INVESTIGATING ON WATER QUALITY AND RADIOACTIVE ELEMENTS IN TRACING THE ORIGIN OF POLLUTANT AT GEBENG INDUSTRIAL AREA

BY

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ABSTRACT

Extensive deterioration of water quality caused by the intensive land use activities in rivers and rapid response of pollutants from different sources may harm the aquatic organisms, human, and environment. This alarming occurrence has inspired the study to measure water quality parameters, the concentration of radioactive elements and heavy metals in surface water and sediment, and investigating the main sources of pollution in rivers. For achieving all these objectives, data collection was done for Balok and Tunggak Rivers in wet seasons for surface water while for sediment, only baseline data were collected. The data were compared and analyzed by using environmetric analysis (Cluster Analysis and Principal Component Analysis) based on different points at the selected rivers in Gebeng, Pahang. The physicochemical parameters such as temperature, specific conductivity, pH, turbidity, dissolved oxygen (DO), and salinity were measured by using the Hydrolab. The water and sediment samples were then collected for tracing the radioactive elements and heavy metals by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Prior to analysis, the sediment samples were undergoing the full-digestion process. Both the Malaysian and International standards were used as a reference and it was found that water quality parameters were all within the permissible limit except for turbidity and specific conductivity. Besides, heavy metals and radioactive elements investigated in surface water showed that the concentration of Iron was exceeding the permissible limit at most of the sampling points and Thorium exceed the permissible limit at SB1 with value of 0.0005 ppm. While for sediment, the concentration of Iron was exceeding the permissible limit at the upstream area of both rivers and the concentration of Arsenic were exceeding at downstream area which recorded at 10.3713 ppm. Then, the finding from the environmetric analysis showed that the main pollutants loading in Balok and Tunggak River were Lead (first component), specific conductivity (second component), Thorium (third component), and pH (fourth component). The study outcomes showed that the presence of the pollutants in rivers were originated from both point and non-point sources.

خلاصة البحث

إن التدهور المستمر في جودة المياه الناجم عن أنشطة الاستخدام المكثف للأراضي في الأنهار والاستجابة السريعة للملوثات من مصادر مختلفة قد تضر بالكائنات المائية والبشرية والبيئة. وقد ألهم هذا الحدث المثير للقلق هذه الدراسة لقياس معايير جودة المياه، وتركيز العناصر المشعة والمعادن الثقيلة في المياه السطحية وفي الرواسب وللتحقيق من المصادر الرئيسية للتلوث في الأنهار. لتحقيق كل هذه الأهداف، تم جمع البيانات من نهري بالوك وتونغجاك في المواسم الرطبة للمياه السطحية بينما للرواسب تم جمع بيانات خط الأساس فقط. تمت مقارنة البيانات وتحليلها باستخدام التحليل البيئي (التحليل الكتلي وتحليل المكونات الرئيسية) استنادًا إلى نقاط مختلفة في الأنهار المختارة في منطقة جيبينغ في ولاية باهانج. تم قياس المعايير الفيزيائية والكيميائية مثل درجة الحرارة، والموصلية النوعية، والحموضة، والتعكر، والأكسجين الذائب، والملوحة باستخدام جهاز Hydrolab. بعد ذلك تم جمع عينات الماء والرواسب لتتبع العناصر المشعة والمعادن الثقيلة باستخدام مطياف الكتلة البلازما المتقارنة (ICP-MS) حيث عولجت عينات الرواسب قبل التحليل بعملية الهضم الكامل. تم استخدام كل من المعايير الماليزية والدولية كمراجع، وتبين أن معايير جودة المياه كانت ضمن الحد المسموح به باستثناء مستويات التعكر والموصلية النوعية. إلى جانب ذلك ، أظهرت المعادن الثقيلة والعناصر المشعة التي تم فحصها في المياه السطحية أن تركيز الحديد تجاوز الحد المسموح به في معظم نقاط جمع العينات وأن الثوريوم تجاوز الحد المسموح به في النقطة SB1 بقيمة 0.0005 جزء في المليون. أما بالنسبة للرواسب فقد تجاوز تركيز الحديد الحد المسموح به في منطقة المنبع لكلا النهرين وقد تجاوز تركيز الزرنيخ في منطقة المصب الحد المسموح بقيمة 10.3713 جزء في المليون. بعد ذلك أظهرت النتائج المستخلصة من التحليل البيئي أن الملوثات الرئيسية المحملة في بالوك ونهر تونغجاك كانت الرصاص (المكون الأول)، والموصلية النوعية (المكون الثاني)، والثوريوم (المكون الثالث)، ودرجة الحموضة (المكون الرابع). أظهرت نتائج الدراسة أن وجود الملوثات في الأنهار قد نشأ من مصادر محددة وغير محددة.

APPROVAL PAGE

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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To everyone who holds my hand,

Keeps it tight till the end, believed me and bring me to the top,

To the one who directly and indirectly makes me stand till today,

Everyone that colors my roller-coaster journey.

Thanks!

May Allah bless and protect us, forgive all our sins and grant us jannah.

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LIST OF SYMBOLS

<	Less than
%	Percent
°	Degree
°C	Degree Celcius
±	Plus Minus
g	Gram
kg	Kilogram
mL	Millilitre
µg/g	Microgram per gram
µg/kg	Microgram per kilogram
mg/L	Milligram per litre
ppb	Parts per billion
ppm	Parts per million

LIST OF ABBREVIATIONS

APHA	American Public Health Association
As	Arsenic
Cd	Cadmium
Cl^-	Chloride ion
CO_3^-	Carbonate ion
Cu	Copper
DO	Dissolved Oxygen
DOE	Department of Environment
EDTA	Ethylenediaminetetraacetic acid
Fe	Iron
HCl	Hydrochloric Acid
HCO_3^-	Bicarbonate ion
HCO_3^-	Bicarbonate ion
HF	Hydrofluoric Acid
HNO_3	Nitric Acid
ICP-MS	Inductively Coupled Plasma Mass-Spectrometry
NWQS	Interim National Water Quality Standard
Mn	Manganese
NH_4^{2-}	Ammonium ion
Ni	Nickel
NO_3^-	Nitrate ion
Pb	Lead
PO_4^{2-}	Phosphate ion

SO_4^{2-}	Sulphate ion
Th	Thorium
U	Uranium
UNSCEAR	United Nations: Scientific Committee on the Effect of Atomic Radiation
USEPA	United States Environmental Protection Agencies
Zn	Zinc

CHAPTER ONE

INTRODUCTION

1.1 RESEARCH BACKGROUND

Everything around us is made of elements or different types of atoms. Radioactive elements refer to the atoms that contain an unstable combination of neutrons and protons which are the elements that have an atomic number higher than 83 in the periodic table. This combination can occur naturally or by altering the atoms. The nucleus of the elements may degenerate at any period of time, which is known as the half-life. While the half-life varies from element to element, it provides a good probability of the life of a radioactive element.

Furthermore, heavy metals have no specific meaning because they have a variety of definitions in term of atomic number, atomic weight, density, and toxicity. However, all heavy metals possess metallic properties such as shiny, high density, and ductile. Heavy metals are considered as very hazardous pollutants to the environment and ecosystem due to their toxicity, persistence, and bioaccumulation problems (Ye *et al.*, 2012). They can be divided into essential metals and lethal metals based on their toxicity. For example, the heavy metals that are dangerous such as mercury, cadmium, arsenic, and lead are the toxic pollutants that can pollute the water resources and rivers.

Malaysia is one of the countries that rich with its bounty of water resources and these resources are contributing to the economic and development of the country. Currently, one of the activities that gave clearly a beneficial economic development for countries is mining exploitation and also industrial activities. Therefore, water is

becoming the natural resources that are very important to the earth and its residents for domestic and industry user. However, the conditions of water resources in Malaysia were changing with the urbanization and industrialization growth. The river quality monitoring program conducted by Department of Environment (DOE) in 2014 found that 52% of the river in the country was found to be clean, 39% slightly contaminated and 9% contaminated, where the major sources of pollution were contributed by the beverage industries (Afroz and Rahman, 2017).

Generally, the industrial activities are generating a lot of pollutants through their production and manufacturing process. Hence, these activities may cause extensive damages to the environment, river ecosystem, and human health if the concentration of toxic pollutants such as heavy metals and radioactive elements in the rivers are higher than the permissible limit. Besides, the leachate, industrial effluents, and wastewater originated from those areas will flow to the rivers and causes the deterioration of surface water quality. In addition, the agricultural activities also tend to be done near the river due to the excellent fertility of soils, caused by the nutrients deposited and agricultural runoff when the river overflows (Singh *et al.*, 2017).

Other sources of pollutants in rivers may come from domestic waste, wastewater from septic tanks, and stormwater runoff. The release of these pollutants into the lakes, streams, rivers, estuaries, and oceans may cause the interference with the beneficial use of the water or with the natural functioning of ecosystems. In addition to the release of substances such as chemicals or microorganisms, water pollution may also include the release of energy, in the form of radioactivity or heat, into the water bodies. In short, river water bodies can be polluted by several pollutants, including the pathogenic microorganisms, organic waste, plant nutrients, toxic chemicals, sediments, heat, petroleum, and radioactive substances.

Hence, the rapid growth of industrial development may impose severe stress on the available water resources in terms of clean water supply. The deteriorating of water quality and the depletion in the availability of water resources due to the radioactive element and heavy metals pollution may harm the public health. Therefore, it has been attracting a lot of public attention recently, especially those researchers in the hydrology and environmental biotechnology field. The previous study showed that the toxicity and accumulation of heavy metals and radioactive elements do not only depend on the metals concentrations but on other factors. These factors include the form in which the metals are present, the type and concentration of other materials present and the integration of physicochemical water quality parameters (Rahman *et al.*, 2017).

This phenomenon has stimulated the search for prevention and treatment strategies against the deteriorating of water quality and the pollution of radioactive elements and heavy metals in rivers such as bioremediation and phytoremediation technology. However, in order to achieve that, a clear picture about the continuous monitoring of surface water quality and the isotopes such as heavy metals and radioactive elements present in it should be identified first, as it will provide keywords or primary data for easier detection of main sources of pollutant in the rivers. The isotope of heavy metals and radioactive elements are the special value for detecting the residence time and monitoring its concentration in rivers that assuming that there is no contamination of the water has occurred.

Hence, this research can be addressed to solve the surface water pollution issue. A number of studies investigated about water quality and heavy metals (Akyuz *et al.*, 2001; McComb *et al.*, 2014), but there is no research that focusing on the radioactive elements in surface water and sediment for tracing the pollution sources by

using environmetric techniques had been done yet. Under this circumstance, an attempt was taken to investigate the present status of rivers by tracing the main sources of pollutant loading in rivers within an industrial area by using an environmetric technique such as Cluster Analysis (CA) and Principle Component Analysis (PCA). Besides, the trend of physicochemical water quality parameters readings and the concentration of heavy metals and radioactive elements measured in surface water and sediment were discussed and compared with local and international permissible limits.

Basically, this research was done in Pahang state, focusing more on Gebeng Industrial Area. The area is about 20 km far from Kuantan City and near to the Kuantan port. There are two rivers are flowing through this industrial area namely as Balok and Tunggak. This area is actively involved in various types of land use activities such as agricultural activities, restaurant and residential area at the downstream part of both rivers and also industrial activities including petrochemical and rare-earth processing plant.

1.2 PROBLEM STATEMENT

Recently, rivers were continuously loaded with numerous chemical pollutants from anthropogenic and non-anthropogenic sources, thus resulted in alarming concentrations of heavy metals and radioactive elements in surface water and sediment. Speedy and prompt developments in the industrial sector at Gebeng threaten the water quality status of the rivers and deteriorating the environmental conditions around the area due to the wastes that produced from this industrial area were alleged to be indirectly discharged into the adjacent rivers (Abdullah *et al.*, 2015). Hence, the random discharge of the wastewater and effluents from the industries and sewerage

treatment plants along the river catchments around Gebeng area were harming the water quality status (Sujaul *et al.*, 2013).

According to records of Department of Environment (DOE) in year 2008, about 17,633 of water pollution cases originated from point sources in Malaysia covered of 54.01% from sewage treatment plants, 38.73% from manufacturing industries, 4.48% from animal farms and 2.78% from agro-based industries (Afroz *et al.*, 2014). This collected data showed that almost all of the point sources are due to the development of industrial activities and this problem also occurred in Gebeng Industrial Area.

Besides, the other activities such as deforestation and reclamation also actively done in this area due to a lot of new construction sites have been developed. Therefore, the sediments in this area had also been contaminated and the process of contamination had been enhanced with the discharge of industrial effluents. The contamination of sediment was a common problem in the rivers of any industrial estate (Krishna and Govil, 2007; Shukurov *et al.*, 2009) just like in Gebeng area. The sediments may act not only as sinks but also as the sources of contamination indicator in the river systems.

Under certain condition, toxic pollutants such as heavy metals and radioactive elements that accumulated in sediments could be released to the surface waters and thus been further taken up by the human (Ghosh and Singh, 2005). They are accumulated in the sediment in Balok and Tunggak River for a long time and therefore pose an auxiliary toxic to the whole aquatic animals and plants that in contact with the river water (Gbaruko and Friday, 2007; Yadav *et al.*, 2017).

The sediments can be deposited when suspended particles settle down to the bottom of a body of water, due to the water flow slows down or stops (Muller *et al.*,

2017). This can significantly reduce the quality of water in Balok and Tunggak River as the turbidity in this area might be higher than the permissible limits. Hence, the surface water pollution and contaminated soil can bother the resident's livelihood because by using this polluted water as their drinking sources may harm the health of residents, and also create several of diseases and disasters especially water-borne disease. Yet, any in-depth study on the tracing of main pollutant sources involving the radioactive elements at Gebeng Industrial Area as well as in east-coast of peninsular Malaysia was never been done; neither the study of surface water nor sediment contamination. Therefore, there are very limited efforts and baseline information that had been produced regarding the treatment of the wastewater from the industries especially from the rare earth treatment plants and also the sewage from the residential area.

Presently, the Department of Environment (DOE) was monitored Tunggak River in the downstream part only (Sujaul *et al.*, 2013). Even though these efforts had gained some information regarding the condition of the river in Gebeng, but it could not indicate the overall real scenario in the rivers because the study should be done from the upstream area until the downstream area. Therefore, there is a need to assess the physicochemical water quality parameters, the concentration of heavy metals and radioactive elements in surface water and sediment from the River of Balok and Tunggak, and lastly to find out the main pollutant sources that can generate several important information for the authority concerned or policymakers to take proper action for better management of river water in Gebeng Industrial Area.

1.3 RESEARCH QUESTIONS

i. What is the *in-situ* physicochemical water quality parameter reading in