



ORIGINAL RESEARCH PAPER

# Natural enrichment of chromium and nickel in the soil surrounds the karst watershed

R.D.P. Astuti\*, A. Mallongi, A.U. Rauf

Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia

## ARTICLE INFO

### Article History:

Received 18 November 2020

Revised 01 March 2021

Accepted 16 March 2021

### Keywords:

Geo-accumulation index

Hazard index

Heavy metals

Pollution load index

Surface soil enrichment

Weathering carbonate rocks

## ABSTRACT

**BACKGROUND AND OBJECTIVES:** As a public concern, monitoring and controlling toxic metals pollution is needed worldwide. Due to the ability of poisonous metals in biomagnification and bioaccumulation, they can cause several adverse impacts on ecological and human health. The study aims to assess chromium and nickel enrichment levels and estimate the soil's ecological risk surrounds the Pangkajene watershed.

**METHODS:** The total concentrations of chromium and nickel were determined using the Flame Atomic Absorption Spectrophotometer. This study used contamination factor, geo-accumulation index, and pollution load index to evaluate soil enrichment status. The ecological hazard index is used to estimate the potential hazard that may occur due to contamination.

**FINDINGS:** The mean concentrations of chromium and nickel were 92.9 and 43.18 mg/kg, respectively. Chromium concentration exceeded the soil quality guideline for the protection of environment and human health, while Ni still below the standards. The geo-accumulation index value indicated no human-made-derived contamination in the soil. Weathering of carbonate rocks is the chromium and nickel major enrichment factor in the Pangkep regency. Contamination factor and pollution load index values showed low pollution in the studied soil. However, all study sites exceeded the ecological hazard index value (Ecological hazard index > 1), which indicates a considerable ecological risk in the Pangkajene watershed area..

**CONCLUSION:** These findings may provide baseline information related to chromium and nickel enrichment in the soil for Pangkep regency municipality. The Pangkep regency municipality must highlight the importance of strengthening environmental standards and monitoring mechanism as the priority to maintain a healthy environment.

DOI: [10.22034/gjesm.2021.03.05](https://doi.org/10.22034/gjesm.2021.03.05)

©2021 GJESM. All rights reserved.



NUMBER OF REFERENCES

70



NUMBER OF FIGURES

6



NUMBER OF TABLES

5

\*Corresponding Author:

Email: [ratnadwipujastuti@gmail.com](mailto:ratnadwipujastuti@gmail.com)

Phone: +6287887138389

Fax: +624115856013

Note: Discussion period for this manuscript open until October 1, 2021 on GJESM website at the "Show Article."

## INTRODUCTION

Soil heavy metals pollution becomes a public concern worldwide due to wide distribution, high latency, irreversibility, remediation distress, and contamination process complexity (Su et al., 2014). This issue is also related to food security, where heavy metals can accumulate through the food chain and cause several health problems to humans. More than 10 million soil sites were polluted globally, and more than 50% of those areas were contaminated with heavy metals/metalloids (He et al., 2015). This situation was impacting on the economic loss worldwide, which estimated at more than 10 billion US\$ per year (He et al., 2015) and it can be more become serious in developing countries such as Indonesia due to the increase of financial burden. Heavy metals accumulation in the soil may come from its parent rocks (metal-enriched rocks such as serpentine and black shale) and geological activity such as volcanic activities, earthquakes, landslides, debris flows (He et al., 2015; Ma et al., 2019). Besides, anthropogenic activities such as wastewater irrigation, open dumping/landfill waste, fossil fuel combustion, incineration, coal ash, smelting, mining, industry, industrial by-products, and agriculture practices such as application of fertilizer and pesticides may enrich the soil with a high concentration of heavy metals. The soil's metal contamination can be transported via dry and wet deposition, stormwater, sewage irrigation, improper disposal of solid waste, and fertilizer application, biosolid, application of manures and pesticides. Moreover, broad land use/land cover shifts after the industrial revolution cause a faster peak of runoffs that ease contaminants' transport. Most toxic metals/metalloids such as Cadmium (Cd), Chromium (Cr), Arsenic (As), Nickel (Ni), Mercury (Hg), and Lead (Pb), are the priority substances to control by ATSDR (USDHHS., 2019). The high concentrations of heavy metals in soil can directly impact the bio-system and indirectly affect animal and human health through the food chain. The human can directly expose to soil heavy metals through inhalation and skin direct contact and indirectly through ingestion of food and groundwater contamination. Most heavy metals can be distributed in the human body through the blood to the tissue (Azeh Engwa et al., 2019). Long-term exposure to toxic metals was associated with a harmful effect on human health and become apparent only after several years of exposure (Khan

et al., 2008; Jaishankar et al., 2014). The heavy metals poisoning on cellular molecules primarily caused by oxidant and antioxidant imbalance (Tchounwou et al., 2012; Azeh Engwa et al., 2019). Moreover, metals/metalloids such as As, Ni, Cd, Cr(VI) are classified as carcinogenic substances. Cr and Ni were known as the micronutrient for plant growth and animal in small concentrations. It becomes toxic substances at a higher concentration. Since the heavy metal accumulation in soil may pose health risks and adverse effects on the terrestrial ecosystem, the toxicity quantification of contaminated soil can be evaluated using several indices such as geo-accumulation index (I-geo), contamination factor (Cf), pollution load index (PLI), and ecological hazard quotient (EHQ). The characterization of contamination levels and ecological risk is essential to develop specific actions to reduce metal contamination hazards in the terrestrial ecosystem. This present study was conducted in Pangkajene dan kepulauan (Pangkep) regency. This regency is a part of the Maros-Pangkep karst forest area. Like other karst areas, this area is also vulnerable to environmental degradation due to anthropogenic activities such as limestone mining and cement industry and land use shifting (Duli et al., 2019; UGM., 2016). A prior study from Mallongi., (2020) showed Hg contamination and low-level ecological risk in soil surrounds industrial area of Pangkep regency. Nonetheless, a research related to soil heavy metal contamination in the Pangkep Regency is very limited. Therefore, this study aims to assess other heavy metals such as Cr and Ni concentration in the surface soil samples; to characterize soil toxicity and to estimate ecological risk of Cr and Ni surrounding the Pangkajene watershed using several geochemical indices. This study has been carried out in Pangkajene dan Kepulauan (Pangkep) Regency, south of Sulawesi Province, Indonesia in 2020.

## MATERIALS AND METHODS

### Study area

This study was conducted in Pangkajene dan Kepulauan (Pangkep) regency, South Sulawesi, Indonesia. Pangkep regency located in the south of Barru regency, South Sulawesi Province (110° longitude and 4° 40' – 8° 00' latitude). The total area of Pangkep regency includes 898.29 km<sup>2</sup> of terrestrial area, and 11.464 km<sup>2</sup> of sea. The climate characteristic in the Pangkep regency is tropical monsoon climate with average annual rainfall

and temperature of 2500 – 3000 mm/year and 26.4°C, respectively. This area is dominated by plain and karst hills which have an elevation ranging from 100 – 1000 meters. Maros and Pangkep Regency, located in South Sulawesi Province, Indonesia, have the most prominent and beautiful Karst area worldwide. The karst area, which served to maintain the regional ecosystem's balance, was vulnerable to progressive environmental degradation due to human activities. Besides, it has thin regolith, high porosity, a low carrying capacity of heavy metals, and flexible transport of heavy metals (Zhang *et al.*, 2019). This studied area was enriched by mining materials including limestone, clay/loam, silica sand/quartz, gravel, marble, alluvial gold, chert, feldspar, kaolin, basalt, slate, coal, trachea, propylite, diorite, sandstone, and radioactive material. Marble and limestone mining are the most extensive mining sector in the studied area. In addition, land-use changes and conversion of agricultural land to non-agricultural land have been continually degraded the watershed ecosystem in the Pangkep regency. This condition is potentially enhanced the heavy metals contamination process in soil.

### Soil sampling

The field sampling was done in April 2020 which is on rain season. Soil samples were obtained from an area near the Pangkajene river in Pangkajene dan Kepulauan (Pangkep) regency, Indonesia. The selected sampling area includes three sub-districts of Pangkep regency (Bungoro, Minasatene, and Pangkajene), representing watershed areas from upstream to the coast. The study site boundary was less than 5 km from the Pangkajene river. The Pangkajene river is used as irrigation water for farmland and aquaculture. The water of the Pangkajene river was used as the irrigation to the farmland. The study area includes 22 sampling sites with different land use, including; 1) agriculture soil (with 13 sampling sites) and 2) non-agriculture soil (9 sampling sites) (Fig. 1). Seven samples were taken from the upstream area (S01-S05 and S08-S09), eight samples from the middle stream area (S06–S07, S10, S14-S18), and eight samples were taken from the downstream region of the Pangkajene river (S11-S13, S19-S22), Pangkep regency, Indonesia. A GPS was used (Garmin 62s) to locate the sampling point during field sampling. Composite soil samples

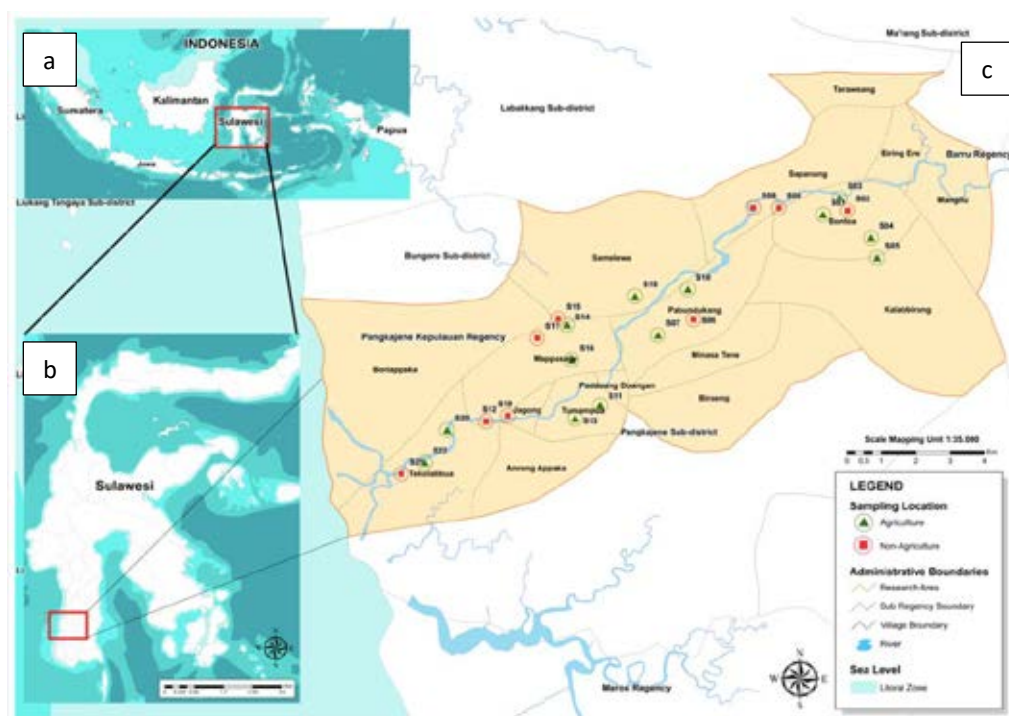


Fig. 1: Geographic location of the study area; (a) Indonesia, (b) Sulawesi Island, (c) Pangkep Regency in Indonesia

Table 1: Analysis method for total Cr and Ni concentration in the studied soil

No	Parameter	Analysis Method	Instrument
1.	Cr	EPA Method 3050b	F-AAS (PerkinElmer PinAAcle 900H)
2.	Ni	SNI 06-6992.6-2004	F-AAS (PerkinElmer PinAAcle 900H)

were collected from the depth 0 – 20 cm of surface soil using a shovel. There are ten individual soils, then they mixed. The interval between an individual sample was 200 meters in an irregular pattern. A 500 gram of soil was labeled and collected into clean zipped polyethene bags after cleaned from rubbish, gravel, grasses, and plant roots. All soil samples were placed at room temperature before brought to the laboratory. Samples were analyzed at the center for plantation-based industry laboratory in Makassar, South Sulawesi Province, Indonesia.

#### Cr and Ni analysis

The soil samples were dried at room temperature. Then, air-dried samples were crushed, sieved through a 2 mm Nylon sieve, homogenized, and placed in the polyethene bottle before acid digestion. The total metal concentration was determined following the analysis method (Table 1). Cr and Ni were analysed using the acid digestion method. To analyse Ni concentration, put 3 g of dried soil samples into Erlenmeyer glass. Added the 25 mL of distilled water and stirred the solution. Then added 5 mL of HNO<sub>3</sub> and three boiling chips into the Erlenmeyer glass. Then, heated the solution at 105°C until the mixtures reached ±10 mL. Then, cooled at room temperature, added 5 mL of nitric acid and 1 mL of perchlorate acid to the solution, and heated until it was transparent, and filtered the mixtures using filter paper Whatman no 42. The final mixes were measured using a flame atomic absorption spectrophotometer (F-AAS, PerkinElmer PinAAcle 900H). For Cr concentration, acid digestion was done by adding 10 mL HCl to 3 grams of soil sample. Then heat the mixture at 95°C for 15 minutes and filter the digested sample through Whatman no 42 and collect in a 100 mL volumetric flask. Total concentration of Cr and Ni was analysed using F-AAS with detection limit 0.2 and 0.2 mg/kg, respectively. The quality assurance and quality control of analysis included standard operating procedures and the NIST standard material (NIST 1646a estuarine sediment), all were measured attentively.

#### Metals Contamination assessment

##### Geo-accumulation index (I-geo)

The I-geo value was determined using Eq. 1 (Müller, 1986).

$$I_{geo} = \log_2 \left( \frac{C_x}{1.5C_b} \right) \quad (1)$$

Where,  $C_x$  is soil-specific heavy metals in the studied area,  $C_b$  is the geochemical/background concentration of specific heavy metals. Due to lack of local background concentration, a background concentration was used from Taylor (1964). The constant of 1.5 accounted to reduce the variation of background concentration which may be influenced by lithologic variation (Laniyan and Adewumi, 2020). The I-geo value interpretation including I-geo £0 means that studied soil is unpolluted with metals; 0< I-geo £1 indicates that the studied soil is uncontaminated up to moderately polluted with metals; 1<I-geo£2 means moderately polluted; 2 < I-geo £ 3 presents that somewhat up to highly contaminated; 3 < I-geo £ 4 indicates highly polluted; 4 < I-geo £ 5 means highly up to extremely polluted; I-geo > 5 demonstrates that the studied soils are significantly/extremely contaminated with metals.

##### Contamination factor ( $C_f$ )

To assess heavy metals contamination in the soil effectively, several pollution indices were used. Two methods were used, including  $C_p$  and PLI to determine the soil heavy metal pollution. Contamination factor ( $C_f$ ) is widely used to determine toxic substances pollution and soil/sediment quality (Kowalska et al., 2018). The pollution index can be calculated using Eq. 2 (Hakanson, 1980):

$$C_f = \frac{C_x}{C_b} \quad (2)$$

$C_f$  is the contamination factor for measured heavy metals. The pollution load index (PLI) is used

Table 2: The heavy metals concentration in soil at the Pangkajene watershed area (mg/kg)

Land use	Samples	HMs	Mean±SD	Min	Max	Background value*	Permissible value
Agriculture land	13	Ni	35.38±17.1	10	60	75	35
		Cr	89.9 ± 16.8	68.9	117.6	100	100
Non-agriculture land	9	Ni	54.4 ± 20.6	20	70	75	35
		Cr	97.18 ± 21.6	60.6	126.6	100	100
Overall	22	Ni	43.18 ± 20.56	10	70	75	35
		Cr	92.9 ± 18.82	60.6	126.6	100	100

\*Background value was obtained from continental crust background value in the study by Taylor (1964)

\*\*Permissible value of heavy metals in soil was obtained from WHO permissible value for heavy metals (WHO, 1996)

to determine the severity level of multiple heavy metals' pollution in soils using Eq. 3 (Gati *et al.*, 2016; Kowalska *et al.*, 2018).

$$PLI = \sqrt[n]{CF1 \times CF2 \times CF3 \times \dots \times CFn} \quad (3)$$

Where, n is the number of trace elements.

#### Ecological hazard quotient (EHQ)

The potential ecological risk was determined using a quantitative screening Ecological Hazard Quotient (EHQ). This index can assess the likelihood that the adverse environmental effects may exist due to toxic substance exposure. This index was used to evaluate adverse biological effects because of heavy metals contamination in the soil (Feng *et al.*, 2011; Mallongi *et al.*, 2014). The specific potential for toxicity in study area soils was estimated by calculating the hazard quotient using Eq. 4.

$$EHQ = \frac{EEC}{\text{screening benchmark}} \quad (4)$$

Where, EEC is the Estimated or maximum soil heavy metals concentration at sampling sites. The screening-level benchmark is the soil concentration below which toxicity is not likely to occur (Beyer and Sample, 2017). The screening value was obtained from the toxicity value for terrestrial plant by Efroymsen *et al.*, (1997). The ecological hazard index is used to determine potential detrimental effects caused by multiple toxic substances (OHIO EPA, 2008). This index is calculated by summing of EHQ.

#### Data analysis

Cr and Ni concentrations in the soil were collected after analysis in the laboratory. Then, the statistical analysis was conducted using SPSS 24.0 version package. Descriptive analysis (mean, standard deviation, minimum and maximum value) was presented in this study. The IDW interpolation was used to map distribution of Cr and Ni concentration at whole study area.

## RESULTS AND DISCUSSION

#### Distribution of Cr and Ni concentration in the studied area

Table 2 presented the concentration of heavy metals in the studied soil. The mean concentrations showed that Cr was higher than Ni. The Cr concentration was below the soil permissible value. Although Cr was below the standard, it can be accumulated in the soil over time. Ni concentration exceeded the allowable value. In Table 3 demonstrated that Cr concentration in present study exceeded the threshold limit value by CCME (2007). While Ni concentration was below threshold limit value by CCME (2007). Cr concentration in Pangkep regency was higher than Cr world average concentration in soil. While Ni concentration is still below the world average concentration. Compared to other study in karst area, soil in Pangkep watershed has lower concentration of Cr than soil in Huixian karst watershed, China (Huang *et al.*, 2020). Whereas, the concentration of Ni is higher in the Pangkep regency than in the Huixian karst watershed, China.

Table 3: Comparison of mean concentration in studied soils to other soil standards and studies (mg/kg)

HMs	Mean <sup>a</sup>	Earth crust <sup>b</sup>	Average shale <sup>c</sup>	Average surface rocks <sup>d</sup>	Threshold limit value <sup>e</sup>	World average soil <sup>f</sup>	Huixian, China <sup>g</sup>	Beke-Cave watershed, Hungary <sup>h</sup>
Cr	92.9	100	90	71	64	70	118.18	-
Ni	43.18	75	68	49	50	50	43.04	37.47

<sup>a</sup> present study, <sup>b</sup> Taylor (1964), <sup>c</sup>Turekian and Wedepohl (1961), <sup>d</sup>Martin and Whitfield (1983), <sup>e</sup>CCME (2007) <sup>g</sup>Huang et al., (2020),

<sup>h</sup>Kaszala and Barany-Kevei (2015)

Based on the Table 3, soil in present study has higher concentration of Ni than soil in the karst watershed Hungary. The soil texture can influence the total concentration of metal in soil due to the ability to absorb and mobilization of metals (Kaszala and Barany-kevei, 2015). The highest concentration of Ni is available in clay soil (Kaszala and Barany-kevei, 2015). Both Cr and Ni concentrations were higher in the non-agricultural land than in the agricultural area. Efe (2014) mentioned that soil content depends on its parent rock material and climate. Based on litho-tectonic, the Pangkep regency was classified in the west mandala structure dominating sedimentary rocks such as alluvial deposits, limestone Tonasa formation, Malawa formation, and volcanic rock (Camba volcanoes) (Sompotan, 2012). Another study by Ramli et al., (2009) mentioned that Pangkep regency was developed by alluvium/sediment material, limestone, breccias, lava, tuffs, conglomerates, ultra-basalt, basalt, trachyte, and mixed rocks. Based on Fig. 2 the highest concentration of Cr is located in S08 from Tonasa formation which has formed by limestone. Sampling site 8 is located near limestone mining and cement industry, the high concentration may be influenced by deposition of dust which is emitted from industry. While the highest concentration of Ni is located in S12, S15 and S19 formed by alluvium sediment and limestone from Tonasa formation. Carbonate rocks and alluvium deposits were dominated the soil parent material in the Pangkep regency. Heavy metal enrichment in the karst area due to the high background concentration of heavy metals in carbonate rocks and secondary enrichment was undergone when the weathering process (Tang et al., 2020). Carbonate rocks may influence the high concentration of Cr and Ni in Pangkep. It has several characteristics, including poor drainage and leaching; thus, it can keep trace elements (Yolcubal and Akyol, 2007; Hasan et al.,

2020). Limestone is the metal stabilization agent to inhibit metal mobility by increasing pH. In contrast, when the soil has high alkaline properties, it can be enhanced metal leaching at high concentration (Yun and Yu, 2015). High rainfall and acid rainfall temporarily reduce the acid buffering capacity in karst soil. The Maros-Pangkep karst area is one of the most beautiful karst areas formed in the late Eocene to middle Miocene (40 million to 15 million years ago). The limestone forming in the Miocene era has a high concentration of CaCO<sub>3</sub> (92%) (Efe, 2014). The CaCO<sub>3</sub> content in the soil can affect heavy metals concentration where it can inhibit the absorption of heavy metals into plants (He et al., 2020). A previous study by Huang et al., (2016) confirmed an effect of carbonate and phosphate on the metals immobilization in the polluted soil. It is caused by the reduction of free-metal activity or the exchangeable fraction of metals in the soil. CaO content in soil karst is much higher than in non-karst soil (Li et al., 2021). It can be caused by the weathering carbonate rocks and pedogenesis. Li et al., (2021) showed the insoluble residues of carbonate rocks which has iron, manganese, aluminium and other trace element was remained as soil parent material, while major elements (potassium, calcium, sodium, and magnesium) were rinsed and leached by soil solution when carbonate rock dissolution in karst ecosystem.

Naturally, Cr and Ni concentrations in limestone are 10 and 20 ppm, respectively (Adriano, 1986). This study showed the enrichment of Cr and Ni in the soil because the concentration of Cr and Ni in the studied soil was higher than the natural concentration in limestone. Based on the geo-accumulation value, all the sites have I-geo < 0 (Fig. 3). It indicates that Pangkep regency's soil was uncontaminated with Cr and Ni, which derived human-made sources. This result is in line with the study by Miko et al., (2003), which mentioned that soil-derived carbonate rocks



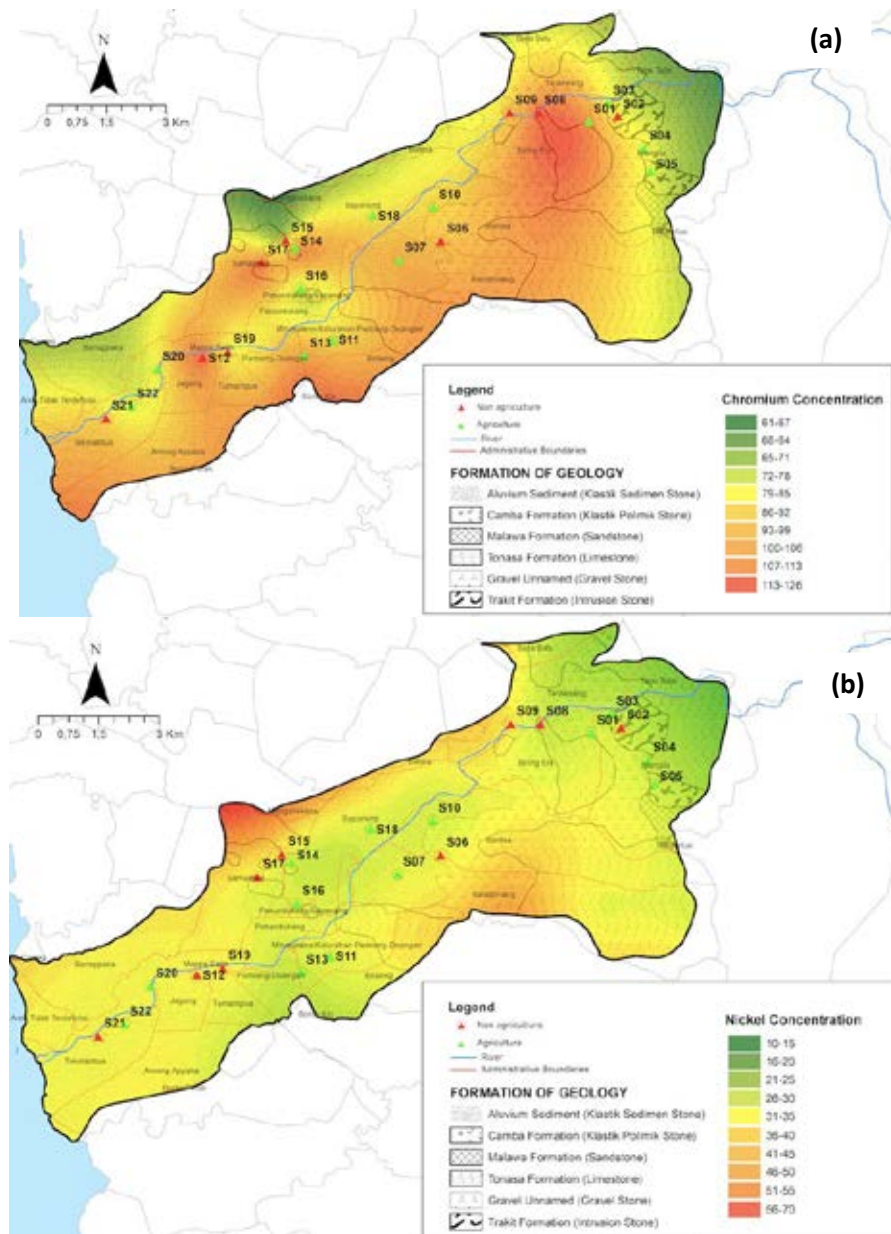
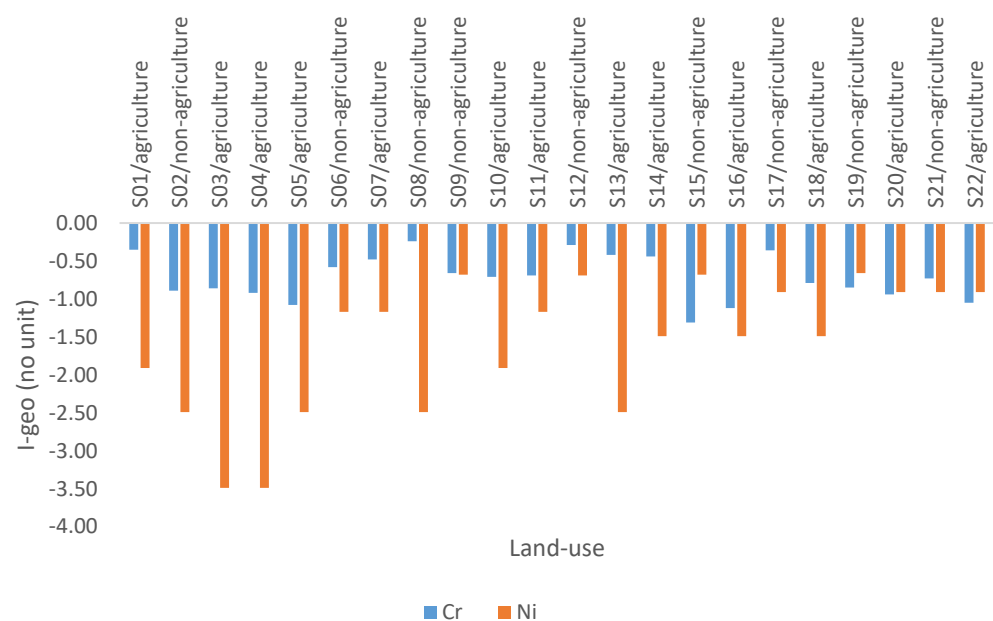


Fig. 2: The distribution of Cr (a) and Ni (b) in the studied soil (mg/kg)

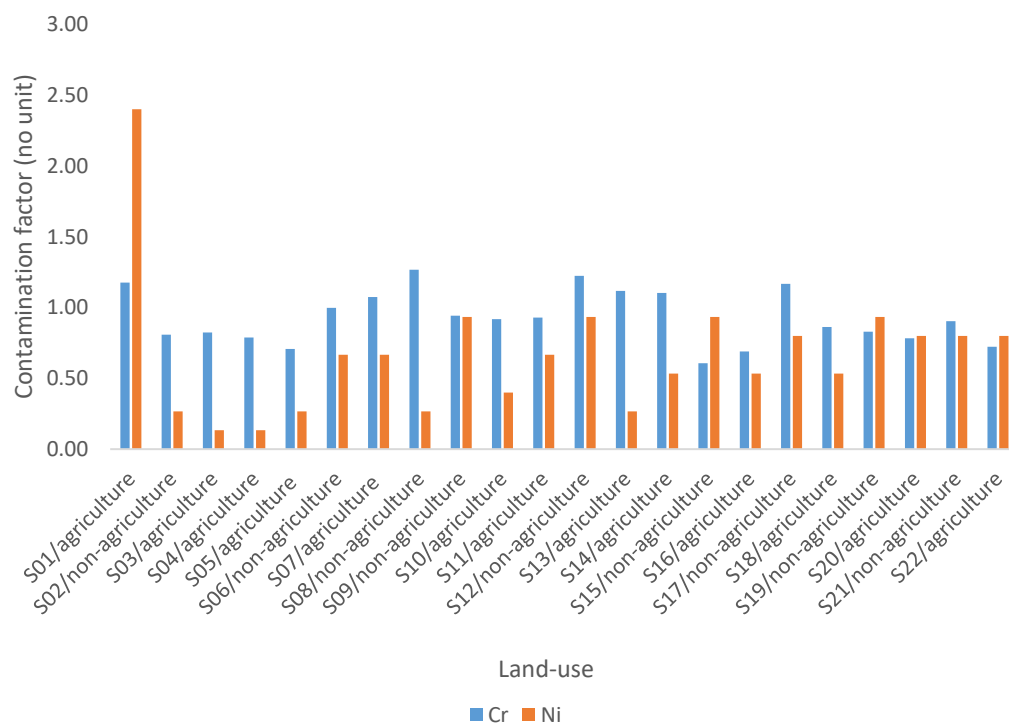
have a higher concentration of Mn, Co, Al, As, Cd, Cr, Ni, Fe, La, Th, V, Cu, and Sr. The high and acid rainfall in the karst area can generate the karst soil loss and progressively enhance the rock weathering process (Kamon *et al.*, 1996; Lyu *et al.*, 2018; Wang *et al.*, 2019; Zhao and Hou, 2019). Moreover, acid rain can cause depleting the surface soil layer, degrade soil nutrients

content and soil carrying capacity, and transfer soil metals to other places. Based on NCEANET (2020)'s data, acid precipitation in Maros regency has a pH ranged from 4.3 to 5.6. The main problem of acid rain is possibly caused by air pollution. Similar to the Maros regency, there are mining and industrial activities in the Pangkep regency area, including cement and

### Chromium and nickel enrichment in the soil



(a)



(b)

Fig. 3: Geo-accumulation index (a) and contamination factor (b) of Cr and Ni in the studied area



Table 4: Summary of metals contamination index value in the studied area

Contamination index	HMs	Mean $\pm$ SD	Range	Contamination status	Contamination factor classification: $C_f < 1$ ; $1 \leq C_f < 3$ ; $3 \leq C_f < 6$ ; $C_f \geq 6$ , representing low, moderate, considerable, and very high pollution (Hakanson, 1980). $PLI \leq 1$ , $PLI > 1$ demonstrating no metals contamination and there is metal contamination, respectively.
Contamination factor	Ni	$0.7 \pm 0.5$	0.1 – 2.4	Low	
	Cr	$0.9 \pm 0.2$	0.6 – 1.3	Low	
Pollution load index		$0.7 \pm 0.3$	0.3 – 1.7	No pollution	

marble. The cement industry contributed 5% of total global anthropogenic  $CO_2$  emission (Mahasenan *et al.*, 2003) and enormous quantities of acid rain precursor such as  $SO_2$ ,  $NO_x$ , CO, and PM to ambient air (Lian *et al.*, 2019). On the lowlands of Pangkep regency, there are alluvial deposits, swamp, and the coast, which were Holocene aged, containing gravel, sand, loam, limestone, coral, and mud (Sompotan, 2012). Based on Fig. 2, Cr's highest concentration is located in non-agriculture land (sampling sites 8). At the same time, high Ni concentration is situated in non-agricultural land (sampling sites 9, 12, and 15). Both high concentration of Cr and Ni were located in non-agricultural land. Based on prior study by Sayadi and Rezaei (2014) high concentration of Ni and Cr may originate from residential-road soil and dairy farm land. High enrichment factor is also occur in the residential and industrial area (Sayadi and Sayyed, 2011). Another study showed that highly concentrated of toxic metals in soil located in areas where people live (Laniyan and Adewumi, 2020). The potential source of Cr are mining, pharmaceutical, metal, textile and leather industries. While, nickel is originated from batteries, power plants or incinerator, combustion of fossil fuels, rubber and plastic industry, electroplating, petroleum by-products and rocks natural weathering. Rauf *et al.*, (2020) and Mallongi *et al.*, (2020) mentioned that the area near cement industry has high concentration of Cr and Hg. The coal combustion is one of the source of metal contamination in soil. In addition to lithogenic sources, human-induced contamination such as domestic, mining, and industry sewages are potentially increased the Cr and Ni concentrations in the soil. Sampling sites 8 and 9 are the residential soil near the cement industry in the Bungoro sub-district. Thus, domestic and industrial sewage is the potential source of pollutants in these sites. Pb, Cr, Ni, and Mn are generally found in areas located near industrial sites, and they potentially pose residents at risk of detrimental health effects. Trivalent chromium

is essential for human nutrient, while hexavalent chromium has carcinogenic effects (Jaishankar *et al.*, 2014; Costa and Klein, 2006). Human exposure to chromium is related to skin cancer and lung cancer. A study from McDermott *et al.*, 2014 demonstrated that a median Cr and Ni concentration of 19.13 mg/kg and 4.58 mg/kg in soil is related to low birth weight cases in pregnant women located near industrial sites in the South Carolina USA. It implicates exposure to contaminated soil metals may cause adverse impact to pregnant women living in the near of industrial contaminated sites. Contamination of Cr also effects on gastrointestinal disease (Costa and Klein, 2006). Human may expose to Cr and Ni through soil contact or through eating contaminated food. Furthermore, leaching of metals to drinking water is also possible source of Cr and Ni. Nickel is also classified as human carcinogenic substance by International Agency for Research on Cancer (Das *et al.*, 2019). Chronic exposure to nickel via soil, water or direct contact may induce allergic dermatitis (Das *et al.*, 2019).

#### Cr and Ni enrichment status

Based on the I-geo value ( $I\text{-geo} < 0$ ) in Fig. 3a, soil in our studied area was naturally enriched by Cr and Ni. Cr and Ni's concentration in the studied soil was lower than the soil's background value. It indicates that lithogenic activities in the studied area caused increased Cr and Ni concentrations. Based on Table 4, the studied soils were low contaminated with Cr and Ni (mean value of  $C_f < 1$ ). The result of Cf showed that the soils in Pangkep regency ranged from low to moderately contaminated with Cr and Ni. PLI mean value showed that Pangkep's soils are uncontaminated with Cr and Ni. However, ranged of pollution load index of soil indicated no pollution to moderate pollution. Based on Fig. 3b, contamination factor ( $C_f$ ) at the studied area was relatively low at agriculture land for nickel contamination, except in sampling site 1 (S01) which had the highest value  $C_f$  for Ni. Geologically, sampling site 1 located in the

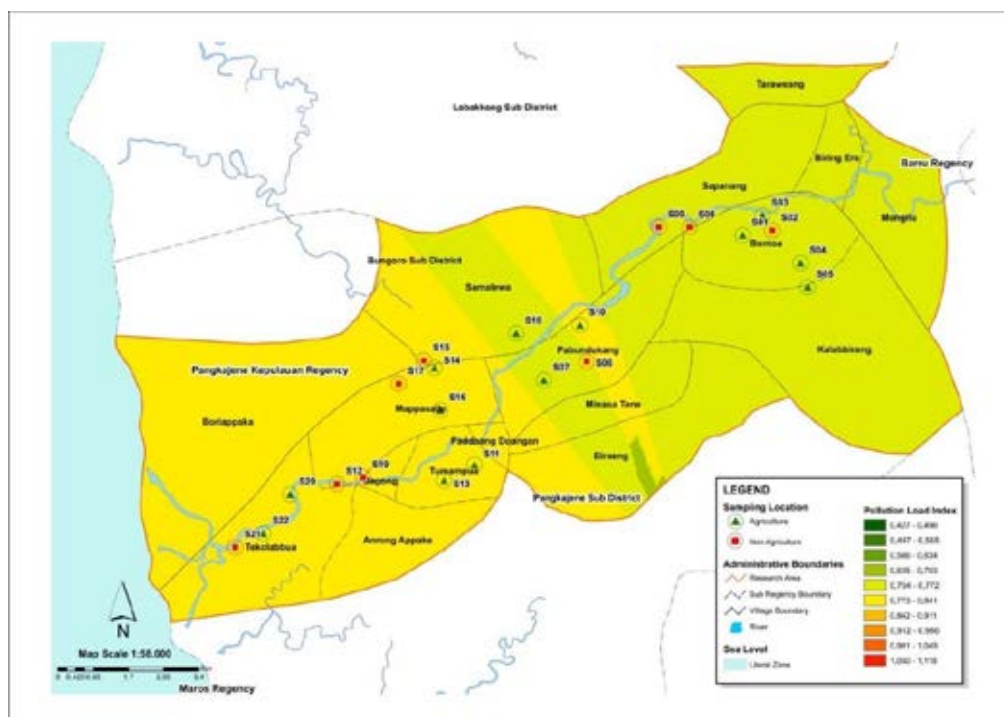


Fig. 4: Pollution load index in the studied soil

Bungoro sub-district was formed by the combination of trachyte formation, Tonasa formation, and gravel stone. Enrichment of metals and minerals little can be influenced by ultramafic and basalt rocks in Pangkep regency (Fatinaware *et al.*, (2019); Suryani and Ritung, 2018; Tonggiroh, 2013; Wilson, 1996). Weathering ultramafic and basalt rocks can cause the high accumulation of Cr and Ni in the soil (Suryani and Ritung, 2018; Sayadi and Sayyed, 2011). Compared to Barru regency in study by Suryani and Ritung, 2018, the total concentration of Cr and Ni in Pangkep regency is far below the total concentration of Cr and Ni in Barru regency. The sampling sites 1 – 9 were used for the mining activities such as limestone, clay, trachyte, feldspar, sandstone, and marble. In addition, there is a cement industry that may influence the contamination of nickel and chromium. According to other study, the soil near cement industry may contaminate with high level of metals such as Pb, Cr, Cd, Ni, Hg, Zn, Cu, Co from aerial deposition (Laniyan and Adewumi, 2020; Mallongi *et al.*, 2020; Ogunkunle and Fatoba, 2014; Rauf *et al.*, 2020). The distribution of metals in top soil can be influenced by the wind

velocity and particle size (Ogunkunle and Fatoba, 2014). Cr and Ni mean concentration in present study was higher than concentration of Cr and Ni in study conducted by Laniyan and Adewumi, (2020). Furthermore, the high value of Cf in agriculture can be influenced by intensive tillage, and application of fertilizers and pesticides. Higher PLI values are distributed in the middle and downstream area (Fig. 4). An alluvial deposit forms the soil in the middle and downstream. Alluvial and alluvial-colluvial areas are commonly considered to have high Cr content, especially in the calcareous environment (Li *et al.*, 2009).

The middle and downstream areas of the Pangkep regency are dominated by domestic/municipal, agriculture and aquaculture activities. The studied area landscapes are dominated by karst hills in the upstream, gently sloping in the middle stream and alluvial plain in the downstream area. Bungoro and Pangkajene sub-district were classified as the critical land in Pangkep regency, and it is vulnerable to undergo worsening environmental degradation. Soil erosion can transfer metals to further sources. When

Table 5: Degree of ecological risk in soil surrounds the watershed area of Pangkajene regency, Indonesia

HMs	EHQ value	Description	Number of samples	Percentage of samples
Cr	< 0.1	No hazard	-	-
	0.1 - 1.0	Low hazard	-	-
	1.1 – 10	Moderate hazard	-	-
	>10	High hazard	22	100
Ni	< 0.1	No hazard	-	-
	0.1 - 1.0	Low hazard	8	36.4
	1.1 – 10	Moderate hazard	14	63.6
	>10	High hazard	-	-
Total			22	100

The classification of hazard based on the prior study by (Lemly, 1996)

The screening benchmark for Cr and Ni was 1 and 30 mg/kg (Efroymsen *et al.*, 1997)

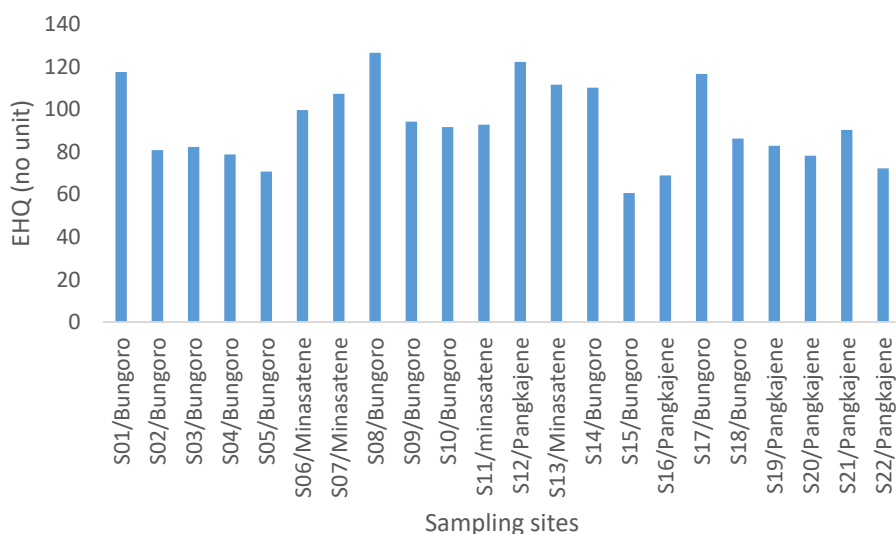
the soil has been disturbed by human activities, including mining, industry, and agriculture, fresh deposits of heavy metals will be transported from higher elevations via the natural process of erosion. It may be remobilized together with excavated soil/sediments (Jarsjö *et al.*, 2017). Besides, soil erosion is related to the physical disturbance from mining activities and infrastructure (roads) and water use. As Mortatti and Probst, (2010) mentioned, transport of particulate heavy metals could be instantaneously discharged from the source and influence the watershed drainage area. It is expressed when the downstream area has a relatively high concentration of Zn, Cr, Ni, and Cu (Mortatti and Probst, 2010). Agricultural land can transport heavy metals to non-agricultural land by eroded soil. Mohammadi *et al.*, (2019) mentioned soil erosion in farmland could transport heavy metals to the rivers.

The agricultural sectors may increase heavy metals content in the soil by applying fertilizers, manures and pesticides, and wastewater irrigation. Phosphate fertilizers are the source of heavy metals (Mendes *et al.*, 2006). Since Pangkep regency still used urea, SP36, and ZA as fertilizers in the farmland, it could be attributed to an accumulation of heavy metals. The soil heavy metal concentration will be influenced by many factors such as pH, soil type, land use pattern, relief of topographic and lithology aspects. Thus, it might affect the various level of content-heavy metals in this study area. The present study only analysed

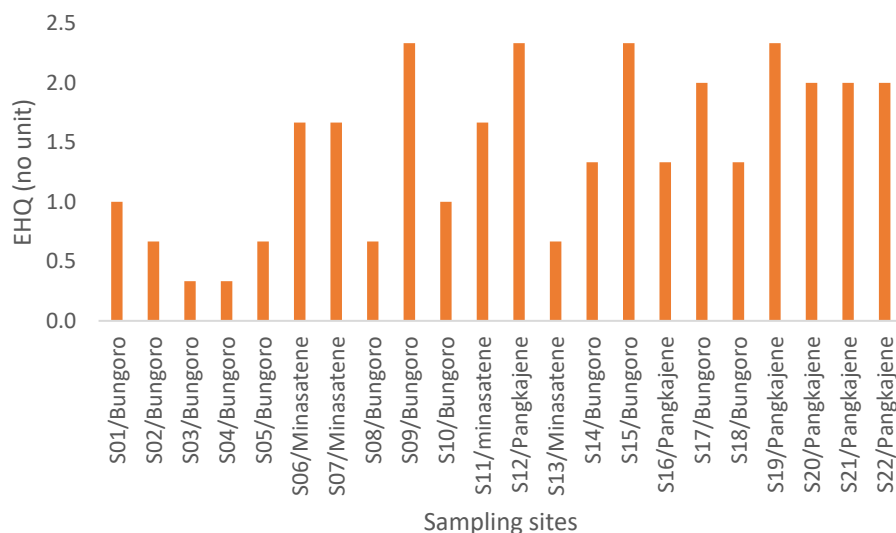
the total concentration of Cr and Ni in soils. Further research should be undertaken to investigate the several factors that may influence metals binding in the soil of the Pangkep regency.

#### *The potential ecological risk*

The US EPA used EHQ calculation to estimate if the risk of adverse effects to the environment is likely or not happened due to the pollutant (USEPA, 2016). Based on Table: 5, all studied soils have a high ecological risk from Cr enrichment. However, Ni enrichment has a low and moderate risk to the ecological system. The ecological risk has a critical value of 1. It means if the value of EHQ > 1, the soil contamination has a potential hazard to the environment, or there is a hazard due to pollutants at the site. Fig. 5 showed sampling site 8 in Bungoro sub-district has the highest EHQ value for Cr, while the highest value of EHQ for Ni is located in Bungoro and Pangkajene sub-district (Sampling site 9, 12, 15, and 19). These results showed that Cr's ecological risk tends to be happened in the upstream area, whereas Ni's ecological risk is likely to occur in the middle and downstream area. Soil is often contaminated with metals which are from far place. Soil erosion can attribute to metal transportation (Amorosi, 2012). Fig. 6 shows that the upstream and the middle stream areas have a high risk from Cr and Ni enrichment. Ecological hazard index (EHI) for studied soils is higher than 1, and it means there is a



(a)



(b)

Fig. 5: EHQ value related to the enrichment of Cr (a) and Ni (b) in the studied area

potential adverse impact on ecology due to Cr and Ni contamination. Cr can have beneficial and adverse effects on humans, plants, and animals. Chromium is not an essential substance for plant (Ertani *et al.*, 2017). Cr can accumulate metals on roots. The toxicity of Cr is depended on its speciation. The

toxic effects of Cr and Ni on the terrestrial plant are related to the generation of reactive oxygen species (ROS), which impair the plant's metabolism and physiological process (Hassan *et al.*, 2019; Sharma *et al.*, 2020; Ertani *et al.*, 2017). Cr toxicity symptoms on plants including a decrease of germination,

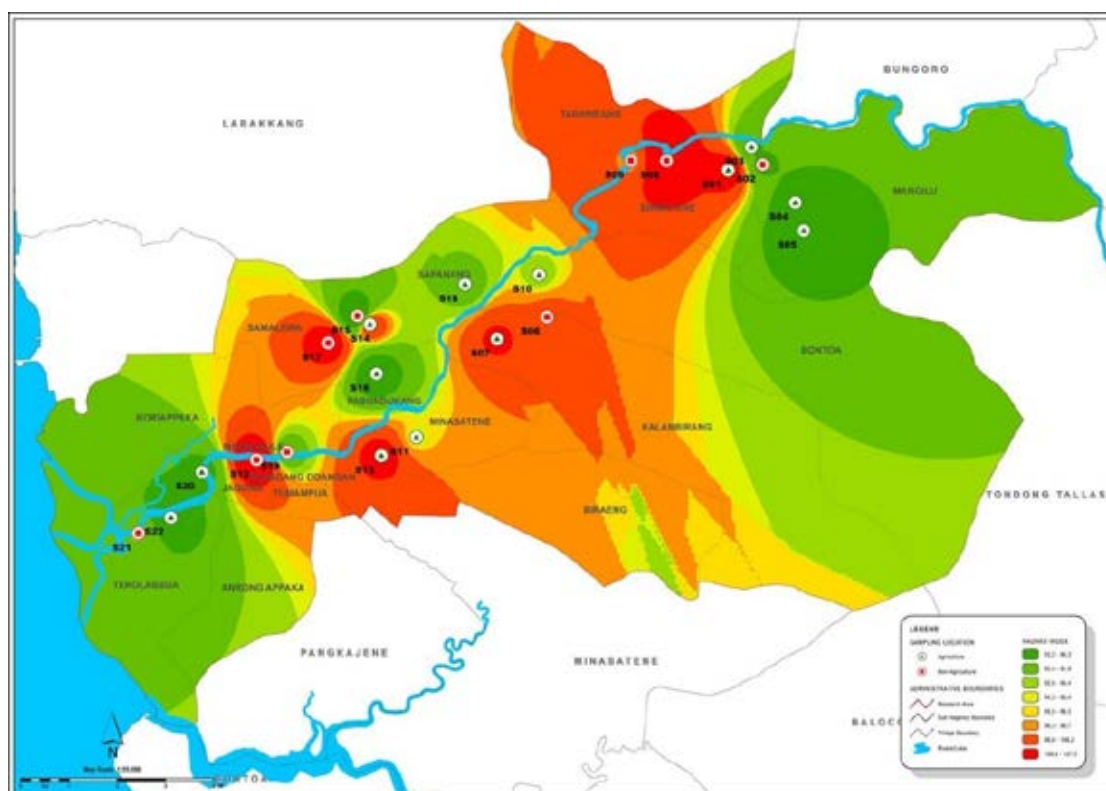


Fig. 6: EHI of Cr and Ni in the studied soil

impairment of enzymatic process, reduction of the growth process, genotoxicity, impairment of photosynthesis, and oxidative shortcoming (Ertani *et al.*, 2017). The higher EHI value is dominated in the upstream area and middle stream area of the watershed, where the mining and industry activities contribute to the accumulation of heavy metals. Besides, in the midstream area, there are municipal/domestic and agriculture activities. Several home-based enterprises surround the middle stream area of Pangkep watersheds, such as tofu factory, automotive services, machine shops, dry cleaning, metal plating, metal mechanic and metal finishing, and furniture which may possibly discharge their pollutants into soil and water river. The upstream area (S01- S03, S08, and S09) in Bungoro subdistrict is dominated by industry and mining activities.

The cement and marble industry were established for a long time in the Bungoro sub-district. A prior study showed high Hg contamination by industrial and mining activities in the Bungoro subdistrict (Mallongi

*et al.*, 2020). Another study in the karst area of Maros regency showed the contamination of Hg and Cr in the area near the cement industry of Maros regency (Rauf *et al.*, 2020). Contamination of soil may be influenced by wind direction and intensive tillage of the agriculture field (Rauf *et al.*, 2020). Study by Rauf *et al.* (2020) also mentioned that Cr tends to accumulate near the cement plant. Thus, limestone mining is one of the contributors to Cr contamination in this area. Since the Cr and Ni tend to be accumulated in the soils and have potentially exposed biota and humans, maintaining and improving the environmental quality is needed in the Pangkep regency. There are several possible actions to reduce Cr and Ni concentration at studied soil including 1) increasing the organic matter content in the soil, 2) applying agricultural lime ( $\text{CaCO}_3$ ), and 3) planting the crops that not consumed such as agroforestry (Suryani and Ritung, 2018). The conducting comprehensive research was used on the amount of heavy metals concentration in agriculture products and heavy metals exposure

on human health through the food chain. Since soil erosion has commonly happened in the watershed area, the importance of maintaining and controlling the watershed area relating to the transportation of heavy metals via the erosion process needs to be highlighted by the regional government.

## CONCLUSION

The results indicated the soils in the Pangkep regency watershed were generally contain a low level of Cr and Ni. The order of mean concentrations is  $Cr > Ni$ . Cr and Ni's highest value is located in the upper and middle stream of the Pangkajene River. This location is dominated by industry, mining, and agriculture activity. I-geo and PLI values indicated no pollution of Cr and Ni in the studied area. The potential sources of Cr and Ni are mainly derived from natural sources. This study area is enriched with carbonate rocks. So, it may influence the immobilization of heavy metals in soil. Soil erosion and flood in the karst area may transport heavy metal from the upstream region to the lowland. These study results also demonstrated that Cr concentration was below WHO permissible value, while Ni concentration exceeded the WHO standard. However, Cr and Ni can accumulate in the soil over time if there is no remediation action at the site. Heavy metal controlling and monitoring activity needs to be done in the studied area due to metals bioaccumulation properties and their adverse impact that may happen in long-term exposure to biota and humans. Increasing the organic matter content in the soil, applying agricultural lime ( $CaCO_3$ ), and developing agroforestry activities are the remediation plan for the studied area. Since lack of standards for heavy metals for soil and information on background concentration in the study area, we recommend to local authorities to develop the standards and environmental monitoring mechanism to reduce the risk of heavy metal accumulation. However, the EHI value  $>1$  means that the metals enrichment has a potential adverse impact on ecological health from Cr and Ni contamination. The importance of landform shifting to transport heavy metals and identifying soil erosion process in the watershed area needs to be concerned in Pangkep regency to control heavy metals contamination better. For further research, there are several suggestions: 1) physical and chemical properties of soil relating to heavy metals contamination, 2) comprehensive study

on the amount of heavy metals content in agriculture products, and 3) the effects of heavy metals exposure on human health.

## AUTHOR CONTRIBUTIONS

R.D.P. Astuti performed research concepts and designs, assembled data, wrote the article, data analysis, and interpretation. A. Mallongi performed research concept and design and critical revision of the article. A.U. Rauf assisted in collecting data and writing the paper.

## ACKNOWLEDGEMENT

This study was supported by the Directorate General of Higher Education Ministry of Education and Culture Republic of Indonesia (DIKTI) [PMDSU program [SK No.6/E/KPT/2019]. Authors are also thankful to Pangkep municipality due to kind cooperation during this research.

## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

## ABBREVIATIONS

Al	Aluminum
As	Arsenic
ATSDR	Agency for toxic substances and disease registry
$CaCO_3$	Calcium carbonate
$C_b$	The geochemical/background concentration of specific heavy metals
CCME	Canadian Council of Minister of The Environment
Cd	Cadmium
$C_f$	Contamination factor
Co	Cobalt
CO	Carbon monoxide
$CO_2$	Carbon dioxide
Cr	Chromium
Cr (VI)	Hexavalent chromium



<i>Cu</i>	Copper
<i>C<sub>x</sub></i>	soil-specific heavy metals in the studied area
<i>EEC</i>	Estimated environmental concentration
<i>EHl</i>	Ecological hazard index
<i>EHQ</i>	Ecological hazard quotient
<i>EPA</i>	Environmental Protection Agency
<i>Eq.</i>	Equation
<i>F-AAS</i>	Flame atomic absorption spectrophotometer
<i>Fe</i>	Iron
<i>g</i>	Gram
<i>GPS</i>	Global Positioning System
<i>HCl</i>	Hydrochloric acid
<i>Hg</i>	Mercury
<i>HMs</i>	Heavy Metals
<i>HNO<sub>3</sub></i>	Nitric acid
<i>IDW</i>	Inverse distance weighted
<i>I-geo</i>	Geo-accumulation index
<i>La</i>	Lanthanum
<i>max</i>	Maximum
<i>mg/kg</i>	Milligram per kilogram
<i>mg/L</i>	Milligram per litre
<i>min</i>	Minimum
<i>mL</i>	Millilitre
<i>mm</i>	Millimetre
<i>Mn</i>	Manganese
<i>n</i>	The number of trace elements.
<i>Ni</i>	Nickel
<i>NIST</i>	National Institute of Standards and Technology
<i>NOx</i>	Nitrogen oxide
<i>Pangkep regency</i>	Pangkajene dan Kepulauan regency
<i>Pb</i>	Lead
<i>pH</i>	Power of hydrogen or basicity/acidity indicator
<i>PM</i>	Particulate matter
<i>PLI</i>	Pollution load index
<i>ppm</i>	Part per million
<i>ROS</i>	Reactive Oxygen Species

<i>SD</i>	Standard deviation
<i>SNI</i>	Standar Nasional Indonesia or Indonesia's National Standard
<i>SO<sub>2</sub></i>	Sulfur dioxide
<i>SP36</i>	Superphosphate 36
<i>Sr</i>	Strontium
<i>Th</i>	Thorium
<i>US\$</i>	United States dollar
<i>V</i>	Vanadium
<i>WHO</i>	World Health Organization
<i>ZA</i>	Diazonium sulfate (Zwavelzure ammoniac)
<i>Zn</i>	Zinc
<i>%</i>	Percent
<i>°C</i>	Celsius degree

## REFERENCES

- Adriano, D.C., (1986). Trace elements in the terrestrial environment, Packaging Magazine. New York, NY: Springer New York (549 pages).
- Amorosi, A., (2012). Chromium and nickel as indicators of source-to-sink sediment transfer in a holocene alluvial and coastal system (Po Plain, Italy). Sediment. Geol., 280: 260–269 (10 pages).
- Azeh Engwa, G.; Udoka Ferdinand, P.; Nweke Nwalo, F.N.; Unachukwu, M., (2019). Mechanism and health effects of heavy metal toxicity in humans. In poisoning in the modern world - new tricks for an old dog? IntechOpen (23 pages).
- Beyer, W.N.; Sample, B.E., (2017). An evaluation of inorganic toxicity reference values for use in assessing hazards to american robins (*turdus migratorius*). Integr. Environ. Assess., 13(2): 352–359 (8 pages).
- CCME, (2007). Canadian soil quality guideline. Canadian soil quality guideline for the protection of environment and human health, (6 pages).
- Costa, M.; Klein, C.B., (2006). Toxicity and carcinogenicity of chromium compound in humans. Crit. Rev. Toxicol., 36 (2): 155 – 163 (9 pages).
- Das, K.K.; Reddy, R.C.; Bagoji, I.B.; Das, S.; Bagali, S.; Mullur, L.; Khodnapur, J.P.; Biradar, M.S., (2019). Primary concept of nickel toxicity – an overview. J. Basic. Clin. Physiol. Pharmacol., 30(2): 141- 152 (12 Pages).
- Duli, A.; Mulyadi, Y.; Rosmawati., (2019). The mapping out of Maros-Pangkep karst forest as a cultural heritage conservation. IOP conf. Ser: Earth Environ. Sci., 270(1): 1- 7 (8 pages).
- Efe, R., (2014). Ecological properties of vegetation formations on karst terrains in the central Taurus Mountains (Southern Turkey). Procedia - Soc. Behav. Sci., 120: 673–679 (7 pages).
- Efroymson, R.A.; Will, M.E.; Suter II, G.W.; Wooten, A.C., (1997). Toxicological benchmarks for screening contaminants of

- potential concern for effects on terrestrial plants: 1997 revision. ES/ER/TM-8 **(123 pages)**.
- Ertani, A.; Mietto, A.; Borin, M.; Nardi, S., (2017). Chromium in agricultural soils and crops: a review. *Water Air Soil Pollut.*, 228(5): 190 **(12 pages)**.
- Fatinaware, A.; Fauzi, A.; Hadi, S., (2019). Kebijakan pengelolaan ruang dan keberlanjutan Kawasan karst Maros Pangkep Provinsi Sulawesi Selatan. *J. Agric. Resour. Environ. Econ.*, 2: 26-37 **(12 Pages)**.
- Feng, H.; Jiang, H.; Gao, W.; Weinstein, M.P.; Zhang, Q.; Zhang, W.; Yu, L.; Yuan, D.; Tao, J., (2011). Metal contamination in sediments of the Western Bohai Bay and adjacent estuaries, China. *J. Environ. Manage.*, 92(4): 1185–1197 **(13 pages)**.
- Gati, G.; Pop, C.; Brudasca, F.; Gurzau, A.E.; Spinu, M., (2016). The ecological risk of heavy metals in sediment from the Danube Delta. *Ecotoxicology*, 25(4): 688–696 **(9 pages)**.
- Hakanson, L., (1980). An ecological risk index for aquatic pollution control a sedimentological approach. *Water Res.*, 14(8): 975–1001 **(27 pages)**.
- Hasan, O.; Miko, S.; Ilijanic, N.; Brunovic, D.; Dedic, Z.; Miko, M.S.; Peh, Z., (2020). Discrimination of topsoil environments in a karst landscape: an outcome of a geochemical mapping campaign. *Geochem Trans.*, 21(1): 1–22 **(22 pages)**.
- Hassan, M.U.; Chattha, M.U.; Khan, I.; Chattha, M.B.; Aamer, M.; Nawaz, M.; Ali, A.; Ullah Khan, M.A.; Khan, T.A., (2019). Nickel toxicity in plants: reasons, toxic effects, tolerance mechanisms, and remediation possibilities—a review. *Environ. Sci. Pollut. Res.*, 26(13):12673-12688 **(16 Pages)**.
- He, G.; Zhang, Z.; Wu, X.; Cui, M.; Zhang, J.; Huang, X., (2020). Adsorption of heavy metals on soil collected from lixisol of typical kareas in the presence of CaCO<sub>3</sub> and soil clay and their competition behavior. *Sustainability*, 12(18): 1 -19 **(19 pages)**.
- He, Z.; Shentu, J.; Yang, X.; Baligar, V.C.; Zhang, T.; Stoffella, P.J., (2015). Heavy metal contamination of soils: sources, indicators, and assessment. *J. Environ. Indic.*, 9: 17–18 **(2 pages)**.
- Huang, L.; Rad, S.; Xu, L.; Gui, L.; Song, X.; Li, Y.; Wu, Z.; Chen, Z., (2020). Heavy metals distribution sources, and ecological risk assessment in Huixian wetland, South China. *Water*, 12 (2): 431-445 **(14 pages)**.
- Huang, G.; Su, X.; Rizwan, M.S.; Zhu, Y.; Hu, H., (2016). Chemical immobilization of Pb, Cu, and Cd by phosphate materials and calcium carbonate in contaminated soils. *Environ. Sci. Pollut. Res.*, 23(16): 16845– 16856 **(12 pages)**.
- Jaishankar, M.; Tsenten, T.; Anbalangan, N.; Mathew, B.B.; Beeregowda, K.N., (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdiscip. Toxicol.*, 7(2): 60–72 **(13 pages)**.
- Jarsjö, J.; Chalov, S.R.; Pietron, J.; Alekseenko, A.V.; Thorslund, J., (2017). Patterns of soil contamination, erosion and river loading of metals in a gold mining region of Northern Mongolia. *Reg. Environ. Change.*, 17(7): 1991–2005 **(15 pages)**.
- Kamon, M.; Ying, C.; Katsumi, T., (1996). Effect of acid rain on lime and cement stabilized soils. *Soils Found.*, 36(4): 91–99 **(9 pages)**.
- Kaszala, R.; Barany-Kevei, I., (2015). Heavy metal concentration in the soils and vegetation of Beke-cave watershed (Aggtelek-karst, Hungary). *Landscape Environ.*, 9(2): 51 – 58 **(8 pages)**.
- Khan, S.; Cao, Q.; Zheng, Y.M.; Huang, Y.Z.; Zhu, Y.G., (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environ. Pollut.*, 152(3): 686–692 **(7 pages)**.
- Kowalska, J.B.; Mazurek, R.; Gasiorek, M.; Zaleski, T., (2018). Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination—a review. *Environ. Geochem. Health*, 40(6): 2395–2420 **(26 pages)**.
- Laniyan, T.A.; Adewumi, A.J.P., (2020). Evaluation of contamination and ecological risk of heavy metals associated with cement production in Ewekoro, Southwest Nigeria. *J. Health. Pollut.*, 10 (25): 1-13 **(14 pages)**.
- Lemly, A.D., (1996). Evaluation of the hazard quotient method for risk assessment of selenium. *Ecotoxicol. Environ. Saf.*, 35(2): 156–162 **(7 pages)**.
- Li, J.; He, M.; Han, W.; Gu, Y., (2009). Analysis and assessment on heavy metal sources in the coastal soils developed from alluvial deposits using multivariate statistical methods. *J. Hazard. Mater.*, 164(2–3): 976–981 **(6 pages)**.
- Li, C.; Yang, Z.; Yu, T.; Hou, Q.; Liu, X.; Wang, J.; Zhang, Q.; Wu, T., (2021). Study on safe usage of agricultural land in karst and non-karst areas based on soil Cd and prediction of Cd on rice: a study of Heng County, Guangxi. *Ecotoxicol. Environ. Saf.*, 208: 111505.
- Lian, M.; Wang, J.; Sun, L.; Xu, Z.; Tang, J.; Yan, J.; Zeng, X., (2019). Profiles and potential health risks of heavy metals in soil and crops from the watershed of Xi River in Northeast China. *Ecotoxicol. Environ. Saf.*, 169: 442–448 **(7 pages)**.
- Lyu, X.; Tao, Z.; Quanzhou, G.; Peng, H.; Zhou, M., (2018). Chemical weathering and riverine carbonate system driven by human activities in a subtropical karst basin, South China. *Water*, 10(11): 1 – 25 **(25 pages)**.
- Ma, Q.; Han, L.; Zhang, J.; Zhang, Y.; Lang, Q.; Li, F.; Han, A.; Bao, Y.; Li, K.; Alu, S., (2019). Environmental risk assessment of metals in the volcanic soil of Changbai Mountain. *Int. J. Environ. Res. Public Health.*, 16(11): 1-17 **(17 pages)**.
- Mahasenani, N.; Smith, S.; Humphreys, K., (2003). The cement industry and global climate change current and potential future cement industry CO<sub>2</sub> emissions. In *Greenhouse Gas Control Technologies - 6th International Conference*. Elsevier. (2): 995–1000 **(6 pages)**.
- Mallongi, A.; Stang.; Syamsuar.; Natsir, M.F.; Astuti, R.D.P.; Rauf, A.U.; Rachmat, M.; Muhith, A., (2020). Potential ecological risks of mercury contamination along communities area in tonasa cement industry Pangkep, Indonesia. *Enferm. Clín.*, 30: 30(4): 119–122 **(4 pages)**.
- Mallongi, A.; Irwan.; Rantetampang, A.L., (2014). Assessing the mercury hazard risks among communities and gold miners in artisanal Buladu gold mine, Indonesia. *Adv. Mater. Res.*, 10(4): 316–322 **(6 pages)**.
- Martin, J.M.; Whitfield, M., (1983). The significance of the river input of chemical elements to the ocean. *Trace metals in sea water*, Springer US, Boston, MA, 265 – 296 **(32 Pages)**.

- McDermott, S.; Bao, W.; Aelion, C.M.; Cai, B.; Lawson, A.B., (2014). Does the metal content in soil around a pregnant woman's home increase the risk of low birth weight for her infant? *Environ. Geochem. Health*. 36(6): 1191-1197 **(7 pages)**.
- Mendes, A.M.S.; Duda, G.P.; Araujo do Nascimento, C.W.; Silva, M.O., (2006). Bioavailability of cadmium and lead in a soil amended with phosphorus fertilizers. *Sci. Agric.*, 63(4): 328–332 **(5 pages)**.
- Miko, S.; Durn, G.; Adamcova, R.; Covic, M.; Dubikova, M.; Skalsky, R.; Kapelj, S.; Ottner, F., (2003). Heavy metal distribution in karst soils from Croatia and Slovakia. *Environ. Geol.*, 45(2): 262–272 **(11 pages)**.
- Mohammadi, M.; Darvishan, K.A.; Bahramifar, N., (2019). Spatial distribution and source identification of heavy metals (As, Cr, Cu and Ni) at sub-watershed scale using geographically weighted regression. *Int. Soil Water Conserv. Res.*, 7(3): 308–315 **(8 pages)**.
- Mortatti, J.; Probst, J., (2010). Characteristics of heavy metals and their evaluation in suspended sediments from Piracicaba River Basin (São Paulo, Brazil). *Open Arch. Toulouse Arch. Ouvert.*, 40(3): 375–379 **(5 pages)**.
- Müller, V.G., (1986). Schadstoffe in sedimenten - sedimente als schadstoffe. *Mitt. Osterr. Geol. Ges.*, 79: 107-126 **(20 Pages)**.
- NCEANET., (2020). EANET data on the acid deposition in the East Asian Region. Network Center for EANET.
- Ogunkunle, C.O.; Fatoba, P.O., (2014). Contamination and spatial distribution of heavy metals in topsoil surrounding a mega cement factory. *Atmos. Pollut. Res.*, 10 (25): 1-13 **(13 pages)**.
- OHIO EPA, (2008). Ecological risk assessment guidance for conducting ecological risk assessments. Ohio: EPA.
- Ramli, M.; Syaifuddin; Baja, S., (2009). Analisis sebaran spasial karakteristik lahan di Kabupaten Pangkajene Sulawesi Selatan. *J. Agrisistem.*, 5(2): 102–112 **(11 pages)**.
- Rauf, A.U.; Mallongi, A.; Astuti, R.D.P., (2020). Mercury and chromium distribution in soil near Maros Karst Ecosystem. *Carpathian J. Earth Environ. Sci.*, 15(2): 453–460 **(8 pages)**.
- Sayadi, M.H.; Sayyed, M.R.G., (2011). Comparative assessment of baseline concentration of the heavy metals in the soils of Tehran (Iran) with the comparable reference data. *Environ. Earth Sci.*, 63(6): 1179 – 1188 **(10 pages)**.
- Sayadi, M.H.; Rezaei, M.R., (2014). Impact of land use on the distribution of toxic metals in surface soils in Birjand city, Iran. *Proc. Int. Acad. Ecol. Environ. Sci.*, 4(1): 18 – 29 **(12 pages)**.
- Sharma, A.; Kapoor, D.; Wang, J.; Shahzad, B.; Kumar, V.; Bali, A.S.; Jasrotia, S.; Zheng, B.; Yuan, H.; Yan, D., (2020). Chromium bioaccumulation and its impacts on plants: an overview. *Plants*. 9(1): 1–17 **(17 pages)**.
- Sompotan, A.F., (2012). Struktur geologi Sulawesi. Perpustakaan Sains Kebumihan. Institut Teknologi Bandung. Bandung: Perpustakaan Sains Kebumihan ITB.
- Su, C.; Jiang, L.; Zhang, W., (2014). A review on heavy metal contamination in the soil worldwide : situation , impact and remediation techniques. *Environ. Skept. Critics.*, 3(2):24–38 **(15 pages)**.
- Suryani, E.; Ritung, S.; Besar, B., (2018). Tanah-tanah dari Batuan ultrabasic di Sulawesi: kandungan logam berat dan arahan pengelolaan untuk pertanian. *Jurnal Tanah dan iklim*, 42(2): 111- 124 **(14 pages)**.
- Tang, M.; Lu, G.; Fan, B.; Xiang, W.; Bao, Z., (2020). Bioaccumulation and risk assessment of heavy metals in soil-crop systems in Liujiang Karst Area, Southwestern China. *Environ. Sci. Pollut. Res.*, (274) **(13 pages)**.
- Taylor, S.R., (1964). Abundance of chemical elements in the continental crust: a new table. *Geochim. Cosmochim. Acta.*, 28(8): 1273–1285 **(13 pages)**.
- Tchounwou, P.B.; Yedjou, C.G.; Patlolla, A.K.; Sutton, D.J., (2012). Heavy metal toxicity and the environment. In Luch, A. (ed.) *molecular clinical and environmental toxicology*. Basel, Switzerland: Springer: 133–164 **(32 pages)**.
- Tonggihroh, A., (2013). Analisis geokimia logam Cu, Fe, pada batuan dasit kabupaten Barru Sulawesi Selatan. Prosiding Hasil Penelitian Fakultas Teknik Unhas **(6 pages)**.
- Turekian, K.K.; Wedepohl, K.H., (1961). Distribution of the elements in some major unit of the earth's crust. *Geol. Soc. Am. Bull.*, 72(2): 175 – 192 **(18 Pages)**.
- UGM, (2016). 9.5 persen kawasan Karst Indonesia rusak.
- USDHHS, (2019). ATSDR's substance priority list. U.S. Department of Health and Human Services.
- USEPA, (2016). Ecological risk assessment. Region 5, Research fund.
- Wang, K.; Zhang, C.; Chen, H.; Yue, Y.; Zhang, W.; Zhang, M.; Qi, X.; Fu, Z., (2019). Karst landscapes of China: patterns, ecosystem processes and services. *Landscape Ecol.*, 34(12): 2743–2763 **(21 pages)**.
- Wilson, M.E.J., (1996). Evolution and hydrocarbon potential of the tertiary tonasa limestone formation, Sulawesi, Indonesia. 25<sup>th</sup> Annual convention proceed. **(14 Pages)**.
- World Health Organization (WHO). (1996). WHO permissible limits for heavy metals in plant and soil.
- Yolcubal, I.; Akyol, N. H., (2007). Retention and transport of hexavalent chromium in calcareous karst soils. *Turk. J. Earth Sci.*, 16(3): 363–379 **(17 pages)**.
- Yun, S.W.; Yu, C., (2015). Immobilization of Cd, Zn, and Pb from soil treated by limestone with variation of pH using column test. *J. Chem.*, 2015: 1 – 8 **(8 pages)**.
- Zhang, Q.; Han, G.; Liu, M.; Liang, T., (2019). Spatial distribution and controlling factors of heavy metals in soils from Puding karst critical zone observatory, Southwest China. *Environ. Earth Sci.*, 78(9): 1–13 **(13 pages)**.
- Zhao, L.; Hou, R., (2019). Human causes of soil loss in rural karst environments: a case study of Guizhou, China. *Sci. Rep.*, 9(1): 1–11 **(11 pages)**.

#### AUTHOR(S) BIOSKETCHES

**Astuti, R.D.P.**, Ph.D. Candidate, Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia. Email: [ratnadwipujiaastuti@gmail.com](mailto:ratnadwipujiaastuti@gmail.com)

**Mallongi, A.**, Ph.D., Professor, Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia. Email: [anwar\\_envi@yahoo.com](mailto:anwar_envi@yahoo.com)

**Rauf, A.U.**, Ph.D. Candidate, Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia. Email: [annisautamirauf@gmail.com](mailto:annisautamirauf@gmail.com)

#### COPYRIGHTS

©2021 The author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers.



#### HOW TO CITE THIS ARTICLE

Astuti, R.D.P.; Mallongi, A.; Rauf, A.U., (2021). Natural enrichment of chromium and nickel in the soil surrounds the karst watershed. *Global J. Environ. Sci. Manage.*, 7(3): 383-400.

DOI: [10.22034/gjesm.2021.03.05](https://doi.org/10.22034/gjesm.2021.03.05)

url: [https://www.gjesm.net/article\\_243011.html](https://www.gjesm.net/article_243011.html)

