

## Monitoring of Nutrients and Bacteria Occurrence in Urban River Water Using GIS Application

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**Abstract:** Urban rivers are often classified as a polluted river because of the location in the middle of urban areas which become a part of waste disposal area for human activities and pathways of waste materials in coastal areas. This study is done to monitoring the occurrence of nutrients and bacteria in urban river (Kerayong River) water. Six different sampling stations were choosen along Kerayong River. The water sample was taken using grab samples. The collection was conducted from April 2015 to October 2015. Based from the result in this study, Kerayong river has high concentration on total phosphorus, ammoniacal nitrogen and *E-coli* due to high urbanized area along Kerayong River.

**Key words:** Urban river, nutrients, bacteria, GIS application, ammoniacal

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### INTRODUCTION

Rapid urbanisation and population growth have increased the environmental pollution problems directly from human wastes, domestic wastes, industrial wastes and also transportation wastes that finally caused the quality of air, land and water become worsen day by day. Sources of water pollution are categorized into point source and non-point source. Point source is referred to identifiable source of discharge such as municipal sewage discharges and industrial discharges. Meanwhile, non-point source is difficult to identify the source such as from rainfall that causes runoff carrying pollutants into the river (Wu and Chen, 2013). According to Department of Irrigation and Drainage, deterioration of river water quality is synonym with the development and is the result of pollution from both point sources and non-point sources.

Study from Zhao *et al.* (2015) revealed that urban land use has the largest impact on river water quality and it has positive relationship with water quality parameters such as total nitrogen, total phosphorus, Chemical Oxygen Demand (COD) and ammoniacal nitrogen. Besides, anthropogenic activities have caused excessive input of nutrients such as nitrate and other forms of nitrogen that originate from the river into the coastal water (Bellos *et al.*, 2004). The study stated that biotic activities in estuaries and coastal seas has influence nutrients carried by rivers and play an important factor of changing conditions in their watersheds. Based on recent study by

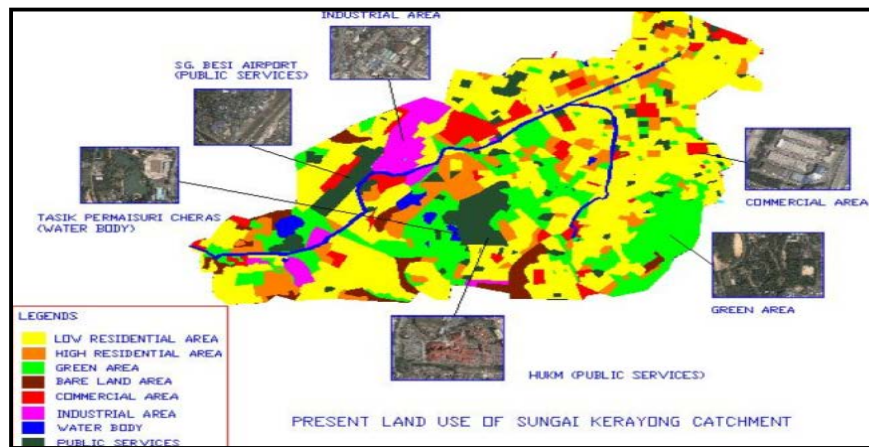
Bu *et al.* (2011), the increased amounts of nutrient rich sewage discharged, agricultural runoff, and industrial wastes has caused eutrophication in large scale and harmful algal bloom in Liaodong Bay of Bohai Sea in 1997. Other than that, bacterium is typically originates from sewage source and the discharge of Sewage Treatment Plants (STP) has contributes the *E. coli*. More importantly, microorganisms tend to growth successfully in rivers that rich with organics and nutrients.

**GIS application:** GIS application is necessary as work tools in conducting environmental management responsibilities. Distribution of environmental pollution sources obtained from the department of database systems displayed in this application. Other spatial information obtained from external sources and internal analysis can be combined together. Table 1 shows several applications of GIS and explanation about its application in various fields.

GIS application has been chosen to control the river water quality. The data acquisition from the sampling activity such as the water quality parameters of the river water, laboratory data and the coordinate of the sampling point were inserted into the database to be stored and analyzed. Besides, it is also able to produce map with the sampling point, river and the land use area which nearby the selected point. Other than that, its common purpose is decision making for managing use of land, resources or any spatial distributed activities or phenomena. It can

**Table 1: Application and description of GIS**

Application of GIS	Description
GIS for surveying and mapping	GIS is use for collection, management and sharing of land survey data and land record information
GIS for health and the environment	GIS can predict outcomes and planning strategies. Besides, it can address environmental health problems by integrating spatially referenced data and statistical analysis
GIS for dengue epidemic mapping	Base- map in arcGIS was created to indicate the larval infestation, locations of tire dumps, areas of standing water that lead to larval development sites, and locations of the homes of dengue cases collected during routine epidemiologic surveying overlaid onto this map
GIS for groundwater hydrology	GIS is capable to coordinate data collection, provide database operations comprehensively and model parameter assignments are supported systematically. Besides, model results can be represented in color-map formats by using GIS
GIS for water quality	GIS for water quality monitoring involve remote sensing for water quality monitoring. According to Ritchie, mapping of water quality for monitoring purposes have successes by using remote sensing techniques (Ritchie <i>et al.</i> , 2003)



**Fig. 1: Land use map of Sungai Kerayong catchment**

processes raw geographical data and capable to produce information for decision making of spatial activities.

**Case study; Kerayong River:** Kerayong river is selected as a study area because of the location at a highly multi-urbanized area in the middle of Kuala Lumpur, Malaysia. It is the main tributary of Klang river that runs from Pandan Indah to Pantai Baru with a catchment area size of 61 km<sup>2</sup> (Dom *et al.*, 2012). The study area is 74% imperviousness and residential areas cover the most of the impervious surface which is about 50%. The land cover classification of the study area can generate the effect of ambient river water quality. The climate of the study area is generally characterized as a warm tropical climate and sunny with heavy rainfall especially during the Southwest Monsoon from April to September (Dom *et al.*, 2012)

Kerayong River is considered as a polluted urban river because it is the tributary of Klang River and according to the study by Othman, Klang River is classified as Class IV category which is defined as polluted water and only suitable for plant and domestic animal uses (Othman and Mohamed, 2012). Water in this category needs complex treatment before being used for agricultural, irrigation and industrial purposed (Ren *et al.*, 2003).

From the study by Abustan, they conducted a land use map using satellite image and digital topographic for Kerayong river as shown in Figure 1 with different types of land use which are residential area, green area, bare land area, commercial area, industrial area, water bodies and public services.

Urban land use include industrial, commercial, public service area and residential. The area is considered as highly urbanized with 77.5% of the total catchment area is imperviousness meanwhile 22.5% is pervious area and water bodies. Study from Sharif stated that squatter settlement along Kerayong river that discharged the domestic waste into the river will increase the water pollution level (Sharif *et al.*, 2015). Table 2 summarize the land use composition in Kerayong river catchment. Low residential area has dominated the total impervious area with 24.04 km<sup>2</sup>.

**Sampling and Parameter observed:** For the study, six different sampling stations were selected along Kerayong river. The collection was conducted from April 2015 to October 2015. Figure 2 indicated the locations of river water have been taken and Table 3 summarized details for each of sampling point.



Fig. 2: Locations of sampling stations in Kerayong River

Table 2: Land use compositions in Sungai Kerayong catchment

Categories	Area (km <sup>2</sup> )
<b>Pervious area and water bodies</b>	
Green area	8.47
Bare land area	1.83
Water bodies	0.55
Total area	10.85
Percentage	22.50%
<b>Impervious area</b>	
Industrial area	1.86
Commercial area	2.66
Public services area	3.47
High residential area	5.44
Low residential area	24.04
Total area	37.46
Percentage	77.50%

Table 3: The coordinates and details for six sampling stations

Sampling point	Sampling station	Description
1	Outfall Taman Desa 3°5'42.20"N 101°41'14.95"E	The most downstream station on the main-stem of Kerayong River. Near to Desa Park detention pond and residential area
2	Kampung Sri Indah 3°6'08.88"N 101°42'09.68"E	Near to the residential area and airport
3	Chan Sow Lin 3°6'52.76"N 101°42'48.49"E	Near to the residential, industrial and commercial area.
4	Jalan Maluri 3°7'21.21"N 101°43'42.08"E	Near to power plant, industrial and commercial area
5	Taman Indah Ampang 3°7'46.60"N 101°44'35.05"E	Near to the residential and commercial area
6	Jalan Kuari 3°6'26.02"N 101°44'36.63"E	Most upstream station location on Kerayong river, located prior to the tributaries (hence discharge points)

## MATERIALS AND METHODS

The parameters of water quality determined under laboratory test are Ammoniacal Nitrogen ( $\text{NH}_3\text{-N}$ ), Total Phosphorus (TP), Nitrate ( $\text{NO}_3$ ), Nitrite ( $\text{NO}_2$ ) and *E. coli*

analysis. Tests were conducted according to the Standard Methods for the Examination of Water and Wastewater (APHA *et al.*, 2005).

**Ammoniacal nitrogen ( $\text{NH}_3\text{-N}$ ):** Ammoniacal nitrogen analysis was followed the procedure for high range level from 0.02-2.50  $\text{mg L}^{-1}$ . The analysis used spectrophotometer test to measure the concentration reading. Spectrophotometer was set to 380 N Ammonia Ness test. The reagent needed were mineral stabilizer, Polyvinyl alcohol dispersing agent and Nessler's reagent. After the reaction takes place, the colour of the water sample turns into yellow colour. Then, the reading for ammoniacal nitrogen concentration was recorded.

**Total Phosphorus analysis (TP):** The procedure for total phosphorus was followed the lab manual for high range from 0.02-2.50  $\text{mg L}^{-1}$  and using the spectrophotometer that set to 490P React PV test. The reagent involved was PhosVer 3 phosphate powder pillow reagent. After the reaction begins, the colour of water sample turns blue. Then, the reading for total phosphorus concentration was recorded.

**Nitrate ( $\text{NO}_3$ ):** Nitrate test was done according in the lab manual for low range from 0.01-0.50  $\text{mg L}^{-1}$ . The test also used the spectrophotometer that set to 351 N Nitrate LR test. The reagents used were NitraVer 6 reagent powder pillow and NitriVer 3 Nitrite reagent powder pillow. Then, pink colour will developed after the reaction takes place. The reading from the spectrophotometer was recorded.

**Nitrite ( $\text{NO}_2$ ):** Nitrite analysis was done for low range from 0.002-0.30  $\text{mg L}^{-1}$  using spectrophotometer that set to 371 N Nitrite LR PP test. The reagent used was NitriVer 3 Nitrite powder pillow reagent. The water sample turns into pink after the reaction. Then, the reading was recorded from the spectrophotometer.

**E. coli analysis:** Microbiological analysis is a method for analyze and enumerate bacteria. The common method used for *E. coli* analysis is the Standard Plate Count (SPC) which relies under proper conditions, *E. coli* bacterium will divide and form a visible colony on an agar plate. The method used in this study to count *E. coli* colonies is according to the Standard Methods for the Examination of Water and Wastewater.

To ensure the numbers of colonies were appropriately detected, serial dilution will be cultured. The procedure during the laboratory analysis is to making several dilutions of the samples (1:10, 1:100, 1:1000) in sterile water and cultured on nutrient agar in a dish and sealed. The dish is then placed into an incubator for 24 h at  $35\pm 2^{\circ}\text{C}$ . The nutrient agar used to detect *E. coli* colonies is MacConkey agar that contains 1% lactose, 0.15% bile salts and the dyes neutral red and crystal violet. The number of *E. coli* colonies that visible on agar plate which in pink colour are then counted.

## RESULTS AND DISCUSSION

From the laboratory analysis result, the average concentrations of nutrients and *E. coli* colonies are then calculated and presented in Table 4 and 5. The results are compared to the threshold limit by Malaysia National Water Quality Standards 2006 (MNWQS).

From the Table, the average value of Total Phosphorus (TP), ammoniacal nitrogen ( $\text{NH}_3\text{-N}$ ) and *E. coli* were found very high at all sampling locations and exceeded the limit from Malaysia National Water Quality Standard. Study from Sharif also found level of phosphate, ammoniacal nitrogen and *E. coli* were high and the water is classified into worst water quality condition (Sharif *et al.*, 2015).

**Total Phosphorus (TP):** The Total Phosphorus (TP) concentrations in Kerayong River are ranging from  $2.58\text{-}3.81\text{ mg L}^{-1}$  which are very high and exceeded the limit from National Water Quality Standard (NWQS). One of the factor Kerayong river has high concentration of (TP) is because the location in between highly urbanized area which surrounded with residential, industrial and commercial area. According to Huang, the area where commercial and residential is mixed is tend to have high level of (TP) (Huang *et al.*, 2013). From the result, the highest average concentration of (TP) is recorded at fifth sampling point in Taman Indah Ampang with value of  $3.81\text{ mg L}^{-1}$ . The fifth sampling point is located at a very crowded residential area. Study from Huang, indicated that high level of (TP) is related with residential household garbage and chemical from industry (Huang *et al.*, 2013). According to The Sun Daily, it was reported that Kerayong River has become a dumping site

Table 4: Average value for nutrients concentration and *E. coli* colonies at SP1 until SP3

Parameters	MNWQS	SP1	SP2	SP3
TP ( $\text{mg L}^{-1}$ )	0.2	2.58	2.92	3.5
$\text{NO}_3$ ( $\text{mg L}^{-1}$ )	7	0.06	0.06	0.12
$\text{NO}_2$ ( $\text{mg L}^{-1}$ )	0.4	0.05	0.03	0.06
$\text{NH}_3\text{-N}$ ( $\text{mg L}^{-1}$ )	0.3	9.3	8.6	8.7
<i>E. coli</i> (CFUm/100 mL)	100	14,786	16,314	12,043

Table 5: Average value for nutrients concentration and *E. coli* colonies at SP4 until SP6

Parameters	MNWQS	SP4	SP5	SP6
TP ( $\text{mg L}^{-1}$ )	0.2	3.14	3.81*	3.01
$\text{NO}_3$ ( $\text{mg L}^{-1}$ )	7	0.13	0.23*	0.04
$\text{NO}_2$ ( $\text{mg L}^{-1}$ )	0.4	0.05	0.11*	0.05
$\text{NH}_3\text{-N}$ ( $\text{mg L}^{-1}$ )	0.3	10.4*	9.4	8.8
<i>E. coli</i> (CFUm/100 mL)	100	16,914*	8,757	9,729

\* indicate highest concentration or colonies

for garbage when there were a lot of garbage accumulated in the river and has caused serious threat to the communities that lived near the area.

**Nitrate ( $\text{NO}_3$ ):** Meanwhile, nitrate ( $\text{NO}_3$ ) concentrations are ranging from  $0.04\text{-}0.23\text{ mg L}^{-1}$  which are considered as relatively low and within the maximum permissible limit set by NWQS ( $<7\text{ mg L}^{-1}$ ).  $\text{NO}_3$  concentrations at all sampling points are within the quality standard. Study by Al-Badaai, found that the concentration of  $\text{NO}_3$  in Semenyih River also below the permissible limit mainly because of  $\text{NO}_3$  is naturally form from nitrogen and very mobile in water (Al-Badaai *et al.*, 2013). According to Effendi,  $\text{NO}_3$  pollution is closely related with the low human activities nearby (Effendi and Wardianto, 2015).  $\text{NO}_3$  is mostly found in agricultural activity where nitrogen fertilizers were used (Fan, 2011). The area around Kerayong river is low with agricultural activity according to land use classification.

**Nitrite ( $\text{NO}_2$ ):** Besides, nitrite ( $\text{NO}_2$ ) concentrations are also considered low and within the range ( $<0.4\text{ mg L}^{-1}$ ) which are ranging from  $0.03\text{-}0.11\text{ mg L}^{-1}$ . At fifth sampling point the value recorded slightly higher than other sampling point with the value of  $0.11\text{ mg L}^{-1}$ . The fifth sampling location is located upper stream and within overcrowded residential areas. Human waste from wastewater and septic tank runoffs may contribute to  $\text{NO}_3$  and  $\text{NO}_2$  pollution (Fan, 2011). Study from Effendi and Wardianto (2015), also indicated that  $\text{NO}_2$  in water bodies are mostly comes from industrial and domestic wastes.

**Ammoniacal Nitrogen ( $\text{NH}_3\text{-N}$ ):** Meanwhile, ammoniacal nitrogen ( $\text{NH}_3\text{-N}$ ) levels ranging from  $8.6\text{-}10.4\text{ mg L}^{-1}$  which are very high and over the range ( $>0.03\text{ mg L}^{-1}$ ). The high level of  $\text{NH}_3\text{-N}$  is due to the catchment location within the commercial, industrial and high number of residential area. The fourth sampling point at Jalan Maluri shows the highest level of  $\text{NH}_3\text{-N}$  which is  $10.4\text{ mg L}^{-1}$  since, the sampling point area is located at the

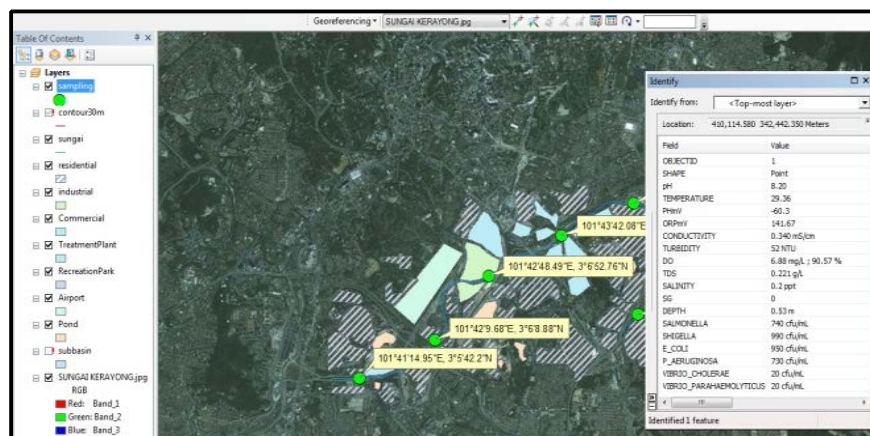


Fig. 3: Digital map of Kerayong River

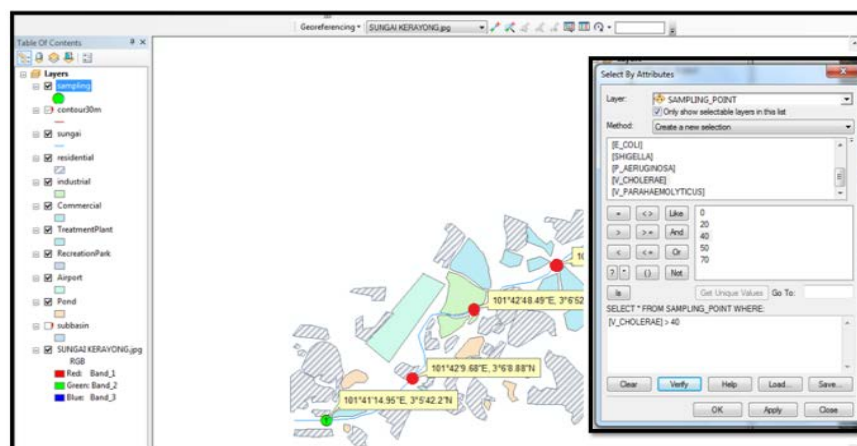


Fig. 4: The result of the query by attributes

overcrowded residential area and commercial area. The amount of ammonia that present in water bodies is the result from sewage inflow (Effendi and Wardianto, 2015). The study stated that the river water is considered as polluted if the amount of ammonia is high. According to Ariffin and Sulaiman, a major source of  $\text{NH}_3\text{-N}$  pollution is from the sewage discharge includes sewage treatment plants, households raw sewage discharges, wet markets and restaurants (Ariffin and Sulaiman, 2015) (Fig. 3).

**E. coli:** The *E. coli* levels at all sampling points are exceeded the range ( $>100$  cfu/100 mL). At fourth sampling point, the value recorded is the highest value which is 16,914 CFU/100 mL. According to Al-Badaii *et al.* (2014), source of *E. coli* contamination in river water are varied which are comes from wastewater, small rubbish dump, directly discharged of untreated sewage, and also from storm water runoff that contains bacteria from human and animal faeces and finally washed into the rivers. Other

than that, according to Zainudin, *E. coli* is typically originates from sewage source and the discharge of Sewage Treatment Plants (STP).

**GIS mapping:** The digital map of Kerayong river display the coordinates of sampling points, the water quality data, the concentration of nutrients and bacteria and area of land use for each of sampling point. The map is useful in identifying locations that involve the threat of contaminated areas (Adhikary *et al.*, 2013). Besides, it is capable to relate the data across layers (Sahmsi, 2005). In addition, it can also provide the tools to identify the most hazardous contaminants with regard to ecological regulations that lead to effective decision making to insure that natural resources are maintained and used correctly. The map produced can be used to describe the relationship and significant hot spots within a river (Graham *et al.*, 2011). For example, it can identify if there is a relationship between the environment conditions and the concentration of pathogens (Fig. 4).



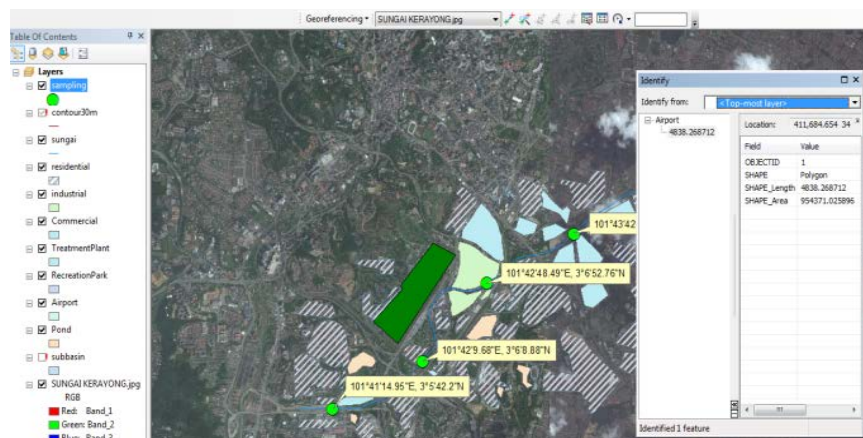


Fig. 5: Coverage area for land use in m<sup>2</sup>

Therefore, safety precautions can be taken like remediation of the contaminated area in order to reduce the risk of contamination of drinking water sources and indirectly the cost of water treatments and disinfections required can be reduced (Fig. 5).

### CONCLUSION

The surface water and rivers water quality degradation become an important issue in Malaysia especially for urban river quality as it undergoes rapid development and it is subjected to pollution from point and non-point sources. Based from the result in this study, Kerayong River has high concentration on three major water quality parameters which are total phosphorus, ammoniacal nitrogen and *E. coli* bacteria due to high urbanized area along Kerayong River. Water quality monitoring must be done to avoid the effects of pollution on water users. Also, by monitoring the occurrence of nutrients and bacteria in river water, the public health risks as well as ecosystem risk can be reduced.

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