TUYỂN TẬP BÁO CÁO HỘI NGHỊ TOÀN QUỐC

KHOA HỌC TRÁI ĐẤT VÀ TÀI NGUYÊN VỚI PHÁT TRIỂN BỀN VỮNG

Hà Nội, 11 - 11 - 2022

ERSD 2022

NHÀ XUẤT BẢN GIAO THÔNG VẬN TẢI

MỤC LỤC

Research and evaluate contents of heavy metals in water of Ba Che river, Quang Ninh province, Vietnam

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ABSTRACT

The article investigates data on heavy metal content from Ba Che River water to the Voi Lon estuary involving Bai Tu Long Bay at Quang Ninh. The article determines the chemical content, and origin of heavy metals in the Ba Che river, which flows into Bai Tu Long Bay related to the above-mentioned region by multivariate statistical analysis, chemical analysis, and pollution indices involving numerical comments by numbers. Results of the research, All heavy metals were detected in sediment samples with mean concentrations of As, Hg, Pb, and Cd range of 0.3-20; 0.2-0.6; 0.7-3.2; and 0.6 µg/l, respectively. Besides, the mean metal concentration in the water samples decreased in the following order: As>Pb>Hg>Cd.

Keywords: Monitoring; heavy metal; pollution indices; inequalities expression; water quality assessment.

1. Introduction

Contamination of heavy metals in the environment has attracted a wide concern due to the ever-increasing pollution of soil, sediment, and water in many regions of the world [1, 2], especially in some developing countries like Vietnamese [3, 4]. Heavy metals such as nickel, chromium, copper, arsenic, cadmium, and lead are considered serious contaminants in the aquatic environment because of their persistence and environmental toxicity [5]. Both natural and anthropogenic activities are responsible for the huge amount of toxic heavy metals discharged into the aquatic environment [6]. Rapid industrial development and urbanization have provoked some serious concerns for the aquatic environment over the last few decades.

Rivers play a key role in preserving freshwater, adjusting the local climate, and improving environmental conditions. However, with accelerated population growth, urbanization, and industrialization, heavy metal pollution of rivers has become a serious issue [7, 8].

The Ba Che river system consists of four major rivers Ba Che River, Quach River, Doang River, and Lang Cong River. Currently, because of the strong development of industrialization, environmental issues are increasingly aggravated. In the river ecosystems, river water can be polluted with various kinds of hazardous substances and heavy metals through several pathways such as disposal of liquid effluents, terrestrial runoff, and leachates carrying chemicals originating from numerous urban, industrial, and agricultural activities. Therefore, this study focused on Ba Che River waters and aimed (1) to investigate total heavy metal anomalies of thirteen heavy metals (As, Hg, Pb, and Cd); (2) to determine the possible sources of these metals contamination and; (3) to assess the Ba Che river risk of heavy metal contamination with pollution indices.

2. Materials and methods

2.1. Description of Study Area

Ba Che River originates from the Northern side of Thien Son mountain range at an elevation of 1,200 m in Hoanh Bo, Ha Long city, continues in the northwest-southeast direction across Ba Che, and discharges into the Bai Tu Long Bay through the Voi Lon estuary. The Ba Che River basin system also includes four rivers, Ba Che River, Quach River, Doang River, and Lang Cong River, all joining Ba Che River in Ba Che District in Quang Ninh Province.

Ba Che River is a 150 km long river, with the total drainage area of the basin being 951 km² (Fig. 1). The average annual flow at the basin outlet is 43.05 m³/s, corresponding to a total water resource of 1357.7 million m³ (accounting for 6.90% of the total surface water resources of the Ba Che basin).

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Figure 1. Locality of the Ba Che River basin.

2.2. Sampling Collection and Analysis

The location of the study area and the layout of the survey stations are shown in Figure 2. A total of 4 water quality survey sites were studied in Table 1. Sample collection and survey studies were conducted in 2019. Vietnamese Standards (TCVN 6663-6:2018; TCVN 6663-3:2016) were chosen as the references for steps and tools in the sample collection process. On each of the sampling sites, two subsamples were taken by randomly collecting fresh surfaces around the center sampling site (3 m). Combined with the center sample, three samples are collected and mixed thoroughly into one composite sample for post-processing analysis. The water samples were acidified with HNO_3 at 0.3% concentration to prevent precipitation. Following the collection, all samples were stored and transported to the qualified laboratory.

Monitoring results are evaluated using national technical regulations on surface water quality (QCVN 08-MT:2015/BTNMT), column A_2 [9].

Table 1. Locations of sampling sites along the Ba Che River in Quang Ninh

No.	Study locations	Symbols	Coordinates (VN 2000)	
1	Ba Che River	SW1	2355481	445206
2		SW2	2353282	450661
3		SW3	2349907	455575
4		SW4	2347576	459983

Figure 2. Study area and sampling sites.

2.3. Metal Analysis in Water

For surface water samples of this study, the concentration of heavy metals (As, Hg, Pb, and Cd) was determined by inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry. To ensure the quality of analysis, the control methods and laboratory quality assurance were implemented, including the use of standard operating procedures, analysis of reagent blanks, calibration with standards, and analysis of replicates.

2.4. Data Analysis

Several statistical tools, mainly including Pearson's correlation analysis, SPSS 20.0, Adonis test,

Procrustes analysis, and constrained ordination principal coordinate analysis (CPCOA), were used to investigate the correlations or differences between heavy metals and samples. Microsoft Excel 2013 was used for other calculations.

3. Results and discussion

3.1. Heavy metal concentration in water

The heavy metals studied include: As, Pb, Hg, and Cd. The content of these metals in water is shown on the chart in Figures 3 to 6.

The results show that the content of heavy metals is all within the allowable thresholds of Vietnamese standards (QCVN 08-MT:2015/BTNMT, column A2). This proves that Ba Che river water has not been contaminated with heavy metals in the water. But the content of metals at different locations has big differences. This difference is described in detail as follows:

* The concentration of arsenic ions (As)

Arsenic content is shown in Figure 3:

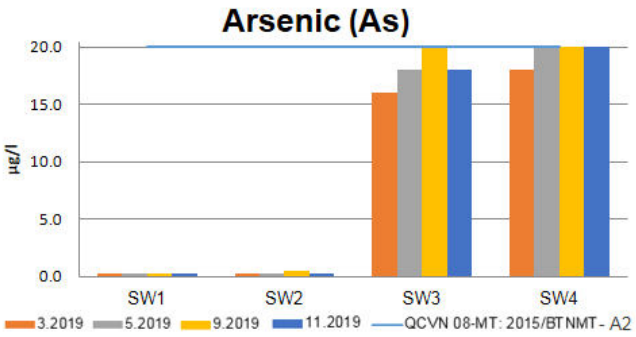

Figure 3. Station wise arsenic concentration (micrograms per liter) in samples of rivers water according to location and sampling time

Arsenic content in Ba Che river water ranges from 0.3 to 20 µg/l. These results are all within the allowable thresholds of Vietnamese standards (QCVN 08-MT:2015/BTNMT, column A2). However, Arsenic concentrations at positions SW3 and SW4, through 4 monitoring periods, are close to the threshold of the standard. Even, the Arsenic content at positions SW3 (Sep. 2019) and SW4 (May, Sep., and Nov. 2019) is equal to the critical value in the standard. Thus, the Ba Che river has a high risk of arsenic pollution downstream. This has the potential to cause heavy metal accumulation in the estuary sediments and affects the Dong Rui aquaculture area.

* The concentration of mercury ions (Hg)

Mercury content is shown in Figure 4:

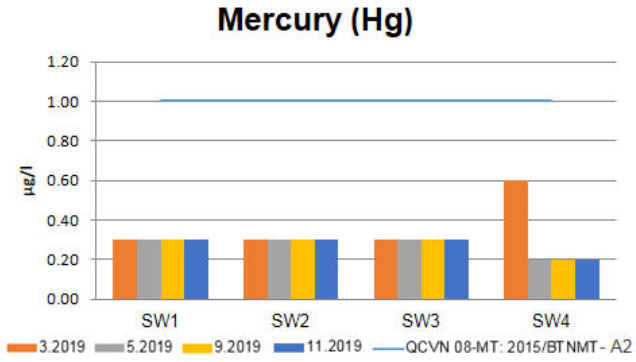

Figure 4. Station wise mercury concentration (micrograms per liter) in samples of rivers water according to location and sampling time

Mercury content in Ba Che river water ranges from 0.2 to 0.6 µg/l. These results are all below the allowable threshold of Vietnamese standards (QCVN 08-MT:2015/BTNMT, column A2). Mercury content is highest at Voi Lon estuary (SW4).

* The concentration of lead ions (Pb)

Lead content is shown in Figure 5:

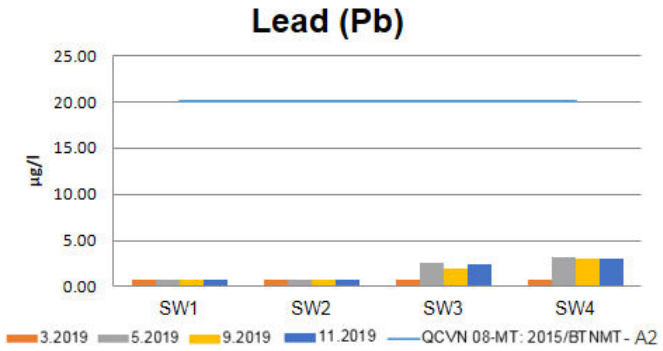

Figure 5. Station wise lead concentration (micrograms per liter) in samples of rivers water according to location and sampling time

Lead content in the Ba Che river water ranges from 0.7 to 3.2 µg/l. These results are all below the allowable threshold of Vietnamese standards (QCVN 08-MT:2015/BTNMT, column A2). Lead content in the Ba Che river tends to increase downstream. The lead content is high at the SW3 and SW4 positions.

* The concentration of cadmium ions (Cd)

Cadmium content is shown in Figure 6:

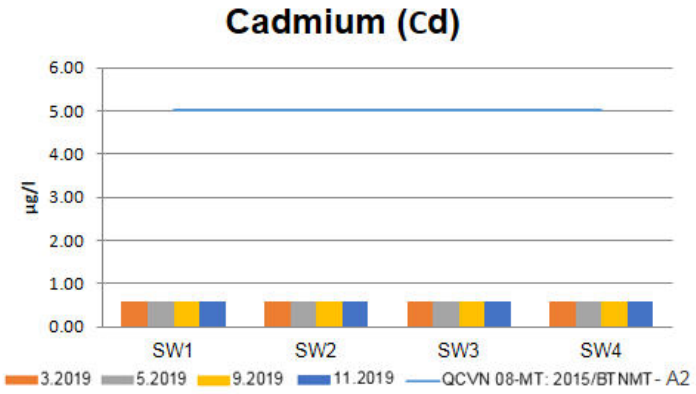

Figure 6. Station wise cadmium concentration (micrograms per liter) in samples of rivers water according to location and sampling time

Cadmium content in Ba Che river water fluctuates around the value of 0.6 µg/l. These results are all below the allowable threshold of Vietnamese standards (QCVN 08-MT:2015/BTNMT, column A2). In general, cadmium content in the water of the Ba Che river is low and there is no fluctuation at the study sites.

3.2. Distribution of Metals in Surface Water

The amount of heavy metals has indicated large variations depending on the locations. This variation may be due to geological and geographical features in different locations [10]. The results of the descriptive statistics of 4 elements for a total of 16 surface water samples are given in Figures 3 to 6. According to the chemical analysis results, the metals are listed in the order of their average concentration value from the highest to the smallest one. Therefore a chain of inequalities formed by the chemical components is given as follows:

As>Pb>Hg>Cd

The analysis results of heavy metal content (As, Pb, Hg, and Cd) showed that they were all small and reached the standard threshold. However, As and Pb concentrations tend to increase and there is a risk of pollution downstream of the Ba Che river. Therefore, it is necessary to take mitigation measures to avoid pollution of water sources downstream of the Ba Che river. This will reduce the risk of heavy metal accumulation in sediments and estuarine organisms.

3.3. Generation Sources and Recommendations

According to research data, the main source of As was aquaculture in the Voi Lon estuary. In this area, aquaculture was the main source of the local economy, the large area of aquaculture caused the disorderly placement of aquaculture feed, and the discharged water will then cause the accumulation of As in the water [11]. Moreover, As was also from the local fine processing industries such as industrial clusters, paper

factories, and other industries. Nam Son is an industrial cluster bordering the Ba Che river to the East, equipped with a large number of metal processing and mechanical equipment industries, which inevitably affect the river water environment in the process of continuous development and growth, thus causing the increase of heavy metals in the water.

From the perspective of aquaculture production, the survey of heavy metals distribution on the Ba Che river can further improve the quality of marine products and effectively evade pollution areas. From the perspective of environmental management, the data of distribution and risk characteristics can provide accurate information for precise heavy metal pollution control and avoid wasting government resources for ecological protection.

Heavy metals are widespread in aquatic environments in the estuary area, and understanding their distribution at the local scare is necessary to advise marine environmental protection policymakers. The key issue for the risk of heavy metal contamination in the Voi Lon estuary is the scarcity of emission control, and it is linked to riverside areas of industrial production, which do not have any option other than polluted rivers as sources for sewage discharge. For better safeguarding and management of the river basin environment, it is paramount that regional heavy metal polluting enterprises implement the most stringent wastewater treatment and discharge control measures in water bodies. Consequently, provisions and specialized supervision departments and supervisors should be introduced, consisting of GIS online monitoring in order to tap into local contamination information, as well as to recognize pollution sources and information requirements.

In addition, advance planning is needed based on Ba Che's special geographical environment and industrial layout. This requires the local government to plan in advance the special disposal institutions and control areas for heavy metal wastewater in order to centralize the management and purification of heavy metal wastewater within the industrial cluster and to achieve zero pollution discharge. Therefore, the local environmental protection department, enterprise regulatory agencies, and local resident representatives need to participate in the development of the regional heavy metal control plan.

4. Conclusion

In this study, the heavy metal content of 16 surface water samples from the Ba Che river in the Ba Che district was investigated in terms of 4 heavy metals (As, Hg, Pb, and Cd). The chemical contents of the samples were determined, and several pollution indices were calculated. The study concludes that the concentrations of the heavy metals As, Pb, Hg, and Cd in water samples were below the A2 levels outlined in the Vietnam Environmental Quality Standards for Surface Water, suggesting low pollution. The average concentration of heavy metals in the Ba Che river was ordered in terms of their excess values: As>Pb>Hg>Cd. Spatial distribution showed that heavy metal concentration of water in different areas remained almost constant, strongly suggesting that the inflow of the tributaries increased the risk of heavy metal concentration. In addition, the results show that the Ba Che river has a high risk of arsenic pollution downstream.

In conclusion, recommendations are more in-depth research, especially to apply these studies into practice. To promote the local government's success in reducing the risk of heavy metal pollution in the Ba Che estuary area.

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TÓM TẮT

Nghiên cứu đánh giá hàm lượng kim loại nặng trong nước sông Ba Chẽ, tỉnh Quảng Ninh, Việt Nam

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Bài báo là kết quả phân tích đánh giá các thông số kim loại nặng trong nước sông Ba Chẽ, đoạn qua thị trấn Ba Chẽ đến cửa sông Voi Lớn, Vịnh Bái Tử Long, tỉnh Quảng Ninh. Các phương pháp sử dụng để xác định hàm lượng hóa học và nguồn gốc phát sinh của kim loại nặng vào nước sông Ba Chẽ, từ đó ảnh hưởng đến Vịnh Bái Tử Long như phương pháp phân tích thống kê đa biến, phân tích hóa học và các chỉ số ô nhiễm liên quan. Kết quả nghiên cứu cho thấy tất cả các kim loại nặng được phát hiện trong các mẫu nước sông có hàm lượng As, Hg, Pb, Cd trung bình dao động trong khoảng giá trị tương ứng là 0,3-20; 0,2-0,6; 0,7-3,2; và quanh ngưỡng 0,6 µg/l. Đồng thời, kết quả tính toán nồng độ trung bình các kim loại nặng trong nước chỉ ra rằng mức độ rủi ro giảm theo thứ tự: As> Pb> Hg> Cd.

Từ khóa: Quan trắc môi trường; Kim loại nặng; Các chỉ số ô nhiễm; Bất đẳng thức theo nồng độ kim loại nặng; Đánh giá chất lượng nước.

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ISBN: 978-604-76-2637-3