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GIS-based analysis of water quality deterioration in the Nerus River, Kuala Terengganu, Malaysia

Hassan Mohammed Ali Alssgeer[a], Muhammad Barzani Gasim[a], Marlia M. Hanafiah[b,*], Elhadi Ramadan Ali Abdulhadi[c], Azman Azid[a]

[a]*East Coast Environmental Research Institute (ESERI), University Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia*
[b]*School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia, email: mhmarlia@ukm.edu.my*
[c]*School of Social, Development and Environmental Studies, Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia*

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ABSTRACT

The Nerus River Basin is located on the east coast of Peninsular Malaysia passes through the populated urban area of northern region of Kuala Terengganu, Malaysia. Over the last 10 years, the Nerus River has experienced population growth and rapid development, resulting in large-scale of land use changes. Changes in land use cause deterioration of the water quality of the Nerus River. This study aimed to estimate land use changes from the past condition (2000–2013) and the present condition (2016) within the Nerus River using geographical information system and statistical approaches. Main factors such as seasonal changes and pollution sources were included in the analysis. The monitoring of water quality was done based on three sampling stations during both dry and wet seasons, involving analysis of six water quality parameters (pH, dissolved oxygen, BOD, chemical oxygen demand, NH_3–N, and total suspended solids). Water quality classification is using the National Water Quality Standard for Malaysia and the Water Quality Index. Multivariate statistical technique such as principal component analysis was conducted to determine sources of water pollution, to evaluate the similarities and dissimilarities between sampling stations, and to determine the influence of sources of pollution on the water quality parameters of the Nerus River based on the available land use database. Overall, the river was classified as Class III (slightly polluted) in accordance with previous studies.

Keywords: Water pollution; Water quality; GIS-based analysis; Nerus River; Malaysia

1. Introduction

Water is the most precious gift of nature and considered as the main element for all living organisms. River water continues to be able to sustain all human beings and other organisms for centuries [1]. Water quality is an important factor to determine environment changes, which are strongly associated with social and economic development [2]. However, water quality in many large rivers in many countries has been deteriorated significantly due to anthropogenic activities in the past few decades [3,4]. River water quality has gained significant attention and is being contaminated due to various human activities, and it needs an urgent effort to ensure its sustainability and safe use [5].

Rivers as one of the substantial arteries for human survival have a significant role in the genesis and development of human societies [6]. Besides, rivers play a significant role in assimilating or conveying municipal and industrial wastewater as well as agricultural runoff. Generally, discharge from municipal and industrial wastewater is the main source

* Corresponding author.

of pollution, whereas surface runoff is a seasonal phenomenon, significantly affected by climate within the river [7]. River is required in almost all the activities of mankind for drinking and municipal use, irrigation to meet the needs of growing food, industries, power generation, navigation, and recreation [8]. The river also plays as an important asset for economic resources due to the important role of water and its contribution, thus more attention need to be given for water quality and its pollutants [9]. In Malaysia, the riverine ecosystem is of particular interest because river water provides about 98% of the country's water requirements. A preliminary study of water quality status in Nerus River in Terengganu, Malaysia, has been conducted previously, and the results showed that the increase in human population density and the development of industries along the river and coastal areas have increased the pollutant inputs and deteriorated the water quality in the surrounding area [10–12].

The municipal and industrial wastewater discharge, land use, eroded soils, and atmospheric pollution are among common major factors of human activities in evaluating the quality of water bodies [13,14]. There is correlation when examining the changes made to an area of land for human needs and the effects that these modified landscapes have on water quality within a watershed. By sampling and quantifying the effects that land use and land cover have on water quality, we can develop recommendations for better watershed management to ensure the quality of our surface waters. Over large parts of the world, rivers and lakes show increasing trends of water pollution. This holds especially for developing countries under economic expansion and increasing population size. Evaluation of the physical, chemical and biological water pollution is essential for the abatement of freshwater pollution [4]. Land cover and land use are very important elements in relation to water quality. Different types of land use and land cover affect the quality of water. Agricultural and household fertilizers have different chemicals within them, such as nitrogen and phosphorus. These chemicals can potentially run off into nearby water sources such as groundwater, streams, and larger bodies of water. In turn, this could damage the nutrient content within that water supply, affecting the overall water quality itself. Excessive concentrations of these variables may result in diverse problems in the aquatic ecosystem such as loss of oxygen, an increase in the extent of algal blooms and general loss of biodiversity. Pollutants enhancement critically deteriorate domestic water supply, agriculture, industry, recreation, and other purposes [15].

Chemical pollution caused by discharge into river mainly comes from organic and inorganic materials. For organic, it may source from degradable and non degradable substances. The most dangerous among these is the non-bio degradable materials (plastics, etc.), which will accumulate and remain toxic across the time. These advanced products do not break down and naturally dissolve in the surrounding land or soil. It requires a very high-cost technology and involves another dangerous chemical to degrade them. As for inorganic compounds, they mainly come from the extraction of mineral fuels, minerals, building materials, cleaning workshops, processing, and packaging of these minerals or materials [16]. Rain also plays a very important role in contributing to urban pollution where it washes away the pollutants in the atmosphere originated from vehicle fumes, boiler, factories, and industrial sites. The rain gets all the pollution that dispersed into the air when it starts to rain. It also washes industrial and urban soils such as factories, highways, parking lots, airports, etc. that contaminated with pollutants such as hydrocarbons, lead, and zinc, which finally end up in the river [17].

The major pollution that affects the river in Malaysia attributed from sewage disposal, small- and medium-sized industry effluents, land clearing, logging, and other earthwork activities. Up to 42% of suspended solids were contributed by poorly planned and uncontrolled land clearance activities alone, while 30% of biological oxygen demand (BOD) from industrial discharges, and 28% of ammoniacal nitrogen due to animal farming activities and domestic sewage disposal [18]. In addition, different human activities have influenced aquatic ecosystems as a result of the discharge of toxic chemicals, modification in hydrology, alternations of physicochemical water characteristic as well as increase in nutrient inputs. Activities related to urbanization and agriculture are basically the main contributors to alterations in the chemical composition of aquatic habitats [3,4]. The scarcity of water has become a major issue due to the fast population growth, summed to the degradation of water resources caused by human activities across the world. A continuous monitoring of water quality is essential to determine the state of pollution in rivers [19].

Water Quality Index (WQI) is defined as the characteristics of water in terms of its biological, physical, and chemical components to measure the condition of water to be consumed by human and other living organisms [20]. The Department of Environment (DOE)-WQI scale classifies the water quality as "clean," "slightly polluted," and "polluted" if the DOE-WQI falls within the range of 81%–100%, 60%–80%, and 0%–59%, respectively. This study adopted the DOE-WQI standard to evaluate the water quality of the Nerus River in Terengganu during 2000, 2013 and 2016. In addition, the beneficial use of the water was also compared with the classification based on the National Water Quality Standards (NWQS). High population, rapid urbanization, and industrialization have reduced the water quality of rivers because of indiscriminate dumping of wastes by all water user sectors into the rivers while the increased rate of erosion as a result of land development cause the siltation of rivers [19]. Geographical Information System (GIS) and WQI, which synthesize different available water quality data into an easily understood format, provide a way to summarize overall water quality conditions in a manner that can be clearly communicated to policy makers [21]. In Malaysia, the classification of rivers by the DOE is based on a WQI. GIS is a computer-based technology for handling geographical data in digital form. It is designed to capture, store, manipulate, analyze, and display diverse sets of spatial or georeferenced data [22,23]. As a spatial analysis tool, GIS has been successfully applied in almost all areas where spatial information has been collected [24].

The Nerus River is one of the most important rivers in Kuala Terengganu, Peninsular Malaysia. The Nerus River plays an essential role in the daily lives of local people as it supplies water for irrigation of agricultural land and supports freshwater aquaculture as well as provides water for domestic usage. Therefore, the study of water pollution of the river is of particular importance because the river receives huge effluents from livestock farms, industrial, and agricultural activities as well as urban runoff, which cause deterioration of the river water quality [25]. Most of the environmental problems occurring in the watershed are due to anthropogenic sources rather than natural causes. For example, water pollution is due to two main factors, that is, from the development of the land and natural resources and the discharge of undesirable waste products and effluents into watercourses [26]. In general, the composition of surface runoff in the drainage area is considered as the initial cause of the change in the quality of the Nerus River [27]. This study aimed to determine WQI of the flowing water in the Nerus River based on the NWQS for Malaysia and the WQI for three different years (2000, 2013, and 2016). GIS tool was applied to classify the water areas and its water quality at the Nerus River for the selected years. Furthermore, multivariate statistical technique such as principal component analysis was conducted to determine sources of water pollution, to evaluate the similarities and dissimilarities between sampling stations and the water quality.

2. Methodology

2.1. Study area

The study area was located in the east coast of Peninsular Malaysia, in Kuala Terengganu city between latitude of 103°00′E–103°06′E and longitude of 05°13′N–05°23′N, encompassing a total area of 851 km^2. The origin of the river starts at Gunung Sat and flows southeastern toward the mouth of Nerus River which discharges its water into Terengganu River estuary before finally discharging into the South China Sea [25]. It belongs to the subtropical zone with a mean annual temperature ranging from 26°C to 28°C and a mean annual precipitation from 1,200 to 3,500 mm [28]. The river water is used for irrigation, domestic water supply, industrial, and other uses. The river flows through villages, farms, and palm oil factories. It also passes through the populated urban area of northeastern Kuala Terengganu, thus receives and carries different kinds of agricultural and urban solid and liquid wastes produced by agricultural based industries and domestic sewage [27,28]. In this study, three sampling stations were selected along the river, from the upstream to downstream, and the selection criterion of the sampling locations was based on the characteristics of the water condition, land use, and anthropogenic activities along the Nerus River.

2.2. Physico-chemical analysis

Water quality data for years 2000 and 2013 that were used in this study were obtained from the Ministry of Environment of Malaysia [29], while data for the year 2016 were obtained through the sampling and laboratory work. The data obtained were collected at regular time intervals. The six selected water quality variables used in this study include dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal-nitrogen (NH_3–N), total suspended solids (TSS), and pH. The WQI formula developed by the DOE Malaysia [30] was used as a basis for the determination of the water quality at Nerus River as follows:

$$\text{WQI} = 0.22{*}\text{SIDO} + 0.19{*}\text{SIBOD} + 0.16{*}\text{SICOD} + 0.15{*}\text{SIAN} + 0.16{*}\text{SISS} + 0.12{*}\text{SIpH}$$

where WQI is water quality index, SIDO is subindex of dissolved oxygen, SIBOD is subindex of biological oxygen demand, SICOD is subindex of chemical oxygen demand, SIAN is subindex of ammoniacal nitrogen, SISS is subindex of suspended solid, and SIpH is subindex of pH value.

Table 1 shows the color indicator used in the GIS map of the Nerus River according to the WQI classification. ArcGIS software 10.2 used to store the information about the study area as a collection of thematic layers that can be linked together by geography. The GIS maps representing WQI of the Nerus River in Kuala Terengganu are shown in Figs. 2–7 for the years of 2000–2013 and 2016 for the three stations. The sampling locations were integrated with the water data for the generation of spatial distribution maps [23].

Analysis of correlation was conducted to identify the relationships among the water quality parameters. One-way analysis of variance (ANOVA) (one way-ANOVA, $p < 0.05$) was used to measure the variation of water quality parameter among stations and between years 2000, 2013, and 2016. The ranges, mean values, and standard deviations of the six water quality parameters were analyzed in this study. Significant differences ($p < 0.05$) for six water quality parameters between the years 2000, 2013, and 2016 were identified. All the mathematical and statistical computations were conducted using EXCEL 2007 (Microsoft Office10) and SPSS software.

3. Results and discussion

The water quality of the Nerus River was recorded between the years 2000, 2013, and 2016 to investigate the

Table 1
Color indicator for WQI used in the GIS map

WQI value	Water quality	
50 > WQI	Excellent	Dark blue
50 < WQI < 100	Good	Blue
100 < WQI < 200	Poor	Green
200 < WQI < 300	Very poor	Yellow
300 < WQI < 400	Polluted	Orange
WQI > 400	Very polluted	Red

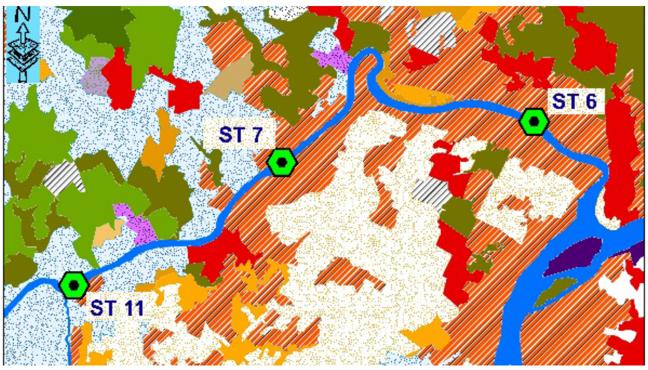

Fig. 1. The sampling sites at Nerus River, Kuala Terengganu in Malaysia.

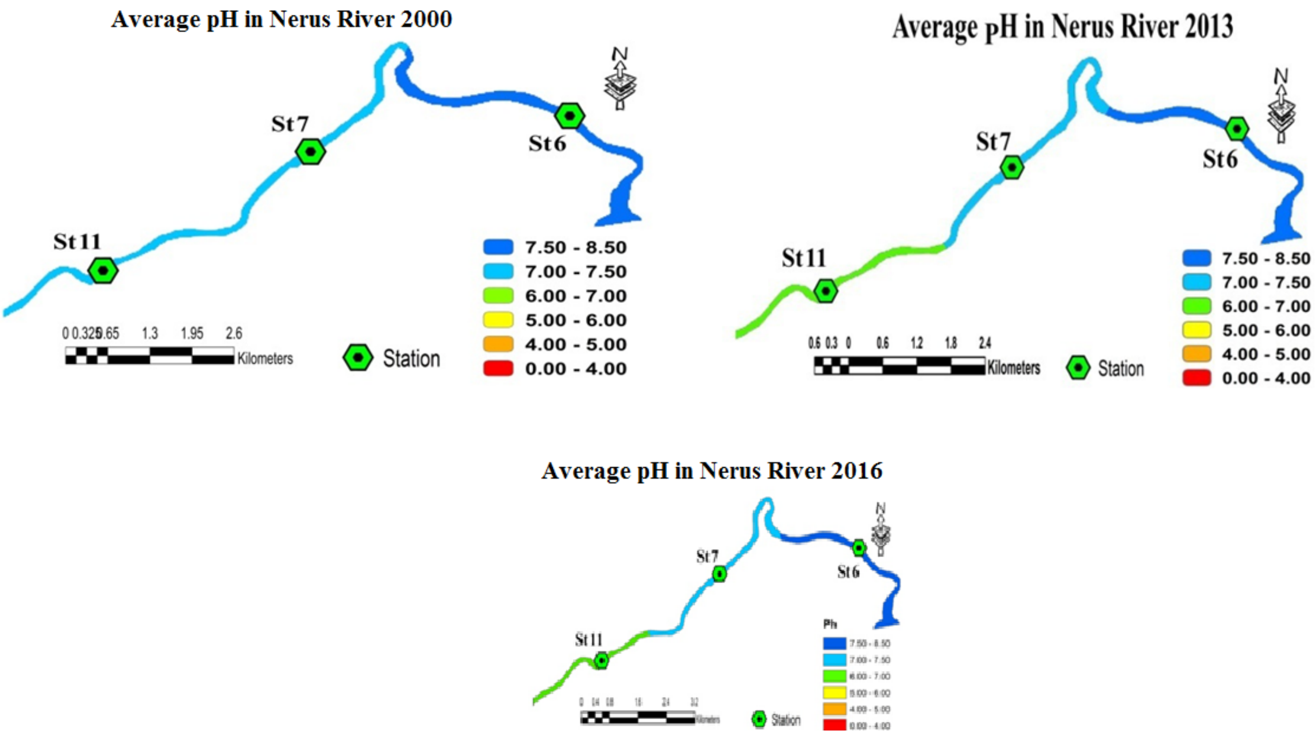

Fig. 2. Average pH value in Nerus River between years 2000, 2013, and 2016.

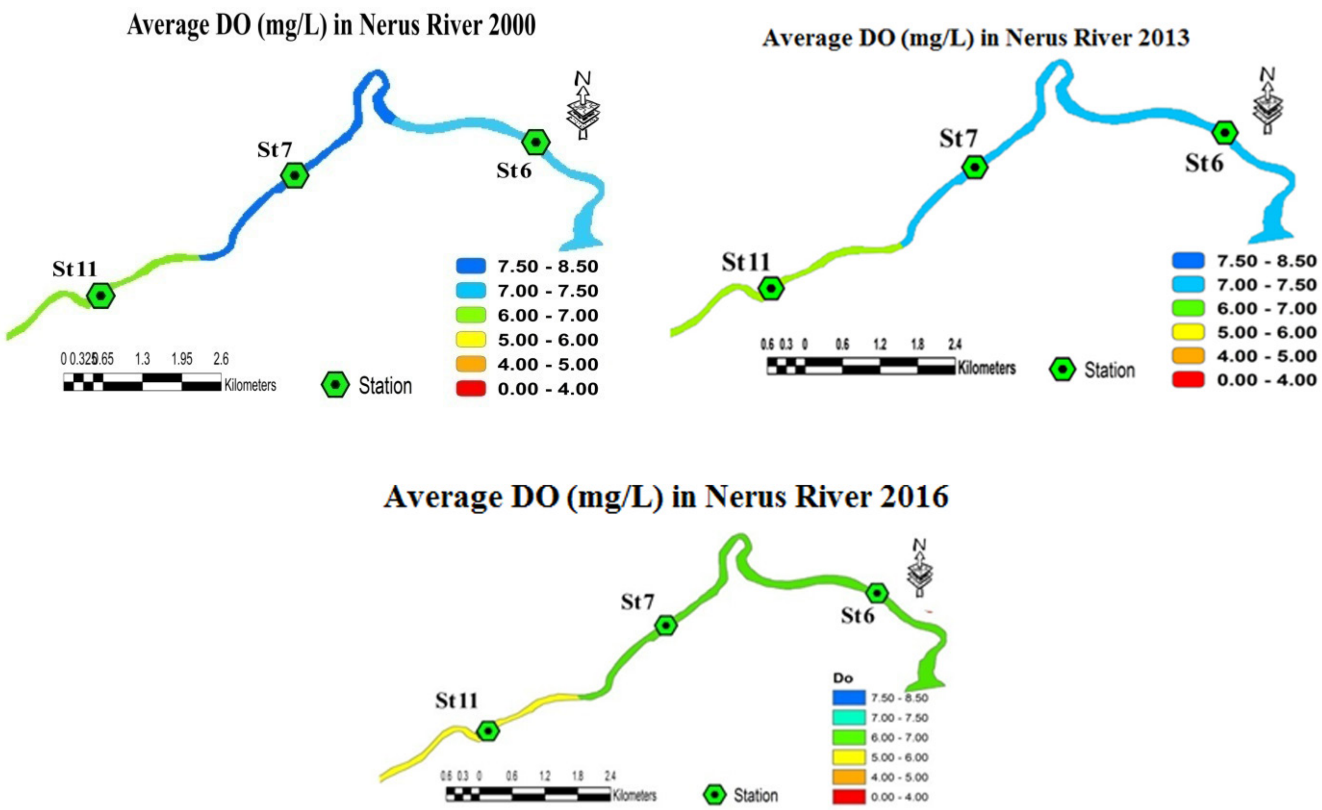

Fig. 3. Average DO (%) value in Nerus River between years 2000, 2013, and 2016.

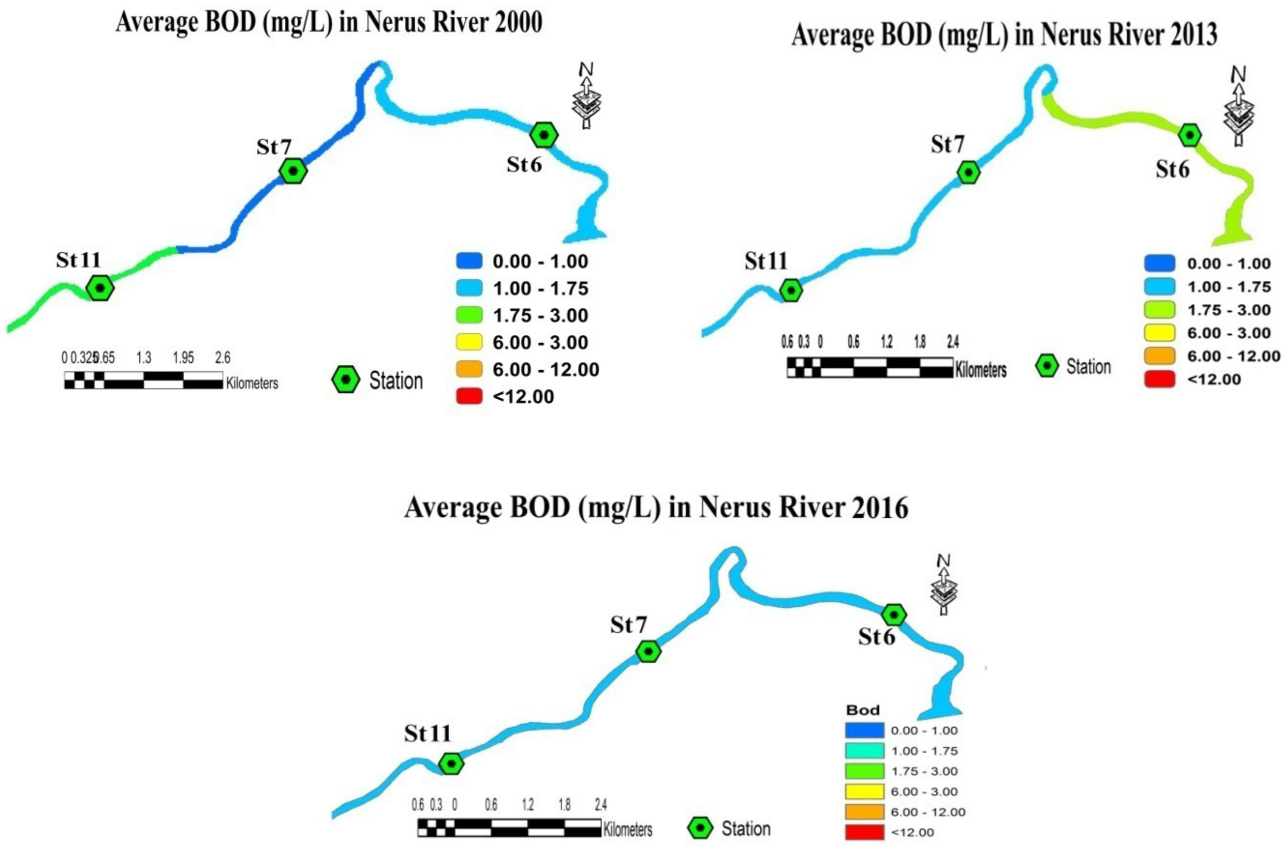

Fig. 4. Average BOD value in Nerus River between years 2000, 2013, and 2016.

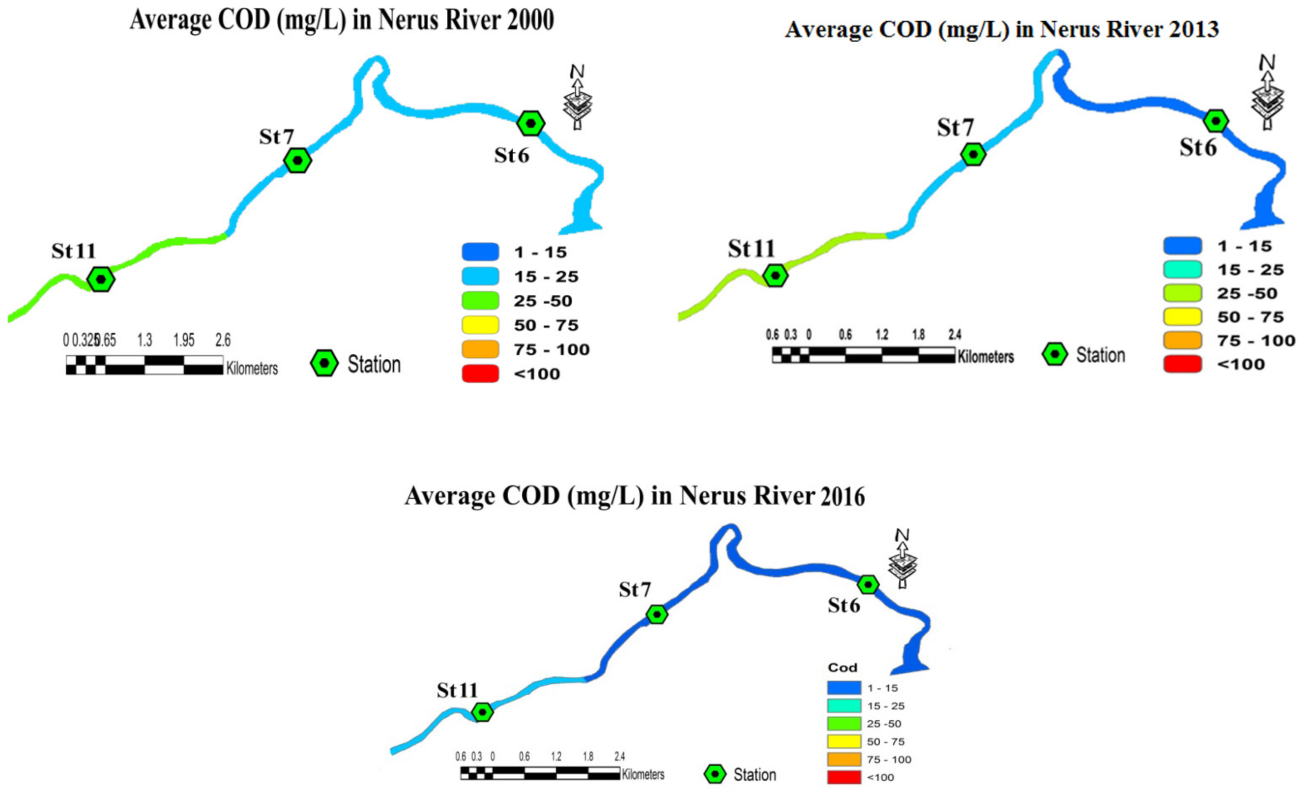

Fig. 5. Average COD value in Nerus River between years 2000, 2013, and 2016.

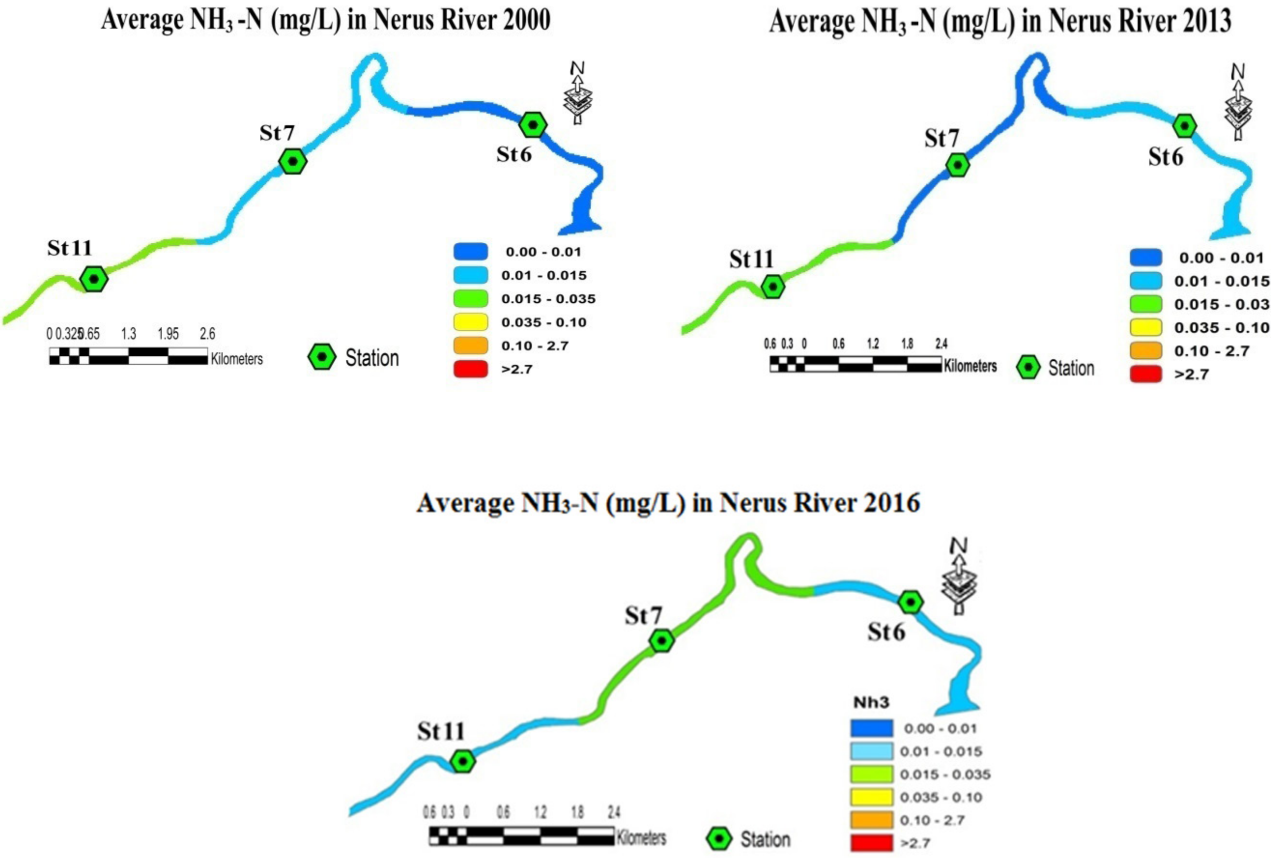

Fig. 6. Average NH_3–N value in Nerus River between years 2000, 2013, and 2016.

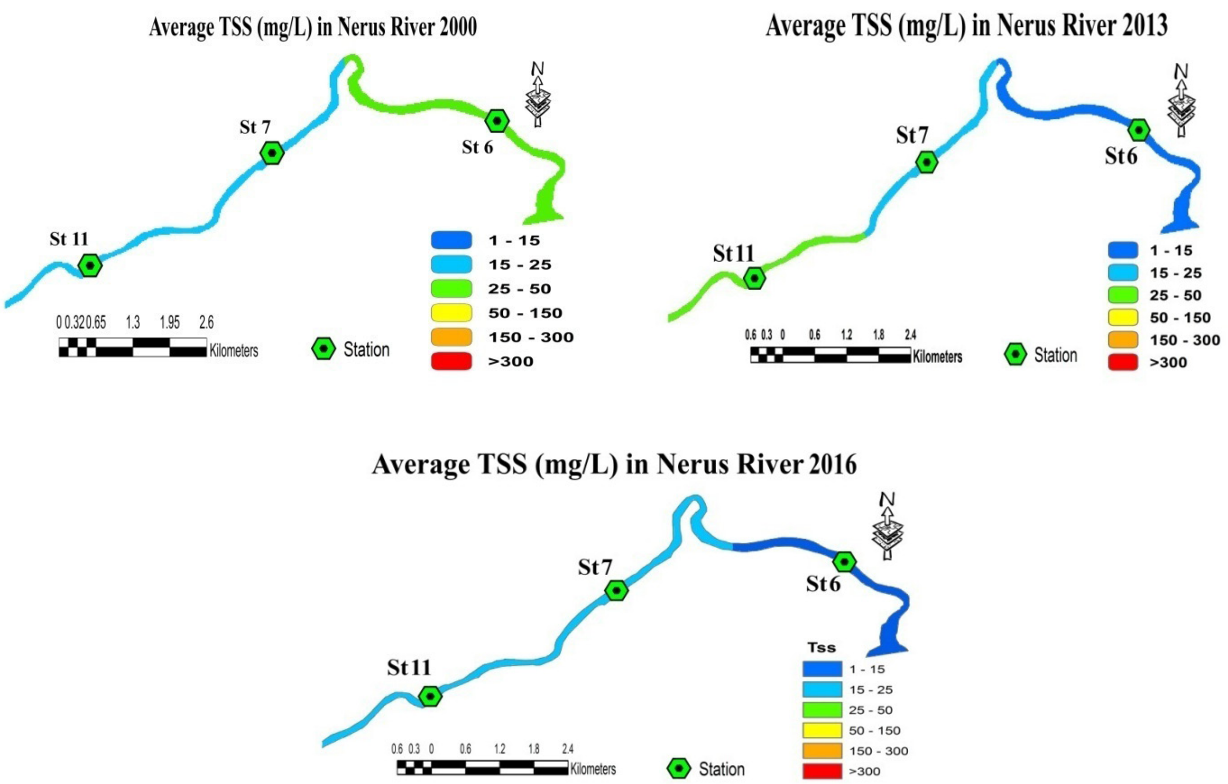

Fig. 7. Average TSS value in Nerus River between years 2000, 2013, and 2016.

spatial changes of the qualitative parameters in the Nerus River. Table 2 illustrates the mean value of six water quality parameters and compared with the NWQS. The classifications of water quality of most of the parameters measured were remained at classes II and III which are suitable for the sustainable conservation of the natural environment and suitable for irrigation and agriculture. The results of the study indicate that land use activities have significantly influenced water quality variations. Based on the GIS maps and combinations of water quality indices, differences in upstream, middle, and downstream river sections were identified in the Fig. 1.

The pH value of the aquatic system is an important indicator of the water quality and the extent pollution in the watershed areas [31]. In this study, the pH values varied from a maximum of 7.21 at sampling Station 6 to the minimum of 6.17 at Station 6 in year 2000 (with an average of 6.63). The average value of pH in 2013 was 5.99, which was ranged from 4.36 at sampling Station 11 to 6.99 at Station 6, whereas, in 2016, the maximum pH was found at sampling Station 6 (6.70) and the minimum value was obtained at sampling Station 11 (4.58) with an average of 5.43 (Fig. 2). Two-factor ANOVA test showed that the pH values were not significantly different ($p > 0.05$) between the selected years (df = 2, $F = 3.364$, $P = 0.062$) as shown in Table 2. In general, there was an increasing trend of pH values in going from the upstream station to the downstream station. The correlation analysis showed a very strong positive correlation ($r > 0.7$, $P < 0.05$) between pH, DO, and BOD; and on the other hand, pH showed a negative correlation ($r < 0.7$, $P > 0.05$) with COD, TSS, and NH_3–H (Table 4). Moreover, based on NWQS classifications, the pH values for most of the stations in 2000 and 2013 were in Class II with the exception of 2016 which was in Class III. Generally, the pH concentration increases as a result of the photosynthetic algae activities that consume dissolved carbon dioxide [32], due to the seasonal variation in rainfall that decreases pH throughout the rainy period and then increases to its highest levels during the dry period [33]. Overall, the range of pH from 6.5 to 8.5 is mainly appropriate for aquatic life. Therefore, it is important to maintain the aquatic ecosystem within this range because higher or lower pH can be destructive to the sensitive aquatic organisms [34,35].

DO is one of the important indicators in determining the quality of water. In this study, the maximum DO was 94.50% at Station 7 and the minimum value was 37.5% at Station 11, an average of 78.16% in 2000. As for 2013, the average value was 76.27%, with minimum and maximum values recorded at 49.70% at sampling Station 11 and 91.50% at sampling Station 6, respectively. The minimum value in 2016 was found at 32.10% (sampling Station 11) and the maximum value for the same year was recorded at 66.30% (sampling Station 6), with an average of 58.01% (Fig. 3 and Tables 2 and 3). The low values of the DO at Station 11 are attributed to the palm oil, untreated sewage from the residential area due to the lack of treatment, surface runoff from animal farms, and fertilizer runoff from agricultural areas along the river. The increase ratios in the DO level toward downstream were due to the discharge of pollutants (organic, inorganic, biological matter) from the urban areas at Terengganu River. The ANOVA test showed that the values were not of significant difference ($p > 0.05$) in the mean DO levels between parameters and

Table 2
The physical–chemical characteristics of Nerus River in different years (2000, 2013, and 2016) and classification of Malaysian Water Quality Index

Parameters	Year 2000				Year 2013				Year 2016				F	df	Significance
	Range	Mean	Standard	Class	Range	Mean	Standard	Class	Range	Mean	Standard	Class			
DO, %	94.5 – 37.5	78.16	21.2	II	49.70 – 91.50	76.27	16.5	II	32.10 – 66.30	58.01	13.65	II	2.449	2	0.120
pH	7.21 – 6.17	6.63	0.41	I	4.36 – 6.99	5.99	1.11	II	4.58 – 6.70	5.43	0.72	III	3.364	2	0.62
BOD, mg/L	1.00 – 5.50	2.00	1.76	II	2.50 – 4.00	3.25	0.61	II	1.38 – 2.19	1.74	0.28	II	3.279	2	0.066
COD, mg/L	15.00 – 24.00	19.75	3.40	II	13.5 – 33.00	20.20	7.11	II	11.67 – 29.33	19.91	7.83	II	0.008	2	0.992
TSS, mg/L	9.50 – 163.5	57.5	63.21	III	17.00 – 109.00	42.58	34.82	II	18.33 – 44.17	26.25	9.63	II	0.830	2	0.455
NH_3–N, mg/L	0.01 – 0.99	0.24	0.40	III	0.06 – 0.36	0.19	0.12	II	0.19 – 0.55	0.30	0.14	II	0.236	2	0.793

different years (ANOVA, $P = 0.120$, df = 2, $F = 2.449$) (Table 2). In addition, the correlation analysis showed a very strong negative correlation ($r < 0.7$, $P > 0.05$) between DO and COD, NH_3–N but showed a positive correlation ($r > 0.7$, $P < 0.05$) with pH, BOD, and TSS during different years (Table 4). The DO value was lower in 2016 compared with 2013, while the highest value was found for the year 2000.

The highest concentrations of BOD were found in the upstream and downstream stations with the highest concentration of BOD at 5.5 mg/L (upstream Station 11) and the lowest concentration of BOD at 1.00 mg/L (station 6 and 7), with an average of 2.00 mg/L in 2000. In 2013, Station 6 recorded the highest BOD (4 mg/L) and the lowest value was found at sampling stations 7 and 11 (2.50 mg/L), with an average of 3.25 mg/L. The lowest BOD in 2016 was obtained at 1.38 mg/L at Station 7, while the highest value of 2.19 mg/L was observed at Station 7 (average of 1.74 mg/L) (Fig. 4 and Tables 2 and 3). Analysis using one-way ANOVA showed no significant differences in BOD (ANOVA, $p > 0.05$, $P = 0.66$, df = 2, $F = 3.279$). On the other hand, the correlation analysis showed a very strong positive correlation ($r > 0.7$, $P < 0.05$) between BOD and all of the water quality parameters for all different years (Table 4).

BOD concentrations are known to increase in the presence of organic content, which encourages the growth of micro-bacteria. High BOD in areas of horticultural land use (villages) may be attributed to faulty sewer systems and non-point source pollution discharges. Sources of organic contamination include leaky sewer pipes, combined sewer overflows and livestock waste in adjacent areas, as well as agricultural runoff and leaky septic tanks in villages [36]. The results obtained in the present study showed that the BOD at stations 6, 7, and 11 were classified under Class II.

COD is a very important parameter when evaluating water quality with respect to the presence of organic and inorganic pollutants. In 2000, the highest value of 24.00 mg/L was recorded at Station 7 and the minimum value of 15.00 mg/L was found at sampling Station 6 (average of 19.75 mg/L). The COD values varied from a maximum of 33.00 mg/L at Station11 in 2013 to a minimum of 13.5 mg/L at the Station 6, with an average of 20.20 mg/L (Fig. 5 and Tables 2 and 3). In 2016, the maximum COD value was found at Station 7 (29.33 mg/L) and the minimum value was 11.67 mg/L at Station 11, with an average of 19.91 mg/L. Two-factor ANOVA test showed that the COD values were not significantly different ($p > 0.05$) between different years (df = 2, $F = 0.008$, $P = 0.992$). In general, there was a decreasing trend of COD values from the upstream to the downstream stations due to the storm water runoff related to the land use activities, which is loaded with high concentrations of organic and inorganic matter (Table 2). In addition, the correlation analysis showed that COD has a very strong positive correlation

Table 3
The physical–chemical parameters of Nerus River in different years (2000, 2013, and 2016)

Year	pH		DO (%)		COD (mg/L)		BOD (mg/L)		TSS (mg/L)		NH_3–NL (mg/L)	
	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep
Station 6												
2000	6.17	7.21	88	87.45	21	15	1.5	1	163.5	9.5	0.01	0.01
2013	6.99	6.91	85.25	79.4	13.5	17.25	4	3.5	20	26	0.18	0.16
2016	6.7	5.2	65	66.3	28.5	15	1.78	1.7	18.33	26	0.2	0.38
Station 7												
2000	6.54	7.01	94.5	88.85	19	17	1	1	100.5	10	0.04	0.01
2013	6.38	6.47	91.5	89	15	19.5	3.5	2.5	52	17	0.06	0.08
2016	5.46	5	53.23	65.2	29.33	13	2.19	1.38	28.33	22	0.23	0.55
Station 11												
2000	6.68	6.21	37.5	72.7	22.5	24	2	5.5	9.5	52	0.44	0.99
2013	4.36	4.86	49.7	62.8	23	33	2.5	3.5	31.5	109	0.36	0.35
2016	5.67	4.58	32.1	66.27	22	11.67	1.53	1.9	18.67	44.17	0.19	0.25

Table 4
Correlation matrix of water quality during different years (2000, 2013, and 2016)

Parameter	pH	DO (% sat)	BOD (mg/L)	COD (mg/L)	NH_3–NL (mg/L)	TSS (mg/L)
pH (unit)	1.000					
DO (% sat)	0.509	1.000				
BOD (mg/L)	0.015	0.052	1.000			
COD (mg/L)	–0.157	–0.418	0.195	1.000		
NH_3–NL (mg/L)	–0.179	0.292	0.045	0.257	1.000	
TSS (mg/L)	–0.374	–0.43	0.548	0.208	–0.112	1.000

($r > 0.7$, $P < 0.05$) with BOD, TSS, and NH_3–N. Additionally, COD indicated a strong negative correlation ($r < 0.7$, $P > 0.05$) with pH and DO during different years (Table 4). Finally, the total mean value COD of the Nerus River was classified as Class II. Normally, the concentration of COD in the surface water can be 20 mg/L or less in unpolluted water. Thus, the high COD value implies the occurrence of the oxidation of organic and inorganic matter [37].

Urban areas and cultivated lands are primarily located along the river, with their impact on the concentration of NH_3–N in Nerus River as expected. NH_3–N concentrations increased in Station11 in 2000 to a maximum of 00.99 mg/L, while the lowest value of 0.01 mg/L was found at stations 6 and 7 with the average of 0.24 mg/L. In year 2013, Station 11 recorded the highest value of 0.36 mg/L and the lowest value at 0.06 mg/L at sampling Station 7 with the average of 0.19 mg/L. The lowest value of NH_3–N in year 2016 was obtained at 0.19 mg/L at Station 11, while the highest value of 0.55 mg/L was found at Station 7 (with an average of 0.30 mg/L) (Fig. 6 and Tables 2 and 3). Excessive agriculture and development activities in these areas together with the accumulation of household wastes, untreated sewage, and industrial effluents have influenced the increased of NH_3–N in Nerus River. Analysis using one-way ANOVA showed no significant differences in BOD (ANOVA, $p > 0.05$, $P = 0.793$, df = 2, $F = 0.236$). The correlation analysis showed a very strong positive correlation ($r > 0.7$, $P < 0.05$) between NH_3–N, BOD, and COD, but a negative correlation ($r < 0.7$, $P > 0.05$) was observed with pH, DO, and TSS for the different years (Table 4).

In the present study, NH_3–N concentrations were found within classes II and III derived from possible diffuse sources of pollution such as agricultural activities. Indeed, the widespread usage of fertilizers and improper management of farming activity in the region may lead to considerable diffuse of NH_3–N pollution triggered by rainwater. There was a positive relationship between NH_3–N with BOD and COD due to the NO_3 that being the final oxidation product of nitrogen [38].

Higher average concentrations of TSS were observed at monitoring stations located at the downstream from sewage effluent discharge points compared with stations located at the upstream. The TSS of the Nerus River varied from 9.50 to 163.50 mg/L, with the average concentration of TSS at 57.5 mg/L. The highest and lowest values were recorded at stations 6 and 11, respectively, in 2000 (Fig. 7 and Tables 2 and 3). In 2013, the average value was 42.58 mg/L, with the highest value was found at 109.00 mg/L at Station 11 and the minimum value of 17.00 mg/L at Station 7. The maximum value for year 2016 was found at 44.17 mg/L at sampling Station 11 and the minimum value was recorded at 18.33 mg/L at sampling Station 6 (average of 26.25 mg/L) (Fig. 7 and Table 2). Two-factor ANOVA test showed that the TSS values have no significant differences ($p > 0.05$) between different years (df = 2, $F = 0.830$, $P = 0.455$). The correlation analysis showed a very strong positive correlation ($r > 0.7$, $P < 0.05$) between TSS, DO, BOD, and COD, however showed a negative correlation ($r < 0.7$, $P > 0.05$) with pH and NH_3–N for the different years (Table 4).

In general, there was a decreasing trend of TSS values from the upstream to the downstream stations. Based on NWQS classifications, the TSS values for most of the stations were classified in Class III in 2000 and Class III in 2013 and 2016. The INWQS recommends maximum value of 50 mg/L, with the INWQS threshold level of TSS for supporting aquatic life in freshwater ecosystems is 150 mg/L [39]. The results for the six parameters of water quality analyzed in the study area are shown in Tables 2 and 3. Overall, the anthropogenic pollution sources were the main reason of the water quality deterioration in the Nerus River [40]. The WQI calculation of the water classification for the three stations (6, 7, and 11) for the three different years were reported within Class II and Class III.

4. Conclusions

Evaluation of the relationship between water quality and GIS-based analysis in the Nerus River basin was conducted in this study. In addition, the detailed dynamic characterization of pollution sources of a particular importance was examined to identify and control new pollution sources. The relationship between land use and water quality in the dry and rainy seasons was based on data from three sampling stations sampled along the Nerus River. The multivariate statistical technique and GIS mapping provided the relationship between land use and water quality, showing that forested land use was negatively associated with nutrients and organic parameters, while the relationship between land use and water quality shows that urbanization was a key factor affecting the river water quality, followed by horticultural anthropogenic activities (rural area) which are often in the vicinity of rivers, due to higher urbanization and agricultural activities. GIS results showed greater significance for the sampling site groups (land-use activities) than for the sampling events. This technique provided the base and overlay maps. Digital scanning plus tablet and on-screen digitizing techniques that were applied to all the maps indicated that the sources of pollution were there during 2000, 2013, and 2016 sampling events and were clearly marked by variations in the concentration of the following parameters: pH, DO, TSS, COD, BOD, and NH_3–N in the Nerus River that were colored slightly suitable for agriculture, irrigation, and domestic use according to INWQS levels by the Malaysian DOE. The WQI calculation of the water classification for the three stations (6, 7, and 11) showed that they fall within the Class II for all six water quality standards during years 2000, 2013, and 2016, except for TSS and NH_3–N were classified in Class III in year 2000 and pH was recorded at Class III in year 2016.

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