DEVELOPMENTAL PRESSURE AND NUTRIENT CONCENTRATIONS OF SUNGAI PETANI CATCHMENT, KEDAH

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ABSTRACT: Developmental pressure is encroaching many small towns and cities in Malaysia. The wave of development has caused small towns like Sungai Petani Town and its surrounding catchment area to be affected by the changing land uses due to developmental pressure in the catchment area. This paper examined the temporal patterns of nutrient concentrations longitudinally along the Sungai Petani River from March 2012 to December 2013 due to the unequal distribution of 'green' areas with respect to the 'grey' areas. Four stations were chosen longitudinally from upper Sungai Petani River downstream towards Sungai Petani Town and were monitored from upstream part of Sungai Petani Town which is the least affected station, through Sungai Petani Town and towards the downstream station below the Sungai Petani Town. Water sampling at all stations were performed through grab sampling technique at depths of about 0.5 m. Water samples were analysed only for dissolved forms of nitrate (NO_3), ammoniacal nitrogen (NH_4), total nitrogen (TN), phosphate ($P0_4$) and total phosphorus (TP).The samples were analysed using standard procedure by Adams (1989) and APHA (1998). Most of the nutrient concentrations increased from upper station to the second station situated in the Sungai Petani Town. Nitrate increases by 6 per cent and 15 per cent in 2012 and 2013 respectively, ammonia increases by 11 per cent and 35 per cent respectively, TN by 16 per cent and 22 per cent respectively, TP by 45 per cent and 44 per cent respectively, and PO_4 by 13 per cent and 90 per cent respectively. On the other hand, the concentration decreases from second to the last station at the outlet downstream of the town. Nitrate decreases by 16 per cent and 27 per cent in 2012 and 2013 respectively, ammonia increases by 28 per cent and 44 per cent respectively. TN by 34 per cent and 41 per cent respectively, TP 16 per cent and 28 per cent respectively, and PO_4 increases another 2.4 per cent in 2012 but decline by 42 per cent in 2013. The effect of urbanisation and development is clearly the main cause of the deteriorating water environment as shown by the increasing nutrient concentration along the Sungai Petani River where most of the parameters are above the permissible threshold limit.
Keywords: urbanisation, development, nutrient concentrations, Sungai Petani River

INTRODUCTION

Today, like many other towns in Malaysia where developmental pressure encroaches many small towns and cities, development has cause small towns like Sungai Petani Town and its surrounding catchment areas to be affected by the changing land uses due to the developmental pressure in the catchment area. As such, inequality refers to the lack of 'green' areas versus urban concrete areas causing water quality to deteriorate.

Historically, from the 1920's to the 1960's, Sungai Petani Town was the backdrop of the rubber industry. With the fall of rubber prices in the 1980's, the State set up an industrial hub in Sungai Petani. Economic growth of Sungai Petani today is centred around the diverse industries established - from electronics to wood-based products. The population of Sungai Petani has increased from about 36,000 in 1970 to 456, 605 in 2010 (Malaysiabooks.com, 2015). Figure 1 shows the land uses in the Sungai Petani which is heavily urbanised with much more acreage of 'grey' infrastructure as compared to the 'green' infrastructure.

In terms of spatial inequality, one of the inequalities observed in developing urban areas is related to the 'green' area versus 'grey' areas. 'Grey' areas are related to areas of impervious surfaces such as roofs and tarmac i.e. buildings and streets found in most of the urban areas, while the 'green' areas are areas of the green forest land, vegetated land, parks and lawns in the urban areas (Svendsen et al., 2012) and aquatic ecosystems are also often included (Francis and Chadwick, 2013). Green area is an indicator of both ecological health and quality of life in urban areas (Ginn and Francis, 2014). Lack of green areas in urban areas is due to lack of planning of the cities.

The effect of unequal mass of 'green' versus 'grey' areas has led to differential effect on water quality of the urban areas. The expanding urbanisation as observed elsewhere in other developing countries, dramatically affects water resources in terms of quality (physical, chemical, biological pollution, etc.) and quantity (Ducrot et al., 2004). This will also leads to competition for water, associated with a competition for access to land, exacerbated in peri-urban areas.

This paper highlight the consequences of the unequal distribution of green versus grey areas in an urbanising catchment area of Sungai Petani Town, depicting some results of the temporal patterns of nutrient concentrations longitudinally along the Sungai Petani River for 2012 and 2013. Furthermore, this paper enables transition from general water quality assessment to specific experiment by describing the inadequacy in previous research that motivates the present study.

STUDY AREA

Sungai Petani River is a major river flowing through the city centre of Sungai Petani, Kedah with a length of 12.5 km and catchment area of 3500 hectares. Sungai Petani experiences equatorial climate, characterised by hot and humid climate as well as high temperature and rain evenly throughout the year. This area also receives convection and precipitation hill rainfall of southwest monsoon winds from the Straits of Malacca. In 2006, Sungai Petani river catchment consists of urban, residential and related (3.22 km^2), swamp forest/mangrove forest (2.14 km^2), open area (0.3 km^2), roads, highways and utilities (0.06 km^2), mix horticulture (0.19 km^2), rubber (0.03 km^2), paddy (0.47 km^2), forest, secondary forest and bush (0.03 km^2) (see Figure 1) (DOE, 2010).

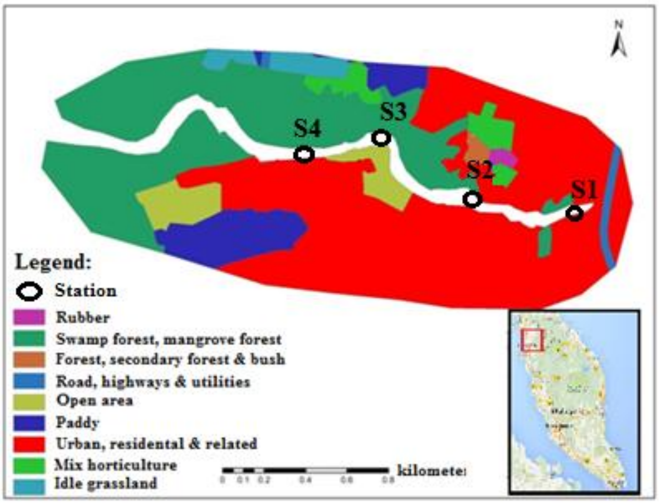

Figure 1: Sungai Petani River catchment showing the encroachment of urban areas in the catchment area
Source: DOE (2010)

DATA AND METHODOLOGY

Four stations were chosen longitudinally along Sungai Petani River from upper section of Sungai Petani River downstream towards Sungai Petani Town. Water sampling program were carried from March 2012 to December 2013 to capture both *in-situ* and *ex-situ* parameters. The sampling program is part of a wider study of the Merbok Catchment areas that include the Sungai Petani catchment (Ismail and Ibrahim, 2015).

Water sampling at all stations were performed using the grab sampling technique. Surface water samples for nitrogen (N) and phosphorus (P) were collected twice per month at depths of about 0.5 m from water surface and directly stored into clean 1 litre polyethylene bottles. Water samples were analysed only for dissolved forms of nitrate (NO_3), ammoniacal nitrogen (NH_4), total nitrogen (TN), phosphate ($P0_4$) and total phosphorus (TP). For nitrate, sample was analysed based on reaction of sulfanil amide in an acid solution. Then, the nitrate in the sample is reduced through a column containing cadmium copper (Adams, 1989). For ammonia, solution of boric acid and sulfuric acid are to used based on phenol-hypochlorite method. For phosphate, reactive phosphate in the sample was determined using ascorbic acid and antimony to a blue-colour molybdate complex (Adams, 1989). For TN, the total N in the sample was determined using potassium persulfate and heat oxidizes method. The oxidizing nitrogen is then reduced in a cadmium copper reduction column. For TP, the total P in the sample was determined by digestion of organically bound using an alkaline persulphate mixture based on alkaline persulphate oxidation method (APHA, 1989).

RESULTS AND DISCUSSIONS

Several nutrients concentrations especially N and P were chosen for discussion. This is because urban activities are amongst major sources of N and P to aquatic ecosystems (Carpenter et al., 1998). Most of the nutrient concentrations increased from upper station to the second station situated in the Sungai Petani Town.

As a result, all of the stations recorded higher average nitrate level during 2013 (ranging from 2.82 mg/l to 4.07 mg/l) compared to 2012 (ranging from 2.68 mg/l to 3.19 mg/l) (see Figure 2). In comparison, average of ammoniacal nitrogen ranged from 1.75 mg/l to 3.12 mg/l in 2013 but produced slightly lower concentration in 2012 (ranging from 1.16 mg/l to 1.63 mg/l) (see Figure 3). Moreover, the average TN concentration were higher in 2013 (ranging from 2.34 mg/l to 3.92 mg/l) compared to the year before (ranging from 2.25 mg/l to 3.41 mg/l) (see Figure 4). On the other hand, hosphate concentration is higher in 2012, compared with 2013. The average concentrations of phosphate in 2013 ranged from 0.45 mg/l to 0.95 mg/l. Compared to the average phosphate concentrations in 2012 which ranged from 1.47 mg/l to 1.71 mg/l (see Figure 6).

The nutrient concentrations in the Sungai Petani River were investigated longitudinally and we found that concentration increases from Station 1 (peri-urban area) to Station 2 (urban area). Nitrate concentrations increases by 6 per cent and 15 per cent in 2012 and 2013, respectively (Figure 2); ammonia increases by 11 per cent and 35 per cent, respectively (Figure 3); TN by 16 per cent and 22 per cent, respectively (Figure 4); TP by 45 per cent and 44 per cent, respectively (see Figure 5); and PO_4 by 13 per cent and 90 per cent respectively (see Figure 6).

The results also showed that all nutrient concentration increases from Station 1 (peri-urban) to Station 2 (urban) and show continued decline when compared to station 3 and station 4. The nutrient concentration decreases from Station 2 to the last station at the outlet downstream of the town. Nitrate decreases by 16 per cent and 27 per cent in 2012 and 2013 respectively (see Figure 2), ammonia increases by 28 per cent and 44 per cent respectively (see Figure 3). TN by 34 per cent and 41 per cent respectively (see Figure 4), TP 16 per cent and 28 per cent respectively (see Figure 5), and PO_4 increases another 2.4 per cent in 2012 but decline by 42 per cent in 2013 (see Figure 6).

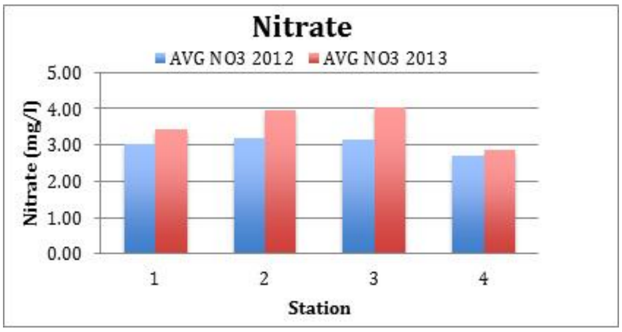

Figure 2: The average nitrate concentrations during 2012 and 2013

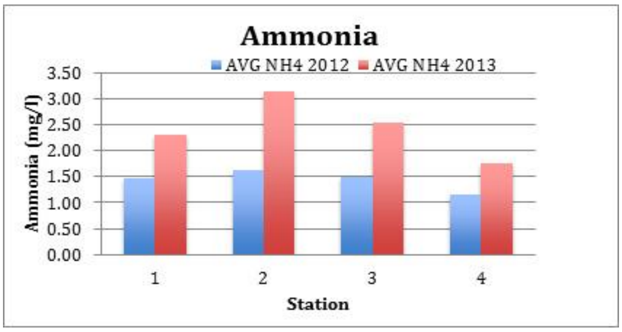

Figure 3: The average ammonia concentrations during 2012 and 2013

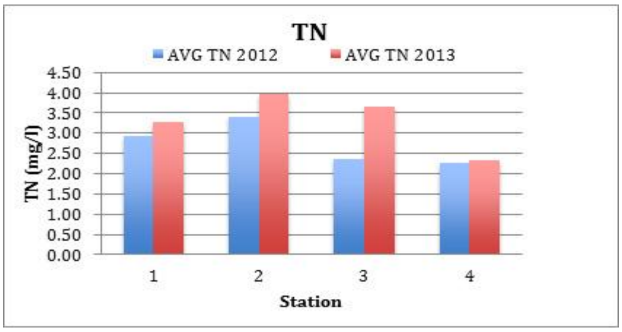

Figure 4: The average TN concentrations during 2012 and 2013

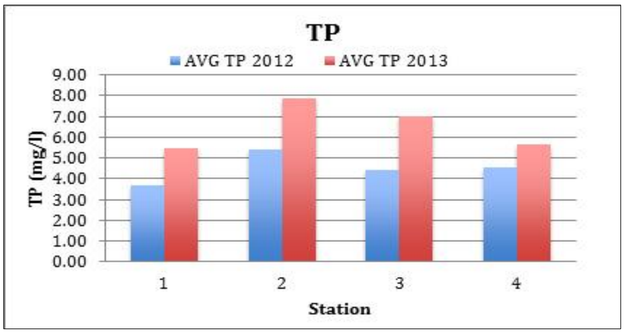

Figure 5: The average TP concentrations during 2012 and 2013

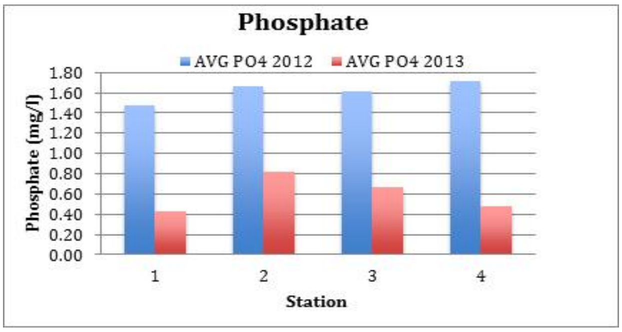

Figure 6: The average phosphate concentrations during 2012 and 2013

All stations, however, exceed the permissible limit of water quality standard. The ammoniacal Nitrogen for example was in Class IV and in Class V due to concentrations higher than limit of 1.75 mg/l at Station 2 (Interim National Water Quality Standards–Malaysia)(WEPA, n.d.). The water classification based on ammonia and nitrate concentrations (LAWA, 1998) showed that the water quality ranging from moderately polluted (Class III) to 'excessively contaminated' in Class IV (see Table 1) when ammoniacal nitrogen concentration is greater than 2.4 mg/l. The level of concentrations of nitrate in 2012 was in moderately polluted Class II-III (see Table 1), but ammoniait is classified as heavily polluted (Class III-IV) (Figure 3). In 2013 however, the nitrate concentrations increases in range from 2.88 mg/l to 4.07 mg/l (Class III – critically polluted water), while ammonia between 1.75 mg/l to 3.12 mg/l (Class III-IV and IV– very heavily polluted and excessively polluted water).

Table 1: Water quality classes for surface water bodies according to LAWA (1998) and their thresholds for NH_4-N, NO_3-N, PO_4-P and TP.

Water Quality Class	**Degree of Pollution**	**NH_4-N**	**NO_3-N**	**PO_4-P**	**TP**
I	Unpolluted or very lightly polluted	<0.04	<1	<0.02	<1
I-II	Lightly polluted	<0.1	<1.5	<0.04	<1.5
II	Moderately polluted	<0.3	<2.5	<0.1	<3
II-III	Critically polluted	<0.6	<5	<0.2	<6
III	Heavily polluted	<1.2	<10	<0.4	<12
III-IV	Very heavily polluted	<2.4	<20	<0.8	<24
IV	Excessively polluted	>2.4	>20	>0.8	>24

Generally, phosphorus is the limiting nutrient in freshwater aquatic systems. That is, if all phosphorus is used, plant growth will cease, no matter how much nitrogen is available. The natural background levels of total phosphorus are generally less than 0.03 mg/l. The natural levels of phosphate usually range from 0.005 to 0.05 mg/l (Kotoski, 1997). The level of phosphate in Sungai Petani compared to the natural background were in the range from 8 folds at Station 1 in 2013 to 34 folds at Station 4 in 2012 (see Figure 6); and they are classified as excessively polluted in 2012.

According to Wetzel (2001), most uncontaminated freshwaters contain between 0.01 and 0.05mg/l of TP. Thus, the level of TP is far higher in the Sungai Petani Catchment and found to be critically polluted river (Class II-III in Table 1). The level of TP were in the range from 70 folds at Station 1 in 2012 to 160 folds at Station 2 in 2013 (see Figure 5).

The study of the relationship between water quality and urbanisation is not new. Specific emphasis has been placed on how urbanisation influenced the chemistry of spring water (Al-Kharabsheh, 1999), the temperature of urban streams (LeBlanc et al., 1997), and the reduction of urban groundwater supplies (Gupta, 2002). Other research has examined how the form and rate of urbanisation influence water quality. Goda (1991) examined the effects of density and industrial activities on a range of water quality classifications. Wang (2001) provides a comprehensive examination of the spatial variation to water quality across an entire watershed. His findings reveal a strong relationship between the degradation of urban water quality and urban land use (Ren et al., 2003).

The data collected for the longitudinal profile by sampling transects of the main river and the numerous tributaries. There is great spatial difference in the level of urbanisation among the four sampling station in this study. Station 2 and 3 are located at the centre of Sungai Petani Town with highly urbanised and mainly covered by commercial, residential and manufacturing lands. These factors have caused the water pollution of Sungai Petani River to become increasingly serious. Meanwhile, station 1 belongs to a less urbanised area which is at the period of transition from a rural urban landscape to an urban landscape. Which means the water quality problem is relatively because of less nutrient contamination.

The results of this study show that the effect of differing land use and unequal distribution of green area against grey areas has caused water quality deterioration. One possible solution to reduce pollution in urban areas like Sungai Petani Town is by tackling the source of urban pollution, and to have more green spaces or buffer zones which act as filter preventing direct entry of pollutant into water course and river channels. Buffer zone is a vegetated strip of land separating runoff and pollutants contributing areas from surface waters. It is one of the most effective tools in coping up with non-point sources pollution (Philips, 1989) and it was an urgent and effective way for filtering runoff and land based pollutants before reaching surface waters (Shen et al., 2015).

CONCLUSION

As Malaysia heads towards urbanisation and industrialisation, it is very important to assess and tackle the issues of land use patterns and trends of water quality degradation during rapid urbanisation process. Our rivers, especially at the urban stretches, are being stressed due to urbanisation and these results in heavy pollution, decreased assimilative capacity and environment deterioration, which are the barriers of city development. The effect of urbanisation and development pressure is clearly the main cause of the deteriorating water environment as shown by the increasing nutrient concentrations longitudinally along the Sungai Petani River. Most of the parameters are above the permissible threshold limit. Both nitrate and ammonia which are indicators of pollution were higher than the permitted level. Implementing river improvement programs and creating green area in Sungai Petani Town are necessary for medium to long-term goal. More green areas as buffer zones is suggested as a remedial measure to combat further water quality deterioration and should be incorporated in future planning of the urban township. It is recommended that the government undertakes strict measures on water quality control and taking preventative actions as well.

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REFERENCES

Al-Kharabsheh, A. A. (1999).Influence of urbanization on water quality at WadiKufranja basin (Jordan). *Journal of Arid Environments*, 43(1), 79-89.

Adams, V.D. (1989). Water and Wastewater Examination Manual 1st Edition. Boca Raton: CRC Press.

APHA. (1989). *Standard methods for the examination of water and wastewater*. 17th ed. Washington, DC: American Public Health Association.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. & Smith, V.H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological applications*, 8(3), 559-568.

DOE (2010).Present land use map Kedah and Langkawi, Department of Agriculture Malaysia, 2010. Putrajaya.

Ducrot, R., LePage C., Bommel, P. & Kuper, M. (2004). Articulating land and water dynamics with urbanization: an attempt to model natural resources management at the urban edge. *Computers, Environment and Urban Systems,* 28, 85-106.

Francis, R.A. & Chadwick, M.A. (2013) *Urban Ecosystems: Understanding the Human Environment*. Oxon: Earthscan from Routledge.

Ginn, F. and Francis, R.A. (2014*)*. Urban greening and sustaining urban natures in London. In R. Imrie and L. Lees (Eds.). *Sustainable London*? *The future of a global city*. Bristol, UK: Policy Press. 283

Goda, T. (1991). Management and Status of Japanese Public Waters. *Water Science Technology,* 23(1-3), 1-10.

Gupta, R. K. (2002). Water and energy linkages for groundwater exploitation: a case study of Gujarat State, India. *International Journal of Water Resources Development*, 18(1), 25-45.

Ismail, W.R. & Ibrahim, M.N. (2015). An Assessment of Sediment and Nitrogen Input in the Upper Merbok River. *Water Quality Exposure and Health,* 7(1), 79-88.

Kotoski, James E. (1997). Information on Phosphorus Amounts & Water Quality. Phosphorus Minifact & Analysis Sheet. Retrieved at http://osse.ssec.wisc.edu/ curriculum/earth/Minifact2_Phosphorus.pdf

LAWA (LanderarbeitsgemeinschaftWasser) (1998).*Beurteilung der ¨ Wasserbeschaffenheit von Fließgewassern in der Bundesrepublik ¨ Deutschland – ChemischeGewasserg ¨ uteklassifikation, Kultur-* ¨ buchverlag Berlin.

LeBlanc, R. T., Brown, R. D., & FitzGibbon, J. E. (1997). Modeling the effects of land use change on the water temperature in unregulated urban streams. *Journal of Environmental Management*, 49(4), 445-469.

myMalaysiabooks.com (2015). Alor Star and Sungai Petani. Retrieved from http://www.mymalaysiabooks.com/Kedah/ASandSP.htm.

Phillips, J.D. (1989). An evaluation of the factors determining the effectiveness of water quality buffer zones. *Journal of Hydrology*, 107(1), 133-145.

Ren, W., Zhong, Y., Meligrana, J., Anderson, B., Watt, W. E., Chen, J., & Leung, H.L. (2003). Urbanization, land use, and water quality in Shanghai: 1947–1996. *Environment International*, 29(5), 649-659.

Shen, Z., Hou, X., Li, W., Aini, G., Chen, L., & Gong, Y. (2015). Impact of landscape pattern at multiple spatial scales on water quality: A case study in a typical urbanised watershed in China. *Ecological Indicators*, 48, 417-427.

Svendsen, E., Northridge, M.E. & Metcalf, S.S. (2012). Integrating Grey and Green Infrastructure to Improve the Health and Well-being of Urban Populations. *Cities and the Environment (CATE), 5*(1), Article 3. Retrieved from http://digitalcommons.lmu.edu/cate/vol5/iss1/3

Wang, X. (2001). Integrating water-quality management and land-use planning in a watershed context. *Journal of Environmental Management*, 61(1), 25-36.

Water Environment Partnership in Asia/WEPA (n.d.). Interim National Water Quality Standards For Malaysia. Retrieved from http://www.wepa-db.net/policies/law/malaysia/eq_surface.htm.

Wetzel, R.G. (2001). *Limnology*. Academic Press, New York. 1006.