Assessment of water quality index and heavy metals in Sungai Bunus, Malaysia

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Abstract. Water Quality Index (WQI) is an indicator of water quality. The index is shown in classes where Class I indicates a Natural Level of water quality, Classes IIA/IIB, Class III and IV indicate the presence of a certain amount of pollutant, and Class V highly polluted water. Hence, this study was conducted to evaluate the current WQI and the extent of heavy metals present in Sungai Bunus, a river in Selangor, Malaysia, by Harkins’s Standardized Distances Method (HSDM). Water samples were taken six times between 24th October 2016 and 11th November 2016 at the upstream, middle stream and downstream of the Sungai Bunus. Five in situ tests and eight laboratory tests were conducted. The findings showed that the upstream of the Sungai Bunus was the cleanest, measured 63.40 % while the downstream the dirtiest, 39.97 %. Secondly, it showed that this river contained the lowest heavy metals in the upstream compared to the other parts. The upstream Harkins index was 12.17, the middle stream between 11.33 and 30.47, and the downstream 15.67 - 28.70. Cadmium, chromium, iron, and manganese were found in the river water, which exceeded the Raw Water Quality and Drinking Water Quality Standards. It was also found that the cadmium and chromium exceeded the highest permissible effluent standards B, where cadmium was 0.02 mg/L while chromium 0.05 mg/L. To improve the water quality of this river to the Class IIB standard, it is recommended that the Bunus Sewerage Treatment Plant (STP) be upgraded and the source of pollutions identified.

1. Introduction
Sustainable water quality has long been a concern in Malaysia. The rivers in Malaysia have been exploited by massive land reclamation, developments for livestock productions, uncontrolled discharge of industrial, domestic wastes and energy development projects. These activities, the roots of land-based and sea-based pollutions, are alarming. Inadequate treatment of sewage or effluent from agro-based and manufacturing industries attributes to high biochemical oxygen demand (BOD) in rivers [1]. As good water quality is essential for living things, better monitoring and management of river water are necessary to obtain high-quality drinking water.

Water management practices can be conducted by river rehabilitation to improve the river longevity as it contributes to long-term natural water resource for public water supply. Malaysia depends on surface water as her main source of public water supplies. The demand for water in Malaysia increased from 9,543 m\(^3\)/day in 1995 to 15,285 m\(^3\)/day in 2010. Studies estimated that in the
year 2020, water use would increase to 60%, which is equal to 20,338 m$^3$/day. An increase of 113% of water use has been predicted for 25 years [2], but only 1% of water consumption is from groundwater [3]. But groundwater source is susceptible to heavy metal pollution due to the natural occurrence and anthropogenic activities [4].

In this light, water quality statistics thus become a greater concern for local authorities, government agencies, and the public. Consequently, the Malaysian Ministry of Health (MOH) had included certain measures or parameters of heavy metals in the National Drinking Water Quality Standard to ensure safe drinking water supplies [5]. The water quality standard has been developed using the nonparametric statistical procedure for combining several water quality parameters adopted from Harkin’s Standardized Distances Method [6]. Drinking water can be harmed by water pollution. In Malaysia, pollution of water is primarily caused by urban runoff, construction sites, faulty septic systems and industrial activities [7]. Hence the Department of Environment (DOE), the public agency responsible for monitoring the river basins, has increased its effort to ensure the water quality of major pollution sources [3].

2. Problem Statement
In the year 2011, the Malaysian Government, under the Greater Kuala Lumpur/Klang Valley National Key Economic Area (GKL/KV NKEA), launched the River of Life (ROL) project. It aimed to develop, clean and beautify the 110 km Klang river, to upgrade its water to Class IIB [8, 9]. The ROL also aimed to transform the Sungai Klang into a vibrant and liveable waterfront for a better economic return [8]. The area of the ROL project was 560 km$^2$. This project is significantly important as Sungai Klang is considered as the main river situated in the heart of Kuala Lumpur, Malaysia.

Sungai Klang has eleven (11) major tributaries, which are Sungai Batu, Sungai Gombak, Sungai Kerayong, Sungai Kuyuh, Sungai Bohol, Sungai Penchala, Sungai Jinjang, Sungai Keroh, Sungai Kemunsing and Sungai Belongkong. The ROL fell within the Federal Territory of Kuala Lumpur, Gombak, Petaling, Klang and Ulu Langat districts. The local authorities involved in managing these rivers are the Kuala Lumpur City Hall (DBKL), Ampang Jaya Municipal Council (MPAJ) and Selayang Municipal Council (MPS).

Sungai Bunus has been considered in the ROL project and a part of the Sungai Klang tributary. Sungai Bunus stretches 9.2 km through 17.5 km$^2$ of the basin of the Federal Territory of Kuala Lumpur and situated in the upstream region of Sungai Klang. However, there is a lot of development and urbanization in this area. This problem contributed to the higher concentration of heavy metals generated by metals and chemicals industries. There are numerous metals which are significantly toxic to human beings and ecological environments; they include chromium (Cr), copper (Cu), lead (Pb), cadmium (Cd), mercury (Hg), zinc (Zn), manganese (Mn) and nickel (Ni) [10]. Due to the threats posed by heavy metals in the environment, it is very important to reduce the presence of these toxic metals. Hence, this research study focused on the water quality monitoring for Sungai Bunus as this river is extremely vital for the outflow downstream of Sungai Klang.

3. Materials and Methods
Site visits were conducted to gain a better understanding and a clearer view of the actual state of the Sungai Bunus. Its water samples were collected six (6) times at three (3) different locations, which were the upstream (Taman Sungai Bunus), middle stream (Projek Perumahan Rakyat Sungai Bunus) and downstream (near the National Library). These samples were taken six (6) times to get the moderate values of water quality for the upstream, middle stream and downstream of Sungai Bunus.

The samples were collected between 24th October 2016 and 11th November 2016 to evaluate the significant impact on the ROL project implemented in the stretch of Sungai Bunus as a part of upstream for Sungai Klang. Pictures were also taken for additional data to show the extent of the Sungai Bunus pollution. In situ test were conducted to determine the dissolved oxygen (DO), pH, turbidity, temperature and total dissolved solids. Eighteen (18) samples were collected for water quality and heavy metals analyses. Lastly, laboratory analysis was conducted to determine the values
of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and ammonia nitrogen (AN) [11].

3.1. Water Quality Index
A water quality index provides a single number (grading system) that expresses the overall water quality at certain locations and time based on several water quality parameters. The objective of an index is to turn complex water quality data into understandable and useable information by the public.

According to the Department of Environment Water Quality Index (DOE-WQI), the WQI is to express the overall water quality based on selected parameters of different stages of the water classes [1]. The WQI represents six main important parameters as shown in table 1. However, heavy metals are not included in this WQI. Table 1 shows the best-fit equation to be used to calculate the Sub-Index (SI) values of the six parameters of the WQI of the Sungai Bunus. Equation 1 for calculating water quality index (WQI) is applied using table 1 [1]. Several recent studies have used WQI to asses the current pollution of point sources and non-point sources that affect the river water quality [12, 13, 14].

### Table 1. Equation of the estimate Sub Index [1].

| Sub - index | WQI Calculation | Range |
|-------------|-----------------|-------|
| SIDO        |                 |       |
| = 0         |                 | For x ≤ 8 |
| = 100       |                 | For x ≥ 92 |
| = -0.395 + 0.03x^2 - 0.0002x^3 | | For 8 < x < 92 |
| SIBOD       |                 |       |
| = 100.4 – 4.23x |           | For x ≤ 5 |
| = 108 e-0.053x – 0.1x | | For x > 5 |
| SICOD       |                 |       |
| = -1.33x + 99.1 |          | For x ≤ 20 |
| = 103 e-0.0157x – 0.04x | | For x > 20 |
| SIAN        |                 |       |
| = 100.5 – 105x |           | For x ≤ 0.3 |
| = 94 e-0.573x – 5 | | For 0.3 < x < 4 |
| = 0 | | For x ≥ 4 |
| SISS        |                 |       |
| = 97.5 e-0.00676x + 0.05x | | For x ≤ 100 |
| = 71 e-0.0061x – 0.015x | | For 100 < x < 1000 |
| = 0 | | For x ≥ 1000 |
| pH (SIpH)   |                 |       |
| = 17.2 – 17.2x + 5.02x^2 | | For x < 5.5 |
| = -242 + 95.5x – 6.67x^2 | | For 5.5 ≤ x < 7 |
| = -181 + 82.4x – 6.05x^2 | | For 7 ≤ x < 8.75 |
| = 536 – 77x + 2.76x^2 | | For x ≥ 8.75 |

3.2. Heavy Metals
The heavy metals detection for Cadmium (Cd), Chromium (Cr), Iron (Fe) and Manganese (Mn) were analyzed using HACH Spectrophotometer DRB 2800 in Environmental Laboratory, Faculty of Civil Engineering, UiTM, Shah Alam. The analysis of heavy metals was done shortly after the sample taken during the day of sampling. This is to gain high accuracy of results for heavy metals detection.

3.3. Harkin's Standardized Distances Method
The Harkin’s Standardized Distances Method was developed by Harkins, (1974) [6]. It is a distribution-free statistical procedure for mapping p-measurements on an object onto a line so that the existing differences in a location in p-space are clearly defined.
4. Result and Discussion

Table 2, table 3 and table 4 show the WQI of three locations along the Sungai Bunus. They indicate that the WQI of all the locations in Sungai Bunus ranged within Classes III, IV and V, which are polluted, highly polluted and very highly polluted.

From the results shown in table 2, table 3 and table 4, the upstream’s WQI has displayed better quality than the middle stream and downstream of Sungai Bunus. However, the status of the upstream’s was still between polluted and highly polluted, which is in Class III to IV.

The laboratory analysis of heavy metals of the water samples from the Sungai Bunus found that four (4) heavy metals reached the permissible limit of Drinking Water Quality Standard [5]. They were Cadmium (Cd), Chromium (Cr), Iron (Fe) and Manganese (Mn).

Table 2. Water Quality Index of the upstream of the Sungai Bunus (Taman Sungai Bunus).

| Sub-index | Dates of Sample Collections in 2016 | 24/10 | 28/10 | 31/10 | 04/11 | 07/11 | 11/11 |
|-----------|-----------------------------------|-------|-------|-------|-------|-------|-------|
| SIDO      | 0                                 | 1.57  | 0     | 2.78  | 1.80  | 0     |
| SIBOD     | 88.73                             | 35.78 | 56.75 | 66.74 | 24.30 | 68.13 |
| SICOD     | 76.49                             | 59.04 | 52.47 | 60.03 | 28.19 | 66.33 |
| SIAN      | 48.25                             | 23.47 | 26.67 | 20.66 | 48.00 | 30.76 |
| SISS      | 95.10                             | 91.63 | 95.69 | 89.4  | 92.77 | 92.19 |
| pH (SIpH) | 98.74                             | 97.99 | 98.55 | 95.98 | 97.80 | 98.99 |
| WQI       | 63.40                             | 46.53 | 50.32 | 51.82 | 43.30 | 54.80 |
| CLASS     | III                               | IV    | IV    | IV    | IV    | III   |
| STATUS    | Polluted                          | Highly Polluted | Highly Polluted | Highly Polluted | Highly Polluted | Polluted |
Table 3. Water Quality Index of the middle stream of the Sungai Bunus (Proyek Perumahan Rakyat Sungai Bunus).

| Sub-index | Dates of Sample Collections in 2016 |
|-----------|-----------------------------------|
|           | 24/10 | 28/10 | 31/10 | 04/11 | 07/11 | 11/11 |
| SIDO      | 0     | 1.75  | 0     | 1.99  | 0     | 2.3   |
| SIBOD     | 15.4  | 6.69  | 29.41 | 30.88 | 6.36  | 20.00 |
| SICOD     | 21.91 | 14.92 | 34.52 | 26.13 | 7.69  | 29.27 |
| SIAN      | 0     | 0     | 0     | 0     | 0     | 0     |
| SISS      | 76.85 | 69.57 | 87.77 | 31.9  | 70.38 | 65.34 |
| pH (SIpH) | 99.25 | 98.24 | 87.88 | 98.95 | 97.99 | 98.49 |
| WQI       | 30.64 | 26.96 | 35.70 | 27.46 | 25.46 | 31.26 |
| CLASS     | V     | V     | IV    | V     | V     | IV    |
| STATUS    | Very Highly Polluted | Very Highly Polluted | Highly Polluted | Very Highly Polluted | Very Highly Polluted | Highly Polluted |

Table 4. Water Quality Index of the downstream (near the National Library).

| Sub-index | Dates of Sample Collections in 2016 |
|-----------|-----------------------------------|
|           | 24/10 | 28/10 | 31/10 | 04/11 | 07/11 | 11/11 |
| SIDO      | 2.59  | 0     | 0     | 2     | 2.19  | 1.43  |
| SIBOD     | 38.75 | 14.48 | 27.79 | 14.35 | 4.27  | 25.16 |
| SICOD     | 44.98 | 26.64 | 31.52 | 23.72 | 4.77  | 41.96 |
| SIAN      | 0     | 0     | 0     | 0     | 0     | 0     |
| SISS      | 82.09 | 75.5  | 84.1  | 65.71 | 72.04 | 67.6  |
| pH (SIpH) | 97.53 | 99.43 | 97.75 | 99.16 | 99.19 | 99.6  |
| WQI       | 39.97 | 31.02 | 35.51 | 29.37 | 25.48 | 34.58 |
| CLASS     | IV    | IV    | IV    | V     | V     | IV    |
The laboratory analysis on the first day (24th October 2016)’s water sampling showed that four out of nine heavy metals showed significant readings. The four were Cadmium (Cd), Chromium (Cr), Iron (Fe) and Manganese (Mn). Figure 1 shows the results of heavy metals of the six days of sampling. The labels are U which symbolizes the upstream, M the middle stream and D the downstream.

Figure 1 shows the amount of Cadmium (Cd), Chromium (Cr), Iron (Fe) and Manganese (Mn) in the samples. Heavy metals pollution can be identified by comparing the upper limit of the effluent standards B mentioned in the Environmental Quality Act, 1974 [1]; Cd 0.02 mg/L, Cr 0.05 mg/L, Fe 5.0 mg/L and Mn 1.0 mg/L.

The cadmium reading of the upstream sampling point on 24/10/2016 was of 0.036 mg/L which is the highest. The second highest was on the same day and in the middle stream sampling point, which is 0.035 mg/L. The third highest was recorded on 11/11/2016 at the upstream that shows 0.034 mg/L. On 28th October 2016 and 31st October 2016, the records showed no cadmium in the three samplings.

The chromium reading on 28th October 2016 in the downstream sampling point was the highest which was 0.089 mg/L, followed by 0.080 mg/L at the middle stream on the same day. The third highest was recorded on 2nd October 2016 in the middle stream which was 0.078 mg/L.

From the results in Figure 1, high detectable of heavy metals pollutions have been determined in Sungai Bunus. This finding causes an alarm to the population and environment surroundings as Sungai Bunus flows in the middle of Kuala Lumpur in the Klang Valley region. Along with Sungai Bunus is also a recreational park. Due to that matter, the occurrences of these pollutants need to be highly considered as a treat to the visitors of the recreational park.

Heavy metals are serious inorganic pollutants that have a high enrichment factor and slow removal rate which enable them to easily affect the aquatic life system [15]. On the other hand, humans are exposed to heavy metals by ingestion, absorption and inhalation pathways. Ingestion is indirect exposure to the food and drinking water that ends in the gastrointestinal tract. The order of ranking for heavy metal exposure routes are absorption, inhalation and lastly ingestion. Thus, ingestion of drinking water is the major source of heavy metal exposure for human and animals [16].
Many cases of Itai-Itai disease (osteomalacia with various grades of osteoporosis accompanied by severe renal tubular disease) and low-molecular-weight proteinuria were reported by those living in contaminated areas in Japan and exposed to cadmium via food and drinking water [17].

In humans, the highest concentrations of cadmium are found in the hilar lymph nodes and lungs, followed by spleen, liver and kidney, and tissue. The chromium level declines with age. In epidemiological studies, an association has been found between occupational exposure to chromium compounds and mortality due to lung cancer [17].

Figure 2 shows a simplified explanation of the Standardized Distances, Sn of the Heavy Metals Index. Figure 2 shows the index of the upstream, which is lower than the middle and downstream. In Figure 2, U represents the upstream, M the middle stream and D the downstream. The analysis showed that the level of heavy metals pollution in the upstream was not severe. In contrast, the levels of heavy metals were more in the middle stream and downstream. The upstream runs through the residential areas thus free from heavy industry pollutions.

Wastewaters such as those generated during galvanometry, metal cleaning, plating and electroplating, and mining may contain undesirable amounts of chromium anions [10]. Cadmium is used mainly as an anticorrosive, electroplated onto steel [17]. The main pollutants of the Sungai Bunus were the wastewater discharged from food outlets, oil, and grease from workshops, as well as residential sewage, silage and rubbish. Fertilizers produced from the phosphate ores constitute a major source of diffuse cadmium pollution [17]. The use of agricultural chemicals has been indicated as the main anthropogenic source of cadmium pollution in aquatic environments [18]. Traces of cadmium element have resulted from mining and smelter wastes [19].
As an example, chromium is a carcinogen discharged by the leather industry into the river. The pollutions from these materials are harmful to many organisms, including humans and their surroundings. Some heavy metals parameters are found to be over the limit level for effluent standards B, Environmental Quality Act 1974 [1]. The heavy metals parameters were cadmium and chromium. These two heavy metals may come from several activities such as workshops, industries (iron, chemical, fertilizer) and sewerage treatment plant.

Site visits and observations at the Sungai Bunus basin indicated that the restaurants/food court/food stalls, wet markets, shop lots/mini markets along the river were possible to have reduced the river water quality down to Class III or Class V. The major contributors for the pollution sources are from the industrial and human activities along the river.

5. Conclusion
To conclude, the understanding of water quality is important to the relationship in our daily activities between the river. Water quality monitoring is important to maintain the allowable water quality for public health. It was found that the WQI of the Sungai Bunus was between 25.46 % to 64.91 %, which are between Class III and Class V. The Department of Irrigation and Drainage (DID) aims is to achieve Class IIB by the year 2020. This target can be achieved if all stakeholders and communities cooperate in limiting the sources of pollution to the Sungai Bunus.

6. Recommendations
There are two recommendations to improve the condition of the Sungai Bunus, which are by increasing the number of sampling stations and increasing the duration of river quality monitoring to forecast good WQI. Sampling must be done continuously and frequently so that the changes in water quality can be detected more regularly. More parameters can be included for future study, for example, oil and grease, total coliform (biological indicators) to secure finer water quality studies.
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