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MANAGING GREY-WATER POLLUTION FROM COMMERCIAL AND RESIDENTIAL CATCHMENTS

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Abstract

Stream-water quality is degraded due to pollutants from point and nonpoint sources. Recent concerns over long-term river water quality objectives have led to a growing awareness to investigate discharges from all pollution sources. Grey-water is one of the important point pollution sources, which come from residential and commercial areas into the rivers without prior treatment. Discharge of untreated sullage adds oxygen demanding substances, nutrients and toxic elements into the water which in turn converts the streams to become unsuitable for aquatic flora and fauna. Though grey-water is generally less polluted than domestic or industrial wastewater, it may still contain high levels of pathogenic microorganisms, suspended solids and substances such as oil, fat, soaps, detergents, and other household chemicals. The amount of pollution loading of grey-water depends on the culture and the everyday life of the people of the certain area. This study determined the pollution characteristics of grey-water from residential and commercial areas of Penchala River which is about 14 km long to evaluate its probable consequences on the water quality of the stream. The data sets of 5 water quality monitoring stations in the study area which comprised of 15 water quality parameters monitored daily over 2 weeks were used for this study. Statistical analyses were done to show the temporal variation of the parameters in each station. It is observed that BOD, COD, E.coli concentrations are high at sites 1 to 4 clearly indicating pollution in commercial and residential areas. Generally, the urban streams do not have enough assimilative capacity to absorb the pollution loads released from various point sources. This study also explored the potential of using aquatic plant as phytoremediation for a sustainable way to mitigate pollution from greywater. Three aquatic plant [duckweed (Lemnoideae), water lettuce (Pistia stratiotes) and water hyacinth (Eichhornia crassipes)] and three location (station 1: residential area, station 2: restaurants area and station 3: industrial area) of greywater were utilized to evaluate the phytoremediation of greywater. The experiments were run for 30 days under laboratory condition and results were taken every 5-day. Duckweed exhibited hyperactive accumulation for nitrogen at station 2 and 3 (66.84% and 57.21% of total reductions, respectively), while water hyacinth station 1 (55.4% of total reductions). Water lettuce exhibited a higher total phosphorus removal efficiency for station 1 and station 3 (100% and 98.77% of reduction, respectively), while the concentration of total phosphorus for station 2 did not have reduction.

Keywords: Grey-water; temporal variation; pollution; phytoremediation; aquatic plant

1 INTRODUCTION

Water is important due to its many roles in life. It is required for various purposes, such as for daily consumption, agricultural, industries, and fisheries. Nowadays it is becoming inaccessible due to increasing water pollution as a consequence of accelerated industrial and urban growth. Hence, an appropriate system is required to save and prevent water degradation. Most countries are concerned about river water quality hence the awareness to investigate outflows from all pollution sources has been increased (Pejman et al., 2009)

Stream-water quality is degraded due to pollutants from point and nonpoint sources. Recent concerns over long-term river water quality objectives have led to a growing awareness to investigate discharges from all pollution sources. Grey-water is one of the important point pollution sources, which come from residential and commercial areas into the rivers without prior treatment. Grey-water is considered to be the major volume of domestic wastewater (60 to 75 percent of whole domestic wastewater) (Elmitwalli, 2007). Therefor it is vital to control the discharge of grey-water into the river.

There are few published studies of the characteristics of sullage in developing countries. Research in the United States of America has shown that nitrate in grey-water is not as much as nitrate in wastewater, but there are more soluble and more biodegradable organic content compare to toilet wastes. The suspended solids load in grey-water is lower than in wastes from toilets, but it contains more grease and is generally at a higher temperature. Higher suspended solids content, higher biochemical oxygen demand and a higher nitrate concentration found in kitchen wastes compare to other types of grey-water outflow. Although the quantity and quality of grey-water vary from source to source, the pollutant loading could be high and should not be allowed to enter into the river system without any treatment (Eriksson et al., 2002; Ismail et al., 2015). Furthermore the amount of pollution loading of grey-water depends on the culture and the everyday life of the people of the certain area (Christova-Boal et al., 1996; Zhu et al. 2017). On the other hand reuse of grey-water for some applications is potentially and economically feasible (Fletcher et al. 2007).

Phytoremediation can be defined the efficient use of plant to remove or immobilize in contaminants in a growth matrix (soil, water or sediment) through the biological, chemical and physical activities of the plant. Phytoremediation is a sustainable way to mitigate pollution from environment. The research on the capacity of marsh plants in the reduction of organic pollutants and nutrients in aquatic systems started in the 1950's in Germany. Plants are known to differ on their mechanism of uptake of various pollutants from the environment (Pilon-Smits 2005; Ernst 2006). The phytoremediator plant should be selected from species that could adapt, tolerant, and grow well in media with high concentration of pollutants. The plants grow in the wastewater by absorbing nutrients at faster rate turning these weeds to a desirable productive use.

Lack of clean water in streams has conducted to a serious danger for human health in recent decades furthermore it is increasing the need to better understand the temporal and spatial variabilities of pollutants within aquatic systems and find a way to control them. Untreated grey-water discharged to streams increases the toxic elements, oxygen demanding substances and nutrients into the water which in turn make the streams an inconvenient place for aquatic life. A regular monitoring of river water quality prevents eruption of diseases, checks water from further failure, and provides a scope to assess the current investments for pollution prevention and control (BU et al. (2010). It is important to know the peaks of the grey-water outflow that mostly are in the morning and evening (Dixon et al., 1999).

In this study, temporal variations of grey-water from residential and commercial areas are monitored and the characteristics of grey-water quality are identified. The variations and characteristics provide insight on source assessments and their impacts on water quality. As such, grey-water should also be treated before discharging into the streams as well as other pollution sources. This study also determines the feasibility of using aquatic plant, namely water hyacinth, water lettuce and duckweed to treat greywater.

2 MATERIALS AND METHODS

2.1 Characterization of Greywater study

The study area is River Penchala which is located in the outskirts of Kuala Lumpur. The length of River Penchala is about 15 km, which is 4 km in the Dewan Bandaraya Kuala Lumpur (DBKL) area and the rest is laid in the Petaling District. The estimate catchment area is about 50 square kilometer. The river flows from Bukit Kiara through urban areas, industrial parks and residential areas into two main tributaries. The first tributary flows down through Kuala Lumpur Golf and Country Club, while the second tributary flows through Kiara Park, TTDI. River Penchala is facing much polluted water with Water Quality Index range from III to V. The critical issues of River Penchala, which its catchment area is mostly located at urban area, are managing the solid waste from the urban household, monitoring and controlling the quality of water discharged to its flow. Moreover it becomes further complex by increasing flash flood during heavy rain.

There were five sampling sites along Sungai Penchala which is situated about 3 km from each other. The sampling sites are labeled as S1 (Seksyen 19, Petaling Jaya) which is a high cost, low density residential area; S2 (Seksyen 14, Petaling Jaya) which is a medium cost, high density industrial and commercial area; S3 (also in Seksyen 14, Petaling Jaya) which is a high cost, low density residential area; S4 (Seksyen 51a, Petaling

Jaya) which is a medium cost, high density industrial and commercial area; and S5 (Taman Desaria, Petaling Jaya) which is a high cost, low density mixed use area.

This study involved 8 hourly sampling of grey-water at the outfall over 24 hours for five days for each site. The morning samples were labeled as "M", the afternoon samples were labeled as "A", and the night samples were labeled as "N". Samples collected from the drainage outlet were sent to the laboratory for analyses. Ice was placed inside the auto sampler in order to minimize the degradation of sample properties. Six sullage properties and pollutants from the sampling sites were tested using standard methods and calibrated sensors or probes.

2.2 Phytoremediation study

Phytoremediation is chosen to evaluate impact of inorganic wastes which focus on nutrient up-take of aquatic plant on greywater. Two sampling sites from River Penchala were selected which were Station A (Jalan 19/22, Petaling Jaya) which is a residential area and Station B (Lot 13, Jalan 225, Petaling Jaya) which is an industrial area. The study involved using three types of aquatic plants: duckweed (DW), water lettuce (WL), and water hyacinth (WH).

Glass containers (400mm x 240mm x 255mm) without the top cover were used and each container was filled with 20 liters of greywater from each station. The container was placed on the rack and 400mm from the windows. Four experiments were done for Station A which was using the three plants individually and one with all of them. For station B, only three experiments using the three plants individually were done. The quantity of the plants used depended on the size of plant to cover the surface of water in the containers. Each experiment was studied at 5 days' interval for 30 days in lab condition. Six physicochemical properties of greywater were determined using a various method.

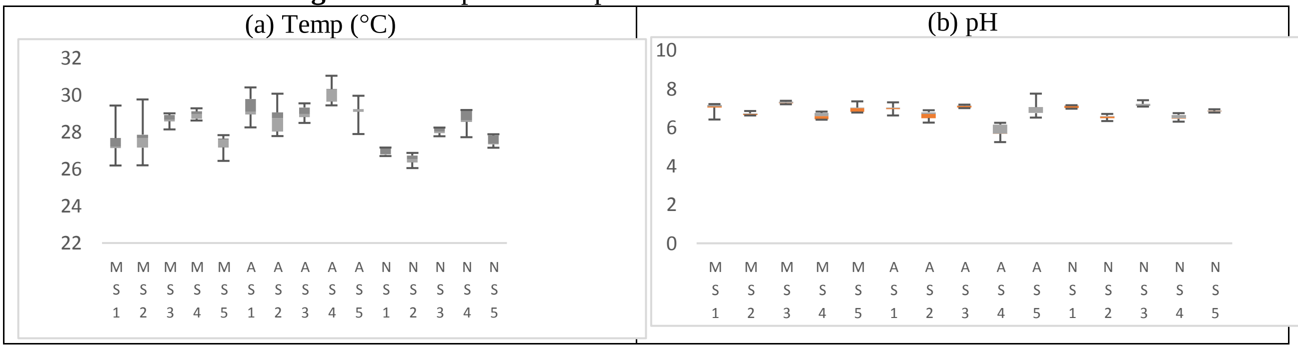
3 RESULTS AND DISCUSSION

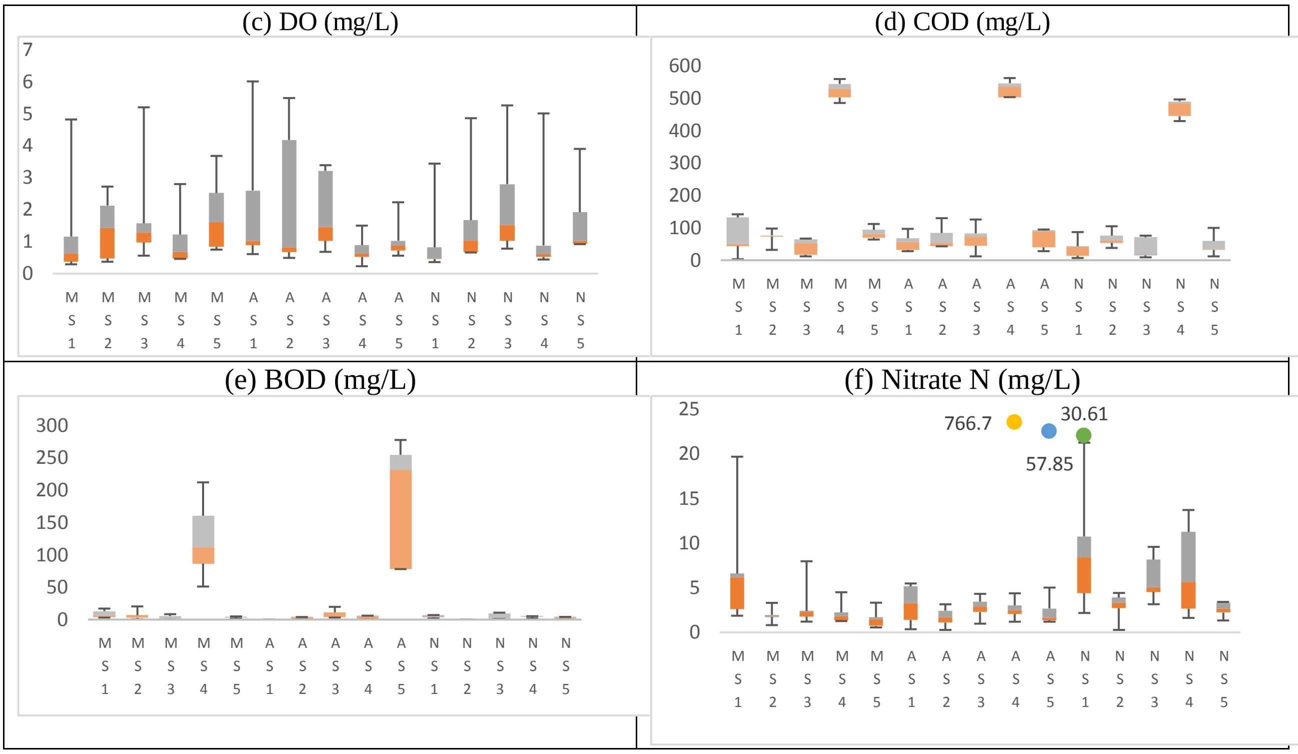
3.1 Temporal and Spatial Characteristics of Greywater

Statistical approach, namely box plots, was used to determine the temporal variations for the six parameters by sampling sites and sampling times. They are shown in Figure 1(a) – (f). They clearly show variation for each parameter during the day and also the sites.

Mean, standard deviation, minimum and maximum of each parameter are shown. The outliers for each distribution also can be shown if present. Grey-water temperatures demonstrated a daily cycle with high values (28.45 to 30.41 C) at noon and low values (26.7 to 29.7 C) in morning and night. Station 4 has the highest value of temperature due to the sullage from commercial area. The pH values of the greywater samples ranged from 5.2 to 7.2, and the values were within the WHO guidelines of 6.5 to 8.5. High DO values were observed and ranged from 0.9 to 6.3 mg/l, while BOD and COD ranged from 4 to 20 and 3 to 126 mg/l, respectively. There is a high value of BOD in station 5 (254) and of COD in station 4 which are outliers. In relation to spatial distribution the maximum values of BOD and COD were found at station 4 while the maximum value of Nitrate was in station 3. The concentration of greywater was high in stations 2 and 4 due to commercial area and lower in stations 1 and 3 because of a new sanitation system. Station 5 also has some problems with its greywater due to its being a mix use area.

Figure 1: Temporal and Spatial Variations of Penchala River





3.2 Effect of Phytoremediation Experiments

The results presented in this section are to show the potential of phytoremediation of aquatic plant in treating the greywater.

Figure 2 (a) – (f) presents the results from experiments using greywater collected from Station A, which is a residential area. For Station A, duckweed experiment showed the lowest minimum of water temperature compared to water lettuce and water hyacinth. The range of water temperature for duckweed is between 26.56 to 30.28 ℃. While the range for water lettuce and water hyacinth is 27.30 to 30.28 ℃ and 27.94 to 30.51 ℃, respectively. pH fluctuated between a low of 7.5 and peak at 7.93, before ending at 7.51 for duckweed experiment. On the other hand, water lettuce experiment showed pH decrease gradually from day 5 to day 15, and then fluctuated from day 20 to day 30. Duckweed showed the dominant value of dissolve oxygen (DO). The higher the DO values the higher quality of water. Dissolve oxygen for duckweed increase dramatically on day 15 to about 8.61mg/L. Water lettuce showed the second highest after duckweed followed by water hyacinth. The largest value for the DO for water lettuce is 7.16mg/L on day 30. The difference on value of DO between duckweed and water lettuce on day 30 was just 0.21mg/L. The peak value of DO for water hyacinth is 6.02mg/L at day 15 and the minimum after phytoremediation process is 2.85mg/L on day 25. All aquatic plants showed the largest value DO on day 15. Combined plants experiment showed slightly higher value than water hyacinth. Chemical oxygen demand (COD) for duckweed experiment fluctuated between a low of 8.32 mg/L in day 15 and reach a peak of 12.16 mg/L in day 20, before ended at 9.6 mg/L in day 30. While value from water lettuce experiment rose gradually from initial of 8.20 mg/L and reach a peak value of 13.44 mg/L in day 10. Then, the value dramatically reduced to 8.32 mg/L in day 20. After that it increase a bit to 10.24 mg/L. Water hyacinth experiment showed a fluctuated trend, which is a peak of 10.88 mg/L in day 10 and a low of 7.04 mg/L in day 20, before ended with value of 13.44 mg/L in day 30.

The concentration of ammonia nitrogen had a slight increase in water lettuce experiment; but for water hyacinth experiment the concentration jumped to 12.44mg/L on day 5. For duckweed and combined plants experiments, the concentration of ammonia nitrogen decreased for day 5. The concentration reduced in day 10 and went slightly up in day 20. Then the concentration decreased again from day 20 to day 25. After that it increased slightly on day 30.Generally, combined plants showed the faster ammonia nitrogen uptake as compared to other experiments using individual plant. Water hyacinth experiment showed the best consistent of ammonia nitrogen uptake. Duckweed and water hyacinth experiments could do 100% nitrogen uptake at day 25, but water lettuce could do only 92.93% ammonia nitrogen uptake.

Figure 2: Phytoremediation for Station A (Residential Area)

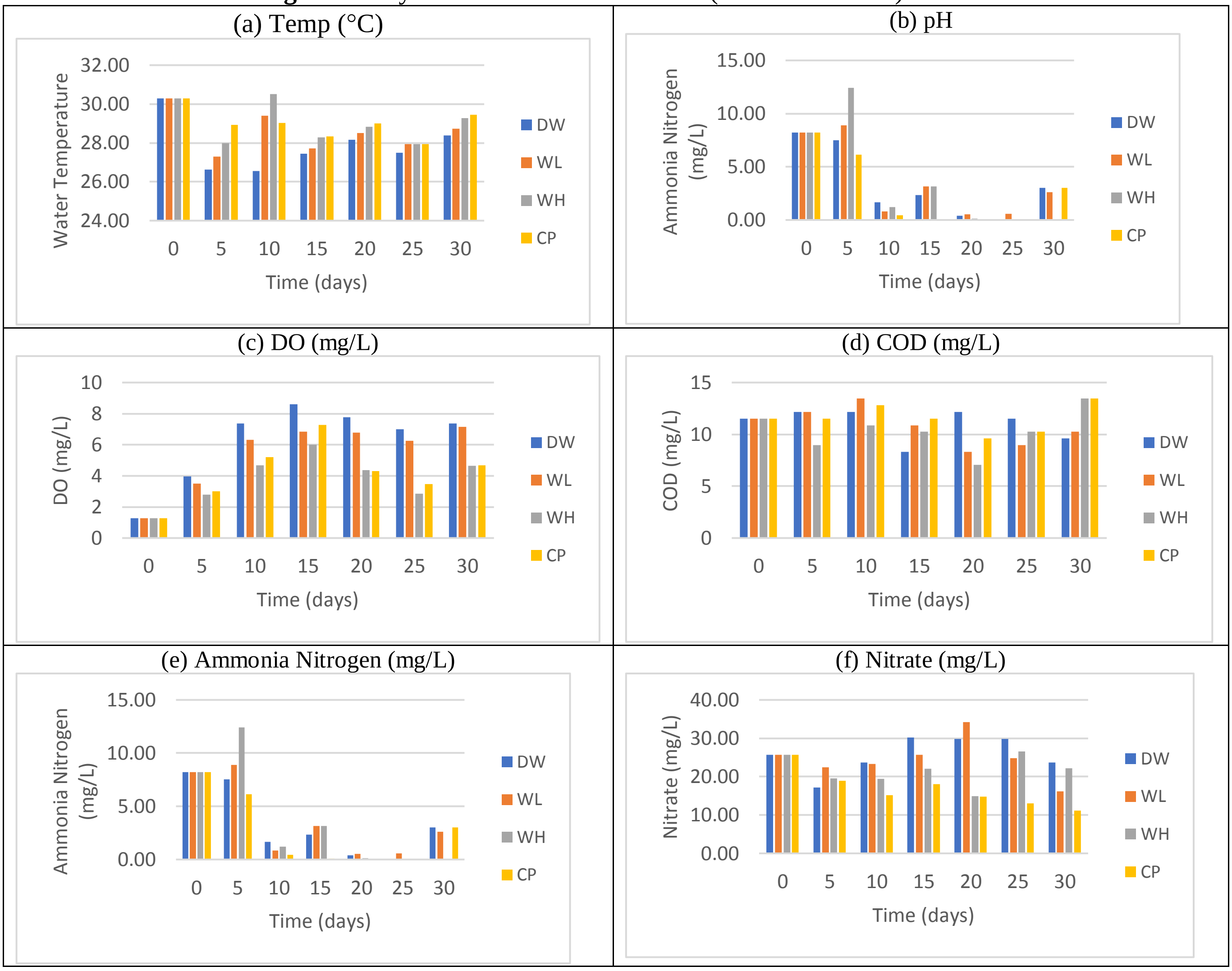
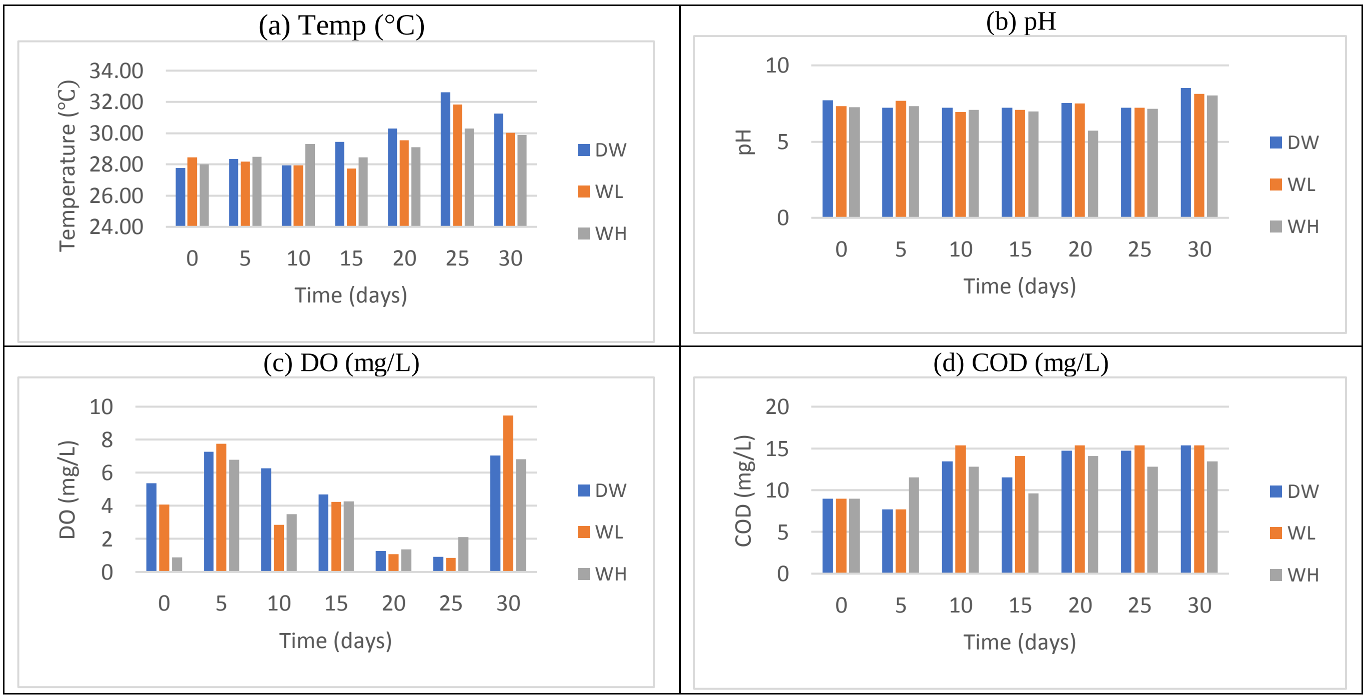
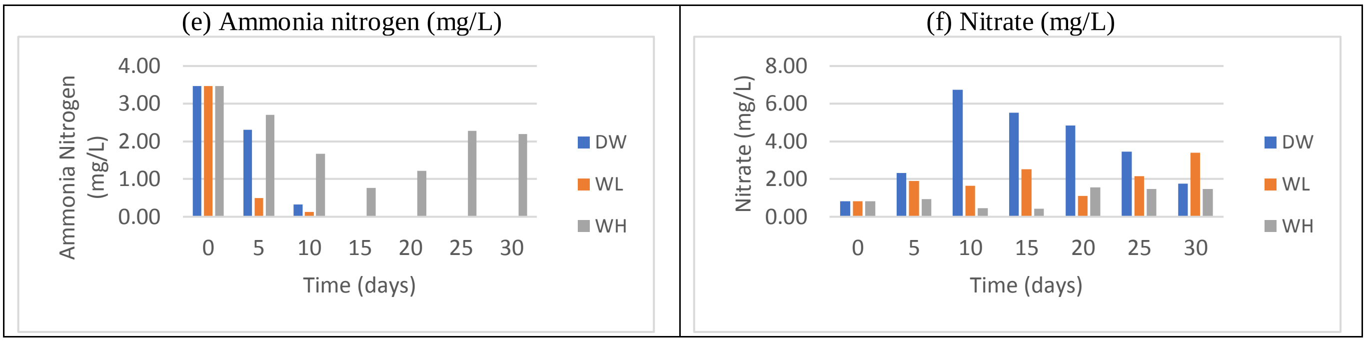


Figure 3: Phytoremediation for Station B (Industrial Area)





Duckweed experiment showed a decrease in nitrate concentration to 17.13 mg/L on day 5, then the concentration increased consistently until day 25, and then it dropped to 23.7mg/L in day 30. Water lettuce experiment also showed a decrease on day 5 and but a slight increase at day 20, and then the concentration of nitrate decreased. Starting at 25.7mg/L, water hyacinth experiment fluctuated from a low value of 14.97mg/L and peak at value 26.57mg/L before ending with 22.2mg/L. Concentration of nitrate decreased gradually for combined plants experiment. Maximum reduction of nitrate is 56.69% by combined plants experiment but for individual plant experiments, the maximum reduction is 41.75% by water hyacinth experiment at day 20.

Figure 3 (a) – (f) exhibits the results from experiments using greywater collected from Station B, which is an industrial area. The water temperature for Station B from the duckweed experiment ranged from 27.78 to 32.61 ℃. The water temperature for water lettuce experiment was in the range of 27.72 to 31.83 ℃ and in water hyacinth experiment was in range of 28.00 to 30.28 mg/L. The range for pH in duckweed experiment was 7.21 to 8.53, while in water lettuce experiment was 6.94 to 8.12. For water hyacinth experiment, pH ranged from 5.73 to 8.03. Then the pH dropped to 5.73 at day 20. For duckweed experiment, DO value started at 5.73 mg/L and reached a peak in day 5 about 7.26 mg/L then it decreased gradually from day 5 to day 15 and fell to 0.92 mg/L in day 25. But in day 30, the DO for duckweed experiment increased to 7.06 mg/L. Starting at 4.08 mg/L, the DO value for water lettuce experiment fluctuated between a high of 7.77 mg/L in day 5 to a low value of 0.85 mg/L in day 25 before it ended to 9.46 mg/L in day 30. Water hyacinth experiment showed fluctuation values of DO between 6.79 mg/L in day 5 to a low value of 1.36 in day 20 and finally in day 30, a peak value of 6.82 mg/L. Water lettuce experiment showed the largest dissolved oxygen value follow by duckweed experiment and then, water hyacinth experiment. Duckweed and water lettuce experiments showed a decreasing value in COD concentration in day 5, while water hyacinth experiment showed a slight increment in day 5. In day 10, water hyacinth experiment reached a peak about 12.8 mg/L but drop to 9.6 mg/L in day 15, and then the concentration of COD fluctuated slightly from day 20 to day 30 with value between 12.8 to 14.08 mg/L. There was a big jump of COD value in duckweed experiment on day 10 to 13.44 mg/L then it dropped to 11.52 mg/L, and then it showed values in the range of 14.72 mg/L to 15.56 mg/L.

In the duckweed experiment, the concentration of ammonia nitrogen reduced moderately. It showed a reduction from 3.47 mg/L to 2.31 mg/L and then reduced again to 0.33 mg/L. The water lettuce experiment showed the same trend, but it also showed higher ammonia nitrogen uptake compared to duckweed. The concentration of ammonia nitrogen reduced from 3.47 mg/L to 0.50 mg/L and further reduced to 0.13 mg/L. The concentration became 0.00 mg/L from day 15 to day 30 for duckweed and water lettuce experiments. For water hyacinth experiment, the concentration of ammonia nitrogen started from 3.47 mg/L and ended with 2.20 mg/L, although it reached a low value of 0.07 mg/L in day 15. Maximum reduction of uptake for water hyacinth experiment was 77.81% while duckweed experiment and water lettuce experiment were 100% reduction. The concentration of nitrate rose dramatically from initial day to day 10, reaching a peak to about 6.73 mg/L in the duckweed experiment. Then the concentration of nitrate declined gradually from day 10 to day 30. Starting with 0.83 mg/L, the concentration of nitrate fluctuated between a low of 1.10 mg/L and peak at 2.53 mg/L, before ending with 3.40 mg/L in the water lettuce experiment. In the water hyacinth experiment, the concentration of nitrate reduced gradually from day 5 to day 15, then stayed the same from day 20 to day 30. Only water hyacinth showed the reduction on nitrate uptake which was about 48.19% while duckweed and water lettuce experiments did not show reduction.

4 CONCLUSION

The sullage pollution in Penchala River is escalating over the years due to vast development of the area. In addition, some section still used old sanitation system and also lack of monitoring on the effluents discharge from commercial area into the drainage. From this study, it is observed that BOD and COD concentrations were high at station 1 to station 4 clearly indicating pollution in commercial and residential areas. Maximum values of BOD and COD were observed in the station 4 because of commercial area and restaurants. High values of nitrate were observed in station 1 and this was due to the detergent use. Thus, it can be concluded that the sullage of this area represents serious threat to the ecosystem due to anthropogenic pollution. In some parts of the river basin new sanitation system has been installed but people still discharge their grey-water into the drainage.

In relation to spatial distribution, the maximum values of BOD and COD were found at station 4 while the maximum value of nitrate belongs to station 1. Concentration of grey water is high in stations 2 and 4 because of commercial area and lower in stations 1 and 3 because of the new sanitation system.

In the phytoremediation study, the plants showed abilities to some extend in reducing physicochemical parameters. However, phytoremediation has a number of inherent technical limitations. The contaminant must be within the root zones of plants that are actively growing which imply water, depth, nutrient, atmospheric, physical, and chemical limitations should be all in agreement. In addition, the site must be large enough to make farming techniques appropriate. It must not present an eminent danger to human health or further environmental harm. The research community from multidisciplinary area should work together to produce a needed technology that is low cost, low impact, visually benign, and environmentally sound. Plant biologists should provide information of basic plant processes for genetic modification and breeding.

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