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Identification of Chromium (Cr) and Nickel (Ni) in Soil in Paddy Fields of Lakardowo Village, Mojokerto Regency

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Keywords

Heavy Metals; Chromium; Nickel; Paddy Fields; Lakardowo.

Abstract

Agricultural land surrounding industrial areas is at high risk of heavy metal contamination, which impacts soil health and the environment. Lakardowo Village, Mojokerto Regency, is one of the areas affected by hazardous waste management activities by PT. PRIA. This study aimed to identify the concentrations of Chromium (Cr) and Nickel (Ni) in paddy soils around the industrial site. Soil samples were collected from nine points at varying distances from the pollution source and analyzed in the laboratory using the wet digestion method. The results showed that all samples contained Ni exceeding the threshold, with the highest concentration found at T2, while Cr exceeded the threshold at several points with the highest concentration found at T3. These findings indicate a high level of soil contamination by heavy metals. Regular monitoring and remediation efforts are necessary to maintain the agricultural environmental quality in the area.

INTRODUCTION

Heavy metal contamination in the environment is a serious challenge in the management of soil fertility and plant health. Heavy metals are natural elements with large atomic mass and high density, being five times greater than that of water (Masindi & Muedi, 2018). These chemical elements can originate from both natural sources and human activities. Heavy metal contamination in the environment is generally caused by human activities, including mining, industrial waste leakage, excessive fertilizer use, vehicle emissions, and the use of wastewater for irrigation (Yi et al., 2018). Heavy metals are toxic and cannot be naturally degraded, and therefore can cause environmental damage (Masindi et al., 2021). The accumulation of heavy metals can affect soil and plant quality. Heavy metal contamination in soil can reduce soil fertility, disrupt the activity of soil organisms, and lead to the accumulation of heavy metals in plants, potentially posing risks to human health through the food chain (Sandeep et al., 2019).

Several potentially toxic metals are commonly detected as environmental contaminants, including lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), and nickel (Ni) (Tanri et al., 2024). Cr and Ni are toxic heavy metals of concern due to their toxicity. The safe limits for Cr and Ni in agricultural soil according to Canadian standards are 64 mg/kg and 45 mg/kg, respectively (Bianchini, 2018). Sources of Cr and Ni contamination in agricultural land can originate from various cultivation activities. The main sources of Cr and Ni in agricultural soil are the use of phosphate fertilizers such as Diammonium Phosphate (DAP) and chemical soil amendments containing heavy metals (Kayode et al., 2022).

The presence of Cr and Ni in soil at excessive concentrations can disrupt soil and plant physiological processes. These heavy metals can reduce soil microbial activity, which plays an important role in nutrient cycling, thereby affecting nutrient availability for plants (Jaiswal & Pandey, 2018). Plants may experience physiological disturbances, including oxidative stress and ionic and water imbalances, particularly when their defense mechanisms are insufficient to

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counteract heavy metal toxicity (Rashid et al., 2023). Cr and Ni in soil threaten not only environmental health but also human health. The impact of heavy metals in agricultural land directly affects human health through agricultural products (Deng et al., 2019). Exposure to Cr can cause liver damage, kidney damage, respiratory disorders, and reproductive disorders (Hossini et al., 2022). Meanwhile, Ni exposure can cause skin allergies and neurological disorders and may increase the risk of cancer through mechanisms involving mitochondrial damage and epigenetic alterations (Genchi et al., 2020).

Lakardowo Village, located in Jetis Subdistrict, Mojokerto Regency, faces serious problems due to environmental pollution from waste management activities conducted by PT. Putra Restu Ibu Abadi (PT. PRIA). This industry is engaged in the management of hazardous and toxic waste (B3) and is located near a residential area, having operated since 2010 (Fadillah, 2025). PT. PRIA manages various types of B3 waste, including paper sludge, used packaging, used thinner, developer, fixer, used toner packaging, ink sludge, used oil, spent earth, activated carbon, laboratory waste, solvent, fly ash, bottom ash, and glass wool. Several heavy metals such as zinc, lead, cadmium, nickel, arsenic, chromium, and copper can be found in fly ash (Robbani et al., 2023). The presence of this industry raises concern because of its potential to contaminate the surrounding ecosystem, including agricultural land that serves as the primary source of livelihood for the local community. The absence of in-depth research on Cr and Ni content in agricultural soil in Lakardowo Village stands in contrast to the potential for soil contamination resulting from B3 waste disposal and stockpiling activities.

Most residents of Lakardowo work as rice farmers, so contaminated environmental conditions have the potential to damage the quality of soil and water, which are the main components in rice cultivation. According to an environmental assessment report by Wijayati & Purwanti (2022), soil around the B3 waste management plant has been contaminated with heavy metals and a number of other hazardous substances. Heavy metal contamination has accumulated in various environmental components, including soil, with chromium as one of the main heavy metals detected (Timothy & Williams, 2019). Several studies indicate that soil around the PT. PRIA site contains high levels of heavy metals. The chromium level in Lakardowo Village soil was recorded to range from 6.9 mg/kg to 250 mg/kg, which exceeds the lower threshold set by the European Union of 200 mg/kg, while the nickel concentration in the soil ranged from 9.1 mg/kg to 200 mg/kg, exceeding the European Union's lower threshold of 100 mg/kg (Bianchini, 2018). This indicates that the land is in an ecologically vulnerable condition.

Based on these findings, assessing Cr and Ni contamination in paddy soils in Lakardowo Village is essential. Although heavy metal contamination has been reported in this area, studies specifically investigating Cr and Ni concentrations in agricultural soils cultivated by local residents remain limited. Heavy metal contamination in agricultural land can accumulate in soil and biota and has the potential to reduce the ecological quality and function of the soil, which can affect the surrounding environment (Liu et al., 2020). Rice is the main commodity relied upon by farmers in the area, so the presence of heavy metals in paddy fields raises concerns regarding the safety of the agricultural environment.

RESEARCH METHODS

This research was conducted from July 1 to August 4, 2025, in the paddy fields of Lakardowo Village, Jetis Subdistrict, Mojokerto Regency. Soil sampling was carried out in three zones differentiated based on distance from the B3 (hazardous and toxic waste) processing facility of PT. Putra Restu Ibu Abadi (PRIA), namely the near zone (0–80 m), the medium zone

(80–150 m), and the far zone (>150 m). The near and medium zones were located on the western side of PT. PRIA, while the far zone was located on the northwestern side. All zones had relatively flat topography and were used for intensive rice cultivation. Details of the distance of each zone from the pollutant source are presented in Table 1.

pollutant source, namely the B3 waste processing facility owned by PT. Putra Restu Ibu Abadi (PRIA). Interview informants were selected based on the criteria of being owners or cultivators of paddy fields at the sampling points and residing in Lakardowo Village. A total of nine farmers were interviewed to obtain information regarding their perceptions of

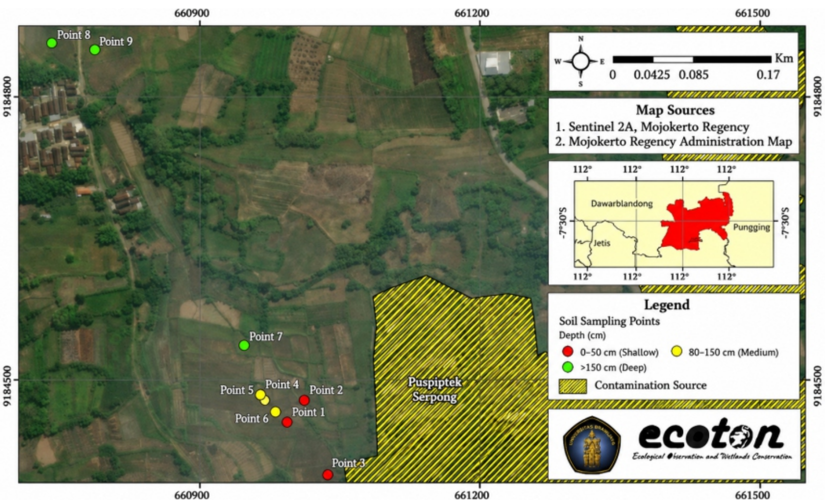
Table 1
Sampling Location Coordinates

Category	Distance from Pollutant Source (m)	Sample Point	Coordinat es
Near	0-80	1	-7.37569, 112.45864
		2	-7.37548, 112.4588
		3	-7.3762, 112.45905
Medium	80-150	4	-7.37542, 112.45838
		5	-7.37548, 112.45844
		6	-7.37559, 112.45853
Far	>150	7	-7.37495, 112.45823
		8	-7.37206, 112.45638
		9	-7.37212, 112.4568

Source: Processed Primary Data (2025)

This research employed a mixed-methods approach, combining laboratory testing of soil samples with in-depth interviews to strengthen the interpretation of the relationship between heavy metal content and land productivity. Sampling was carried out at nine points selected using the purposive sampling method, based on the criterion of proximity to the soil quality, water conditions, and land productivity. The locations of the sampling points are shown in Figure 1. At each point, five sub-samples were collected compositely at a depth of 0–20 cm (root zone) using a soil trowel that had been rinsed with distilled water to avoid cross-contamination.

The soil samples obtained were



Source: Processed Primary Data (2025)

Figure 1
Soil Sampling Locations in Lakardowo Village

subsequently analyzed for heavy metal content at the Laboratory of the Ecological Observation and Wetland Conservation Institute (ECOTON). The initial stage of analysis included sample preparation, beginning with oven-drying at a temperature of 100–150°C, followed by grinding using a mortar. Extraction of chromium (Cr) and nickel (Ni) was carried out following the US EPA Method 3050B (1996) procedure, using a mixture of 37% HCl and 65% HNO_3 at a volume ratio of 3:1. The sample solution was then heated on a hotplate at 95°C for 1.5 hours, followed by filtration using Whatman filter paper.

The concentrations of chromium (Cr) and nickel (Ni) in the sample extracts were measured using a Hanna Checker HI 749 High Range for chromium, with readings in ppb, and a HI 780 High Range for nickel, with readings in g/L. The instruments were first calibrated using standard solutions according to the guidelines. The measurement results were then converted into mg/kg units based on the soil mass (0.01 kg) and extract volume (V liters). The conversion formula for the instrument readings is as follows:

$$K = \frac{c \times v}{w} \times 1000 \quad (1)$$

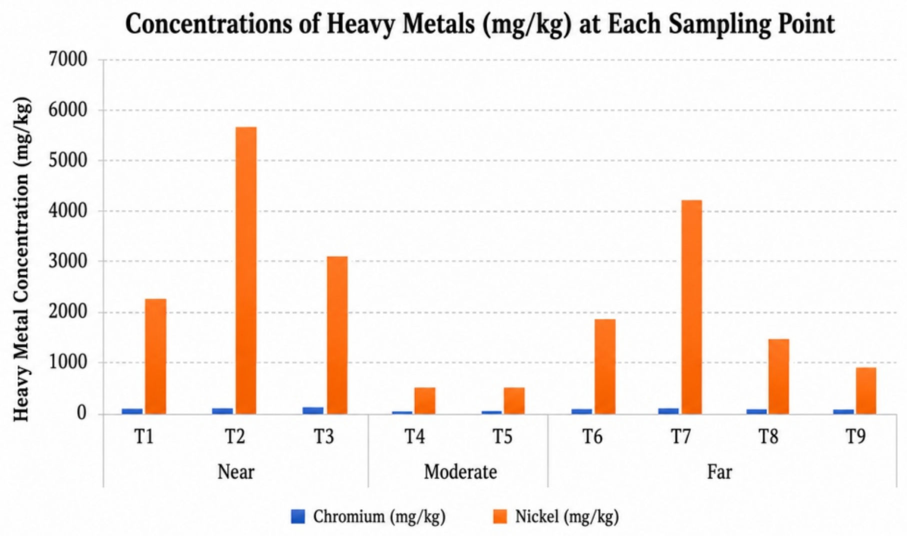
Where K is the metal content in the soil (mg/kg), C is the metal concentration read from the Hanna Checker instrument (mg/L), V is the volume of the extract solution (mL), and W is the weight of the dry soil sample (g).

Data processing focused on descriptive statistics to describe the Cr and Ni content at each sampling point. For each element, the minimum, maximum, mean, and standard deviation values were calculated and summarized in a single summary table to facilitate comparison between locations. Visualization was carried out using boxplots showing the median, quartiles, and outliers, along with bar charts of the means complete with error bars (±1σ) to illustrate variation. With this approach, the study highlighted the spatial patterns and distribution of heavy metal content without the use of inferential analysis. In addition, supporting data on rice productivity were obtained through in-depth interviews with landowners using an open-ended questionnaire. The interview data were used to explain the perceptions of farmers in Lakardowo Village regarding the potential negative impacts of heavy metal contamination on the land they manage.

RESULTS AND DISCUSSION

Environmental pollution by heavy metals is a serious issue that not only affects environmental quality and human health, particularly in agricultural areas surrounding industrial zones. The observation results show that, in general, the distribution pattern of heavy metals is influenced by distance from the pollutant source. Nickel (Ni) content was higher than chromium (Cr) at all sampling points, with the highest Ni content at T2, which belongs to the near zone, reaching 5,750 mg/kg (Figure 2). After that, Ni content decreased, with an average of 983.3 mg/kg in the medium zone, then increased again to 4,300 mg/kg at point T7 in the far zone. The opposite condition occurred for Cr content in the soil. Cr content was relatively low across all zones and was only found at points T1, T3, T5, T7, and T9, with an average of 38 mg/kg. This distribution pattern is consistent with the findings of Handayani et al. (2022) and Kang et al. (2020), which show that the spatial gradient of heavy metal level is strongly influenced by the distance and direction of surface flow from the pollutant source. The position of the pollutant source, in this case PT. PRIA, is higher in elevation than the local community's paddy fields.

This condition has the potential to facilitate heavy metal transport through surface runoff during rainfall. The large number of stockpiling areas created by the industry results in diverse potential sources and dispersal processes, a condition indicated by the increase in Ni content observed in the far zone. Undulating topography is also a factor that may influence the distribution pattern of



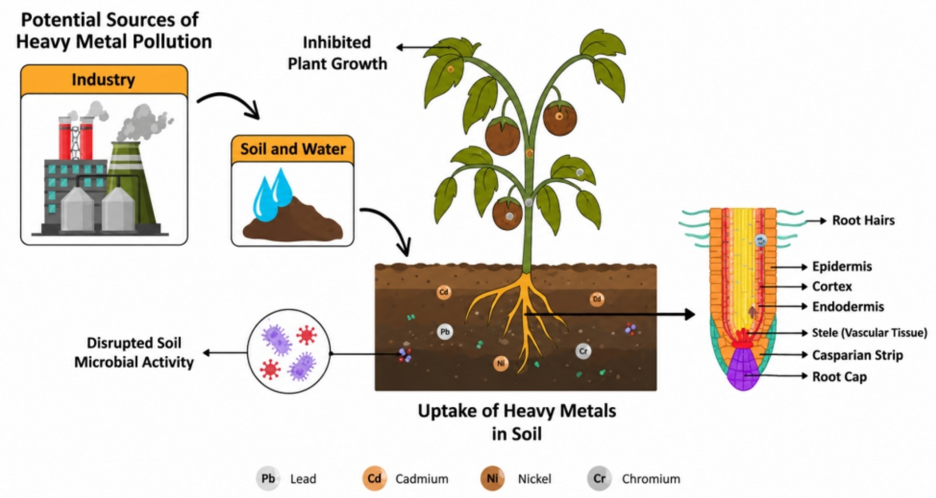
Source: Processed Research Data, (2025)

Figure 2
Distribution of Chromium (Cr) and Nickel (Ni) Content Based on Distance Category from the Pollutant Source

heavy metals at the sampling points. Lateral transport of heavy metals carried by surface runoff has been shown to contribute to the expansion of pollutant distribution, particularly on land with undulating topography and high rainfall (Qiao et al., 2023). In addition, the sampling points are also located within the near zone, which is directly adjacent to the waste stockpiling area created by the B3 waste processing plant. This is supported by research conducted by Putri (2023), which found that 51% of farmer respondents cultivating land around PT. PRIA reported changes in soil quality following the establishment of the plant, particularly on land adjacent to the waste stockpiling site.

The analysis results show that chromium content exceeded the threshold at several sampling points, while nickel exceeded the threshold at all sampling points. The highest chromium and nickel contents were found in the near zone, at 5,750 mg/kg and 95 mg/kg, respectively. Based on soil quality standards for agricultural land, the maximum threshold limits for Cr and Ni are 100 mg/kg and 50 mg/kg, respectively (PP 22/2021), while European Union regulations applicable to all soil types set limits of 200–300 mg/kg for Cr and 100–150 mg/kg for Ni (Bianchini, 2018). This condition indicates that there are environmental factors and human activities influencing the distribution of heavy metals. High heavy metal concentrations are generally associated with a combination of natural processes such as rock weathering and human activities such as mining, fertilizer and pesticide use, and irrigation with wastewater (Zhang & Wang, 2020). In addition, industrial waste disposal activities containing heavy metals also contribute to the contamination of soil, water, and air (Hashem et al., 2021).

Cr and Ni content exceeding the threshold limits (e.g., Cr >100 mg/kg, Ni >50 mg/kg; PP 22/2021) in paddy fields negatively affects soil fertility and the physiological activity of rice plants. As heavy metal pollutants that are difficult to degrade and easily accumulate, the accumulation of these two elements damages rhizosphere microbes such as phosphate-solubilizing and nitrogen-fixing bacteria, thereby inhibiting nutrient availability (Handayani et al., 2022). Furthermore, increased metal bioavailability in the rhizosphere, as shown in Figure 3, can exacerbate root exposure, inhibit root growth, reduce nutrient uptake efficiency, and ultimately reduce crop yield (Peng & Yu, 2024; Zakaria et al., 2021). This condition indicates that heavy metal accumulation



Source: Processed Primary Data, (2025)

Figure 3

Mechanism of Heavy Metal Uptake and Transport in Soil

in paddy fields not only affects biotic aspects within the soil but also directly threatens the productivity and sustainability of the rice farming system.

The average productivity of paddy fields showed an increasing trend as the sampling point distance from the pollutant source increased. Productivity in the near zone was 5.65 tons/ha, then decreased to 5.27 tons/ha in the medium zone, and reached the highest average of 11.28 tons/ha in the far zone (Table 2). This indicates that the proximity of the land to the pollutant source influences rice yield. The lower productivity in the near zone is presumed to be related to the high accumulation of heavy metals in that area. High Ni content in soil causes rice plants to experience reduced root and shoot length, as well as reduced fresh and dry plant weight (Rizwan et al., 2017). In addition, high chromium content can also reduce germination rate, inhibit root and stem growth, disrupt photosynthesis and nutrient assimilation, and damage plant tissue due to oxidative stress (Ertani et al., 2017). This is consistent with the findings of Nagarajan & Ganesh (2015), which showed that high chromium exposure (>100 mg/L) was proven to reduce the morphophysiology of plants, including germination percentage, seedling length, and dry weight of rice plants. This condition indicates that heavy metal accumulation in soil affects the growth, development, and yield of rice plants.

This research also strengthened field validity through primary information obtained from in-depth interviews with the owners of the data collection points. The owner of plot T2, Nafsiyah (52 years old), in an interview conducted on July 18, 2025, confirmed that the land she manages is directly adjacent to the PT. PRIA waste stockpiling area used to expand the plant's industrial grounds. Nafsiyah stated that the soil in her paddy field has taken on a dark yellow color, resembling the color of iron rust, since the waste processing began. This statement indicates a change in soil quality directly perceived by the farmer. Sutamah, a coordinator of Green Women from the "Lakardowo Mencari Keadilan" (Lakardowo Seeking Justice) movement, in an interview conducted on July 17, 2025, also stated that the plant had previously discharged liquid waste directly into the surrounding paddy fields, affecting both the soil and water. This shows that the decline in productivity is not only confirmed by laboratory measurement results but is also supported by field realities experienced by local farmers. The respondents' statements above are consistent with the findings of Putri (2023), which showed that more than 33% of respondents, all of whom were farmers around PT. PRIA, agreed that

Table 2
Average Paddy Field Productivity
Based on Distance Category from the Pollutant Source

Category	Distance from Source (m)	Sample Point	Productivity (ton/ha)	Average Productivity (ton/ha)
Near	0-80	1	4,17	5,65
		2	2,8	
		3	10	
Medium	80-150	4	3,8	5,27
		5	2	
		6	10	
Far	>150	7	11,25	11,28
		8	2,6	
		9	20	

Source: Processed Primary Data (2025)

there had been changes in production yields following the establishment of the industry. Respondents in that study noted that the observed changes were reflected in a yearly reduction in harvest yields. TThe combination of laboratory analysis and farmer interviews provides a more comprehensive understanding of the relationship between heavy metal concentrations and crop yield decline, consistent with the mixed-methods approach in environmental risk studies (Husnatarina et al., 2025).

CONCLUSION

The results of this study indicate that paddy fields in Lakardowo Village have been contaminated with heavy metals, particularly nickel (Ni) and chromium (Cr). All soil samples showed nickel content exceeding the agricultural soil quality threshold, with the highest level found at T2. Meanwhile, chromium content exceeded the threshold at four out of seven sampling points, with the highest concentration at T3. This heavy metal exposure has affected soil health and crop yield, as reflected in the lower rice productivity in zones near the pollutant source compared to zones farther from it. This decline in productivity is presumed to be related to disruption of microbial activity, reduced soil biochemical function, and physiological inhibition of plants due to heavy metal accumulation in the root zone. These findings are further supported by farmers' reports of declining crop yields following the establishment of industrial activities near the paddy fields. Therefore, periodic soil quality monitoring and appropriate remediation measures are needed to mitigate the impacts of heavy metal contamination and support sustainable agriculture in the region.

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