

Distribution of chromium in water and sediment in the Cibaligo River, Cimahi City, West Java Province

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Abstract. The Cibaligo River functions as a disposal station for industrial liquid waste that has gone through waste treatment. However, many industries in the Cibaligo area do not comply with liquid waste management, so chromium, which has the highest concentration compared to other metals, has the potential to accumulate in water and sediment. If the accumulation exceeds the quality standard, it can have a negative impact, such as hematological disorders in both aquatic organisms and humans. This research aimed to determine the distribution of chromium (Cr) pollution in the Cibaligo River, influenced by textile industry waste, in Cimahi City, West Java Province. The method employed in this research is a survey approach with a quantitative orientation. The sampling method employed is a purposive sampling approach. The sample collection techniques used are the grab sampling method and composite sampling. The in-situ parameters used are temperature, dissolved oxygen, pH, and water discharge, while the ex-situ parameter is the total Cr in water and sediment. The data analysis employed is a combination of comparative, descriptive and statistical analysis. The results of the research indicate that the average concentration of Cr in water is consistently 0.001 ± 0 mg L⁻¹ across all stations. The average distribution of Cr in the highest sediment is found at station 4 (downstream) at 22.99 ± 4.06 mg kg⁻¹, while the lowest is at station 1 (upstream) at 3.15 ± 1.35 mg kg⁻¹. The conclusion of this study shows a pattern of average Cr distribution in sediments that increases from upstream to downstream of the Cibaligo River.

Key Words: heavy metal accumulation, biomagnification, heavy metal toxicity.

Introduction. The river is a form of aquatic ecosystem that plays a crucial role in the hydrological cycle, serving as a reservoir, irrigation storage, source of drinking water, and catchment area for the surrounding region (Setiari et al 2012). According to the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal revised in 2023, waste disposal into rivers falls under the category of disposal operations that do not lead to resource recycling (Basel Convention 2023). However, this can only be carried out after appropriate management, compliance with applicable environmental standards, and obtaining permission from the relevant authorities. Waste that requires management includes waste from the production, formulation, and use of inks, dyes, pigments, paints, lacquers, and varnishes, including the textile industry. One area dominated by the textile industry is the Cibaligo Industrial area in Cimahi City. According to Diatara et al (2019), the textile industry in Cimahi City discharges its waste into the Cibaligo River. However, many industries in the Cibaligo area violate the established regulations for liquid waste management.

The Environmental Agency of Cimahi City (2023) stated that, out of approximately 212 industries, only 68 industries held Liquid Waste Disposal Permits (Izin Pembuangan Limbah Cair), called IPLC. Additionally, between 2020 and 2023, 21 sanctions were issued to industries in Cimahi City for violating regulations on liquid waste disposal procedures. Violations of these procedures include the disposal of untreated wastewater, failing to test wastewater quality, not submitting water quality standard inspection

reports, not installing flow meters, and not constructing waterproof wastewater channels to prevent seepage into environmental media. The submission of quality standard inspection reports by industries to the Environmental Agency of Cimahi City from 2020 to 2023 was carried out by only 25% of the total industries in Cimahi City (Environmental Agency of Cimahi City 2023). Due to the numerous violations, industrial waste has the potential to contaminate the water and sediment in the Cibaligo River. One of the substances from the liquid waste of the textile industry that has the potential to cause pollution is heavy metals.

The textile industry's liquid waste produces heavy metals derived from dyeing agents. These heavy metals include arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), and zinc (Zn) (Komarawidjaja 2017). According to Witono & Miryanti (2015), the textile industry's liquid waste has a relatively higher content of heavy metal Cr than other heavy metal ions. Heavy metal Cr is used as a color binder on fabric fibers during the dyeing process, which can result in the production of residual dyes and heavy metals that are not bound to the fabric (Nurventi 2019). Heavy metals that are not bonded to these fabrics can enter the water and sediment. However, heavy metals can be found in higher amounts in sediments compared to water because they can bond with organic materials to form complex compounds that eventually settle to the bottom of the water, accumulating in sediments (Marchand et al 2006).

The heavy metal Cr in natural waters is usually found in the form of trivalent chromium (Cr^{3+}) and hexavalent chromium (Cr^{6+}) (Vitasari et al 2020). According to Murti & Sugihartono (2020), Cr^{6+} has 100 times the toxicity of Cr^{3+} , both for acute and chronic exposure. This is because Cr^{6+} has mutagenic, carcinogenic, persistent, bioaccumulative, toxic, and non-degradable properties in the environment (Hardoyo et al 2018), while Cr^{3+} chromium has non-toxic properties, is the most stable ion, and in trace amounts is an essential nutrient in humans for the metabolism of insulin, sugar, and lipids (Irhamni et al 2017). If Cr^{3+} is present in large quantities, it can be hazardous because it can be oxidized into Cr^{6+} (Maryudi et al 2021). The dangers of this metal can impact various human activities, including aquaculture.

Fisheries cultivation is growing rapidly in the Saguling Reservoir in the form of Floating Net Cages (Keramba Jaring Apung) called KJA (Kanda & Nugraha 2024). KJA in this reservoir receives water supply from the Citarum River and its tributaries (Wardhani et al 2016). One of the tributaries of the Citarum River is the Cibaligo River (Ruswati 2023), so the pollution that occurs in the Cibaligo River will affect the Citarum River (Nuryanta et al 2023), which can impact the survival of fish in the KJA area of Saguling Reservoir. This is caused by the accumulation of heavy metals in aquatic organisms through the food chain, gill absorption, and diffusion across the skin surface. The greater the heavy metal absorption, the higher their concentration in the organism (Ghosh & Saha 2022).

One of the effects of Cr concentrated in freshwater fish is impaired hematology and immune response (Vitasari et al 2020). If the heavy metal Cr in fish exceeds the quality standards and is consumed by humans, it has the potential to cause various diseases, both in the short and long term (Sumantri & Rahmani 2020). According to Vitasari et al (2020), Cr^{6+} ingested intentionally or accidentally in very high doses by humans results in severe respiratory, cardiovascular, digestive, hematological, hepatic, renal, and neurological effects and can cause death in patients undergoing medical treatment. Therefore, this research aimed to determine the distribution of Cr from the textile industry waste in the Cibaligo River, Cimahi City, West Java Province.

Material and Method

Description of the study stations. The research was conducted in the Cibaligo River, Central Cimahi District, Cimahi City, West Java Province (Figure 1), from July to September 2024, using a survey method with a quantitative approach.

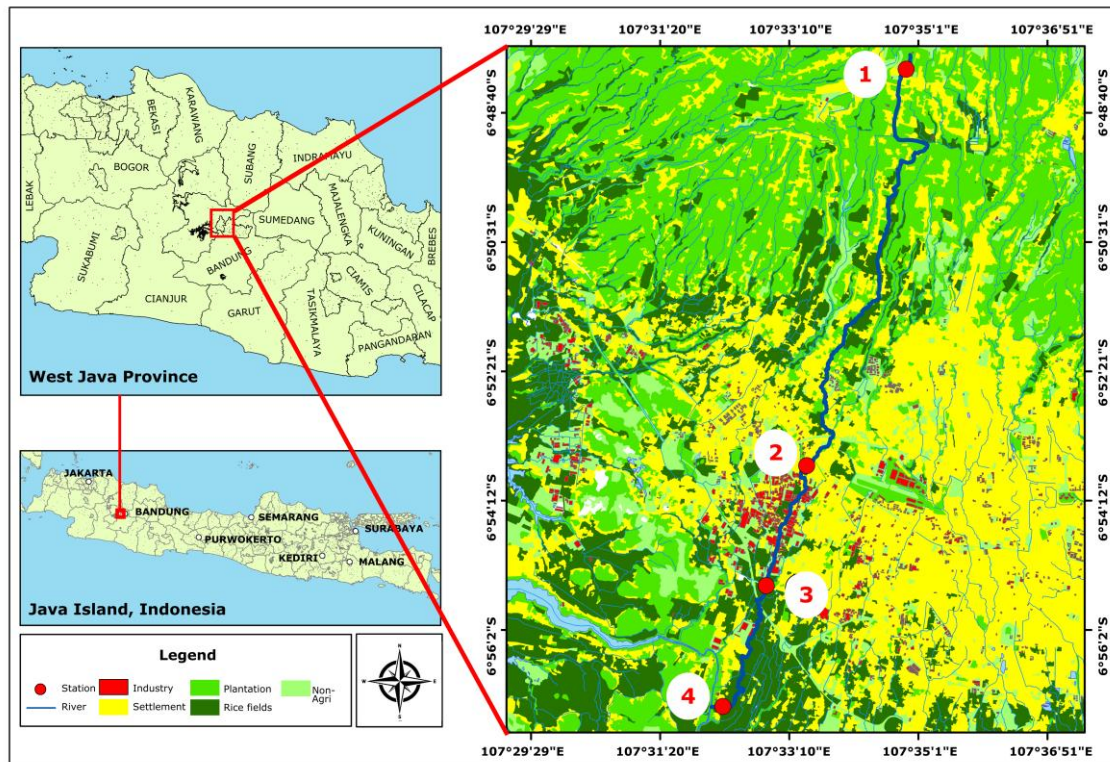


Figure 1. Research location map.

The determination of the research location uses the purposive sampling method based on land use and textile industry density. Samples were taken at four stations (Figure 1) with six repetitions at the peak of the dry season (20-50 mm) and moderate rainfall (150-200 mm) (Climate Change Information Center Deputy for Climatology of the Meteorology, Climatology, and Geophysics Agency 2024). The characteristics of the research location are shown in Table 1.

Table 1

Characteristics of the research location

<i>Station</i>	<i>Latitude</i>	<i>Longitude</i>	<i>Characteristics</i>
1	6°48'04.7"S	107°34'49.0"E	Dominated by limestone mining activities and plantations with few settlements.
2	6°53'52.4"S	107°33'20.0"E	Dominated by settlements with few plantations.
3	6°55'21.8"S	107°32'49.9"E	Dominated by textile industry activities. Sampling was carried out in areas where textile industry waste accumulated.
4	6°57'08.5"S	107°32'03.6"E	Areas included in the Citarum Hulu Watershed (DAS) before the river water enters the Saguling Reservoir. It is dominated by rice field activities, with little plantation and waste from previous station activities.

Sampling method. Sampling of water and sediment in succession refers to the Indonesian National Standard called SNI No. 6989.17-2009 and Hudoyo et al (2021). Cr destruction in water uses HNO₃ (wet digestion), while Cr in sediment uses HNO₃ + HClO₄ (dry digestion), after which tests are carried out using Atomic Absorption Spectroscopy (AAS)-Flame (Table 2) at a wavelength of 357.87 nm. At the same time, other methods for measuring physico-chemical parameters are listed in Table 2.

Table 2

Methods of measuring physico-chemical parameter

<i>Parameters</i>	<i>Reference</i>	<i>Method</i>
Temperature	Indonesian National Standard 06-6989.23-2005 (2005)	Thermometer
Water discharge	Indonesian National Standard 8066-2015 (2015)	Ping-pong ball (Floating method)
Dissolved oxygen (DO)	-	DO meter
pH	Indonesian National Standard 06-6989.11-2004 (2004)	pH meter
Cr on water	Indonesian National Standard 6989.17-2009 (2009b)	AAS-flame
Cr on sediment	Indonesian National Standard 2354.13-2014 (2014)	

Data analysis. The data analysis method used is comparative descriptive data analysis between stations. Physico-chemical parameters compared to the Government Regulation of the Republic of Indonesia Number 22 of 2021, Class II, and Indonesian National Standard 7550:2009 (2009). At the same time, the concentration of Cr in water and sediment is compared to the quality standards shown in Table 3.

Table 3

Quality standards

<i>Cr parameter</i>	<i>Allocate</i>	<i>Threshold</i>	<i>Quality standards</i>
Water	Freshwater aquaculture	0.05 mg L ⁻¹	Government Regulation of the Republic of Indonesia Number 22 (2021)
	Drinking water	0.05 mg L ⁻¹	Regulation of the Minister of Health of the Republic of Indonesia (2016)
	Textile industry waste	1 mg L ⁻¹	Regulation of the Minister of Environment and Forestry (2019)
Sediment	Seawater for aquatic conservation	52.3 mg kg ⁻¹	National Oceanic and Atmospheric Administration (1999)
	Freshwater for aquaculture	37.3-90 mg kg ⁻¹	Canadian Council of Ministers of the Environment (1999)
	Sea and fresh water for ecosystem protection	80-370 mg kg ⁻¹	Simpson et al (2013)
Aquatic organisms	Fish and its processed products	2 mg kg ⁻¹	NHFPC and CFDA 2017 in USDA Foreign Agricultural Service (2023)
	Crustacea	12 mg kg ⁻¹	U.S. Department of Health and Human Services Public Health Service Food and Drug Administration (2001)
	Mollusks	13 mg kg ⁻¹	
Human	Daily intake for the human body	0.0017-0.0033 mg kg ⁻¹ day ⁻¹	FAO/WHO (2015)

The contamination factor (CF) is the ratio between the concentration of a heavy metal in a sediment sample and its natural concentration (Hidayati et al 2022). The natural concentration of Cr in the earth's crust is approximately 90 mg kg⁻¹ (Suyatno et al 2021). The CF value can be calculated using the formula Hidayati et al (2014):

$$CF = \frac{Mc}{Bc}$$

Where:

Mc - concentration of Cr in sediment;

Bc - natural concentration of Cr.

The classification of CF values by Nugraha et al (2022) are as follows:

- Low contamination levels ($CF < 1$);
- Moderate contamination levels ($1 \leq CF < 3$);
- Quite high contamination levels ($3 \leq CF < 6$);
- Very high contamination levels ($CF \geq 6$).

Statistical analysis. The statistical analysis conducted was a one-way ANOVA test followed by a post-hoc Tukey HSD test on Cr water and sediment, and CF to determine the significance of Cr concentration differences between stations. Additionally, a Principal Component Analysis (PCA) test was conducted to investigate the relationship between Cr in sediment and physico-chemical parameters. This analysis also identifies the most influential factors of the physico-chemical parameters. Statistical analysis is carried out through the R Studio application version 2024.9.0.375.

Results and Discussion

Physical and chemical parameters. The average values of the physico-chemical parameters are presented in Table 4.

Table 4

Average physico-chemical parameters on the Cibaligo River

Parameters	Station (mean±SD)				Quality standards	
	1	2	3	4	GR No. 22/2021	Indonesian National Standard 7550:2009
Temperature (°C)	20.29 ±1.60	23.57 ±2.64	27.95 ±1.70	22 ±3.65	Dev 3 (22-28)	25-32
Water discharge (m ³ s ⁻¹)	0.002	0.044	0.092	0.052	-	-
River width (m)	0.60	2.42	3.35	2.21	-	-
Water depth (m)	0.14	0.23	0.21	0.14	-	-
DO (mg L ⁻¹)	6.00 ±2.94	4.17 ±2.24	4.70 ±3.29	5.45 ±3.14	> 4	≥ 3
pH	6.73 ±0.51	7.00 ±0.14	7.51 ±0.34	7.33 ±0.61	6-9	6.5-8.5

Table 4 shows that the parameters in all stations still meet the quality standards except for temperature. The temperature at station 1 did not meet the quality standards of GR No. 22/2021 and Indonesian National Standard 7550:2009 (2009). Meanwhile, stations 2 and 4 did not meet the Indonesian National Standard 7550:2009 (2009b) quality standards. Even so, fish and bivalves can still tolerate temperatures of 20-30°C (Fajar 2021).

Physico-chemical parameters can affect the solubility of heavy metals, such as Cr (Marlinda et al 2020). The higher the temperature, the greater the solubility of heavy metals in water (Pradona & Partaya 2022). The heavier the water discharge, the higher the quantity of heavy metals carried to the next station (Febrita & Roosmini 2022). In oxygenated water conditions, the solubility of heavy metals will increase. The higher the pH of the water, the more the heavy metals will precipitate (Barus et al 2024).

Distribution of Cr in water. Cr heavy metal is one of the heavy metals that can be dissolved in water or accumulate in sediments in the aquatic environment (Marlinda et al 2020). The results of Cr measurements in water and sediment are presented in Table 5 and illustrated in Figure 2.

Table 5

Average chromium values in water and sediment in the Cibaligo River

<i>Cr</i> parameter	<i>Station (mean±SD)</i>				<i>Threshold</i>
	1	2	3	4	
Water	0.001±0	0.001±0	0.001±0	0.001±0	0.05 mg L ⁻¹ 1 mg L ⁻¹
Sediment	3.15±1.35	3.39±0.75	12.81±3.87	22.99±4.06	52.3 mg kg ⁻¹
					37.3-90 mg kg ⁻¹
					80-370 mg kg ⁻¹
					2 mg kg ⁻¹
					12 mg kg ⁻¹
					13 mg kg ⁻¹
					0.0017-0.0033 mg kg ⁻¹ day ⁻¹

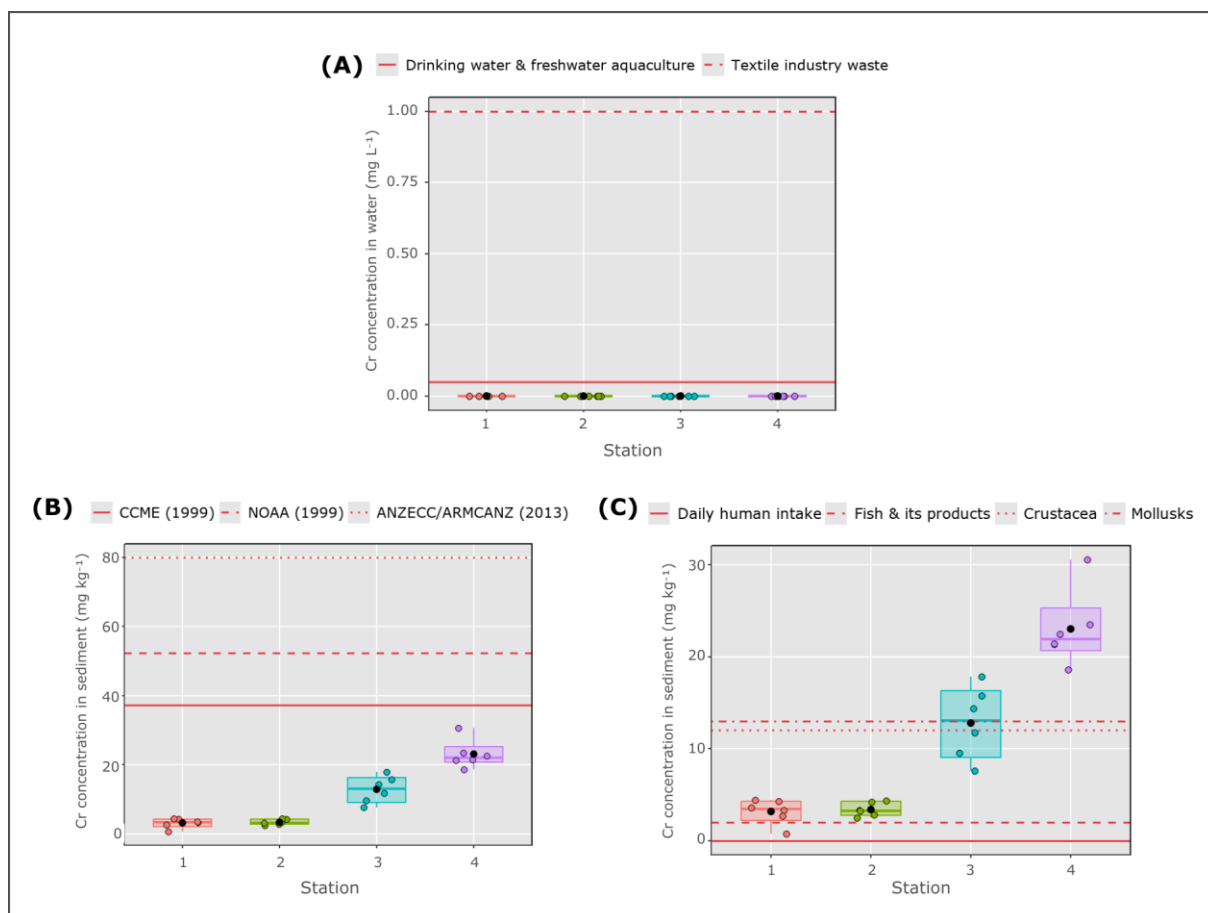


Figure 2. Comparison of chromium measurement results in water (A), sediment (B) and comparison of chromium in sediment with the quality standards for humans and aquatic organism (C) between stations.

Figure 2A shows that Cr in the water at station 3, dominated by the textile industry (Figure 1), has the same concentration value (Table 5). This can be due to the low disposal of dissolved Cr waste. According to Rohmawati et al (2018), low Cr metal in water can be caused by the improper management of industrial waste before it is discharged into the water. According to the Regulation of the Minister of Environment and Forestry (2019), each textile industry is required to process a maximum of 1 mg L⁻¹ of total chrome waste. Additionally, the low disposal of textile industry waste during sampling can also have an impact. According to Marlinda et al (2020), the solubility of Cr

is also affected by environmental parameters, such as temperature, pH, and DO. When the water temperature rises and the pH of the water decreases, the concentration of Cr^{6+} dissolved in the water increases (Wireshpathi et al 2012). Although high temperatures can accelerate chemical reactions, Cr itself is one of the heavy metals that is resistant to oxidation (Makosim et al 2020). This is supported by research by Apte et al (2006), which states that the aerobic oxidation of Cr_2O_3 to CrO_3 only occurs at high temperatures, between 200°C and 300°C. Additionally, oxidation of Cr^{3+} , which tends to settle into Cr^{6+} dissolved by DO, occurs very slowly in the aquatic environment (Apte et al 2005). Therefore, the conditions of temperature, pH, and DO (Table 4) in the Cibaligo River did not increase the solubility of Cr. The comparison of Cr in water with quality standards (Figure 2A) indicates that the Cr levels in water at all stations are suitable for drinking water activities, freshwater aquaculture, and textile industry waste treatment, in accordance with regulations. Nonetheless, the concentration of dissolved Cr (Cr^{6+}) in the water must still be monitored, considering its highly toxic and bio-accumulative nature (Aminatun et al 2024).

Distribution of Cr in sediment. Chromium is one of the heavy metals that can accumulate in sediments (Ghosh & Saha 2022). The results of Cr measurements in the sediment, as shown in Figure 2B, indicate an increase in concentration from upstream at station 1 to downstream of the Cibaligo River at station 4. The significant differences of Cr concentration in sediments between stations are determined through statistical analysis using one-way ANOVA and post-hoc Tukey HSD, as presented in Table 6, and illustrated in Figure 3.

Table 6

Tukey HSD post-hoc test results

Station	1	2	3	4
1	-			
2	0.9989446 ^{ns}			
3	0.0000689**	0.0000943**		
4	0.0000000**	0.0000000**	0.0000347**	-

P-value > 0.05 (not significantly different), *: P-value < 0.05 (significantly different), **: P-value < 0.01 (very significant difference)

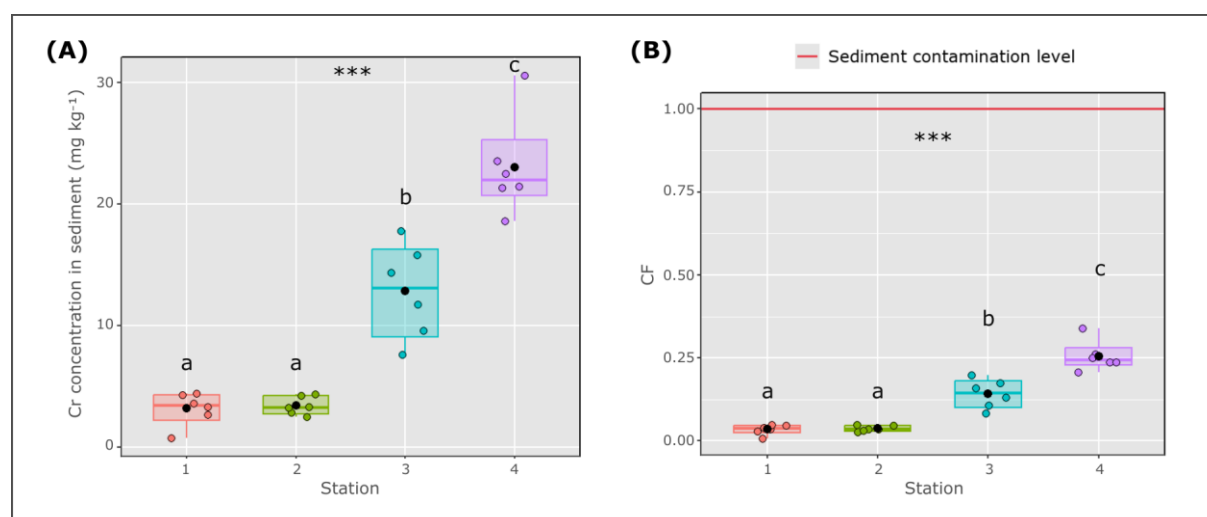


Figure 3. Significance of chromium in sediments (A) and CF (B) between stations. One-way ANOVA analysis *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ letters denote significant differences ($p < 0.05$) with a post-hoc Tukey HSD test.

The concentration of Cr in the sediment between stations 1 and 2 did not differ significantly ($p = 0.9989446$; Figure 3A). This can be caused by plantation activities at station 1 and settlements at station 2 (Figure 1), which dominate and provide a small

amount of Cr. According to Awaluddin & Tangahu (2020), one of the sources of Cr is pesticides and compost in agricultural activities. Meanwhile, according to Nielsen & Stefanakis (2020), residential waste has a relatively low content of heavy metals. The concentration of Cr in the sediments between stations 1, 2, and 3 showed a very significant difference ($p=0.0000689$; Figure 3A). This can be caused by the textile industry at station 3, which dumps Cr waste in the form of Cr^{3+} that settles. According to Hafni (2012), in general, the treatment of wastewater containing Cr is preceded by a reduction process in which Cr^{6+} is reduced to Cr^{3+} before settling and sedimentation. This is supported by the Regulation of the Minister of Environment and Forestry (2019), which states that every textile industry is required to treat its waste to a pH level of 6-9 before discharging it into the water, so that the Cr formed is in the Cr^{3+} states. When there is Cr^{6+} that is wasted by the textile industry into the water, the condition of the Cibaligo River, which is affected by lime from station 1, can support the reduction of Cr^{6+} to Cr^{3+} .

The change in stability from the form of lime carbonate to hydroxide, which forms bonds with heavy metal particles, produces complex compounds in water bodies that settle to form sludge, thereby increasing the pH (Barus et al 2024). The complex compound is Cr(III) hydroxide ($\text{Cr}(\text{OH})_3$), which is the primary Cr species at pH levels between 5 and 9 (Gorny et al 2016). The heavy metal Cr in the sediments between stations 1-3 and 4 has very significant differences ($p=0.0000000$; 0.0000000 ; and 0.00000347 ; Figure 3A). This can be caused because the Cibaligo River's ability to carry out self-purification is lower than the amount of incoming waste. According to Aminatun et al (2024), the farther away from the point source, the river has experienced self-purification; however, this self-purification ability occurs only under pollution conditions that do not exceed the environmental threshold or carrying capacity. Additionally, water discharge also affects the presence of Cr in sediments at each station.

Water discharge is highly effective in exchanging water masses that contain pollutants and organic matter (Ahyar et al 2017). This water discharge can cause Cr in the sediment at station 3, the location with the highest water discharge (Table 4), to be eroded and carried away to station 4, where it then settles. According to Febrita & Roosmini (2022), heavy metals can be carried by water discharge to the next station and then settle. Meanwhile, at station 4, Cr in sediment has the highest concentration value (Figure 2B), due to the water discharge slowing down again (Table 4). The results of the PCA of the Cr concentration in sediments its dependence on the physico-chemical parameters are illustrated in Figure 4.

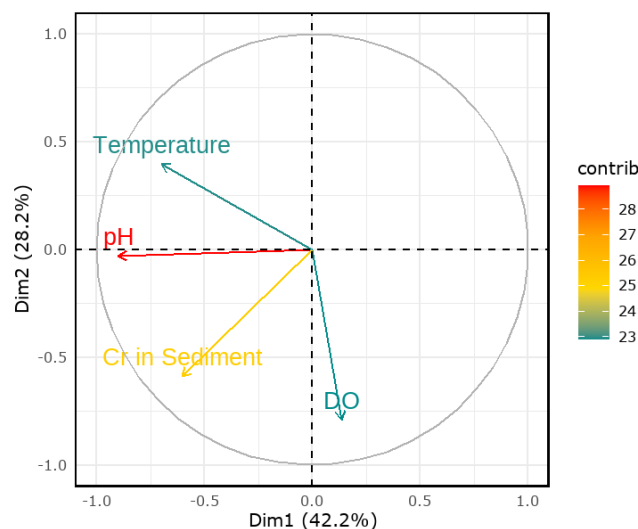


Figure 4. Variable contribution from high (reddish arrow) to low (greenish arrow).

The results of the PCA in Figure 4 indicate that Cr in sediments has a relationship with temperature and pH, with the strongest relationship observed at specific pH values. The four stations with a neutral pH (Table 4) can enhance the adsorption and precipitation of free heavy metals in water, whereas lower pH levels can weaken the binding capacity of

heavy metals (Geng et al 2024). This is supported by Putri & Afdal (2023), who state that a neutral pH value can indicate that the solubility of heavy metals in the river is lower, thereby reducing the toxicity of heavy metals. At slightly acidic or neutral pH levels, the dominant form in the water is the Cr^{3+} form, $\text{Cr}(\text{OH})_3$, which does not dissolve easily (Kotaś & Stasicka 2000). The temperature at the four stations with a temperature value of $>15^\circ\text{C}$ (Table 4) resulted in a weak relationship between Cr in the sediment and temperature (Figure 4), compared to the relationship with pH. According to Liu et al (2024), the rate of Cr deposition is more stable at low temperatures (around $10\text{-}15^\circ\text{C}$). According to Buelow & Robinson (1999), $\text{Cr}(\text{OH})_3$ can be oxidized into a form of Cr^{6+} , such as CrO_4^{2-} , at high temperatures (above 125°C) if nitrate oxidizers are present. The relationship between Cr in sediments and DO exhibits a weak correlation (Figure 4). This is supported by Gorny et al (2016), who show that in the oxic states ($\text{DO} > 2 \text{ mg L}^{-1}$) (Kurniawati & Rachmanto 2024) between water-sediment surfaces, DO can oxidize Fe^{2+} to become Fe^{3+} , which results in the production of Cr^{3+} , albeit at a lower level. In this research, all stations have a DO value $> 2 \text{ mg L}^{-1}$ (Table 4), which results in low Cr^{3+} production through heavy metal deposition facilitated by DO in the presence of Fe^{2+} .

The comparison of heavy metal Cr in sediment shows values that still meet the three sediment quality standards (Figure 2B), but that exceed the quality standards of aquatic organisms (Figure 2C), especially for fish at all stations and mollusks and crustaceans at stations 3 and 4. According to Marlinda et al (2020), 90% of heavy metals can enter the bodies of aquatic organisms through their food. Therefore, aquatic organisms foraging at the bottom of the waters, such as mollusks and crustaceans, will have a huge chance of being contaminated with heavy metals (Palar 2008). Heavy metals that enter mollusk shells and crustaceans can re-enter the food chain, particularly in carnivorous fish. This is supported by Cristina et al (2023), the carnivorous fish group has the highest heavy metal content compared to the omnivorous fish group and the lowest in the herbivorous fish group through the biomagnification process. The toxic effects of Cr^{3+} in fish occur the form of symptoms such as: opening the mouth to pant, mucus discharge, erratic swimming movements, color changes, and shadows (Ghosh & Saha 2022). Cr in sediments has exceeded the quality standard for daily Cr intake in humans (Figure 2C). According to Ma'dika et al (2021), if mollusks that have been contaminated with Cr are consumed by humans, they can cause disorders in the liver and kidneys, and can cause cancer.

Contamination factor. The contamination factor (CF) is a comparison of the levels of heavy metals found in sediment samples with the natural levels of these metals in the environment (Hidayati et al 2022). In general, the concentration of Cr in sediments increased from upstream at station 1 to downstream of the Cibaligo River at station 4 (Figure 3B). The CF between stations 1 and 2 showed no significant difference in value ($p=0.9989446$; Figure 3B). Meanwhile, stations 1, 2, and 3 have very significant differences ($p=0.0000689$ and 0.0000689 ; Figure 3B). The comparison between stations 1-3 and 4 shows a very significant difference ($p=0.0000000$; 0.0000000 ; and 0.0000347 ; Figure 3B). According to Milasari et al (2023), factors contributing to environmental degradation in the upstream area include land conversion, agricultural and plantation activities, erosion, and fish farming.

Station 4 has the highest CF value (Figure 3B) due to the accumulation of Cr from the previous station. According to Nugrayani et al (2024), stations located downstream get more pollution because the pollution is carried by river water discharge. Cr pollution carried from previous stations can come from domestic waste, urban liquid waste, residential liquid waste, mining activities, industrial waste, agricultural waste, aquaculture waste, and shipping wastewater. According to Ghosh & Saha (2022), one of the main anthropogenic sources of Cr comes from the textile industry.

The CF value on all stations is included in the category of low contamination level (Figure 3B). Although the level of contamination is relatively low, heavy metals cannot be degraded and are easily accumulated, allowing them to have a significant impact on aquatic organisms and humans (Nuraini et al 2017). Typical fish responses to acute and chronic toxic exposures to Cr, which are increasing, include lamellar epithelial necrosis,

gill lamella fusion, increased mucus count, and ion balance disturbances, which can cause prolonged stress in fish (Vitasari et al 2020). If Cr^{6+} , which has high oxidative properties and is toxic, enters the human bloodstream, it can damage blood cells. The entry of large amounts of Cr^{6+} into the body can lead to kidney and liver failure due to damaged blood cells (Prasad et al 2021).

Conclusions. The concentration of Cr in water has the same value at all stations, namely $0.001 \pm 0 \text{ mg L}^{-1}$. The highest concentration of Cr in the sediment was found at station 4 (downstream of the Cibaligo River), of $22.99 \pm 4.06 \text{ mg kg}^{-1}$, while the lowest concentration was at station 1 (upstream of the Cibaligo River), of $3.15 \pm 1.35 \text{ mg kg}^{-1}$. The average distribution pattern of Cr in sediments showed an increase in Cr from upstream to downstream of the Cibaligo River as an accumulation area due to the contribution of textile industry waste.

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Conflict of interest. The authors declare that there is no conflict of interest.

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