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An Assessment of Surface Water Quality and Heavy Metals Involving the Radioactive Elements in Sungai Tunggak and Sungai Balok, Gebeng, Kuantan, Pahang: Comparison between Year 2014 and 2015

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Abstract— **INTRODUCTION:** Water pollution caused by radioactive elements and heavy metals has become serious threats to the survival of aquatic organisms, human, and environment especially in Pahang. This alarming circumstance has inspired the study to measure water quality parameters, concentration of radioactive elements and heavy metals in the rivers within an industrial area. For achieving these objectives, collected data was done for Balok and Tunggak Rivers in dry seasons (April – June) in the year 2014 and 2015. Both data were compared and analyzed based on different locations at the selected rivers in Gebeng industrial area, Pahang. **METHODS:** The physical parameters such as temperature, specific conductivity, pH, turbidity, and dissolved oxygen (DO) were measured by using hydrolab. The water samples were then collected for tracing the radioactive elements and heavy metals by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Malaysian Interim National Water Quality Standard (INWQS) was used as reference. **RESULTS:** Heavy metals and water quality parameters were all within the permissible limit except for turbidity and specific conductivity in both years 2014 and 2015. Besides, radioactive elements investigated in this study showed that the concentration of one of the investigated elements was thorium, exceeded the permissible limit at the upstream area which recorded 2.54ppb in year 2014 and 0.75ppb in 2015. **CONCLUSIONS:** The study outcomes showed the pollutants presence were reflected to some water quality parameters from upstream, middle stream and downstream for both years.

Keywords— water quality, radioactive elements, heavy metals, industrial area

I. INTRODUCTION

Radioactive elements are naturally present in the environment. They can be defined as elements that have unstable nucleus. For heavy metals, they have no definite meaning. They have various definitions in term of density, atomic weight, atomic number, and toxicity. Despite their diverse definition, all heavy metals possess metallic property such as high density, ductile and shiny. Heavy metals are considered as very hazardous pollutants to the environment because of their toxicity, persistence, and bioaccumulation problems [1]. They also can be sorted into lethal metals and essential metals according to their toxicity.

Heavy metals are needed and played their own role in human life. For instance, some metals such as Zn, Cu, Mn, Ni, and Co are classified as micronutrients that played a vital role in aquatic ecosystems. However, they are also able to give worst impact towards the health of consumers if they are in quantity that more than necessary. The increase need and demand on petrochemical industries and mining industries gave rise to concentration of radioactive elements in the water besides heavy metal pollution, which is another source of pollution [2].

The higher accumulation of heavy metal concentration in the aquatic environment is catastrophic to aquatic ecosystem, human and has been progressing in Malaysia [3]. Besides, the presence of heavy metal at higher concentration can cause poisoning, damage or death in animals, humans, and plants. Due to the impact of radioactive elements and heavy metals, their concentration in water surface in Malaysia should be periodically monitored and examined. Water quality assessment can also be done through evaluation of physical parameters such as temperature, pH, conductivity, dissolved oxygen (DO), and turbidity. If not managed properly, radioactive elements can pollute water supplies such as river and sea. Since they have a tendency to dilute in the river, their prescribed average safety levels in water are often misleadingly high.

However, the research in this area is still quite limited. Therefore, the research was conducted to measure the water quality parameters and concentration of radioactive elements and heavy metals in the rivers within an industrial area. The permissible limit of these radioactive elements and heavy metals in rivers was discussed. The research was done in Pahang state, focusing more on Gebeng Industrial Area.

II. MATERIALS AND METHODS

A. *Study Area Description*

All the samples were collected at Sungai Balok and Sungai Tunggak, Pahang. **T**hree transect lines (TL 1, TL 2, TL 3) were set up with 6 sampling points fixed along each transect line for both rivers. The transect lines were classified as upstream (TL 1), middle stream (TL 2), and downstream (TL 3). SB1, SB2, and SB3 were located in Sungai Balok area while ST1, ST2, and ST3 were located in Sungai Tunggak area. Station SB1 and ST1 were situated in the upstream area while station SB2 and ST2 were located in the middle stream area. Station SB3 and ST3 were located in downstream zone. In short, the total sampling points for both rivers is 6.

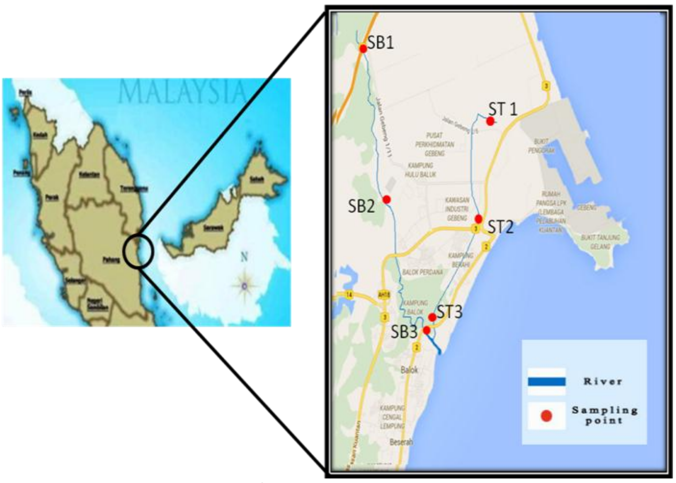

Fig. 1. Map of Sampling Locations in Gebeng

B. *Sampling Methodology*

Prior to the sampling process, all sampling gears were well prepared a few days earlier. The apparatus that was used for sampling such as falcon tube were dipped in 5% nitric acid (HNO_3) overnight. After that, all the apparatus was rinsed with distilled water and left to dry.

The method for *in-situ* parameter was adapted from [4] with some adjustment. Sampling activity was carried out for upstream, middle stream, and downstream in the similar time of sampling at the selected rivers. The sample from each sampling points were taken duplicated to get more accurate result. The sampling collection was done for 2 times in each month for three months to get an average of the result. Physical parameters that were measured involved water temperature, specific conductivity, pH, turbidity, and dissolved oxygen (DO). Physical parameter readings were measured by using Hydrolab, while water samples were collected by using a horizontal water sampler. Then, they were kept in 1L PTFE bottle for each sampling point for laboratory analysis. The PTFE bottles were labeled according to the sampling point taken, and they were placed in an ice box in order to preserve the nature and content of the water. Preservation of the samples was done by adding 2mL of 2% nitric acid (HNO_3) in PTFE bottles.

C. *Laboratory Analysis*

The samples were analyzed in accordance with the APHA standard method [5-6] with some adjustment. The samples were filtered by using 0.45µm nylon filter syringe. The filtered solutions were stored in the refrigerator (-20˚C) until analysis. Filter solution, then were injected and ran in Inductively Coupled Plasma-Mass spectrometer (ICP-MS) to determine the content of heavy metal and radioactive elements. The concentration was recorded in ppb units.

D. *Radioactive Elements and Heavy Metals Analysis*

Before the analysis process takes place, the standard stock solution was prepared by using the Multi-Element Calibration Standard supplied by Perkin Elmer. The Multi-Element Calibration Standard that was used for heavy metals and radioactive elements was different according to the metals and elements measured. The multi-element was used as it is compatible with ELAN9000 ICP-MS. This was a vital step in order to obtain a good calibration curve. The best calibration curve was crucial as it is a benchmarked that ICP-MS could produce an acceptable quantitative data for detection of heavy metals or rare earth elements. The best value for calibration curve was ≥0.995 of correlation coefficient (R^2).

E. *Analytical and Statistical Analysis*

The collected data for water quality parameters were compiled using Microsoft Excel (version 2010) and analyzed by using SPSS version 22. Then, water quality parameter readings were compared to the Interim National Water Quality Standard for Malaysia (INWQS) adopted by the Department of Environment (DOE), while concentration of heavy metals and radioactive elements in the water samples were compared with the permissible limit standard.

III. RESULT AND DISCUSSIONS

A. *Water Quality*

Overall, there were five water quality parameters that included in this research. They are Dissolved Oxygen (DO). pH, specific conductivity, temperature, and turbidity.

1) *Dissolved Oxygen (DO) of Total Sampling*

The average dissolved oxygen (DO) of the total sampling for sampling location SB1 until ST3 are shown in Figure 2. The average of DO observed at the Balok River in the year 2014 was very high compared with the average of DO observed for both Balok River and Tunggak River in the year 2015 especially at sampling point SB3 with 5.945 mg/L. Based on INWQS, the acceptable limit for DO under class III is 3 mg/L to 5 mg/L. Therefore, for the year 2014, all sampling points (SB1, SB2, SB3) which indicate the higher level of DO more than 3 mg/L were falling within class III. However, for the year 2015, only sampling point SB3 and ST3 were falling within class III while the other sampling points were fall within class IV.

The DO concentration in the river reveals the amount of oxygen supply in the water. It is closely related to many factors such as flow of the river, present of sources of organic pollution, temperature of water and assimilative capacity of the river. Besides, biological activity also plays an important role in controlling DO level. Other than that, this could be due to the lack of aquatic organism in the river water. Reference [7] mentioned that low DO levels could result from lacking of aquatic plant and aerobic organism in water. Microorganism breaks down organic materials and uses all the available oxygen in river water, which is supplied by aquatic plants. The process of photosynthesis releases oxygen while respiration and nitrification consume oxygen [4]. As observed, it can be noticed that residential areas, factories, and food stalls which is located along both rivers were focusing more on upstream and middle stream part rather than downstream area. Most of their wastes are flowing into the river. Thus, the low concentration of DO recorded at most sampling points in year 2015 indicates that the input of organic pollutants from upstream affect the DO concentration at another part of rivers due to the utilization of DO by microorganism to break down the organic matter.

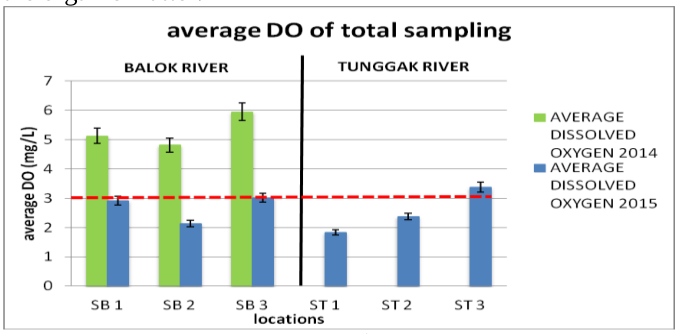

Fig. 2. Average DO of total sampling.

2) pH of Total Sampling

Figure 3 showed the average pH of the total sampling for sampling location SB1 until ST3. pH was shown to be the most stable parameter which did not show drastic differences between all sampling points. Both of the rivers in this study recorded pH of about 5-9 for both years 2014 and 2015. Compared to INWQS, the acceptable limit for pH under class III and IV is 5 until 9. Thus, the average pH of the total sampling in all sampling points for both years was within the permissible limit and categorized under class III or IV.

The pH value which showed the acidic value at the upstream area of Tunggak River (ST1) and at middle stream area of the Balok River (SB2) were the nearest to the selected study area which occupied by most of the industries. SB2 was located near industrial area and factories while ST1 was located near the mining area. The low value of pH could be strongly associated with acidic substance in the excreted industrial effluents from various industries in that area including chemical and mining. However, according to [4], there were some other factors that might affect the pH value of water. A few factors stated were photosynthetic activity, microbial respiration, and decomposing activities, especially when it involves rivers. However, the alkaline pH value at other locations, especially at downstream areas might be resulting from industrial effluents consist of polymer, chemical, metal, gas and power industries [8].

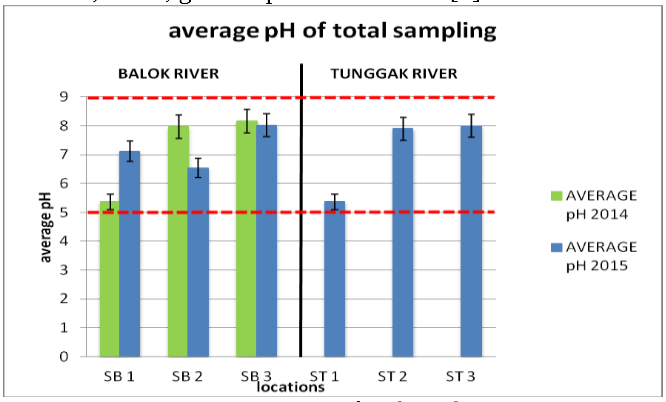

Fig. 3. Average pH of total sampling.

3) Specific conductivity of Total Sampling

The average specific conductivity of the total sampling for sampling location SB1 until ST3 are presented in Figure 4, ranged between 0 to 60mS/cm. Based on INWQS, the acceptable limit for specific conductivity under class IV is 6000µS/cm or 6mS/cm. Generally, the average specific conductivity of the total sampling in all sampling locations for the year 2015 was exceeding the permissible limit that complies with Class IV of INWQS except for ST1 and ST2, while for year 2014, only SB2 and SB3 were exceeding the permissible limit of class IV.

Specific conductivity refers to the ability of the water to conduct electricity and it is closely related to dissolve ion content in the water [6]. Both downstream areas of the river have the highest value of conductivity because of inflowing of saline water during high tide from the South China Sea. Besides, there is other sources of wastewater of the housing area, industrial area, urban and surface run-off that influence the concentration of ions in water, such as natrium ion (Na^+) and chloride ion (Cl^-) which is contributed by the seawater that affect the level of conductivity. This was supported by [9]. They were reported that ionic pollutants from the industries and other anthropogenic activities also contribute to the level of conductivity in water. In short, the higher the concentration of ions, the higher the level of specific conductivity in water.

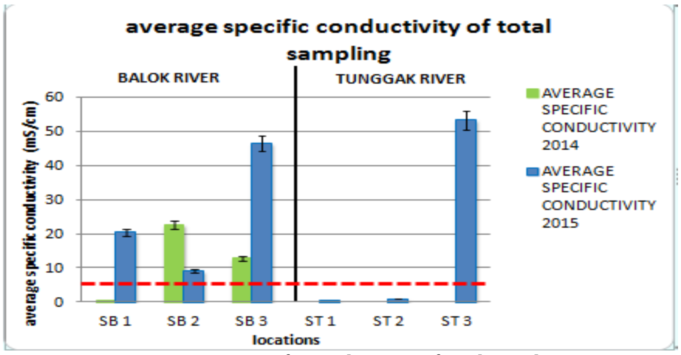

Fig 4. Average specific conductivity of total sampling.

4) *Temperature of Total Sampling*

The average temperature of the total sampling for sampling location SB1 until ST3 are shown in Figure 5. Same as pH, temperature also showed slightly different between all sampling points for both years 2014 and 2015 which were range of 25 to 35˚C. Referring to INWQS, the level of temperature for all sampling points for both years were normal as the reading shown higher than 2˚C. In short, all the temperature readings for both years were falling within class IIA and III.

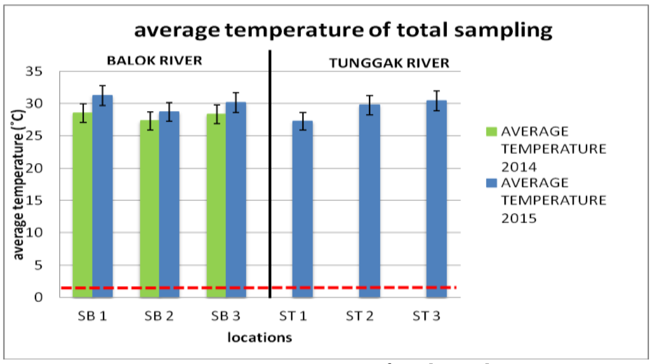

Fig. 5. Average temperature of total sampling.

5) **Turbidity of Total Sampling**

Figure 6 represented the average turbidity of the total sampling for sampling location SB1 until ST3. Both of the rivers in this study recorded high turbidity for both years 2014 and 2015 which is SB1 showed the highest with 171.37 NTU for the year 2015. Based on INWQS, the average turbidity of the total sampling in all sampling points for both years was exceeding the permissible limit of class IIA and IIB (50 NTU) except for SB3 for year 2014 and SB2 for the year 2015.

Turbidity refers to the concentration of particulate matter suspended in water. The factors that affect turbidity in water include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organism. As observed, the day before sampling was a rainy day. Therefore, rainfall might be contributing to the high level of river water turbidity for all sampling points. It was because a large amount of fine sediment was eroded from the land and washed into the rivers. This statement was supported by [4] in their study. They mentioned that heavy rainfall could result in runoff, which increases the presence of clay.

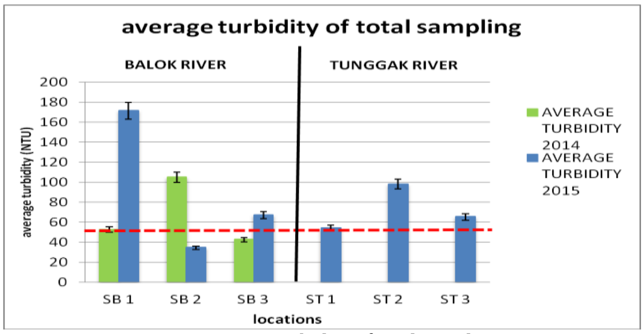

Fig. 6. Average turbidity of total sampling.

B. *Heavy Metals*

Lead (Pb) was determined in year 2014, while for year 2015, Lead (Pb), Cadmium (Cd) and Arsenic (As) were determined. Figure 7 shows the average concentration of heavy metal in Balok River for year 2014 while figure 8 shows for 2015. Compared to INWQS, all heavy metals which are Lead, Cadmium, and Arsenic concentration in both Balok River and Tunggak River for year 2015 were within the acceptable limit while for year 2014, SB2 (middle stream) and SB3 (downstream) were exceeding the acceptable limit.

The high level of heavy metals in Balok and Tunggak River maybe occurring due to industrial effluent water discharged.The reasons for high Pb level at SB2 and SB3 might be due to leaded petrol spill from fishing boats and from lorry that flow into the river. Reference [10] supported this statement by mentioning in their study that the potential source of lead contamination was might be occur due to leaded petrol, industrial effluents and residential sewage.

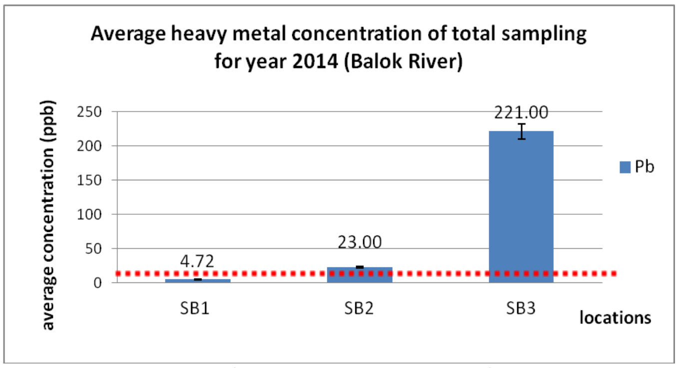

Fig. 7. Average of Heavy Metal Concentration for Year 2014

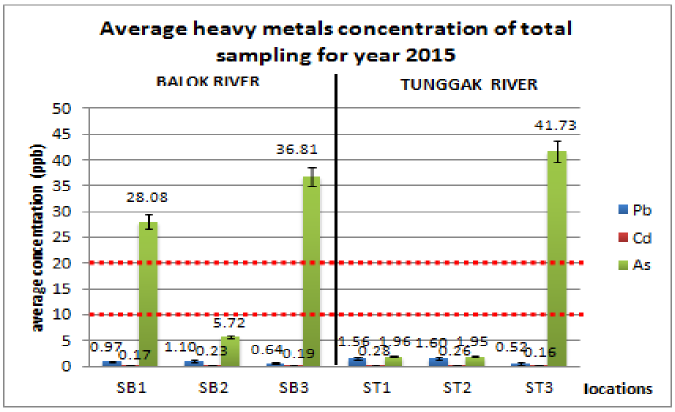

Fig. 8. Average of Heavy Metals Concentration for Year 2015

C. Radioactive Elements

Two types of radioactive elements were determined in year 2014 and 2015. They were Thorium-232 and Uranium-238. Figure 9 shows the average concentration of radioactive elements in Balok River for year 2014 while figure 10 shows the average for year 2015. As observed, concentration of Thorium (Th) was decreasing from upstream (SB1), middle stream (SB2) and downstream (SB3) for both years 2014 and 2015.The concentration of Uranium (U) was almost the same at all locations for year 2014 where the highest concentration was recorded at SB3 with -4.34 ppb and the lowest concentration recorded at SB2 with -4.58 ppb. However, the concentration of U for year 2015 showed the positive results. Despite the negative value, the concentration of U at all locations for both years 2014 and 2015 was within the acceptable limit while for Th, the reading at SB1 exceeding the limit for both years 2014 and 2015.

The highest concentration of Th might be occurred due to the presence of rare earth refining activities near the sampling location. As Th and U was not the target of refining process, so they can be detected in waste stream. Despite the controlled treatment outlined and measures taken by industries, the huge amount of effluent water could cause mobilization of radioactive pollutant to the environment.

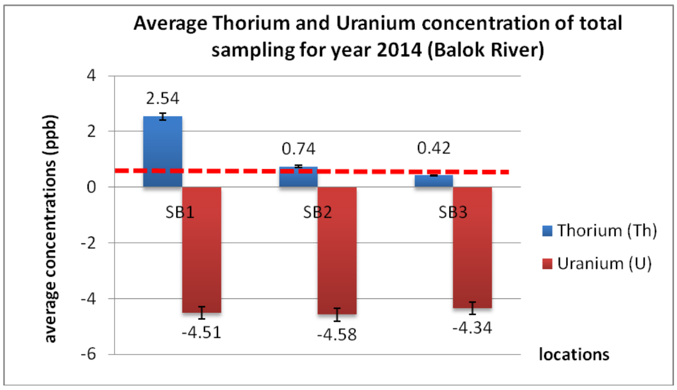

Fig. 9. Average of Radioactive Elements Concentration for Year 2014

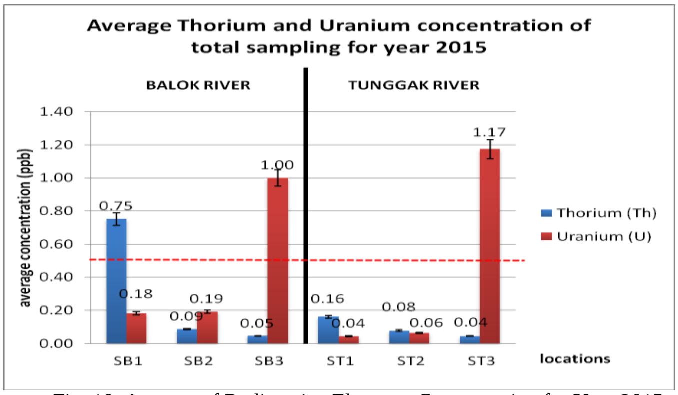

Fig. 10. Average of Radioactive Elements Concentration for Year 2015

IV. Conclusion

The assessment of water quality in Balok River and Tunggak River was done based on INWQS adopted by DOE. Overall, the average values of water quality parameters (DO, pH, temperature) at all locations of Balok River and Tunggak River for both years 2014 and 2015 were within the permissible limit except for turbidity and specific conductivity. On the other hand, the concentration of all heavy metals detected (Lead, Cadmium and Arsenic) were within the permissible limit in all locations except for Lead in year 2014. However, the concentration of Th was beyond the acceptable limit in the upstream area of Balok River (SB1) for both years, while for U, the concentration was within the acceptable limit for all locations for both years.

Acknowledgment

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