International Journal of GEOMATE, April 2019, Vol.16, Issue 56, pp. 135 - 140
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.56.4693
Special Issue on Science, Engineering & Environment

WATER QUALITY ASSESMENT BASED ON THE WATER QUALITY INDEX (WQI) APPROACH USING GEOSPATIAL ANALYSIS

*Rina Febrina[1], Abu Bakar Sambah[23]

[1] Faculty of Civil Engineering, University of Malahayati, Indonesia; [2] Faculty of Fisheries and Marine Science, University of Brawijaya, Indonesia; [3]Marine Resources Exploration and Management Research Group, University of Brawijaya, Indonesia

*Corresponding Author, Received: 30 Oct. 2018, Revised: 15 Nov. 2018, Accepted: 20 Dec. 2018

ABSTRACT: Water quality refers to the chemical, physical, or biological characteristics of water, in which assessing the condition of water relative to the requirements of biotic species or to any human purposes. The aim of this study was to analyze the water quality of the Way Kuripan River based on the Water Quality Index (WQI) calculation method. Water samples were taken from five different areas (WK01, WK02, WK03, WK04 and WK05). WQI was calculated on the basis of six parameters; dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, total suspended solid (TSS) and ammoniac-nitrogen (NH3-N). The calculation started by identifying the equation of the Sub-Index (SI) based on the parameter value, calculating the Sub-Index (SI) of each parameter, and calculating the Water Quality Index. The results show that WK01 and WK04 have WQI values of 70.3 and 70.11. Those values show that water quality of the Way Kuripan River was in class III or slightly polluted. WK02 (WQI = 55.8) and WK03 (WQI=53.8) were highly polluted. The lowest WQI of the Way Kuripan River was in WK05 = 38.3, and classified as Class V (highly polluted). Moreover, Geospatial analysis was done to identify the distribution of water quality geographically. It shows that home industry and human activities, were spread along the river flow, and it caused the fluctuation of water quality. The results of this study can be used as a reference by the local government for water resources management.

Keywords: Water quality index, Way Kuripan River, Chemical, Physical and biological characteristics

1. INTRODUCTION

Water pollution increases day by day in many places in the world. On the other hand the availability of water supply decreases continuously. Based on the circumstance, water quality in many parts in the world is dropped continuously. Water quality is always an important and interesting topic to discuss.

Water quality is one of the most important factors that must be considered when evaluating the sustainable development of region [1]. The most useful tool to monitor and assess the water quality is by using the water Quality Index (WQI) which is a single number like a grade explains the total water quality at a certain area and time based on several water quality parameters [2]. It also assesses the suitability of the quality of the water for a variety uses such as agriculture, aquaculture, and domestic use [3]. WQI was first proposed by Horton 1965, later, numerous of indices have been developed all over the world such as Weight Arithmetic (WA), National Sanitation Foundation (NSF), Canadian Council of Ministers of the Environment (CCME), British Columbia, Oregon etc [4,5,6,7]. Over the years, many researchers have been conducted to monitor and study water quality [8,9,10,11,12,13,14].

In Southeast Asia regions, the most recognized WQI is DOE WQI. The WQI was developed by the Department of Environment of Malaysia [15]. DOE WQI calculation has been used as standard calculation for water quality in Water Quality Monitoring Program in Malaysia [7].

In this study, DOE-WQI method [9] was applied to analyze the water quality of Way Kuripan River. Way Kuripan River is one of the largest rivers in Bandar Lampung city, Indonesia. Along the river, there are landfill, industrial, residential and agriculture. The water body of the river practically receives, industrial waste, liquid waste from landfill, domestic wastes and drainage water from the residential area. The river were utilize for some purposes such as cleaning and sanitizing by the people living in surrounding areas. To identify the distribution of water quality in the Way Kuripan River some approach is needed. The integrated analysis of geospatial and water quality index calculation will describe the distribution of water quality along the river and determine the class of polluted water.

2. METHOD

2.1 Study Area

The analysis applied in the area of Way Kuripan River, Bandar Lampung city. In general, Lampung can be described as hilly to mountainous terrain, and characteristic of steep slopes with a slope of more than 25% and an average altitude of 300 meters above sea level. Way Kuripan River was created by the confluence of Way Simpang Kiri River and Way Simpang Kanan River. The length and the catchment area of the Way Kuripan River were 9.6 km and 60.81 km^2. Research location as described on Fig. 1.

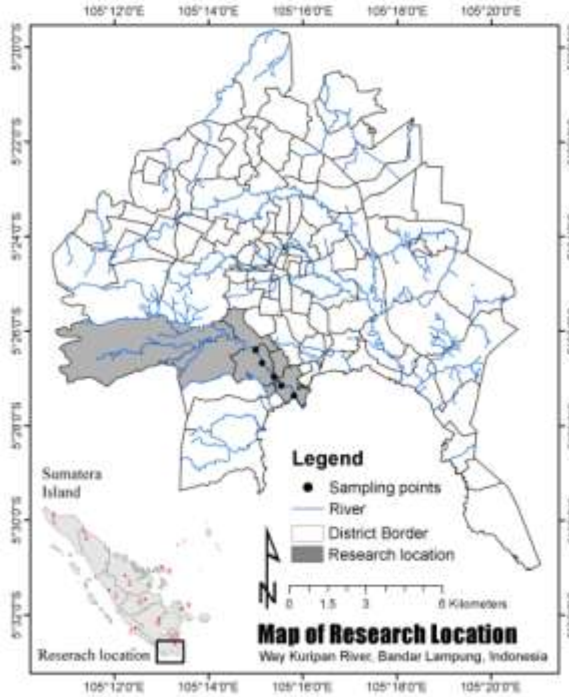

Fig.1 Research location

2.2 Data Collection

The water samples consist of 5 points and were taken during January 2017. Each sampling site was positioned by Global Positioning System (GPS), as illustrated in Table 1 and Fig. 2.

Table 1 Sampling point coordinate

ID	Latitude (S)	Longitude (E)
WK01	05˚26.458'	105˚15.026'
WK02	05˚26.712'	105˚15.169'
WK03	05˚26.910'	105˚15.387'
WK04	05˚26.194'	105˚15.461'
WK05	05˚26.212'	105˚15.778'

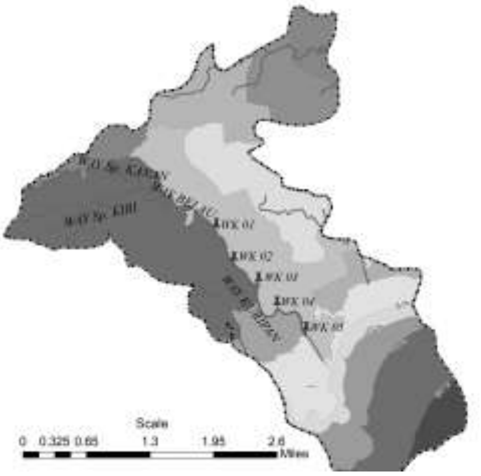

Fig.2 Sampling point

The surface water sample was collected about a half of the river depth due to the velocity of water flow less than 5m^3/s [16]. Water samples from each station were stored in one-liter polyethylene bottles for analysis of selected parameters included: pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolve Oxygen (DO), Ammoniac Nitrogen (NH3-N), Total Suspended Solid (TSS).

2.3 Data Analysis

The algorithm applied for calculating WQI was developed by the Department of Environment of Malaysia. The algorithm was described as follows:

$$WQI = (0.22SIDO) + (0.19SIBOD) + (0.16SICOD) + (0,15SIAN) + (0.12SIpH) \quad (1)$$

Where, *WQI* = Water Quality Index, *SIDO* = Sub-index *DO*, *SIBOD* = Sub-index *BOD*, *SICOD* = Sub-index *COD*, *SIAN* = Sub-index *AN*, *SISS*= Sub-index *TSS*, *SIpH*= Sub-index *pH*.

Every sub-index was calculated based on the equation in certain condition which is:

SIDO; SIDO = 0 for x ≤ 8; SIDO = 100 for x ≥ 92; SIDO = -0.395 + 0.030 x^2 - 0.00020x^3 for 8 < x < 92. SIBOD; SIBOD = 100.4 – 4.23x for ≤ 5; SIBOD = 108 exp (-0.055x) – 0.1x for x >5. SICOD; SICOD = -1.33x + 99.1 for x ≤ 20; SICOD = 103*exp (-0,0157x) – 0.04x for x > 20. SIAN; SIAN = 100.5 – 105x for x ≤ 0.3; SIAN = 94*exp (-0.573x) – 5*│x - 2│ for 0.3 < x <4; SIAN = 0 for x ≥ 4. SISS; SISS = 97.5* exp (-0.00676x) + 0.05x for x ≤ 100; SISS = 71*exp (-0.0061x) – 0.015 for x < 1000; SISS = 0 for x ≥ 1000. SIpH; SIpH = 17.2 – 17.2x + 5.02x^2 for x < 5.5; SIpH = -242 + 95.5x – 6.67x^2 for 5.5 ≤ x < 7; SIpH = -181 + 82.4x - 6.05x^2 for 7 ≤ x < 8.75; SIpH = 536 – 77x + 2.76x^2 for x ≥ 8.75.*

General rating scale for the DOE WQI was between 0 and 100. The interpretation of the value applied in some water resources development purposes is described below:

- **For general use of water**: $0 \leq x < 60$ = high polluted water; $60 \leq x < 80$ = slightly polluted water; $x > 80$ = clean water. For classification of water: $0 \leq x < 40$ = Class V; $40 \leq x < 50$ = Class IV; $60 \leq x < 80$ = Class III; $80 \leq x < 90$ = Class II; $x > 90$ = Class I.
- **For public water supply**: $0 \leq x < 40$ = not acceptable for public water supply; $40 \leq x < 50$ = doubtful for public water supply; $60 \leq x < 80$ = needs expensive treatment for public water supply; $80 \leq x < 90$ = needs minor purification for public water supply; $x > 90$ = no need treatment for public water supply.
- **For recreation water**: $0 \leq x < 20$ = not acceptable for recreation; $20 \leq x < 30$ = obvious pollution appearing, still not acceptable for all recreation; $30 \leq x < 40$ = only for boating; $40 \leq x < 50$ = doubtful for water contact; $50 \leq x < 70$ = acceptable for water contact but needs bacteria count; $x > 70$= acceptable for all water sport.
- **For fisheries**: $0 \leq x < 30$ = not acceptable for fisheries; $30 \leq x < 40$ = only for coarse fish; $40 \leq x < 50$ = only for handy fish; $50 \leq x < 60$ = doubtful for sensitive fish; $60 \leq x < 70$ = marginal for trout; $x > 70$ = acceptable for all fish.
- **For navigation**: $0 \leq x < 30$ = not acceptable for navigation; $30 \leq x < 40$ = obvious pollution appearing; $x > 50$ = acceptable for all navigation.
- **For water transportation**: $0 \leq x < 10$ = not acceptable for water transportation; $x > 10$ = acceptable for water transportation.

3. RESULT AND DISCUSSION

3.1 Water Sample Analysis

Water samples were analysis at Health Laboratory of UPTD/Local technical implementation unit includes five parameters; Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia (AN), Suspended Solid (SS) and Degree of Acidity (pH). The result of the analysis as described in Table 2.

Table 2 Analysis result

No	Para Meters (mg/l)	Analysis Result WK 01	WK 02	WK 03	WK 04	WK 05
1	DO	3.69	3.56	4.04	1.45	3.05
2	BOD	2	30	29	4	131
3	COD	6	9	32	6	468
4	AN	0.03	0.03	0.12	0.16	0.03
5	SS	1	1	1	1	1
6	pH	7.56	7.36	7.20	7.47	7.61

The value as shown in Table 2 were compared with the water quality standard in accordance with Government Regulation of the Republic of Indonesia No. 82, the year of 2001 (Table 3) on the Management of Water Quality and Control of Water Pollution [17].

Table 3 Government regulation of the Republic of Indonesia No. 82, the year of 2001

Quality Standard Class I (mg/l)	Class II (mg/l)	Class III (mg/l)	Class IV (mg/l)
6	4	3	0
2	3	6	12
10	25	50	100
0.5	-	-	-
50	400	400	400
6-9	6-9	6-9	5-9

Table 2 shows the value of Dissolved Oxygen (DO) at sample points of WK01, WK02, WK05 was 3.69 mg/l; 3.56 mg/l and 3.05 mg/l, and it included in water quality standard of class III [14]. While at the sample points WK03 and WK04 have to DO value of 4.04 mg/l (Class II) and 1.45 mg/l (almost close to Class IV). DO is one of the important parameters in water quality analysis. The DO value indicates the amount of oxygen available in a body of water. The greater the DO value on water, indicating the water has good quality. Conversely, if DO value is low, it can be seen that the water has been contaminated. The value of DO also shows the extent to which the water body is able to accommodate water biota such as fish and microorganisms. The results show that the value of DO increasingly smaller the downstream. As for the BOD value, there was an increase from upstream to downstream. The increasing of BOD value was above the standard of the class IV water quality, and this occurred at sample points of WK02, WK03, and WK05; 30 mg/l, 29 mg/l and 131 mg/l, respectively.

The highest BOD value occurred in the downstream area (WK05=131mg/l) while the upstream of the river had a low BOD value of 2 mg/l, and included in class I. The BOD value indicates the amount of oxygen required by microorganisms to decompose dissolved organic substance and some of the organic substances suspended in water. The greater the value of BOD means the process of decomposition of organic substance occurs in large quantities and will absorb oxygen in water thereby reducing the amount of dissolved oxygen (DO). The increase in BOD value from upstream to downstream indicates the quality of river water has decreased. This is because the source of pollutants is not only from the previous water flow but also from the surrounding settlements that dispose of domestic waste directly into the river. In addition, the activities of ships entering the estuary by disposing of waste from ships such as engine oil and others also increase the source of pollutants to downstream areas.

In addition, COD value at sample point of WK01, WK02, WK04 was 6 mg/l, 9 mg/l, and 6 mg/l, and included in the standard of water quality class I. COD value at sample point of WK03 was 32 mg/l, and it almost close to the standard of water quality class III. While the COD value for the downstream area (WK05) was very high, equal to 468 mg/l, far exceeds the water quality standard required by the government.

The downstream region requires the greatest amount of oxygen compared to other regions for chemical reaction processes to decompose the contaminants. Level of ammonia (AN) at sample point of WK 02 to WK 04 has increased with the highest AN concentration occurring at sample point of WK 04 (0.16 mg/l). It did not exceed recommended quality standard based on Government regulation No. 82, 2001 (equal to 0.5 mg/l). In this area, the dominant activity is the settlements whose effluents are directly discharged into river bodies and poor sanitation of the people. This is in accordance with the statement of Effendi (2003) which states that high ammonia level is an indication of the contamination of organic materials derived from domestic waste, industries and run-off agricultural fertilizers [16].

SS (Suspended Solid) parameter of Way Kuripan River at sample point of WK01 up to WK05 has the same value (1 mg/l). Concentrations of SS from upstream to downstream described the water quality standard of class I and Class II based on Government Regulation, so that SS content of river water of Way Kuripan did not affect to the allocation of raw water, facilities/infrastructure of recreational water, animal husbandry and fishery interests. Although SS was not toxic but with the increasing value of SS means increasingly penetration of light obstructed into the river.

Moreover, pH was classified as normal, and it indicated that life of aquatic biota still in good enough condition. The overall analysis of water quality of Way River Kuripan illustrated that some the result did not meet the criteria of quality standard according to Government Regulation of Republic of Indonesia No. 82, the year of 2001 on the Management of Water Quality and Control of Water Pollution [17].

3.2 Analysis of DOE - WQI

Based on the analysis of Way Kuripan River water samples (Table 2), it can be calculated the sub-index value of each parameter. The analysis of water quality used DOE-WQI method applying the equation (1). The results of DOE-WQI calculations are presented in Table 4.

Table 4 WQI Value of Way Kuripan River

No.	Sample Location	WQI	Class
1	WK01	70.3	III (Slightly Polluted)
2	WK02	55.8	IV (Polluted)
3	WK03	53.8	IV (Polluted)
4	WK04	70.11	III (Slightly Polluted)
5	WK05	38.3	V (Highly Polluted)

The analysis of WQI described the decreasing value of water quality from upstream to downstream; it is related to the contamination level. At the sample point of WK01 the WQI value was 70.3, it means that the water quality in the upper river area is slightly polluted. Based on the investigation of pollution source in upstream area occurred due to the erosion of vacant land and residential area. Upstream water can be used for drinking water needs, although it requires processing first. It also safe for fisheries activities and suitable for all types of water sports, shipping and water transportation. The areas between upstream and downstream at the sample points of WK02, WK03, WK04 have WQI values of 55.8, 53.8 and 70.11. The source of pollution was dominated by domestic and household wastes generated from the contribution of Karang City urban village with dense population Village (see land use map on Fig 3).

The water quality at the sample points of WK02 and WK03 were worse compared to WK04, due to the existence of SABO DAM between sample points WK03 and WK04. The high concentration of contaminants from the previous water flow (WK02 and WK03) became lower when through SABO DAM due to an increase in water discharge. Water discharge gives a significant influence on the improvement of water quality level. Water quality on WK02 and WK03 were doubtful for drinking water use because the pollution level was higher than WK01. The class category of this area was Class IV (polluted). It needs routine bacterial control if apply for sport in contact with water. While for fisheries only allowed for fish that are cultivated but still doubtful for more sensitive fish but permitted for shipping and water transportation.

WK04 has a value approaching WK01. While the downstream of Way Kuripan River (WK05) has a WQI value of 38.3, including in the highly polluted category (Class V). The source of pollution was caused by market or shops (Purwata and Karang City urban village), home industry, a temporary shelter which is widely located along the river flow, the flow of in and out of traditional fishing boats and from dense settlements in Purwata. River water in the downstream area can not be used for drinking water, whereas for fisheries only fish can live in permissible dirty water. Sailing and water transportation were permitted even though there was still polluted. Overall the Way Kuripan River condition from upstream to downstream has been contaminated with varying levels of pollution.

3.3 Geospatial Analysis

The spatial analysis describes an approach which studies entities using geographic properties. It also defined as an approach to applying statistical analysis and other analytic techniques to geo-reference dataset [18]. All sampling points and the result of measurement were plotted based on its geographical information on the thematic map. The maps showed not only the information about water quality value but also illustrated the relationship between water quality distribution and surrounding land use.

Sampling point of Way Kuripan River spatially spread from coastal line to the hinterland in around 2.8 km of length. The land use surrounding sampling point illustrated urban or settlement area (Fig. 3), in which the forest area found at north and west part of the area.

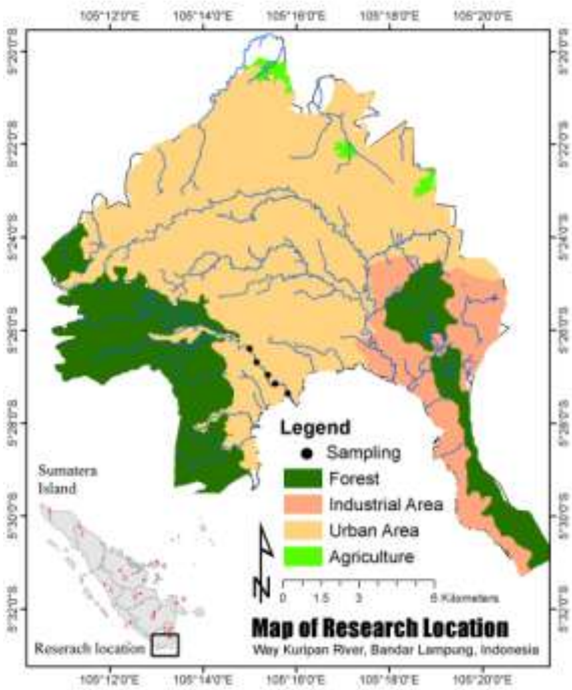

Fig.3 Land use map

As described in a laboratory test of water quality, the sampling point of WK02 and WK03 illustrated highly polluted water. This area consists of two different sub-district in both sides of the river, in which mostly covered by urban area.

Mapping the water quality parameters using spatial analysis, a Geographical Information System approach can be useful for taking quick decisions as a graphical representation. It would be easy to facilitate government or policy maker in taking a decision, especially in water resources management. The analysis specially designed for handling geographical data. The advantage of using a geospatial analysis is handling attribute data in conjunction with spatial features.

4. CONCLUSION

In general, the water quality of Way Kuripan River is in contaminated status with varying level of pollution. The results of the analysis show that WK01 and WK04 have WQI values of 70.3 and 70.11, with the category of river water quality of class III (slightly contaminated). At the sample points of WK02 and WK03 have WQI values of 55.8 and 53.8. The water quality at the sample points is included in the polluted category (Class IV). The value of WQI at the sample point of WK05 is 38.3 with the status of highly polluted water quality (Class V). The results of this study can be used as a reference by the local government to overcome the contamination of Way Kuripan River water with water pollution control strategy, utilization, monitoring and maintenance of water resources in Way Kuripan watershed.

5. REFERENCES

[1] Cordoba E. B., Martınez A. C., and Ferrer E. V., Water quality indicators: comparison of a probabilistic index and a general quality index. The case of the Confederacion Hidrografica del Jucar (Spain). Ecological Indicators, vol 10, pp 1049–1054, 2010.

[2] Al-Obaidy A. M. J. and Moulood B. K. J., Evaluating raw and treated water Quality of Tigris River within Baghdad by index analysis. Journal of Water Resource and Protection, Vol. 2, pp. 629 – 635, 2010.

[3] Cude C., Oregon Water Quality Index: a tool for evaluating water quality management effectiveness, Journal of American Water Resource Association, Vol.37, No.1. 2001.

[4] Brown R. M., Clelland N. I. Mc., Deininger R. A. and Tozer R. G., A water quality index - do we dare. Water and Sewage Works, vol. 2, pp. 339-343, 1970.

[5] CCME (Canadian Council of Ministers of the Environment). Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. 2001.

[6] Kannel P. R., Lee S., Lee Y. S, Kannel S. R. and Khan S. P., Application of water quality indices and dissolved oxygen indicators for river water classification and urban impact assessment. Environmental Monitoring and Assesment, Vol. 132, pp.93-110, 2007.
[7] Rahman Z. A., Water Quality Management in Malaysia. Department of Environment Malaysia. Article retrieved in 2002 from internetwebsite:http://www.iges.or.jp/jp/ltp/pdf/fr2.pdf.
[8] Al-Shujairi S. H., Develop and apply water quality index to evaluate water quality of Tigris and Euphrates Rivers in Iraq., International Journal of Modern Engineering Research, 3 (4), 2119, 2013.
[9] DOE (Department of Environment Malaysia). Malaysia Environmental Quality Report 2000. Department of Environment, Ministry of Science, Technology and Environment Malaysia, pg 86. Maskha Sdn. Bhd: Kuala Lumpur. 2001.
[10] Kim A.G and Cardone C. R., Scatterscore a reconnaissance method to evaluate changes in water quality. Environmental Monitoring and Assessment, Vol. 111, pp.207-295, 2005.
[11] Liou S.M., Lo S. L. and Wang S. H., A generalized water quality index for Taiwan. Environmental Monitoring and Assessment, vol 96, pp. 35-32, 2004.
[12] Meher P.K., Sharma P., Gautam Y. P., Kumar A. and Misha K. P., Evaluation of water quality of Ganges River using water quality index tool. Environment Asia, 8 (1), 124, 2015.
[13] Sargaonkar A. and Deshpande V. Development of an overall index of pollution for surface water based on a general classification scheme in the Indian context. Environmental Monitoring and Assessment, Vol. 89, pp. 43-67, 2003.
[14] Tsegaye T., Sheppard D., Islam K. R, Johnson A. W., Tadesse, Atalay A. and Marzen L. Development of the chemical index as a measure of in-stream water quality in response to land use and land cover changes. Water, Air, and Soil Pollution, Vol.174, pp. 161-179, 2006.
[15] Sari I. and Omar W. M. M., Assessing The Water Quality Index of Air Itam Dam, Penang, Malaysia, Proceeding of International Conference on Environmental Research and Technology (ICERT), pp. 601-605, 2008.
[16] Effendi H., Telaah Kualitas Air: Bagi pengelolaan sumber daya dan lingkungan perairan, pp. 19, 2003.
[17] Republik Indonesia. Peraturan Pemerintah Nomor 82 Tahun 2001. *Tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air*. Jakarta; Sekretaris Negara. 2001.
[18] Hemakumara, GPTS, and Rainis, Ruslan. Geostatistical modeling to evaluate the socio-economic impacts of households in the context of low-lying areas conversion in Colombo metropolitan region-Sri Lanka. Paper presented at the AIP Conference Proceedings. 2015.