter length. The cross-sectional area of the stream will be measured by using the average stream width and depth. The float will be released at the upstream site. Using a stopwatch, the time it takes to reach the downstream tape will be recorded. The measurement will be repeated to get the average time taken. According to the recorded data, the stream velocity can be calculated by dividing the distance traveled by the average amount of time it took the float to travel the distance. The discharge flowrate for each interval will then calculated in cubic meter per second (m^3/s) by multiplying velocity (m/s) with the cross-sectional area (m^2) of the stream.

C. Pollutant load analysis

After collecting the wastewater samples from the wet market, these samples were tested by using the parameters of pH, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS) and ammoniacal nitrogen (NH3-N).

D. Experimental design

EM was prepared according to the method described. The tests of enhancement of biological activity in wastewater were carried out by adding 100 ml of EM into each 1 liter of wastewater sample. This composite has been prepared by adding all the samples taken at each interval within the sampling period. Then, the solution was allowed to mix thoroughly in a beaker with magnetic stirrer and the measurement for each parameter has been taken at every one hour until four hours. The changes in the concentration for all parameters were recorded and analyzed. The changes in color and texture of the wastewater were also observed after the addition of EM.

3. RESULTS AND DISCUSSION

A. Characterization of Wastewater Discharged from Selayang Wet Market

In this project, temporal monitoring of the effluent discharged from Selayang wet market were collected at 5-hours basis with one hour interval starting from 7.00 a.m. till 12.00 p.m. The flow rates of the stream were varies and depend on the amount of the discharged wastewater at particular time (Figure 1(a)). The highest flow rate was 0.015 m^3/s recorded at 8.00 a.m. with while the lowest was at 10.00 a.m. It can be assumed that the peak hour of the market activities was at 8.00 a.m. as the discharged stream was at the highest flow rate. The flow rate gradually decreased after reaching 8.00 a.m. and increased again at 11.00 a.m. with 0.012 m^3/s due to lunch hour.

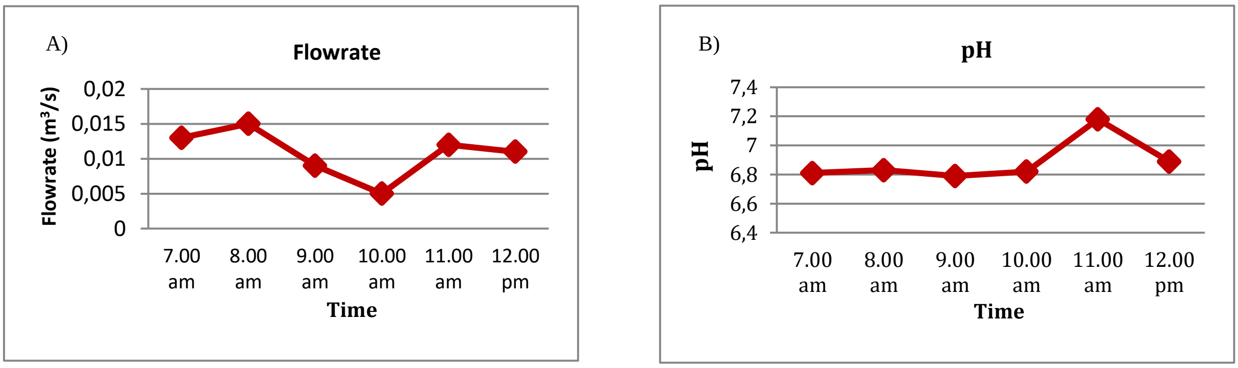

Figure 1. (a) Flowrate and (b) pH profile of Wastewater Discharged from Selayang Wet Market

Table 1. Characterization of Wastewater Discharged from Selayang Wet Market

Time (a.m.)	pH	DO (mg/L)	BOD_5 (mg/mL)	COD (mg/mL)	TSS (mg/mL)	NH_3-N (mg/L)
7.00	6.81	7.38	178	1054	366.7	0.07
8.00	6.83	7.43	159	1332	233.3	0.05
9.00	6.79	7.53	164	1566	933.3	0.14
10.00	6.82	7.48	423	1091	300.0	0.1
11.00	7.18	7.45	291	1238	233.0	0.05
12.00	6.89	7.46	244	1173	266.0	0.07

The flow rate measurement is also used to calculate the loading for each parameter in relation to control the pollutant discharged. The loading can be calculated by multiplying the concentration with the flow rate. This mass loading approach has been adopted in the United States and is termed as Total Maximum Daily Load (TMDL). TMDL takes into consideration the ability of natural cleansing of a water body through bio-chemical processes. TMDL is the maximum quantity of pollutant that can be discharged into a water body without adversely affecting the beneficial uses of the water body or designated water quality standards. The first quality been tested on the wastewater discharged from Selayang wet market was pH level. The hydrogen ion concentration, which expressed as pH, was one of the important parameter analyzed for wastewater because suitable concentration of hydrogen allows the survival and growth of most biological life that exist in the effluent discharged. pH means hydrogen power which represents the effective concentration (activity) of hydrogen ions [H+] in water. It is important that the condition of the water is basic to enhance the activity of EM. From Table 3.1, all the samples were in acidic conditions except for the sample at 11.00 a.m.. It could be influenced by the alkalinity of the soap used for washing the dishes at the restaurants during lunch hour. As in the pH profile, it can be seen that the highest pH is at 11.00 a.m. with 7.18 while others were in the range of below than 7 (Figure 1(b)). After measuring the pH, characterization of the wastewater was continued with biological oxygen demand (BOD) parameter. Biological oxygen demand is a measure of the amount of oxygen used by microorganisms to breakdown the organic matter at certain temperature over a specified period of time. For this test, the time taken was 5 days and was stored at dark location with the temperature of $20^{O}C$. The BOD_5 concentration is determined by comparing the DO level of a water sample between the first and the fifth day. The difference between the two DO levels represents the amount of oxygen required for the decomposition of any organic material in the sample and it is a good approximation of the BOD_5 level. When BOD_5 concentration is high, dissolved oxygen (DO) concentration will decrease because the oxygen that is available in the water is being consumed by the bacteria. Based on Table 3.1, the DO concentrations within the 6 hours period were in the same range about 7.38 to 7.46 mg/L. The highest loading for DO was at 8.00 a.m. with 9.63 kg/day and the average of the loading was 6.97 kg/day.

The bacteria existed in the wastewater is the organism that are not tolerant in a lower dissolved oxygen level so they need oxygen to survive and decompose the organic compound in the wastewater. When untreated wastewater is discharged into the river, the fish and other aquatic animal cannot survive with low dissolved oxygen level and they eventually will die. Higher concentrations of organic waste in the water supply increase bacteria population and activities in the reservoir which in turn increase the demand for oxygen required by the bacteria for metabolism. It was found that in Selayang market, the effluent discharged had highest BOD_5 at 10.00 a.m. with 423 mg/mL with the lowest level of BOD_5 concentration was at 8.00 a.m. with 159 mg/L.

The chemical oxygen demand (COD) concentration of the wastewater was then tested to determine the amount of organic pollutants found in surface water. This useful measure of water quality indicates the mass of oxygen consumed per liter of solution. COD is a parameter to determine the quantity of oxygen required to oxidize the organic matter in water or wastewater sample, under specific conditions of oxidizing agent, temperature and time. The temperature used for COD test is $150^{O}C$ and the heat was applied until 2 hours. Generally, COD test is more preferred compared to BOD test for process control measurements because COD results are more reproducible and are available in just 30 minutes rather than five days.

The total suspended solid (TSS) gives a measure of the turbidity of the wastewater as the solid collected at the filter paper used in the test can be observed directly. The data shown in Table 3.1 show that the highest value for TSS concentration was 933.3 mg/L at 9.00 a.m.. Other concentrations were in lower range between 233.3 mg/L and 366.7 mg/L. Within the 6 hours period, the average TSS loading was 424.79 kg/day with the highest loading of 1209.56 kg/day at 9.00 a.m.. Nitrogen is an essential nutrient required by all plants and animals to be used in the formation of proteins for cell growth. However, abundance and high concentration of nitrogen can cause detrimental impact to the environment such as eutrophication, which is known as the massive algae bloom lead to oxygen depletion in the water. Nitrogen absorption by the animals and plants requires the presence of nitrogen binding bacteria or other microorganisms that able to bind to the surrounding nitrogen for nutritional uptake by the plant. Also bacterias function in the conversion of ammonia to safer and lower molecular weight substances is critical in the creation of synergistic environment that able to purify and promote bio-safety and health as it cannot be used by most aquatic plants in its molecular form. Ammoniacal nitrogen (NH_3-N) in terms of water quality management consists of free ammonia (NH_3) and ammonium ion (NH_4+). Excess NH_3-N concentration above the recommended limits may harm the aquatic life. The concentration of NH_3-N was measured to determine the water quality as it reflects to the toxicity of the water just as both pH and temperature. $_3$-N concentrations shown in Table 1 depicts that the highest concentration was 0.14 mg/L at 9.00 a.m. while the lowest concentration was at 8.00 a.m. with 0.05 mg/L. Based on the National Academic Sciences in National Academy of Engineering Committee (USA), the recommended concentration of NH_3-N should be no more than 0.02 mg/L present in the receiving waters. For the loading, the average was 0.069 kg/day with the highest value at 9.00 a.m. with 0.109 kg/day. The data shown in Table 1 summarizes the worst condition of the wastewater measured for each parameters. For the pH level, the most acidic condition is the most inconvenient for EM activity whereas for the DO measurement, the lower the concentration, the lower the quality of the water. For BOD_5, COD, TSS and NH3-N, the higher the concentration, the worst the water quality. Based on the quality of the water taken at each interval, wastewater discharged at 9.00 a.m. had a poorest quality for almost all the parameters and that was recognized as the peak hour for the activities at the Selayang market.

B. The effect of EM on Discharged Waste Water Quality

- Application of EM has reduced the pH level from basic to neutral condition in four hours by 7.8 % from 8.96 to 8.26 (Table 2). Odor substances in the wastewater are in weak alkaline, usually represented by ammonia and will be neutralized with the organic acids in EM solution. No significant changes were observed in DO measurement while reduction of BOD5 concentration to from 549 mg/L to 182 mg/L of 66.8 % was observed after 4 hours. Significant reduction of COD and TSS concentration from 1328 mg/L to 1074 mg/L, of 19.1% and from 466.67 mg/L to 200.00 mg/L, respectively after three hours of treatment with EM. For NH3-N, reduction of 85.7 % from 0.07 mg/L to 0.01 mg/L was recorded. The reduction of NH3-N concentration was attributed to the use of EM to synergistically working with other organisms to disintegrate and utilize these nutrients for metabolism. Table 3.2 below summarizes the water quality characteristics of the wastewater discharged from Selayang wet market after the treatment with EM for four hours.

Table 2. The effects of Pretreatment with EM on the pH, DO, BOD5, COD, TSS and NH_3-N Parameters of Water Qualities

Time (hour)	pH	DO (mg/mL)	BOD_5 (mg/mL)	COD (mg/mL)	TSS (mg/mL)	NH_3-N (mg/L)
0	8.96	7.74	549	1328	466.67	0.07
1	8.69	7.62	332	1262	433.33	0.04
2	8.56	7.61	273	1163	233.33	0.02
3	8.4	7.54	242	1153	200.00	0.01
4	8.26	7.71	182	1074	200.00	0.01

4. CONCLUSION

The construction of the wastewater treatment plants at wet markets in Selangor is part of Kuala Lumpur City Hall's scope under the River of Life (ROL) project. This project which is started from 2014 aims to transform and preserve rivers in the city into vibrant and liveable recreational waterfronts with high economic value. The Kuala Lumpur City Hall has spent RM 12.7 million to build waste treatment plants in five wet markets in the city which one of them is at Selayang wet market while the allocated cost for the maintenance for each of the plant is RM 25,000. Before there is treatment plant at Selayang wet market, the wastewater discharged gave a detrimental impact to Sungai Batu. Introduction of EM before the wastewater will protect the membrane in the treatment plant from the severe fouling and burden to the membrane. The membrane and filtration performance will decrease with increasing operation time due to deposition of soluble and particulate materials passing through the membrane. Therefore, the use of EM for pretreatment of waste water management will not only reduce the cost of operation, but help to lengthen the life-time usage of membrane and filter in the system.

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