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Ecosystem Health Assessment of Sungai Pengkalan Chepa Basin: Water Quality and Heavy Metal Analysis

(Penilaian Kesihatan Ekosistem Lembangan Sungai Pengkalan Chepa: Analisis Kualiti Air dan Logam Berat)

MOHD SAIFUDDIN MALIKI ABDULLAH*, MALIKI HAPANI, NUR FATIEN MUHAMAD SALLEH & WAN MOHD SAHNUSI WAN ALIAS

ABSTRACT

This study was to determine the ecosystem health status at Sungai Pengkalan Chepa Basin based on Water Quality Index (WQI) and heavy metal concentration in the river water. Water samples were collected from 11 stations along the river and they were analyzed using YSI 556 MPS and laboratory analysis for in-situ *test and* ex-situ *test, respectively. Meanwhile, heavy metal concentrations were analyzed using AAS. Water sampling was carried out starting from November 2018 until June 2019. The results for total median value of water quality parameters were as follows; DO (2.72 mg/L), BOD (6.42 mg/L), COD (33.5 mg/L), AN (1.02 mg/L), TSS (27 mg/L), and pH (6.97). According to WQI, Sungai Pengkalan Chepa Basin is classified under Class III, therefore, it is considered as slightly polluted. The order of concentration of heavy metals in water is Fe > Cr > Zn > Cu > Cd. Most of the heavy metals were found within the permitted level of National Drinking Water Quality Standard (NDWQS) except for Cd. Based on the Kruskal Walis test, there was a significant difference between parameters namely DO, BOD, COD, AN, pH, Zn, and Cd with sampling locations ($\rho < 0.05$). Based on this study, it can be concluded that the ecosystem health of Sungai Pengkalan Chepa Basin is not healthy from the aspects of DO, BOD, COD, AN, and Cd. The water quality status of Sungai Pengkalan Chepa Basin was mainly affected by the anthropogenic activities from urban development.*

Keywords: Ecosystem health; heavy metal; river water quality; water quality index

ABSTRAK

Kajian ini dijalankan untuk menentukan status kesihatan ekosistem di Lembangan Sungai Pengkalan Chepa berdasarkan Indeks Kualiti Air (IKA) dan kepekatan logam berat di dalam air sungai. Sampel air diambil dari sebelas stesen persampelan di sepanjang lembangan sungai dan dianalisis menggunakan YSI 556 MPS untuk ujian in-situ *dan analisis makmal untuk ujian* ex-situ*. Kepekatan logam berat pula dianalisis menggunakan AAS. Persampelan air dijalankan bermula November 2018 hingga Jun 2019. Hasil kajian menunjukkan nilai median untuk parameter fizikokimia adalah seperti berikut; DO (2.72 mg/L), BOD (6.42 mg/L), COD (33.5 mg/L), AN (1.02 mg/L), TSS (27 mg/L), dan pH (6.97). Berdasarkan WQI, Lembangan Sungai Pengkalan Chepa dikelaskan di bawah Kelas III dan seterusnya dianggap sebagai sedikit tercemar. Kepekatan logam berat di dalam air sungai mengikut turutan Fe> Cr> Zn> Cu> Cd. Hampir kesemua logam berat didapati mematuhi had yang dibenarkan oleh Garis Panduan Kualiti Air Minum Kebangsaan (GKAMK) kecuali Cd. Ujian Kruskal Walis menunjukkan perbezaan yang signifikan antara parameter DO, BOD, COD, AN, pH, Zn dan Cd dengan lokasi persampelan ($\rho < 0.05$). Berdasarkan kajian ini dapat disimpulkan bahawa kesihatan ekosistem Lembangan Sungai Pengkalan Chepa adalah tidak sihat berdasarkan aspek DO, BOD, COD, AN dan Cd. Status kualiti air Lembangan Sungai Pengkalan Chepa adalah dipengaruhi oleh aktiviti antropogen akibat daripada proses pembangunan bandar.*

Kata kunci: Indeks kualiti air; kesihatan ekosistem; kualiti air sungai; logam berat

INTRODUCTION

Through the ages, rivers are the most important freshwater resources for humans. Rivers are essential as drinking water as well as for irrigation and fishing purposes as they are the sources of natural water. Rivers are also important as main carriers of water and nutrients to areas all around the globe. Rivers provide not only habitat, nourishment and means of transport to most organisms but they are also an essential source of valuable deposits of sand gravels and electrical energy (Anhwange et al. 2012).

In pursuits of developing a nation, rivers have been utilized to fulfil the urbanization process, causing the modification of the natural conditions and ecosystem of rivers in river basins. Degradation of the river water quality is damaging the ability and the system of the whole river to perform essential functions thus causing major consequences which lead to long-term economic losses and affect the population's quality of life. Excessive exploitation of the rivers can cause significant environmental damage which adversely affects the very resource that people depend on for their well-being and survival.

The sources of pollution come from domestic and industrial sewerage, effluents from livestock farms, manufacturing and agro-based industries, suspended solids from mining, housing, and road construction (Azwad 2019). Environmental heavy metals analysis is useful to provide data on distribution, principal sources, and consequence of these elements in the environment and their bioaccumulation in the food chains (Ali et al. 2019).

MATERIALS AND METHODS

STUDY AREA AND SAMPLING STATIONS

Sungai Pengkalan Chepa basin is located in the northeast of Kelantan, with basin area of 17129.24 hectare (DOE 2009) as shown in Figure 1. The river flows over the most populated area of Kota Bharu district and drains into the South China Sea (DOSM 2010). Sungai Pengkalan Chepa basin regularly has bank overflows from November to March during the northeast monsoon season because Kelantan has an annual rainfall ranging from 0 to 1750 mm (MMD 2019).

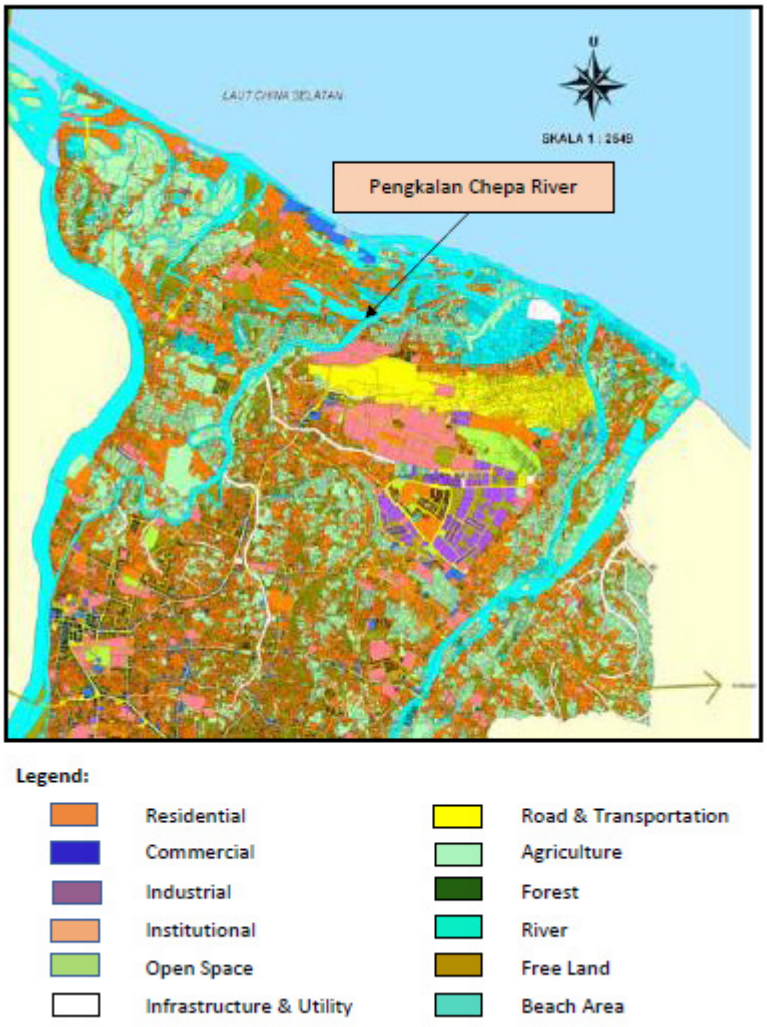


FIGURE 1. Location and land use at Sungai Pengkalan Chepa Basin, Malaysia

Source: MPKB (2008)

Water sampling was collected monthly starting from November 2018 until June 2019. The sampling was done during daytime for all eleven sampling stations (Figure 2). The sampling method used in this study was grab sampling, consisted of surface water sample taken at 30-50 cm below the water surface. Water samples were collected in a polyethylene bottles, stored at 4 °C and transferred to the laboratory within 24 h and analyzed by complying to the Standard Method for Examination of Water and Wastewater (APHA 2012).

FIGURE 2. Location and land use at Sungai Pengkalan Chepa Basin, Malaysia
Source: Google Maps (2018)

TABLE 1. Location and coordinate of sampling stations

Station	Location	Coordinates
1	Sungai Keladi	6°08’32.2”N, 102°14’16.7”E
2	Alor A	6°08’44.4”N, 102°14’49.0”E
3	Alor B	6°08’36.6”N, 102°15’01.2”E
4	Sungai Baung	6°08’58.6”N, 102°16’07.1”E
5	Alor C	6°07’46.5”N, 102°16’15.1”E
6	Alor Baung Tapang	6°07’49.3”N, 102°16’28.9”E
7	Alor Lintah	6°09’34.7”N, 102°16’35.5”E
8	Tok Sadang	6°10’39.7”N, 102°17’17.1”E
9	Pulau Pak Amat	6°10’53.9”N, 102°18’16.9”E
10	Sungai Raja Gali	6°10’27.0”N, 102°19’27.1”E
11	Sungai Pulau Hilir	6°05’48.9”N, 102°17’42.7”E

WATER QUALITY INDEX ANALYSIS

National Water Quality Standard (NWQS) by the Department of Environmental (DOE) and National Drinking Water Quality Standard (NDWQS) by the Ministry of Health (MOH) were used as a tool for guidelines in maintaining the quality of river water in Malaysia. The objective of NWQS is to create a benchmark of water quality for the protection and management of the surface water. Six water quality parameters such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solid (TSS), pH, and Ammoniacal Nitrogen (AN) were used to determine the Water Quality Index (WQI) of the river. The results were used to classify the water quality of Malaysia's river and the range of classes. All of the parameters were multiplied with their specific index:

WQI=[0.22*SIDO]+[0.19*SIBOD5]+[0.16*SICOD]+[0.16*SISS]+[0.12*SIpH]+
[0.15*SIAN] (DOE 2017).

SAMPLES ANALYSIS METHOD

Water samples were analyzed following the methods outlined in the Standard Method for Examination of Water and wastewater (APHA 2012). Physical water qualities, namely pH and DO were measured *in-situ* using Multi-Probe System (YSI 556 MPS). The chemical parameters analysis was conducted in laboratories. AN determined by Salicylate method was measured by Colorimeter (HACH DR/890). BOD values were determined based on the DO difference before and after the sample was stored in an incubator at 20 °C for 5 days. The COD concentrations were based on open reflux methods in which each water sample was refluxed for 2 h in an acidic medium, using potassium dichromate as an oxidizing agent.

TSS were separated by filtering water samples through a pre-weighed membrane filter with a pore size of 0.45 µm. The filter was weighed in again after it was left to dry in an oven at 103-105 °C to remove the water. Concentrations of heavy metals, namely Cu, Cr, Fe, Zn, and Cd were analyzed using Atomic Absorption Spectrometer (AAS, Analyst 800, Perkin Elmer, Massachusetts, USA). All reagents used were analytical grade and ultrapure water was used for the preparation of solutions and blank sample. Water was purified using the LABCONCO water purification system from LABCONCO Instruments.

STATISTICAL ANALYSIS

The Statistical Package for the Social Science (SPSS) version 24 was used for data analysis, at a significance level of $\rho < 0.05$. As the data obtained was not normally distributed, descriptive results were presented in median and interquartile range (IQR) (Helsel 2009). The comparison of physicochemical and heavy metal parameters with the location of the station was done using Kruskal Wallis test. Dunn's post hoc test was used to determine the possibility of linear association between the stations.

RESULT AND DISCUSSION

DESCRIPTIVE OF PHYSICOCHEMICAL PARAMETERS

Table 2 shows the water quality parameters descriptive data which include median values, Interquartile Range (IQR), minimum and maximum values of the physicochemical parameters from eleven sampling stations along the Sungai Pengkalan Chepa Basin. DO, BOD, COD, and AN exceeded the threshold limit according to INWQS with median values of 2.72, 6.42, 33.5 and 1.02 mg/L, respectively. However, pH and TSS parameters were within the standard for Malaysian river (Figure 3).

TABLE 2. The concentrations of physicochemical parameters at all sampling station

Parameter	Median (IQR)	Minimum	Maximum	WQI	Threshold[1]
DO	2.72 (2.97)	0.17	7.48	IV	>6 mg/L
BOD	6.42 (4.94)	2.44	35.46	IV	<3 mg/L
COD	33.5 (19)	16.0	86.0	III	<25 mg/L
AN	1.02 (1.65)	0.00	11.0	IV	<0.9 mg/L
TSS	27.0 (22.5)	10.0	95.00	II	<150mg/L
pH	6.97 (0.99)	5.49	8.26	II	5.5 - 9.0

[1] National Water Quality Standard (NWQS), Department of Environmental Malaysia

TABLE 3. Physicochemical parameters of water at different sampling stations

Station	Parameters (mg/L) Median (IQR)					
	pH	DO	BOD	COD	AN	TSS
1	6.54 (0.51)	2.80 (3.50)	5.02(1.95)	30.5 (10)	0.25 (0.78)	62.50 (59.25)
2	6.51 (0.59)	1.82 (2.38)	8.04 (13.64)	37.0 (8)	2.55 (3.53)	39.00 (60.50)
3	6.58 (0.70)	0.75 (0.64)	19.56 (18.09)	61.0 (32)	4.35 (7.13)	40.00 (20.25)
4	6.75 (0.62)	1.78 (1.17)	5.73 (4.88)	40.0 (17)	1.14 (0.80)	26.00 (21.25)
5	6.28 (0.65)	1.77 (2.37)	4.64 (4.30)	30.0 (16)	1.39 (2.60)	33.50 (23.25)
6	6.81 (0.77)	2.83 (4.22)	7.68 (4.43)	27.5 (10)	1.63 (1.23)	50.50 (23.75)
7	7.42 (0.39)	1.81 (3.92)	26.7 (7.93)	56.0 (9)	2.30 (1.38)	38.50 (10.25)
8	7.59 (1.23)	3.72 (3.03)	5.10 (2.24)	27.0 (9)	0.74 (1.23)	30.00 (23.25)
9	7.68 (0.27)	3.47 (2.31)	5.84 (1.16)	24.0 (7)	0.51 (1.21)	35.00 (10.75)
10	8.04 (0.27)	5.38 (0.61)	6.32 (1.66)	33.5 (11)	0.21 (0.50)	31.00 (11.50)
11	7.02 (0.19)	3.93 (1.12)	7.26 (3.93)	34.0 (27)	0.50 (1.07)	33.00 (23.25)
Total	6.97 (0.99)	2.72 (2.97)	6.42 (4.94)	33.5 (19)	1.02 (1.65)	37.00 (20.75)

The pH values varied from 5.49 to 8.26, with a median value of 6.97±0.99 as shown in Table 2. The lowest and highest pH values were recorded at station 5 and station 10, respectively. Generally, the average pH values were within the recommended permitted limit by NWQS and they were categorized as class II. The highest pH value was recorded at the downstream section nearby the coast but it was still within the normal range. According to Ahmad et al. (2009), water samples located close to the estuary were more alkaline due to the infusion of saltwater from the sea during high tide. Therefore, the pH variation between stations was significantly different (Kruskal Wallis, $\rho < 0.05$).

The highest DO median value recorded was 5.38 mg/L at Station 10 as shown in Table 3. Meanwhile, the lowest DO median value recorded was 0.75 mg/L at Station 3. The average DO (2.72±2.97 mg/L) showed that the results were lower than the minimum threshold therefore fell into class IV. This result was slightly lower than the ones reported by Siti Zulfarina (2015) for similar basin (range 0.3-8.6 mg/L). This study indicates that in terms of DO, the ecosystem health status at Sungai

Pengkalan Chepa Basin is unhealthy. The DO level found in almost all station was inadequate for the planktons to survive and not suitable for human to do physiological activities. The average value of DO level at 6 mg/L was required in order for aquatic organisms to live (Ruth 2003).

The findings showed that DO with the lowest median value was at Station 3 which was located near an urban area which comprised of extremely dense populations, settlement and institutional. A study conducted by Kaushal and Belt (2012) stated that the urbanization and development of watershed affect the amount of dissolved oxygen available in the stream flowing through it. The results of the Kruskal-Wallis test indicated that significant differences were found between DO and sampling stations ($\rho < 0.05$). This shows that land-use activities contribute to the water quality status. The findings are similar to a study done by Noraini et al. (2010) in Sibu, Sarawak. The DO was lower in the upstream and middle stream areas, which were urban areas compared to the rural area at the downstream section.

The highest BOD recorded was 35.46 mg/L at Station 7 while the lowest BOD recorded was 2.44 mg/L at Station 6. The BOD average values (6.42 mg/L) exceeded the recommended permitted limit by NWQS therefore they are categorized as class IV. Hence, in terms of BOD, it is believed that the ecosystem health in Sungai Pengkalan Chepa Basin is unhealthy and at unsafe level for biological aquatic life. The two highest levels of BOD were detected at station 3 and station 7 at 19.56 and 26.7 mg/L, respectively. Both stations were located at urban area with dense population. Based on the observation done, the number of fish and other aquatic animals that lived in this area were relatively minimal. Moreover, the BOD variation between stations was found to be significantly different (Kruskal Wallis, $\rho < 0.05$). According to a study by Amneera et al. (2013) on Sungai Perlis, the range of BOD varied from 3.05 to 9.08 mg/L, in which if they were compared to this study could be considered low with the range of 2.44 to 35.46 mg/L.

High concentration of BOD indicated that the biodegradation process caused by microorganisms had occurred in river water especially at station 7 which generated higher sewage production from the industrial park, residential, commercial building and other related activities. Prevention is an essential strategy to control pollution. Prevention steps and education program should be introduced to the citizen.

The highest COD recorded was 86 mg/L at Station 3 while the lowest COD recorded was 16 mg/L at Station 9. Nevertheless, the average median of COD (33.5 mg/L) exceeded the maximum permitted limit by NWQS, which is 25 mg/L or less therefore it was classified as class III. Due to this, Sungai Pengkalan Chepa Basin can be considered as an unhealthy ecosystem based on the COD aspect, which can be harmful to the biodiversity. High concentration of COD in the river was noticeable at Station 3 which was located at the upstream of Sungai Pengkalan Chepa Basin. Station 3 was a dense area with human population and received municipal wastewater from Kota Bharu. This situation reinforces the fact that land use activity contributes to the distribution of COD. This result indicated high existence of organic substances which were non-biodegradable and reactive in river water. Domestic waste also contributes to high COD content and can bring harmful effects to living things. Moreover, statistical significant differences of COD were found between stations (Kruskal Wallis, $\rho < 0.05$). In contrast, the range values of COD concentration from this study (16 - 86 mg/L) were high compared to the ones reported by Al-Badaii et al. (2013) at Sungai Semenyih with the range of 0.32 to 4.56 mg/L.

The concentration of AN in the measurement of river water quality is essential as AN acts as the indication of pollution effect due to domestic sewage or industry, animal waste, fertilizers, and nitrogen fixation process discharged into the streamflow without proper treatment (EPA 2013). The concentration of AN at Sungai Pengkalan Chepa Basin varied between 0.00 mg and 11.0 mg. Lower and higher concentrations of AN were measured at station 1 and station 3, respectively. The median concentration of all station in this study was 1.02 mg/L, which exceeded the standard therefore fell into class IV. Kruskal-Wallis test also showed that the AN concentrations were significantly different among the sampling stations ($P < 0.05$).

Station 3 recorded the highest level of AN with median of 4.35 mg/L. Meanwhile, the lowest median result was at Station 10 with 0.21 mg/L. Station 3 was located at Kota Bharu city which received domestic sewage from dense population along with hospitals, municipal sewage and construction sites. Based on the observation done, domestic waste and animal remains from a slaughterhouse were spotted at this site. The second-highest level of AN was at station 7, which was located near an industrial park. This result indicated that there are possibilities of improper industrial sewage management which cause the river to be polluted. In terms of AN, the ecosystem health at Sungai Pengkalan Chepa Basin can be considered unhealthy.

This study indicated that Station 1 had the highest TSS concentration (98 mg/L) while Station 4 had the lowest TSS concentration (14 mg/L). TSS results in this study can be considered to be on the lower side compared to the values reported by Siti Zulfarina (2015) for the same basin, which were between 6 mg/L and 367 mg/L. Typically, soil erosion is considered as the primary source for suspended solids from the surrounding area, caused by human activities. Generally, Sungai Pengkalan Chepa Basin does not face any erosion problem hence preserve

the river from excess suspended solids. Kruskal-Walis test showed that significant differences were not found between stations. This study showed that the average TSS was within the standard therefore fell into class II. Therefore, in terms of TSS values, this river can be categorized as healthy ecosystem and it is safe for biological aquatic life.

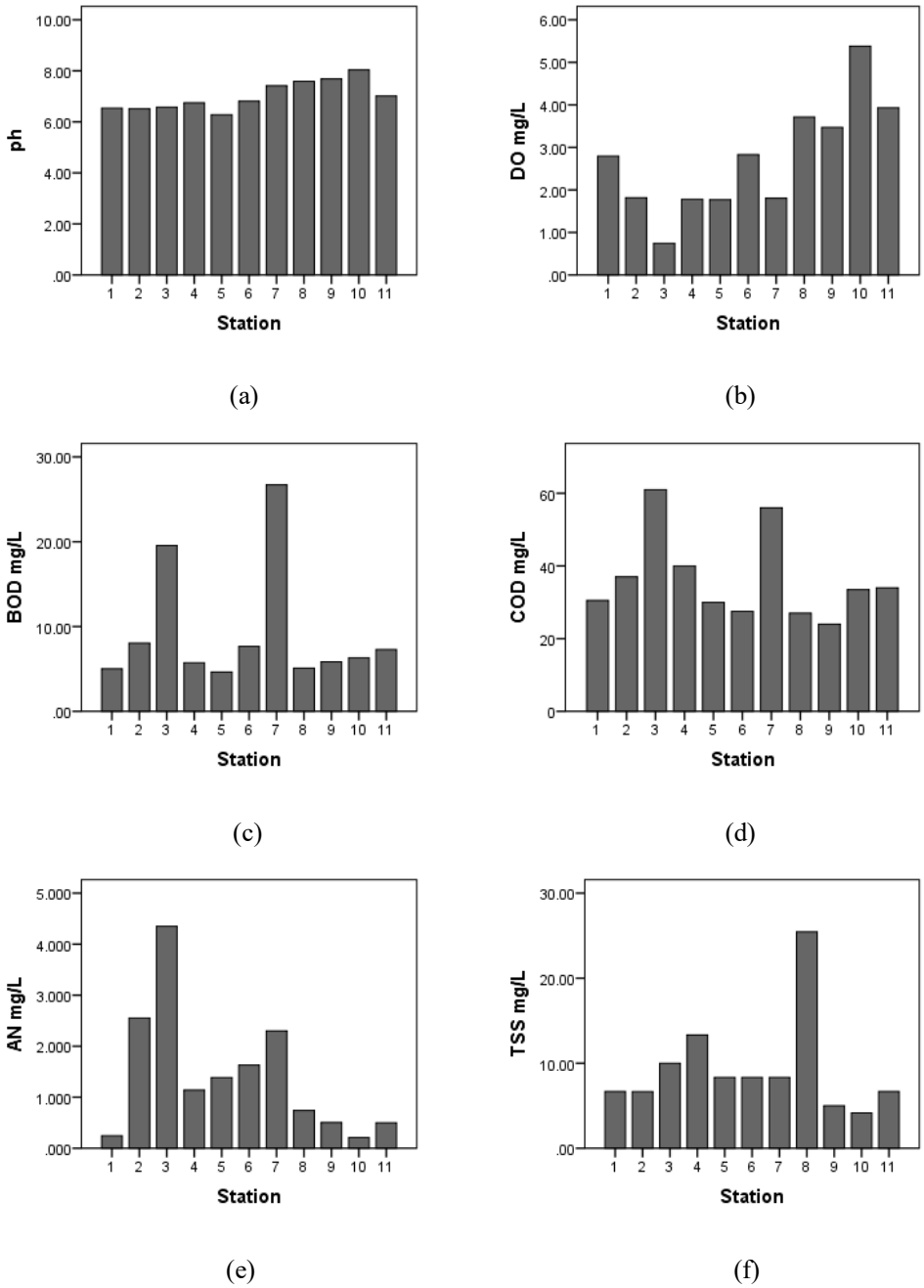


FIGURE 3. Distribution of physicochemical parameters values for (a) pH, (b) DO, (c) BOD, (d) COD, (e) AN, and (f) TSS at Sungai Pengkalan Chepa Basin, Malaysia, Stations 1-11. **

TABLE 4. WQI and status of sampling stations

Station	WQI[1]	Class[2]	Status[3]
1	73	III	Slightly polluted
2	54	III	Slightly polluted
3	41	IV	Polluted
4	61	III	Slightly polluted
5	61	III	Slightly polluted
6	65	III	Slightly polluted
7	49	IV	Polluted
8	71	III	Slightly polluted
9	72	III	Slightly polluted
10	79	III	Slightly polluted
11	68	III	Slightly polluted
Mean	63	III	Slightly polluted

[1,2,3] National Water Quality Standard (NWQS), Department of Environmental, Malaysia

The calculation of WQI showed that the water class for almost all station fell within class III except for station 3 and station 7, which fell within class IV (Table 4). The highest WQI recorded was 79 at station 10 and the lowest WQI was at station 3 at 45. WQI for whole station was within class III at 63. According to NWQS, class III river is defined as suitable for common and moderately tolerant aquatic species. Besides that, water under this classification can be used for water supply with extensive treatment. This class of water is also suitable for livestock drinking needs. Therefore, the water quality of Sungai Pengkalan Chepa Basin can be considered as slightly polluted.

The two most polluted sampling stations were stations 3 and 7 due to municipal and domestic sewage, settlement, and industrialization. These stations were located at the upstream and middle stream section, respectively. Meanwhile, the downstream area was found to be less polluted because of its location which was at the outskirt of Kota Bharu, a semi-developed area. It should be noted that by improving the quality, more water could be sustainable at the upstream and mid-stream stretches of the river basin.

HEAVY METAL PARAMETERS

Table 5 shows the descriptive concentrations of heavy metal recorded at Sungai Pengkalan Chepa Basin. The findings stated that the Fe concentration was the highest, and that of Cd was the lowest in water. The accumulation of heavy metals in water followed the order Fe > Cr > Zn > Cu > Cd. Most of the metals were found within the permitted level except for Cd, which exceeded the permissible limit set by NDWQS.

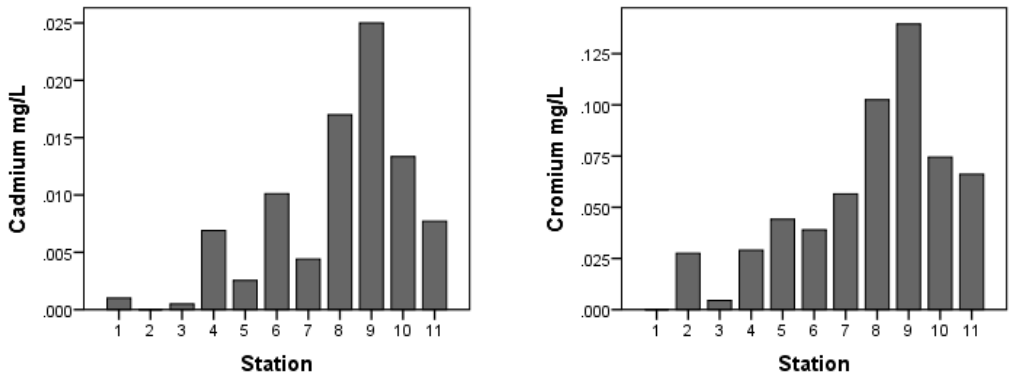
TABLE 5. The concentrations of heavy metal parameters at all stations

Parameters (mg/L)	Median (IQR)	Minimum	Maximum	[1]Maximum threshold limit
Cr	0.042 (0.13)	0.00	0.560	0.05
Fe	0.754 (1.87)	0.00	4.044	1.0
Zn	0.027 (0.18)	0.00	1.282	3.0
Cd	0.008 (0.02)	0.00	0.087	0.003
Cu	0.018 (0.04)	0.00	0.121	1.0

[1]National Drinking Water Quality Standard, Ministry of Health, Malaysia

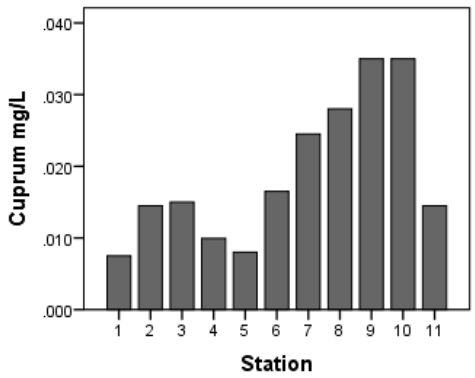
TABLE 6. Heavy metal parameters concentration of water at different sampling stations

Station	Parameters (mg/L) Median (IQR)				
	Cr	Fe	Zn	Cd	Cu
1	0.000 (0.005)	0.626 (1.73)	0.014 (0.023)	0.001 (0.010)	0.008 (0.067)
2	0.028 (0.084)	1.160 (2.019)	0.025 (0.031)	0.000 (0.014)	0.015 (0.047)
3	0.005 (0.087)	1.225 (2.225)	0.021 (0.037)	0.001 (0.009)	0.015 (0.043)
4	0.029 (0.128)	1.546 (2.110)	0.023 (0.018)	0.007 (0.013)	0.010 (0.053)
5	0.044 (0.124)	2.013 (2.104)	0.029 (0.052)	0.003 (0.043)	0.008 (0.050)
6	0.039 (0.213)	2.000 (4.646)	0.022 (0.036)	0.010 (0.021)	0.017 (0.062)
7	0.057 (0.153)	1.145 (2.302)	0.261 (0.829)	0.004 (0.021)	0.025 (0.068)
8	0.103 (0.190)	0.692 (0.876)	0.042 (0.040)	0.017 (0.044)	0.028 (0.069)
9	0.140 (0.353)	0.705 (1.293)	0.035 (0.032)	0.025 (0.044)	0.035 (0.086)
10	0.075 (0.413)	0.321 (0.523)	0.034 (0.029)	0.013 (0.025)	0.035 (0.032)
11	0.066 (0.193)	0.686 (1.333)	0.032(0.033)	0.008(0.018)	0.015 (0.060)
Total	0.042 (0.156)	0.754 (1.868)	0.027 (0.036)	0.008 (0.018)	0.018 (0.046)



(a)

(b)



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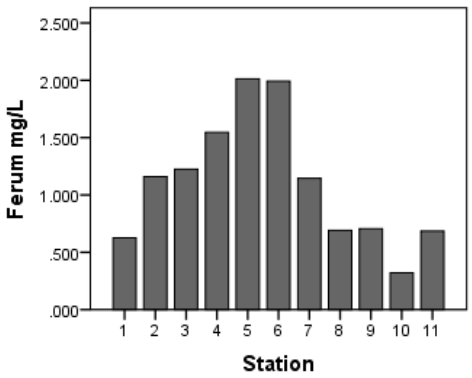

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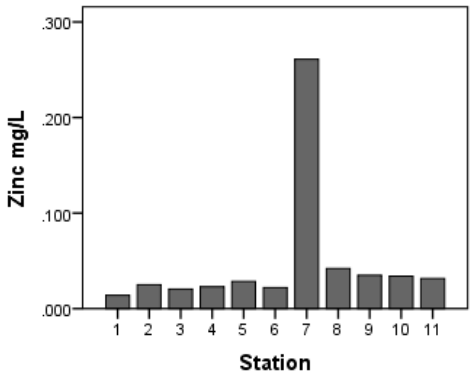

(e)

FIGURE 4. Distribution of heavy metal parameters concentration for (a) Cd, (b) Cr, (c) Cu, (d) Fe and (e) Zn at Sungai Pengkalan Chepa Basin, Malaysia, Stations 1-11

Figure 4 shows the distribution of heavy metal parameters concentration at all stations. Kruskal Walis test indicated Zn and Cd concentration were found to be significantly different between sampling stations; other parameters however were not found to be significantly different with sampling stations.

Cadmium concentrations were consistently low at all sampling locations as compared to other heavy metals but they exceeded the threshold level according to NDWQS (MOH 2004). Cd level was shown to be relatively higher value at the downstream section compared to other sections. The highest concentration of Cd in downstream might be due to the runoff from non-point sources. The primary possible pollution source is from a former dumping site located around this downstream area. Open municipal landfill called Teluk Kitang dumpsite, was located nearby an airport and it covered about 32 hectares' area. The Teluk Kitang dumpsite used to receive approximately 300 tons of municipal solid waste on daily basis (Zulkefle 2006).

Leachate can migrate to groundwater and surface water through the flaws in the liners. The leachate production decreases very slow and some parameters might be of environmental relevance for many decades or centuries to come. The main constituents of landfill leachate are dissolved methane, fatty acids, sulfate, nitrate, nitrite, phosphates, calcium, sodium, chloride, magnesium and trace metals such as chromium, manganese, iron, nickel, copper, zinc, cadmium, mercury, and lead (Danthurebandara 2013). The locations of sampling stations were found to be significantly difference with Cd concentration ($\rho < 0.05$). Hence, this strengthens the findings that location does affect Cd distribution in the river basin. In terms of Cd concentration, Sungai Pengkalan Chepa Basin can be considered as an unhealthy ecosystem and hazardous for biological aquatic life.

The values of Zn among sampling stations showed a very significant distribution in which station 7 was found to have higher readings than other stations (Table 6). However, all concentrations level was still below the permitted limit. This situation is conceivable due to waste from industrial parks nearby station 7. According to Wuana and Okieimen (2011), Zn contamination in water occurred due to the presence of large quantities of wastewater from industrial plants. Industrial sources or toxic waste sites may affect public health through contamination in water. Although the findings of Zn concentration indicated compliance with the standards, it should be prioritized in the early stages to prevent things from getting worse.

LAND USE ACTIVITIES THAT INFLUENCE WATER QUALITY RIVER

Figure 1 shows the current land use at Kota Bharu District. Kota Bharu covers up 39,939,80 hectare of an area and plays a significant role in Kelantan as the capital city. The estimated population is about 438,440, making it one of the largest towns in the east coast of Peninsular Malaysia with 7,502 hectare land use for residential purpose (MPKB 2008). Other land uses in Kota Bharu District include business and commercial, industrial, institutional, agricultural and infrastructure and utility.

The industrial area located near Alor Lintah which is one of the main tributaries of Sungai Pengkalan Chepa and effluent from an industrial area is categorized as the main source of pollution. According to the sampling section in this study, the industrial area was active in the middle stream area. It was the reason for the increasing of AN and COD in this section, especially at station 7. Station 4, which was also located at the middle stream area, also recorded a high reading of COD and AN, even though there was no main source of pollution there. It is because the industrial waste detected at station 7 was nearby the industrial area in which the effluent was flowing in it and eventually ended up at station 4 in Sungai Baung.

The upstream river section also recorded low water quality results. This section consisted of three stations located in Kota Bharu Sub-District. The most polluted station in this section is station 3 which had load from municipal sewage, hospital, commercial activities such as wet market, food premises, carwash, workshop and surface runoff from urban areas. This river section showed that the degradation of water quality was due to the increasing of AN and COD along with the decreasing of DO. The downstream river section however was less polluted because of less land-use activity.

CONCLUSION

The findings of this study concluded that Sungai Pengkalan Chepa Basin showed sign of deterioration in water quality and it is only suitable for common and moderately tolerant aquatic species and livestock drinking needs. Besides that, the river water can also be used for water supply with extensive treatment. The hazard bioaccumulation and biomagnification of the pollutants possess significant risk to human health and the ecosystem. Hence, important and drastic measures must be taken to minimize the dangerous effluent deposited into the Sungai Pengkalan Chepa. We suggested that various sources of pollution should be closely monitored, and domestic sewage and industrial effluent discharged should be reduced.

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REFERENCES

Ahmad, A., Mushrifah, I. & Shuhaimi, O.M. 2009. Water quality and heavy metal concentrations in sediment of Sungai Kelantan, Kelantan, Malaysia: A baseline study. *Sains Malaysiana* 38(4): 435-442.

Al-Badaii, F., Shuhaimi-Othman, M. & Gasim, M. B. 2013. Water quality assessment of the Semenyih River, Selangor, Malaysia. *Journal of Chemistry* 2013: 1-10.

Ali, H., Khan, E. & Ilahi, I. 2019. Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *Journal of Chemistry* 2019: 1-14.

Amneera, W., Najib, N., Yusof, S.R.M. & Ragunathan, S. 2013. Water quality index of Perlis River, Malaysia. *International Journal of Civil & Environmental Engineering* 13(2): 1-6.

Anhwange, B., Agbaji, E. & Gimba, E.C. 2012. Impact assessment of human activities and seasonal variation on River Benue within Makurdi Metropolis. *International Journal of Science and Technology* 2(5): 248-254.

APHA. 2012. *Standard Methods for the Examination of Water and Wastewater*. Vol. 10. Washington, DC: American Public Health Association.

Azwad, M. N. 2019. Threats to rivers. http://www.wwf.org.my/about_wwf/what_we_do/freshwater_main/freshwater_conserving_river_basins/threats_to_rivers/. Accessed on 10 April 2018.

DOE. 2017. *Malaysia Environmental Quality Report.* Putrajaya: Department of Environment, Ministry of Natural Resources and Environment, Malaysia.

DOE. 2009. *Environmental Quality Report.* Putrajaya: Department of Environment, Ministry of Natural Resources and Environment, Malaysia.

DOSM. 2010. *Population and Housing Census of Malaysia*. Putrajaya: Department of Statistics Malaysia.

Google Maps. 2018. Kota Bharu, Kelantan. https://www.google.com.my/maps/place/15200+Kota+Bharu,+Kelantan/@6.187419,102.228971,12z/data=!4m5!3m4!1s0x31b6afd8841d6f33:0xbf251986c16f7589!8m2!3d6.124785!4d102.2543825. Accessed on 25 February 2018.

Kaushal, S.S. & Belt, K.T. 2012. The urban watershed continuum: Evolving spatial and temporal dimensions. *Urban Ecosystems* 15(2): 409-435.

MMD. 2019. Fenomena Cuaca *Met Malaysia.* http://www.met.gov.my/pendidikan/cuaca/fenomenacuaca. Accessed on 1 February 2019.

MOH. 2004. *National Drinking Water Quality Standard (NDWQS)*. Engineering Services Division, Ministry of Health Malaysia.

MPKB. 2008. *Draf Rancangan Tempatan Jajahan Kota Bharu 2020*. Kelantan: Unit Rancangan Pembangunan Kota Bharu, Majlis Perbandaran Kota Bharu.

Noraini, R., Seca, G., Johan, I. & Mohd, I.J. 2010. Comparative study of water quality at different peat swamp forest of Batang Igan, Sibu Sarawak. *American Journal of Environmental Sciences* 6(5): 416-421.

Ruth, F.F. 2003. *Dissolved Oxygen for Fish Production*. Texas A&M AgriLife. https://agrilifecdn.tamu.edu/fisheries / files/2013/ 09/Dissolved-Oxygen-for-Fish-Production1.pdf.

Siti Zulfarina, F. 2015. Zooplankton community structure in Pengkalan Chepa River Basin. Universiti Sains Malaysia, Kelantan. Masters Thesis(Unpublished).

USEPA. 2013. *Report on the 2013 U.S. Environmental Protection Agency (EPA).* International Decontamination Research and Development Conference. Washington: United States Environmental Protection Agency.

Wuana, R.A. & Okieimen, F.E. 2011. Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. *International Scholarly Research Notices ISRN Ecology* 2011: 1-20.

Zulkefle, C.A. 2006. From dumpsite to a resort city. *The Star Online.* https://www.thestar.com.my/news/nation/2006/12/12/from-dumpsite-to-a-resort-city. Accessed on 11 August 2019.

Mohd Saifuddin Maliki Abdullah*, Maliki Hapani, & Nur Fatien Muhamad Salleh
Environmental and Occupational Health Programme
School of Health Sciences, Health Campus
Universiti Sains Malaysia
16150 Kubang Kerian, Kelantan Darul Naim
Malaysia

Wan Mohd Sahnusi Wan Alias
Forensic Science Programme
School of Health Sciences, Health Campus
Universiti Sains Malaysia
16150 Kubang Kerian, Kelantan Darul Naim
Malaysia

*Corresponding author; email: saifuddinppsk@student.usm.my

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