Environment and Ecology Research 11(4): 689-695, 2023 http://www.hrpub.org
DOI: 10.13189/eer.2023.110414

Statistical Evaluation on Water Pollution Level of Code River, Yogyakarta Based on Heavy Metals Concentrations and Sampling Locations

Qomariah Hasanah[1], **Andang Sunarto**[1,*], **Jackel Vui Lung Chew**[2], **Mohammad Fadhli Asli**[2]

[1]Tadris Matematika, Universitas Islam Negeri (UIN) Fatmawati Sukarno, Indonesia

[2]Faculty of Computing and Informatics, Universiti Malaysia Sabah Labuan International Campus, Malaysia

Received May 11, 2023; Revised August 6, 2023; Accepted August 23, 2023

Cite This Paper in the following Citation Styles

***(a)**: [1] Qomariah Hasanah, Andang Sunarto, Jackel Vui Lung Chew, Mohammad Fadhli Asli, "Statistical Evaluation on Water Pollution Level of Code River, Yogyakarta Based on Heavy Metals Concentrations and Sampling Locations," Environment and Ecology Research, Vol.11, No.4, pp. 689-695, 2023. DOI: 10.13189/eer.2023.110414*

***(b)**: Qomariah Hasanah, Andang Sunarto, Jackel Vui Lung Chew, Mohammad Fadhli Asli (2023). Statistical Evaluation on Water Pollution Level of Code River, Yogyakarta Based on Heavy Metals Concentrations and Sampling Locations. Environment and Ecology Research, 11(4), 689-695. DOI: 10.13189/10.13189/eer.2023.110414*

Abstract Heavy metal concentrations in four different media like river water, river sediment, silver rasbora fish, and water spinach can be observed to determine the level of river pollution. A statistical evaluation based on two-way analysis of variance can be used to obtain detailed information about the effects of heavy metal concentrations and four different media on the level of river pollution. This study aims to investigate the river pollution level via the effects of heavy mental concentrations and four various media based on sampling locations of Code River, Yogyakarta, Indonesia. The samples of river water, river sediment, silver rasbora fish, and water spinach are sent to Yogyakarta Nuclear Research Center for chemical analysis. The data retrieved from the chemical analysis is used in the statistics analysis. The statistical analysis results indicate an alarmingly high concentration of zinc element compared to the other elements based on the sample taken from river sediment, water spinach, and silver rasbora fish. In addition, the concentration of arsenic in the river water is the highest compared to the other elements. Besides that, the sampling from the downstream area reveals the highest pollution level compared to the other four sampling locations. This study also compared the concentrations of As, Hg, Cr, and Zn in silver rasbora fish and water spinach with the maximum limit set by Codex Alimentarius Commission (1995). This study suggests that the silver rasbora fish and wa-ter spinach in Code River are unsafe for human consumption. The findings of this study can be used as supporting evidence for the government to take necessary actions in reducing river pollution and improving water quality of Code River, Yogyakarta, Indonesia.

Keywords River Pollution, Heavy Metal Concentration, Sampling Location, Descriptive Statistics, Two-way Analysis of Variance

1 Introduction

Code River is one of the rivers that divide the city of Yogyakarta, Indonesia, and it passes through the central city with very dense settlements. Before the river enters the city, it passes through a large area of fertile agriculture. Agricultural chemical waste has likely polluted the river water from upstream. Subsequently, the source of pollutants along the river flow increases with industrial and housing wastes ranging from hospitals, factories, and households. Based on the observation at the study location, the increased amount of waste in the river has polluted the environment until its downstream. The Code River water is now loaded with pollutants from the agricultural area and Yogyakarta. Then, the river water downstream that the residents use for agricultural irrigation, bathing, washing, and restrooms becomes highly polluted. During the dry season, the discharge of Code River water has also turned very low. It reveals many shallow riverbeds full of sediments, consequently increasing the concentration of pollutants in the river water. With this condition, aquatic inhabitants like water spinach and silver rasbora absorb the toxic heavy metals that dissolve in the polluted river water.

Heavy metals are chemical elements with a solid structure, conductor, and luminous. These metals become dangerous if they get into the system of an organism. However, if they enter the human body, some heavy metals, such as iron (Fe), do not have a toxic effect. The reason is that Fe helps to bind oxygen in the blood [1]. In contrast, heavy metals such as arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), and chromium (Cr) will induce human poisoning [2]. According to Ali et al. [3], elements such as As, Pb, Cd, and Cr can cause ecological and human health risks to the river ecosystem. These elements can be accumulated by aquatic biota and cause damage to the enzyme system and harmful biochemical effects on the living system. There are, in total, twelve heavy metal elements that can be found in polluted rivers [4].

Several researchers have studied the water quality at Code River. For instance, Sriyono et al. [5] investigated well water quality at riverbanks using parameters such as dissolved oxygen, pH, electrical conductivity, temperature, total dissolved solids, and amount of E. coli bacteria. Their findings directly correlate pollution accumulation from high-elevation to low-elevation regions. In another article, Musfirah and Rangkuti [6] investigated human health risks of well water consumption at Code River using an observational design with an Environmental Health Risk Assessment approach. They found that most research sites' noncarcinogenic risk level of Pb has a Risk Quotient coefficient larger than 1, indicating a high potential risk to human health. Then. Pratama et al. [7] studied spatial and temporal trends in water quality using Code River water quality data and Landsat image data from 2011 to 2017. They found that the concentrations of total dissolved solids, nitrite, nitrate, and zinc (Zn) increased from upstream to downstream over the nine years. Next, Widyastuti et al. [8] analyzed the river water quality based on the concentrations of Fe, Pb, Cd, Cr, and copper (Cu). Their study showed that the heavy metal pollution index composite of rich metal parameters could be classified as excellent, showing the river has a better water quality status when compared with the water quality standard issued in Governor Regulation No. 20/2008.

Besides that, there are abundant studies of river water quality at different rivers in Indonesia [9, 10, 11, 12]. Among many statistical methods that can be used to study river water quality, this study utilizes the two-way analysis of variance. This method allows researchers to simultaneously examine the effects of two independent variables on the dependent variable and the interaction effects between the two independent variables. In addition, by including two independent variables in the analysis, researchers can control potential confounding variables that influence the dependent variable.

Motivated by an ongoing interest in reducing the level of pollution at Code River and the desire to provide statistical information regarding the river pollution due to the interaction effects of heavy metal concentrations and sampling locations, this study aims to investigate the effects of heavy metal concentrations and four different media based on sampling locations at Code River. The objectives of this study are:
(a) To analyze the most affecting heavy metal element towards the pollution level at Code River.
(b) To identify the most dominant stratum with the highest mean pollution level at Code River.
This paper is organized as follows. Section 2 describes the research methodology used in this study. Section 3 then presents the study results and discusses the findings. Finally, the conclusion of this study is presented in Section 4.

2 Methodology

2.1 Heavy Metals, Sampling Locations, and Materials

Among many elements of heavy metals that can be obtained from Code River, this study focuses on the elements such as As, Hg, Cr, Zn, and Cu, subject to the availability of the data source. Then, this study limits the use of chemical samples from four different media, namely river water (RW), river sediment (RS), silver rasbora fish (SRF), and water spinach (WS). In addition, this study applied a stratified sampling technique to collect the sample based on the partitioning of Code River into five different locations called strata (or stratum in singular). The strata can be defined as follows:
Stratum 1: This stratum considers the upstream area that starts from a large agricultural field.
Stratum 2: This stratum considers the river area at Sardjito Hospital and Garuda Hotel in Yogyakarta.
Stratum 3: This stratum considers the river area at Melia Purosani Hotel and the tanning factory, which are in the city of Yogyakarta.
Stratum 4: This stratum considers the river area at the Batik industrial factory and Madya City Hospital in Yogyakarta.
Stratum 5: This stratum considers the small agricultural village's downstream area.

Biasedness in statistical analysis is common to all studies, including river water quality and pollution. Therefore, this study systematically sampled the available chemical sample to minimize bias. For each stratum, one drop is chosen randomly from every ten drops as a sample before the selected samples are sent to Yogyakarta Nuclear Research Center, Batan, Yogyakarta, Indonesia, for chemical analysis. This study uses the data of As, Hg, Cr, Zn, and Cu concentrations for statistical analysis.

2.2 Statistical Methods

The methods used for the statistical analysis in this study are descriptive analysis and two-way analysis of variance. The descriptive analysis is carried out to find the mean pollution level due to the heavy metal concentrations in four different media and five sampling locations. Next, the two-way analysis of variance is performed to compare the mean differences among groups broken into two factors defined as follows.
Factor A: heavy metals concentrations in four different media measured in parts per million (ppm).
Factor B: five sampling locations (strata)

Before the two-way analysis of variance, assumptions such as data normality and homogeneity of variances for each combination of the groups of the two factors are tested and fulfilled. Then, the mathematical model used in the two-way analysis of variance can be expressed in the form of

$$Y_{ij} = \mu + A_i + B_j + \epsilon_{ij}, \quad (1)$$

where
Y_{ij} is the level of pollution caused by the interaction effect of the concentration of heavy metal elements in four media and the five strata with i representing the type of element and j representing the stratum,
μ is the external cause,
A_i is the effect of the concentration of heavy metal with element i,
B_j is the effect by the strata with stratum j,
ϵ_{ij} is the model error due to the factor interaction effects. Based on Eq. (1), the value of i is 1, 2, 3, 4, and 5, corresponding to As, Hg, Cr, Zn, and Cu, respectively. Meanwhile, the value of j is 1, 2, 3, 4, and 5, which correspond to the stratum number defined in Section 2.1

2.3 Research Hypotheses

This study considers the hypotheses based on the four different media shown in Tables 1, 2, and 3.

Table 1. Hypotheses for the level of pollution by heavy metals in four different media

Medium	Null (H_0) and Alternative (H_a) Hypotheses
RW	H_0 = There is no difference in the level of pollution by the five heavy metal elements in the river water H_a = There is a difference in the level of pollution by the five heavy metal elements in the river water
RS	H_0 = There is no difference in the level of pollution by the five heavy metal elements in the river sediment H_a = There is a difference in the level of pollution by the five heavy metal elements in the river sediment
SRF	H_0 = There is no difference in the level of pollution by the five heavy metal elements contained in the body of silver rasbora fish H_a = There is a difference in the level of pollution by the five heavy metal elements contained in the body of silver rasbora fish
WS	H_0 = There is no difference in the level of pollution by the five heavy metal elements contained in water spinach H_a = There is a difference in the level of pollution by the five heavy metal elements contained in water spinach

Table 2. Hypotheses for the level of pollution in the medium from five different strata

Medium	Null (H_0) and Alternative (H_a) Hypotheses
RW	H_0 = There is no difference in the level of pollution in the river water among strata H_a = There is a difference in the level of pollution in the river water among strata
RS	H_0 = There is no difference in the level of pollution in the river sediment among strata H_a = There is a difference in the level of pollution in the river sediment among strata
SRF	H_0 = There is no difference in the level of pollution in the body of silver rasbora fish among strata H_a = There is a difference in the level of pollution in the body of silver rasbora fish among strata
WS	H_0 = There is no difference in the level of pollution in the water spinach among strata H_a = There is a difference in the level of pollution in the water spinach among strata

Table 3. Hypotheses for the level of pollution by both factors (heavy metals and strata)

Medium	Null (H_0) and Alternative (H_a) Hypotheses
RW	H_0 = There is no influence by both factors on the level of pollution in river water H_a = There is an influence by both factors on the level of pollution in river water
RS	H_0 = There is no influence by both factors on the level of pollution in river sediment H_a = There is an influence by both factors on the level of pollution in river sediment
SRF	H_0 = There is no influence by both factors on the level of pollution in the body of silver rasbora fish H_a = There is an influence by both factors on the level of pollution in the body of silver rasbora fish
WS	H_0 = There is no influence by both factors on the level of pollution in water spinach H_a = There is an influence by both factors on the level of pollution in water spinach

2.4 Decision Rule

Based on the stated hypotheses in Section 2.3, the F test of two-way analysis of variance is used in the decision-making. The decision is required to determine whether the influence of metal elements in the four media and sampling locations is significant on the pollution level at Code River. The decision rule used in this study is stated as follows.

$$\text{Reject } H_0, \text{if the value of } p \leq \alpha, \text{where } \alpha = 0.05, \quad (2)$$

where p is the observed probability and α is the significant level.

3 Study Results and Findings

Using IBM SPSS for Windows version 28 to carry out the data analysis as described in Section 2, the analysis results are presented as follows.

Table 4 indicates that the pollution level by As is greater than other elements in the river water, while the level of pollution by the Zn element is the greatest among the elements

Table 4. Mean pollution level (ppm) by the five heavy metal elements in four media

Medium	As	Hg	Cr	Zn	Cu
RW	0.0117	0.0113	0.0106	0.0115	0.0113
RS	31.546	1.496	110.558	238.142	33.328
SRF	1.489	2.048	3.248	3.635	3.244
WS	0.428	0.166	2.108	40.512	9.674

Table 5. Mean level of pollution (ppm) by the strata in four media

Medium	Stra. 1	Stra. 2	Stra. 3	Stra. 4	Stra. 5
RW	0.0101	0.0107	0.0111	0.0117	0.0127
RS	773.770	806.920	827.640	863.040	879.380
SRF	2.252	2.469	2.671	2.980	3.293
WS	9.480	9.922	10.926	11.088	11.472

using the sampled river sediment, silver rasbora fish, and water spinach. Next, Table 5 shows that the pollution level at stratum 5 is greater than at other sampling locations for all media used. Based on the results in Tables 4 and 5, this study further investigates the mean pollution level by heavy metal elements for media such as silver rasbora fish and water spinach. This investigation is imperative because these two natural products are part of highly consumed products by Indonesian citizens. This study compares the mean pollution level by heavy metals in silver rasbora fish and water spinach (Table 4) against the maximum limit set by Codex Alimentarius Commission [13] shown in Table 6.

Table 6. Maximum limit of heavy metals (ppm) in media

Medium	As	Hg	Cr	Zn
SRF	1.00	0.50	0.10	50.00
WS	1.00	0.50	0.10	50.00

By comparing the concentrations of As, Hg, Cr, and Zn in silver rasbora fish and water spinach to the maximum limit shown in Table 6, this study found that the concentrations of As, Hg, and Cr in silver rasbora fish exceed the maximum limit set by Codex Alimentarius Commission [13]. Then, the concentration of Cr in water spinach is also higher than the maximum limit set by Codex Alimentarius Commission [13]. This result indicates that the silver rasbora fish and water spinach in Code River are unsafe for human consumption.

Table 7. Two-way analysis of variance of the level of pollution by the five heavy metal elements and five sampling locations using river water

Sources	d.f.	Mean Squares	F	p
Elements	4	7.739E-07	4.959	0.009
Locations	4	4.791E-06	30.703	0.000
Model	8	2.783E-06	17.831	0.000
Residual	16	1.560E-07		
Total	24	1.032E-06		

Based on Table 7, it can be concluded that all H_0 stated for river water medium are rejected. There is a difference in the pollution level by the five heavy metal elements in the Code River water and between the five strata. Moreover, there is a significant influence of the two factors on the level of pollution at Code River.

Table 8. Two-way analysis of variance of the level of pollution by the five heavy metal elements and five sampling locations using river sediment

Sources	d.f.	Mean Squares	F	p
Elements	4	45732.758	3401.894	0.000
Locations	4	90.445	6.728	0.002
Model	8	22911.602	1704.311	0.000
Residual	16	13.443		
Total	24	7646.163		

Based on the analysis result in Table 8, all H_0 stated for river sediment medium are rejected. There is a difference in the pollution level by the five heavy metal elements in the Code River sediment and between sediments of the five strata. Moreover, there is a significant influence of the two factors on the level of pollution at Code River.

Table 9. Two-way analysis of variance of the level of pollution by the five heavy metal elements and five sampling locations using silver rasbora fish

Sources	d.f.	Mean Squares	F	p
Elements	4	4.194	149.347	0.000
Locations	4	0.849	30.235	0.000
Model	8	2.522	89.791	0.000
Residual	16	2.808E-02		
Total	24	0.859		

Based on the result shown in Table 9, all H_0 stated using silver rasbora fish medium is rejected. It explains a difference in the pollution level by the five heavy metal elements in the silver rasbora fish from Code River and silver rasbora fish taken from the five different strata. In addition, there is a significant influence of the two factors on the pollution level at Code River.

Table 10. Two-way analysis of variance of the level of pollution by the five heavy metal elements and five sampling locations using water spinach

Sources	d.f.	Mean Squares	F	p
Elements	4	1475.043	1977.803	0.000
Locations	4	3.520	4.720	0.010
Model	8	739.282	991.262	0.000
Residual	16	0.746		
Total	24	246.925		

Based on the tabulated result in Table 10, all H_0 stated using water spinach as the medium is rejected. In words, there is a difference in the pollution level by the five heavy metal elements in the water spinach that grows around Code River and from the five different strata. In addition, there is a significant influence of the two factors on the pollution level at Code River.

Furthermore, this study analyzed the data in depth to detect how far the mean of each group differs from one another. The extended analysis used Tukey's double comparison test with $\alpha = 0.05$, which yields the following results.

Table 11. Tukey's double comparison test result using the mean level of pollution by heavy metals in river water

Mean Difference	Confidence Interval
$\mu_{As} - \mu_{Hg}$	$-0.001660 \leq \mu_{As} - \mu_{Hg} \leq 0.002148$
$\mu_{As} - \mu_{Cr}$	$-0.00094 \leq \mu_{As} - \mu_{Cr} \leq 0.003012$
$\mu_{As} - \mu_{Zn}$	$-0.001804 \leq \mu_{As} - \mu_{Zn} \leq 0.002148$
$\mu_{As} - \mu_{Cu}$	$-0.001562 \leq \mu_{As} - \mu_{Cu} \leq 0.002390$
$\mu_{Hg} - \mu_{Cr}$	$-0.001256 \leq \mu_{Hg} - \mu_{Cr} \leq 0.02696$
$\mu_{Hg} - \mu_{Zn}$	$-0.002120 \leq \mu_{Hg} - \mu_{Zn} \leq 0.001832$
$\mu_{Hg} - \mu_{Cu}$	$-0.001878 \leq \mu_{Hg} - \mu_{Cu} \leq 0.002074$
$\mu_{Cr} - \mu_{Zn}$	$-0.02840 \leq \mu_{Cr} - \mu_{Zn} \leq 0.00112$
$\mu_{Cr} - \mu_{Cu}$	$-0.002598 \leq \mu_{Cr} - \mu_{Cu} \leq 0.001354$
$\mu_{Zn} - \mu_{Cu}$	$-0.001734 \leq \mu_{Zn} - \mu_{Cu} \leq 0.002218$

Table 12. Tukey's double comparison test result using the mean level of pollution by heavy metals in river sediment

Mean Difference	Confidence Interval
$\mu_{As} - \mu_{Hg}$	$19.89 \leq \mu_{As} - \mu_{Hg} \leq 40.21$
$\mu_{As} - \mu_{Cr}$	$-89.17 \leq \mu_{As} - \mu_{Cr} \leq -68.85^{*}$
$\mu_{As} - \mu_{Zn}$	$-216.76 \leq \mu_{As} - \mu_{Zn} \leq -196.44^{*}$
$\mu_{As} - \mu_{Cu}$	$-11.94 \leq \mu_{As} - \mu_{Cu} \leq 8.38$
$\mu_{Hg} - \mu_{Cr}$	$-119.22 \leq \mu_{Hg} - \mu_{Cr} \leq -98.90^{*}$
$\mu_{Hg} - \mu_{Zn}$	$-246.81 \leq \mu_{Hg} - \mu_{Zn} \leq -226.49^{*}$
$\mu_{Hg} - \mu_{Cu}$	$-41.99 \leq \mu_{Hg} - \mu_{Cu} \leq -21.67^{*}$
$\mu_{Cr} - \mu_{Zn}$	$-137.74 \leq \mu_{Cr} - \mu_{Zn} \leq -117.42^{*}$
$\mu_{Cr} - \mu_{Cu}$	$67.07 \leq \mu_{Cr} - \mu_{Cu} \leq 87.39$
$\mu_{Zn} - \mu_{Cu}$	$194.65 \leq \mu_{Zn} - \mu_{Cu} \leq 214.97$

Table 13. Tukey's double comparison test result using the mean level of pollution by heavy metals in the body of silver rasbora fish

Mean Difference	Confidence Interval
$\mu_{As} - \mu_{Hg}$	$-1.3880 \leq \mu_{As} - \mu_{Hg} \leq 0.2712$
$\mu_{As} - \mu_{Cr}$	$-2.5884 \leq \mu_{As} - \mu_{Cr} \leq -0.9292^{*}$
$\mu_{As} - \mu_{Zn}$	$-2.9748 \leq \mu_{As} - \mu_{Zn} \leq -1.3156^{*}$
$\mu_{As} - \mu_{Cu}$	$-2.5840 \leq \mu_{As} - \mu_{Cu} \leq -0.9348^{*}$
$\mu_{Hg} - \mu_{Cr}$	$-2.0300 \leq \mu_{Hg} - \mu_{Cr} \leq -0.3708^{*}$
$\mu_{Hg} - \mu_{Zn}$	$-2.4164 \leq \mu_{Hg} - \mu_{Zn} \leq -0.7572^{*}$
$\mu_{Hg} - \mu_{Cu}$	$-2.0256 \leq \mu_{Hg} - \mu_{Cu} \leq -0.3664^{*}$
$\mu_{Cr} - \mu_{Zn}$	$-1.2160 \leq \mu_{Cr} - \mu_{Zn} \leq 0.4432$
$\mu_{Cr} - \mu_{Cu}$	$-0.8252 \leq \mu_{Cr} - \mu_{Cu} \leq 0.8240$
$\mu_{Zn} - \mu_{Cu}$	$-1.2204 \leq \mu_{Zn} - \mu_{Cu} \leq -0.04388^{*}$

Table 14. Tukey's double comparison test result using the mean level of pollution by heavy metals in water spinach

Mean Difference	Confidence Interval
$\mu_{As} - \mu_{Hg}$	$-1.895 \leq \mu_{As} - \mu_{Hg} \leq 2.419$
$\mu_{As} - \mu_{Cr}$	$-3.837 \leq \mu_{As} - \mu_{Cr} \leq 0.477$
$\mu_{As} - \mu_{Zn}$	$-42.241 \leq \mu_{As} - \mu_{Cr} \leq -37.927^{*}$
$\mu_{As} - \mu_{Cu}$	$-11.403 \leq \mu_{As} - \mu_{Cu} \leq -7.089^{*}$
$\mu_{Hg} - \mu_{Cr}$	$-4.099 \leq \mu_{Hg} - \mu_{Cr} \leq 0.215$
$\mu_{Hg} - \mu_{Zn}$	$-42.503 \leq \mu_{Hg} - \mu_{Zn} \leq -38.189^{*}$
$\mu_{Hg} - \mu_{Cu}$	$-11.665 \leq \mu_{Hg} - \mu_{Cu} \leq -7.351^{*}$
$\mu_{Cr} - \mu_{Zn}$	$-40.561 \leq \mu_{Cr} - \mu_{Zn} \leq -36.247^{*}$
$\mu_{Cr} - \mu_{Cu}$	$-9.723 \leq \mu_{Cr} - \mu_{Cu} \leq -5.409^{*}$
$\mu_{Zn} - \mu_{Cu}$	$28.681 \leq \mu_{Zn} - \mu_{Cu} \leq 32.995$

Based on the tabulated results shown in Tables 11 until 18, this paper firstly defines the confidence intervals with an asterisk symbol $(*)$ as the confidence intervals that do not contain zeros but negative values only. Then, by focusing on confidence intervals that are located on the left side of zero, the followings are the interpretation for confidence intervals in each medium: In river water medium, all confidence intervals of the level of pollution by heavy metals contain zeros; thus, the significance of the mean difference between a group and another group cannot be determined (see Table 11); In river sediment medium, since there are six intervals located on the left side of zero and it follows that $\mu_{Zn} \geq \mu_{Cr} \geq \mu_{Hg}; \mu_{Zn} \geq \mu_{As}$. It can be said that a high concentration of Zn produces a higher mean pollution level than other elements (see Table 12); In silver rasbora fish medium, seven intervals are located on the left side of zero. It follows that $\mu_{Cu} \geq \mu_{Zn} \geq \mu_{Hg}; \mu_{Cu} \geq \mu_{As}; \mu_{Zn} \geq \mu_{As}; \mu_{Cr} \geq \mu_{Hg}; \mu_{Cr} \geq \mu_{As}$. Thus, Cu caused a higher pollution level than most elements considered in the study (see Table 13); In water spinach medium, six intervals are located on the left side of zero, and it follows that $\mu_{Zn}, \mu_{Cu} \geq \mu_{Cr}, \mu_{As}, \mu_{Hg}$. Zn and Cu caused a higher pollution level than the remaining elements considered in the study (see Table 14).

Table 15. Tukey's double comparison test result using the mean level of pollution using river water by strata

Mean Difference	Confidence Interval
$\mu_1 - \mu_2$	$-0.0016064 \leq \mu_1 - \mu_2 \leq -0.0003984^{*}$
$\mu_1 - \mu_3$	$-0.00220244 \leq \mu_1 - \mu_3 \leq 0.0000196$
$\mu_1 - \mu_4$	$-0.0025784 \leq \mu_1 - \mu_4 \leq -0.0015776^{*}$
$\mu_1 - \mu_5$	$-0.0035824 \leq \mu_1 - \mu_5 \leq -0.0015776^{*}$
$\mu_2 - \mu_3$	$-0.0014204 \leq \mu_2 - \mu_3 \leq 0.0005844$
$\mu_2 - \mu_4$	$-0.0019744 \leq \mu_2 - \mu_4 \leq 0.0000304$
$\mu_2 - \mu_5$	$-0.0029784 \leq \mu_2 - \mu_5 \leq -0.000936^{*}$
$\mu_3 - \mu_4$	$-0.0015564 \leq \mu_3 - \mu_4 \leq 0.0004484$
$\mu_3 - \mu_5$	$-0.0025604 \leq \mu_3 - \mu_5 \leq -0.0005556^{*}$
$\mu_4 - \mu_5$	$-0.0020064 \leq \mu_4 - \mu_5 \leq -0.0000016^{*}$

Table 16. Tukey's double comparison test result using the mean level of pollution using river sediment by strata

Mean Difference	Confidence Interval
$\mu_1 - \mu_2$	$-184.3 \leq \mu_1 - \mu_2 \leq 177.7$
$\mu_1 - \mu_3$	$-186.4 \leq \mu_1 - \mu_3 \leq 175.6$
$\mu_1 - \mu_4$	$-190 \leq \mu_1 - \mu_4 \leq 172.1$
$\mu_1 - \mu_5$	$-191.6 \leq \mu_1 - \mu_5 \leq 170.5$
$\mu_2 - \mu_3$	$-183.1 \leq \mu_2 - \mu_3 \leq 179$
$\mu_2 - \mu_4$	$-186.6 \leq \mu_2 - \mu_4 \leq 175.4$
$\mu_2 - \mu_5$	$-188.3 \leq \mu_2 - \mu_5 \leq 173.8$
$\mu_3 - \mu_4$	$-184.6 \leq \mu_3 - \mu_4 \leq 175.9$
$\mu_3 - \mu_5$	$-186.2 \leq \mu_3 - \mu_5 \leq 175.9$
$\mu_4 - \mu_5$	$-182.7 \leq \mu_4 - \mu_5 \leq 179.4$

Next, based on the result in Table 15, which is for river water medium, since these are six intervals located on the left side of zero and it follows that $\mu_5 > \mu_4 > \mu_1; \mu_5 > \mu_3; \mu_5 > \mu_2 > \mu_1$, it can be said that the fifth sampling location has the highest mean pollution level compared to other locations. Meanwhile,

Table 17. Tukey's double comparison test result using the mean level of pollution using silver rasbora fish by strata

Mean Difference	Confidence Interval
$\mu_1 - \mu_2$	$-1.9718 \leq \mu_1 - \mu_2 \leq 1.5394$
$\mu_1 - \mu_3$	$-2.1741 \leq \mu_1 - \mu_3 \leq 1.3371$
$\mu_1 - \mu_4$	$-2.4830 \leq \mu_1 - \mu_4 \leq 1.0282$
$\mu_1 - \mu_5$	$-2.7963 \leq \mu_1 - \mu_5 \leq 0.7149$
$\mu_2 - \mu_3$	$-1.9579 \leq \mu_2 - \mu_3 \leq 1.5533$
$\mu_2 - \mu_4$	$-2.2668 \leq \mu_2 - \mu_4 \leq 1.2444$
$\mu_2 - \mu_5$	$-2.5801 \leq \mu_2 - \mu_5 \leq 0.9311$
$\mu_3 - \mu_4$	$-2.0645 \leq \mu_3 - \mu_4 \leq 1.4467$
$\mu_3 - \mu_5$	$-2.3778 \leq \mu_3 - \mu_5 \leq 1.1335$
$\mu_4 - \mu_5$	$-2.0689 \leq \mu_4 - \mu_5 \leq 1.4423$

Table 18. Tukey's double comparison test result using the mean level of pollution using water spinach by strata

Mean Difference	Confidence Interval
$\mu_1 - \mu_2$	$-32.97 \leq \mu_1 - \mu_2 \leq 32.08$
$\mu_1 - \mu_3$	$-33.97 \leq \mu_1 - \mu_3 \leq 31.08$
$\mu_1 - \mu_4$	$-34.13 \leq \mu_1 - \mu_4 \leq 30.92$
$\mu_1 - \mu_5$	$-34.52 \leq \mu_1 - \mu_5 \leq 30.53$
$\mu_2 - \mu_3$	$-33.53 \leq \mu_2 - \mu_3 \leq 31.52$
$\mu_2 - \mu_4$	$-33.69 \leq \mu_2 - \mu_4 \leq 31.36$
$\mu_2 - \mu_5$	$-34.07 \leq \mu_2 - \mu_5 \leq 30.97$
$\mu_3 - \mu_4$	$-32.69 \leq \mu_3 - \mu_4 \leq 32.36$
$\mu_3 - \mu_5$	$-33.07 \leq \mu_3 - \mu_5 \leq 31.98$
$\mu_4 - \mu_5$	$-32.91 \leq \mu_4 - \mu_5 \leq 32.14$

the significance of the mean difference between a group to another group considered in media such as river sediment, silver rasbora fish and water spinach cannot be determined, see Tables 16, 17 and 18.

4 Conclusions

Based on the presented results, this study has discovered that Zn is the most dominant heavy metal element and severely influences the water pollution in Code River. Evidently, Zn is in alarming concentration as indicated by the most significant mean values in all observed media. Furthermore, Zn is concentrated mainly in hazardous river sediment, especially during the dry season. This study has found that element As is the most affecting element towards the pollution level for water composition in Code River. Next, using five different sampling locations called strata, the most dominant stratum with the highest mean pollution level at Code River is stratum five, which is the downstream area. The findings of this study concurs with the work of Sriyono et al. [5] and Pratama et al. [7] that the level of pollution and heavy metal concentration increase from high-elevation to low-elevation regions. This study also compared the concentrations of As, Hg, Cr, and Zn in silver rasbora fish and water spinach to the maximum limit set by Codex Alimentarius Commission [13]. This study suggests that the silver rasbora fish and water spinach in Code River are unsafe for human consumption. Lastly, the presented study highlights differences in the mean pollution level by two factors: heavy metal concentrations and strata for all media (river water, river sediment, silver rasbora fish, and water spinach). The findings of this study can be used as supporting evidence for the government to take necessary actions to reduce river pollution and improve water quality at Code River, Yogyakarta, Indonesia.

Acknowledgements

We want to thank the experts and reviewers for their constructive criticisms and recommendations to improve this paper.

REFERENCES

[1] C. P. Gupta, Role of Iron (Fe) in Body, IOSR J. Appl. Chem., Vol.7, 38-46, 2014.

[2] M. Balali-Mood, K. Naseri, Z. Tahergorabi, M. R. Khazdair, M. Sadeghi, Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic, Front. Pharmacol., Vol.12, 643972, 2021.

[3] M. M. Ali, S. Rahman, M. S. Islam, M. R. J. Rakib, S. Hossen, M. Z. Rahman, T. Kormoker, A. M. Idris, K. Phoungthong, Distribution of Heavy Metals in Water and Sediment of an Urban River in a Developing Country: A Probabilistic Risk Assessment, Int. J. Sediment Res., Vol.37, No.2, 173-187, 2022.

[4] Q. Zhou, N. Yang, Y. Li, B. Ren, X. Ding, H. Bian, X. Yao, Total Concentrations and Sources of Heavy Metal Pollution in Global River and Lake Water Bodies from 1972 to 2017, Glob. Ecol. Conserv., Vol.22, e00925, 2020.

[5] E. Sriyono, Sardi, N. C. Kresnanto, Assessment of the Quality of Well Water in the Spatial Terraces of River Code in Yogyakarta Indonesia, IOP Conf. Ser.: Mater. Sci. Eng., Vol.650, 012057, 2019.

[6] M. Musfirah, A. F. Rangkuti, The Lead Exposure Risk due to Wells Water Consumption in Code Riverside Community, Yogyakarta City. KEMAS: Jurnal Kesehatan Masyarakat, Vol.14, No.3, 318-325, 2019.

[7] M. A. Pratama, Y. D. Immanuel, D. R. Marthanty, A Multivariate and Spatiotemporal Analysis of Water Quality in Code River, Indonesia, Sci. World J., Vol.2020, 8897029, 2020.

[8] M. Widyastuti, G. D. Jayanto, M. R. Irshabdillah, Water Quality Analysis of Code River Based on Metal and Nonmetal Parameters Using Heavy Metal Pollution Index, Jurnal Geografi, Vol.13, No.2, 145-158, 2021.

[9] M. Nasir, Z. A. Muchlisin, S. Saiful, S. Suhendrayatna, M. Munira, M. Iqhrammullah, Heavy Metals in the Water, Sediment, and Fish Harvested from the Krueng Sabee River Aceh Province, Indonesia. J. Ecol. Eng., Vol.22, No.9, 141643, 2021.

[10] G. Prayoga, B. A. Utomo, H. E. F. N. I. Effendi, Heavy Metals Contamination Level and Water Quality Parameter Conditions in Jatiluhur Reservoir, West Java, Indonesia. Biotropia, Vol.29, No.1, 7-17, 2022.

[11] L. N. Fadlillah, S. Utami, A. A. Rachmawati, G. D. Jayanto, M. Widyastuti, Ecological Risk and Source Identifications of Heavy Metals Contamination in the Water and Surface Sediments from Anthropogenic Impacts of Urban River, Indonesia. Heliyon, Vol.9, No.4, e15485, 2023.

[12] A. M. S. Hertika, D. Arfiati, E. D. Lusiana, R. B. Putra, Performance of Metallothionein Biomarker from Sulcospira testudinaria to Assess Heavy Metal Pollution in the Brantas River Watershed, Indonesia, J. Ecol. Eng., Vol.24, No.3, 276-286, 2023.

[13] Codex Alimentarius Commission, General Standard for Contaminants and Toxins in Food and Feed. CODEX STAN 193-1995, 1995.