Iranica Journal of Energy & Environment 3 (2): 129-133, 2012
ISSN 2079-2115
IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology
DOI: 10.5829/idosi.ijee.2012.03.02.0295

BUT

Domestic Wastewater Quality and Pollutant Loadings from Urban Housing Areas

[1]T.Y Ling, [1]M.J. Dana, [1]S. Bostam and [2]L. Nyanti

[1]Department of Chemistry, Faculty of Resource Science and Technology,
Universiti Malaysia Sarawak, Malaysia
[2]Department of Aquatic Science, Faculty of Resource Science and Technology,
Universiti Malaysia Sarawak, Malaysia

(Received: January 31, 2012; Accepted: February 29, 2012)

Abstract: Wetlands are important spawning and nursery ground for fish and prawns. However, wetlands have been reported to be polluted in different parts of the world. One of the pollution sources is domestic wastewater. Therefore, in this study, domestic wastewater quality was studied at three major housing areas. Samplings were conducted in three trips. Results showed that pH ranged from 6.64 to 7.31 and temperature ranged from 23.5 to 31.7 °C. DO values were low, that is, below 3.5 mg/L for all trips at all areas studied indicating that it was not suitable for aquatic life. Nutrients such as ammoniacal nitrogen and soluble reactive phosphorus of the housing areas ranged from 11.1 to 17.2 mg/L and 1.05 to 2.43 mg/L respectively. Biochemical oxygen demand and total suspended solids concentrations at all the housing areas exceeded the Standard B maximum permitted values of Effluent Discharge Standard of Environmental Quality Act 1974. Loadings of pollutants from housing areas in Kuching were computed. This study shows that domestic wastewater was low in DO, high in oxygen demand, high in solids and nutrients thus loading the rivers with pollutants. Therefore, domestic wastewater must be treated before being channeled to the adjacent water bodies to avoid eutrophication in the receiving water and to recover nutrients.

Key words: Household wastewater; Water quality; Pollutant loading; Nutrients

INTRODUCTION

Wetlands are important spawning and nursery ground for many species of fish and prawns. However, pollution of wetland has been report in different parts of the world such as China, Bangladesh and India [1- 3]. One of the pollutant sources was reported to be domestic other than industrial and agricultural activities [1]. Discharge of domestic waste among others into coastal waters has led to increasing impairment of coastal waters and that has affected the aquaculture profitability [4]. In Kuching Division of Sarawak, Kuching City population is increasing mostly due to rural urban migration in response to job and educational opportunities. Nearby the city is situated wetlands such as the Kuching Wetlands National Park, one of the six Ramsar sites in Malaysia and they are important spawning and nursery ground for aquatic organisms such as fish and prawns [5]. High nutrients such as phosphorus and nitrogen could lead to eutrophication which depletes the aquatic organisms of oxygen required for healthy growth and survival. High organic matter will result in high oxygen consumption by bacteria in the process of oxidation thus competing with the aquatic organism for oxygen. As such, the protection of the water quality of the rivers and the coastal zone near Kuching City is important for the health of the aquatic ecosystem.

However, water quality studies of the Santubong River, a river near Kuching City in Kuching Division, Sarawak, show that total suspended solids and biochemical oxygen demand were elevated near residential and construction sites [6]. In addition, in the Semariang Batu River sediment oxygen demand, total Kjeldahl nitrogen and total phosphorus in the sediment were high

Corresponding Author: Teck-Yee Ling, Department of Chemistry Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Malaysia. E-mail: tyling@frst.unimas.my.

near human settlement [7]. This degradation of water and sediment quality is due to effluent from household septic tanks and waste from the kitchen and bathrooms. In urban areas in Sarawak such as Kuching City, there is no central sewage treatment system and a septic tank is installed for each housing unit for the treatment of black water. Outflow of septic tanks and wastewater from other household appliances were discharged into the storm drains which eventually flow to the river [8]. Household wastewater was reported to be high in biochemical oxygen demand and *E. coli* [9, 10]. However, solids and ammoniacal nitrogen were not studied. Therefore, the objective of this study was to determine the quality of domestic wastewater in three major urban housing areas in Kuching.

MATERIALS AND METHODS

Grab samples of wastewater were collected from three housing areas, RPR at Batu Kawa (RPR) and Satria Jaya (TSJ) of Stutong Road and Taman Malihah (MLH) between 9:00 am and 1:15 pm in December 2007 and February and March of 2008 during dry days. RPR and MLH are low cost housing area of about 25 and 17 years old respectively whereas TSJ is a middle income area of detached, semi-detached and terrace houses developed in two phases, 68% were 13 years old and the rest were 5 years old. The samples were collected from the storm drains and placed in 2-L polyethylene bottles and stored in an icebox for transportation to the laboratory for analysis. *In situ* parameters such as pH, temperature and dissolved oxygen were measured. pH and temperature were measured using a portable pH meter (Eutech Cyber Scan pH10). Dissolved oxygen (DO) was measured using a portable DO meter (Eutech Cyber Scan 100).

Water samples were analyzed for total suspended solids (TSS), 5-day biochemical oxygen demand (BOD_5), ammoniacal nitrogen (TAN), nitrate nitrogen (nitrate-N) and soluble reactive phosphorus (SRP). TSS and BOD_5 were analyzed according to standard methods [11]. For BOD_5, water samples were diluted and initial DO readings were measured before incubation. Final DO readings were measured after 5 days incubation at 20°C. Water samples were filtered using Whatman GF/C glass fiber filters prior to analyses of TAN, nitrate-N and SRP. TAN analysis followed that of Nessler's method after preliminary distillation using Kjeltec 2200 Auto Distillation Unit (FOSS Tecator) [12]. Concentration of TAN was determined using a spectrophotometer [12]. Nitrate-N was analyzed using cadmium reduction method [12]. For SRP, the sample was filtered immediately and analysis followed that of ascorbic acid method and the concentration was determined using a DR 2010 spectrophotometer [12]. All samples were analyzed in triplicate. For statistical analysis, two-way ANOVA was used to compare results of the three housing areas and the three sampling trips. All statistical analyses were conducted using PASW 18.0 software. Loading of pollutants were computed according to Ling *et al*. [9].

RESULTS AND DISCUSSION

Table 1 shows the temperature, pH, BOD_5 and Nitrate-N concentrations of the wastewater from the two housing areas. Temperature ranged from 23.5 in TSJ to 31.7 °C in MLH. Mean temperature among trips were significantly different with third trip recording the highest temperature ($P \leq 0.007$). The mean temperature for the MLH was significantly higher than RPR and TSJ ($P \leq 0.0005$) most likely due to the exposure of the water in the drain to solar radiation. Mean pH values of RPR wastewater showed that the water was acidic in all trips and the values lower than that of TSJ and MLH ($P \leq 0.0005$). pH values were also significantly different among the three trips ($P \leq 0.014$). Both pH and temperature of the wastewater discharged did not violate the Standard B (5.5-9.0 and 40 °C respectively) of Effluent Discharge Standard of Environmental Quality Act 1974.

Mean BOD_5 ranged from 127 mg/L at RPR to 189 mg/L at MLH (Table 1). There was no significant difference between the trips (P=0.179) and among the three areas (P=0.488). The high BOD_5 indicates the presence of high organic matter in the wastewater which originates from kitchen sink as well as partially treated septic tank. According to Huang *et al*. [13], in domestic wastewater, fibers, proteins and sugars accounted for 20.64%, 12.38% and 10.65% of total organic carbon, respectively. BOD_5 in all areas in all trips exceeded the Standard B maximum permitted value (50 mg/L) of Effluent Discharge Standard of Environmental Quality Act 1974. All the values obtained in the present study were in the range of 110 - 400 mg/L for untreated household wastewater [14].

Nitrate-N concentrations were low and they ranged from 0.01 mg/L in TSJ to 0.12 mg/L in RPR (Table 1). The low concentrations of nitrate-N in the three areas observed in the present study were due to the low dissolved oxygen in septic tank as nitrate is the end product of nitrification which requires oxygen.

Table 1: Temperature, pH, BOD_5, nitrate-nitrogen concentrations of wastewater of the three housing areas during the sampling trips

Variables	Location	Trip 1	Trip 2	Trip 3	Mean
Temperature (^oC)	RPR	24.37 ± 0.06	27.20 ± 0.17	27.67 ± 0.32	26.41 ± 1.79a
	TSJ	23.50 ± 0.00	28.07 ± 0.15	28.17 ± 0.06	26.58 ± 2.67a
	MLH	27.27 ± 0.31	28.13 ± 0.46	31.73 ± 0.25	29.04 ± 2.37b
	Mean	25.05 ± 1.97a	27.80 ± 0.52b	29.19 ± 2.21c	27.34 ± 1.47
pH	RPR	6.93 ± 0.02	6.8 ± 0.08	6.64 ± 0.02	6.79 ± 0.15a
	TSJ	7.28 ± 0.02	7.21 ± 0.01	6.74 ± 0.00	7.08 ± 0.29b
	MLH	7.31 ± 0.03	7.08 ± 0.06	6.97 ± 0.17	7.12 ± 0.17b
	Mean	7.17 ± 0.21a	7.03 ± 0.21b	6.78 ± 0.17c	7.00 ± 0.18
BOD_5 (mg/L)	RPR	126.8 ± 10.7	157.9 ± 1.4	180.1 ± 2.5	154.9 ± 26.8a
	TSJ	136.9 ± 3.5	179.5 ± 4.3	186.3 ± 5.0	167.6 ± 26.8a
	MLH	188.9 ± 8.0	148.5 ± 3.5	145.5 ± 1.4	161.0 ± 24.2a
	Mean	150.9 ± 33.3a	162.0 ± 15.9a	170.6 ± 22a	161.2 ± 6.4
Nitrate-N (mg/L)	RPR	0.12 ± 0.00	0.04 ± 0.01	0.02 ± 0.01	0.06 ± 0.05a
	TSJ	0.05 ± 0.01	0.01 ± 0.01	0.03 ± 0.00	0.03 ± 0.02ab
	MLH	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01b
	Mean	0.06 ± 0.05a	0.03 ± 0.02b	0.03 ± 0.01b	0.04 ± 0.02

For the each variable, means in the same row or column with the same letters are not significantly different at 5% level.

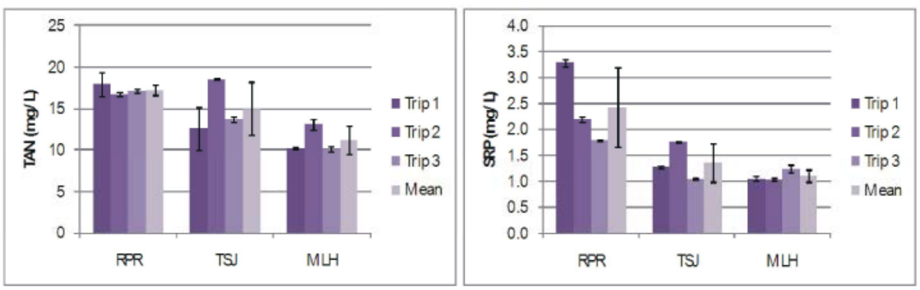

Fig. 1: a) Total suspended solids (TSS) and b) dissolved oxygen (DO) concentrations of the wastewater at the three housing areas during the sampling trips.

Wastewater at the three housing areas showed high TSS concentrations (170 - 292 mg/L) and the mean concentrations at the housing areas were in increasing order of TSJ<RPR<MLH as shown in Fig. 1(a). Pair-wise comparisons indicated that the mean TSS concentration at all areas were significantly different (P=0.036). Solids from households originate mostly from the kitchen sink other than laundry, bath water and septic tank outflow. From the kitchen, food particles are flushed out of the house into the storm drain. In laundry wastewater, solids may originate from soiled baby wears. According to Metcalf and Eddy [15], in a wastewater of medium strength, about 75% of the suspended solids are organic in nature and these are derived from plant and animal kingdom including protein (40 - 60%), carbohydrates (25 - 60%) and fats and oil (10%). For organic materials, Huang *et al*. [13], reported that fibers are the largest group in the domestic wastewater. TSS in all areas in all trips exceeded the Standard B maximum permitted value of 100 mg/L of the Effluent Discharge Standard of Environmental Quality Act 1974.

TSJ recorded the highest for all trips and the mean was significantly higher than other areas (P=0.0005). However, all the DO values were low, below 3 mg/L except Trip 2 at TSJ (Fig. 1 (b)). The low DO values in domestic wastewater were due to the consumption of oxygen by microorganisms to break down the high organic matter in the wastewater as reflected by the high BOD_5 values in this study (Table 1). All DO values observed were lower than the minimum required (5 mg/L) for healthy growth of warm water fish [16]. Compared with the values in Ling *et al*. [9], the range of DO in the present study was in the range reported.

TAN of wastewater from the three areas ranged from 11.1 mg/L at MLH to 17.2 mg/L at RPR as shown in Fig. 2(a). In all the trips, RPR showed consistently high values and the mean of the three trips was significantly higher than the other two areas. All the areas showed significantly different TAN (P=0.022). The mean TAN of wastewater from RPR was significantly higher than TSJ (P=0.004) and there was no significant difference between the trips (P=0.527).

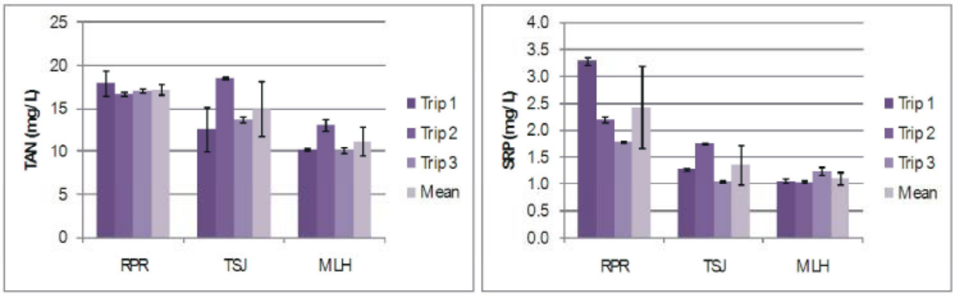

Fig. 2: a) Ammoniacal nitrogen (TAN) and b) soluble reactive phosphorus (SRP) concentrations of wastewater at the three housing areas during the sampling trips.

Table 2: Daily loadings of different pollutants into rivers around Kuching city

Variables	Mean concentrations (mg/L)	Load* (kg/d) Mean	Min.	Max.
TSS	231.0	15,551	21,945	28,182
DO	2.05	138	195	250
TAN	14.4	969	1,368	1,757
Nitrate-N	0.04	3	4	5
SRP	1.63	110	155	199
BOD_5	161.2	10,850	15,310	19,662

* Based on mean, minimum and maximum flow (111, 95, 122 L/c/d respectively) [9].

According to Metcalf and Eddy [15], urea and protein are the main source of nitrogen in wastewater. In the treatment of black water using septic tank, in anaerobic condition, organic nitrogen is converted to TAN [15] and due to low oxygen present, minimal amount of it is converted to nitrate, thus explaining the high TAN observed. The concentrations were much higher than the safe limit of 1.0 mg/L for long term exposure of fish [16].

SRP concentrations ranged from 1.1 mg/L in MLH to 2.4 mg/L in RPR. RPR recorded the highest concentrations of SRP in all trips as shown in Fig. 2(b) and it was significantly higher than TSJ and MLH (P=0.0005). However, the concentrations at TSJ and MLH were not significantly different (P=0.373). SRP concentrations in different housing areas in the present study were lower than that commonly found in untreated domestic wastewater of 3-10 mg/L [15]. The main sources of phosphorus were the septic tank effluent and laundry detergent. Phosphorus is an important element in plants and animals and therefore is a constituent of organic matter in wastewater. Septic tank is not designed for the removal of nutrients such as nitrogen and phosphorus, though some nitrogen may be lost in the form of ammonia gas or nitrogen gas [15]. Therefore, phosphorus and nitrogen will be removed through the outflow or sludge removal in the septic tank. The potential danger of SRP when discharged into surface water is the phytoplankton blooms as it is readily available in soluble form and most surface water is phosphorus limited though estuaries are nitrogen limited [17].

Based on the population of Kuching which was reported to be 606,500 [18] and the mean flow of 111 L/c/d, minimum flow of 95 L/c/d and maximum flow of 122 L/c/d from different residential areas studied previously [9], pollutant loadings from Kuching City were computed and shown in Table 2.

From this estimation, 67,322 cubic meters of wastewater of low DO (2.05 mg/L), high oxygen demand, high solids content and high nutrients were being discharged into the river daily from residential areas in the city with mean loads of 15,551 kg TSS, 972 kg of inorganic nitrogen, 110 kg of SRP and 10,850 kg of oxygen demand. This potentially results in the enrichment of surface water which can lead to phytoplankton blooms, causing eutrophication and creating hypoxia which threatens aquatic life in the surface water nearby the city. Therefore, both nitrogen and phosphorus have to be controlled for coastal ecosystem health [17]. Residential pollutant reduction requires education of the public on the reduction of water usage and wastewater treatment before discharging to rivers.

CONCLUSION

This study shows that domestic wastewater in three housing areas studied was low in dissolved oxygen, high in suspended solids, biochemical oxygen demand, inorganic nitrogen and soluble reactive phosphorus. There were significant variations in the water quality among trips. To safe guard the wetland ecosystem, domestic wastewater needs to be treated before being channeled to rivers. Such treatment should also include recovery of nutrients such as nitrogen and phosphorus.

ACKNOWLEDGEMENTS

The authors appreciate the support provided by Universiti Malaysia Sarawak, Malaysian Ministry of Science, Technology and Innovation (e-sci Grant No. 06-01-09-SF0026) and Ministry of Higher Education (Grant No. FRGS/07(02)/749/2010(35)).

REFERENCES

1. Yang, H.J., Z.M. Shen, J.P. Zhang and W.H. Wang, 2007. Water quality characteristics along the course of the Huangpu River (China). Journal of Environmental Sciences, 19: 1193-1198.
2. Chowdhury, N.S., 2006. Industrial Pollution and its Threat to Wetlands in Bangladesh: Example of Mokesh Beel Wetland in Kaliakoir. MACH (Management of Aquatic Ecosystems through Community Husbandry) Policy Brief 8, USAID. 4.
3. Mohanraj, R., M. Sathishkumar, P.A. Azeez and R. Sivakumar, 2000. Pollution status of wetlands in urban Coimbatore, Tamilnadu, Indian Bulletin of Environmental Contamination and Toxicology, 64(5): 638-643.
4. Paez-Osuna, F., S.R. Guerrero-Galvan and A.C. Ruiz-Fernandez, 1998. The environmental impact of shrimp aquaculture and the coastal pollution in Mexico, Marine Pollution Bulletin, 36(1): 65-75.
5. Nyanti, L., Nur'Asikin R., T.Y. Ling and G. Jongkar. Status and threats to fish diversity and water quality of the Semariang Mangrove Area, Sarawak, Malaysia, Sains Malaysia, (In press).
6. Ling, T.Y., M.C. Miod, L. Nyanti, I. Norhadi and J.J.J. Emang, 2010a. Impacts of aquaculture and domestic wastewater on the water quality of Santubong River, Malaysia, Journal of Environmental Science and Engineering, 4(4): 11-16.
7. Ling, T.Y., C.S. Ng, L. Nyanti and D. Buda, 2009a. Oxygen demand of the sediment from the Semariang Batu River, Malaysia, World Applied Science Journal, 7(4): 440-447.
8. Bradley, M. and G.R. Dhanagunan, 2004. Sewage sludge management in Malaysia, International Journal of Water, 2(4): 267-283.
9. Ling, T.Y., T.F. Siew and L. Nyanti, 2010b. Quantifying pollutants from household wastewater in Kuching, Malaysia, World Applied Science Journal, 8(4): 449-456.
10. Ling, T.Y., K. Apun and S.R. Zainuddin, 2009b. Performance of a pilot-scale biofilters and constructed wetland with ornamental plants in grey water treatment, World Applied Science Journal, 6(11): 1555-1562.
11. APHA, 1998. Standard Methods for Examination of Water and Wastewater. 20th Ed. Washington D.C., American Public Health Association.
12. Hach, 2000. Manual for Hach Spectrophotometer DR2010. Hach Company, USA.
13. Huang, M., Y. Li and G. Gu, 2010. Chemical composition of organic matters in domestic wastewater, Desalination, 262(1-3): 36-42.
14. Butler, D., E. Friedler and K. Gatt, 1995. Characterising the quantity and quality of domestic wastewater inflows, Water Science Technology, 31(7): 13-24.
15. Metcalf and Eddy, 1991. Wastewater Engineering: Treatment, Disposal and Reuse, McGraw-Hill, Inc., New York, pp: 641-662.
16. Lawson, T., 1995. Fundamentals of Aquacultural Engineering, Chapman and Hall, New York, 355.
17. Howarth, R.W. and R. Marino, 2006. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over three decades, Limnology and Oceanography, 51(1, part 2): 364-376.
18. DOS, 2008. Population, Household and Living Quarters, Department of Statistics, Malaysia.