g_sediments_from_lateritic_nickel_post-mining_areas_in_Motui.pdf

by

Submission date: 06-Jul-2022 07:48AM (UTC+0700)
Submission ID: 1867081753
File name: g_sediments_from_lateritic_nickel_post-mining_areas_in_Motui.pdf (919.15K)
Word count: 3801
Character count: 19316

JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 9, Number 2 (January 2022):3273-3279, doi:10.15243/jdmlm.2022.092.3273
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

Determination of heavy metal elements concentration in soils and tailing sediments from lateritic nickel post-mining areas in Motui District, Southeast Sulawesi

Muhardi Mustafa[1], Adi Maulana[2*], Ulva Ria Irfan[2], Adi Tonggiroh[2]

[1] Earth Science and Technology Study Program, Geology Department, Hasanuddin University, Jl. Poros Malino, Gowa, Indonesia
[2] Department of Geology, Hasanuddin University, Jl. Poros Malino, Gowa, Indonesia

*corresponding author: adi-maulana@unhas.ac.id

Article history:
Received 15 October 2021
Accepted 24 November 2021
Published 1 January 2022

Keywords:
heavy metal
lateritic nickel
Motui
post-mining
soil
tailing sediment

Abstract

Heavy metal elements concentration study has been determined from soils and tailing sediments in laterite nickel post-mining area in Motui District Southeast Sulawesi. This study aimed to determine the concentration of some heavy metal elements, especially Fe, Co, Mn and Cr, from surface soils sediments in waste dump sites and tailing sediments in settling ponds from lateritic nickel post-mining areas. A total of 20 samples consisting of 18 soil samples and 2 tailing sediments samples were systematically collected for the study. The soil samples from the waste dump site profile were collected from 3 layers which were divided based on the colour of the soils from top to bottom, namely Layer C, Layer D and Layer E. Six soil samples were taken from each layer with space between each sample in one layer was about 50 – 60 cm. The samples were sent to the laboratory and analysed using Atomic Absorption Spectrometer (AAS) method to determine the concentration of heavy elements. Metal-bearing minerals detected from the bedrock consists of chromite, manganese, magnetite and limonite which are responsible for the Cr, Mn and Co, and Fe content, respectively. The result showed that Fe content is significantly higher in soil samples from Layer C and tailing sediments with dark red to brown in colour, suggesting the strong relation between Fe content and colour index. The general element mobility trend showed that Mn and Co are positively correlated in soil sampling from all layers and tailing samples, whereas Fe and Cr show a negative correlation trend in Layer C, D and tailing sediments but positively correlated in Layer E.

To cite this article: Mustafa, M., Maulana, A., Irfan, U.R. and Tonggiroh, A. 2022. Determination of heavy metal elements concentration in soils and tailing sediments from lateritic nickel post-mining areas in Motui District, Southeast Sulawesi. Journal of Degraded and Mining Lands Management 9(2):3273-3279, doi:10.15243/jdmlm.2022.092.3273.

Introduction

Post-mining laterite nickel areas are widely distributed in Motui District Southeast Sulawesi. The mining activities have been causing changes in element concentration, soil compaction, hydrodynamics, and geochemistry in soils and tailings (Soltani et al., 2017; Prematury et al., 2020). One of the characteristics of laterite nickel mining is surface mining since the nickel ore will be concentrated in a saprolitic layer above the bedrock. Typically, there are four main layers in the laterite nickel profile which are (from lower to the upper or surface layer) bedrock, saprolite, limonite and top soil (overburden) (Akane et al. 2021). Surface mining is conducted to extract the upper layer of laterite soil from the surface or upper to the bottom layer.

Surface mining creates tailings and has a significant environmental impact on surrounding areas due to its relatively great volume of the material that has been moved (Lin et al., 2025). Post-mining will leave waste, abandoned areas, and changes in topography, leading to land degradation. Degradation of post-mining areas will include changes in soil structure and increased metal mobility (Alexandre-Kwaterczak and Helios-Rybicka, 2009; Festin et al., 2019) as well as concentrations of chemical elements. It is reported that elements in mining and ore processing cause different changes to the environment (Larondelle and Haase, 2012) and will lead to health problems (Kierczak et al., 2021).

Generally, laterite soils are brown to dark reddish-brown representing iron, aluminium, and magnesium contents. This soil is rich in trace elements that originated from weathered ultramafic rocks. Atomic structures of trace elements in the original mineral are very different from the soil. For example, in weathering conditions, chromite ($FeCr_2O_4$) absorbs Fe, Mn, Cr, Co, which are also originated from pyroxene, amphibole, micas (Kierczak et al., 2021). The element correlation of Fe, Ni, Cr, and Co in soils, waters, and vegetation in lateritic profile reflect their association with the ultrabasic rocks and with the Fe-Ni mineralization (Vardaki and Kelepertsis, 1999; Ilyas et al. 2016). Geochemical change in lateritic profile due to weathering process was reported from New Caledonia. It is reported that Co and Mn concentration changes along with the weathering stage in a laterite profile (Dublet et al., 2017).

Motui District is an area in North Konawe Regency that has been planned to be an industrial area according to local government policy. There are four nickel mining companies that are operating in Motui area. Some mining companies have already closed their mining operation and left an abandoned area, or post-mining area in which soil is exposed to the surface. Generally, mining activity will have an impact on soil compaction, erosion, and mobility of elements. It has been reported the mobilization and redistribution of elements in the soil profile occurred in lateritic nickel area caused by chemical reaction (Vardaki and Kelepertsis, 1999; Roca et al., 2008; Dublet et al., 2017). Changes in soil compaction will affect the distribution of traces in post-mining areas and hence will control the geochemical environment of the area. This study aimed to evaluate the concentration of trace elements, especially Fe, Mn, Co, Cr in soils sample from waste dump profiles and tailing sediment in post-mining areas in Motui district.

Materials and Methods

The Motui area is situated in the Motui District, Konawe Regency, Southeast Sulawesi (Figure 1a). The study focused on the post-mining area with a topography of slopes less than 60° which is connected to tailing dams (Figure 1b). Soil and tailing sediment samples were taken as material for this study. Twenty-one samples consist of 18 soil samples from the waste dump site, 2 tailing sediment from the tailing pond and 1 sample from a boulder at the bottom of the waste dump. The waste dump area was divided into three layers according to soil colour and location from which the sample was taken (Figure 2b). The first layer (layer C) is located at the bottom of the waste dump with pink to bright yellow in colour, whereas the second layer (layer D) is in the middle of the waste dump showing red to yellowish colour and the third layer (layer E) was taken from the top part of the waste dump with dark red to brown colour. Six (6) soil samples were systematically taken from each layer to get a representative samples condition.

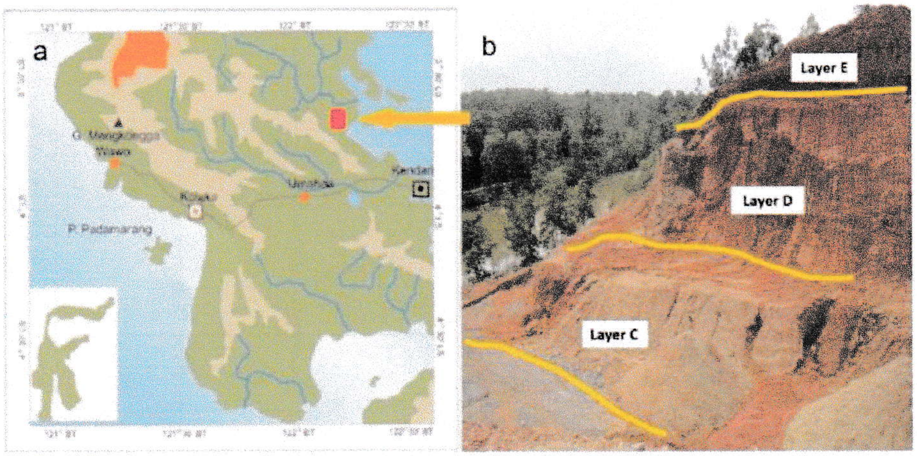

Figure 1. (a) Location map of the study area; (b) waste dump site profile for soil sampling showing 3 layers (Layer C, D and E). Six soil samples were collected in every layer.

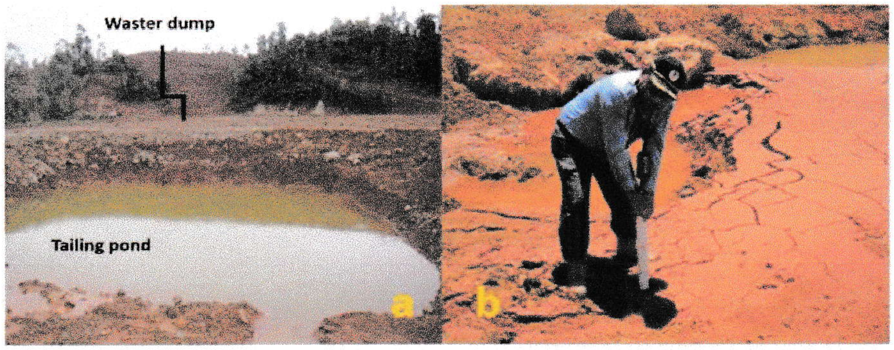

Figure 2. (a) Tailing dams, (b) Sample collecting process in tailing sediment.

The space between each sample in one layer was about 50 – 60 cm. Two (2) samples from 2 tailing ponds nearby the waste dump site were collected as tailing sediment samples. One (1) sample from weathered boulder was also taken for mineragraphic analyses from the bottom of the waste dump to get the information of metal-bearing minerals in the bedrock.

The soil surface samples were dried and dissolved using distilled water with a ratio of 2:1 (hydrochloric acid: nitric acid) then diluted appropriately for metals analysis (Mn, Co, Cr, and Fe) using AAS (Atomic Absorption Spectrophotometer) method at PT Intertek Jakarta. Next to the waste dump site (Figure 2a, 2b), polyvinyl chloride (PVC) tubes were used to collect tailing sediment samples (Wuana and Okieimen, 2011). Two tailing sediments samples were dried and analysed using the AAS method to determine the metal concentration, especially Fe, Cr, Mn, Co. In order to determine the metal-bearing mineral, a boulder rock at the bottom of the waste dump was collected and then sent to a rock preparation laboratory in Geological Engineering Department, Universitas Hasanuddin. The boulder is considered as the bedrock. The sample was cut and cleaned and processed for polished section analyses. Polish section samples analyses were carried out using a Nikon petrographic microscope with 10 eyepieces and 5x, 10x, 20x and 40x objective lenses, equipped with a Nikon E4500 camera mounted on the trinocular port for mineragraphy.

Results and Discussion

Bedrock

The metal-bearing minerals in the bedrock consist of chromite, magnetite, hematite and limonite, as shown in Figure 3. The bedrock shows a high serpentinization process as evidenced by the occurrence of serpentine mineral in the form of strings replacing olivine and pyroxene. It is very difficult to determine the type of bedrock since the main minerals have been replaced or pseudomorphed by secondary minerals due to serpentinization or weathering. The rock also displays a significant weathering process, as indicated by the presence of some oxidized minerals. Serpentinization and weathering process has decomposed magnetite, hematite, chromite, and limonite minerals, causing a portion of iron oxide and clay minerals to fill space and cracks (Figures 3a and 3b).

Soil and tailing sediment geochemistry

Concentrations of Co, Fe, Mn and Cr in soil sampling from each layer are listed in Table 1. Layer E, which is located at the top of the waste dump profile, is characterized by the higher Fe value average but lower Cu, Co and Mn content compared to other layers. Fe content shows a wide range value from 21.23% to 30.35%, whereas Mn displays a more varying value (5748 ppm – 13.428 ppm). Co content ranges from the lowest in the MC-E2 sample (357 ppm) to the highest in the MC-E5 sample (845 ppm). Cr content in this layer ranges from 7643 ppm to 9273 ppm.

On average, layer D shows a significantly higher concentration for Mn and Co but only slightly higher for Cr compared to Layer E, whereas Fe shows a significantly higher value. Co value ranges from 667 ppm to 1990 ppm. Fe content shows a narrow range of 22.13% to 31.95%. Mn and Cr display values starting from 5338 ppm to 14.085 ppm and 7913 ppm to 10.590 ppm, respectively. Compared to the other two layers, the average value of the heavy elements in layer C (located at the bottom of the profile) shows the highest value of Co, Cr and Mn. However, Fe content shows the lowest value than other layers (26.89%). Co content ranges from 735 ppm to 1985 ppm, Mn = 5748 ppm to 13428 ppm, Cr = 8343 ppm to 11088 ppm. Heavy elements concentration in tailing sediments exhibits a lower value than soil sampling concentration except for Fe concentration which is significantly higher than soil samples. Co shows an extremely lower value (255 ppm on average), whereas Cr and Mn also display lower values of 8751 ppm and 2760 ppm on average, respectively. Fe value ranges from 36 to 39 % (37% on average), about 20% to 30% higher concentration than the value of soil sampling sample.

Metal bearing mineral

A polished section of the bedrock shows the occurrence of some metal-bearing minerals, including chromite, magnetite, limonite and hematite (Figure 3). Chromite is the source of Cr elements in ultramafic rocks, whereas olivine is mostly responsible for Fe content if the rocks are still fresh and magnetite if the rocks have been serpentinized (Kierczak et al., 2021). The occurrence of chromite in the ultramafic rocks from the waste dump profile has been confirmed both in the polished section and geochemical result (Table 1). The highly serpentinized rock as shown by the intensive serpentinization process in the polished section suggests that Fe was originated from magnetite. The enrichment of Cobalt in heavily weathered lateritic Ni deposits is controlled by the occurrence of Mn-oxide mineral as the major Co-bearing mineral (Dublet et al., 2017). Mn-oxide minerals are widely found in the ultramafic rocks in the study area. The Mn-oxide mineral occurs in the form of manganese wad within the lateritic profile, especially in the transition zone between saprolite and limonite, as seen in Figure 4.

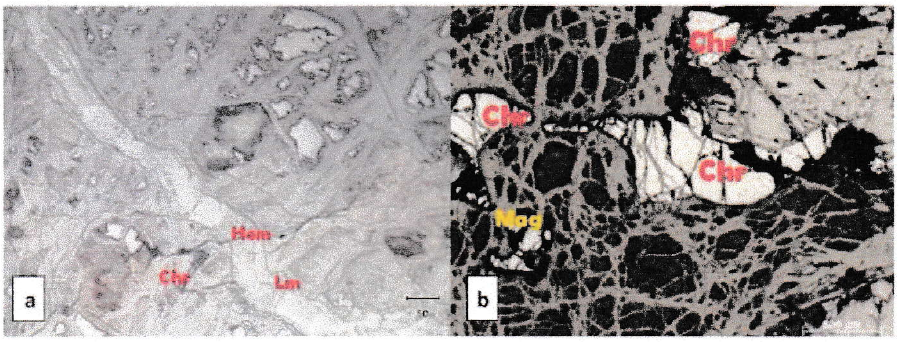

Figure 3. (Cross nicol photomicrographs of weathered ultramafic polished section, (a) Chromite trapped in limonite oxide (b) Chromite and magnetite that has been weathered. Hem = hematite, Chr = Chromite, Lim = Limonite, Mag = Magnetite.

Figure 4. Manganese wad found in the transition zone between saprolite and limonite in the laterite profile in Motui area. The manganese is the best host for Mn and Co in the weathering product.

Geochemical constraint

Overall, heavy elements concentration average in soil samples from waste dump profile shows that layer E contains a much lower value for all elements except Fe, which show the highest content compared to other layers. There is a regular pattern that can be concluded from the soil sample in terms of the soil colour of the profile. Layer E shows dark red to brown in colour, suggesting high Fe content due to the oxidation process and the occurrence of hematite and limonite (Roca et al., 2008; Maulana et al., 2016). The Fe content of Layer C (pink to bright yellow), which is located at the bottom of the profile, are lower than Layer D, which has red to yellowish colours. The result shows that Fe content will be much higher in the layer with the dark colour. It is reported that Fe content will be much higher in limonite and ferrigenous cap which has red dark to brown colour in lateritic nickel deposit from Kolonodale area in Sulawesi (Fu et al., 2014). Concentrations of heavy metals in tailing sediments samples show a similar trend to the soil sediments in the waste dump profile. Mn and Co in tailing sediments show a decreasing pattern compared to soil samples with almost 80% loss compared to Layer C and 70% loss compared to Layer D but only 50% compared to Layer E. Fe content in the tailing sediment is relatively higher than those in the soil sampling from the waste dump. This is expected since Fe is a mobile element in the water and tend to be oxidized in the form of ferric hydroxide.

General element mobility trend

General element mobility trend display that Co, Cr and Mn exhibit an increasing trend toward the bottom of the layer, especially Co, whereas Fe content shows a decreasing trend. It is proposed that the higher Fe content of Layer E at the top of the profile was due to the occurrence of Fe-bearing minerals such as magnetite, hematite and limonite, which leads to the enrichment of Fe. Co, Cr and Mn, an increasing trend to the bottom of the profile was probably due to the different sources of material in each layer rather than the leaching process. It is noteworthy that Mn and Co concentrations in the soil show a significant value, especially in Layer C. It is further noticeable that both elements are positively correlated. Dublet et al. (2017) reported the downward migration of Mn and Co along with lateritic nickel deposits in New Caledonia and found the long-term stabilization of Mn and Co in lateritic nickel deposits, which developed in the tropical region. Figures 5a and 5b show a general element mobility trend of the soil samples and tailing sediments. We made two diagrams to compare the element mobility trend, namely Fe vs Cr and Mn vs Co. It is shown from the figure that Fe and Cr in Layer C, D and tailing sediments show a negative correlation trend, whereas in Layer E they are positively correlated. Mn vs Co exhibits a strong positive correlation in all layers, suggesting that they are positively correlated to each other both in soil sediment from waste dump profile and from tailing sediments (Figure 5b).

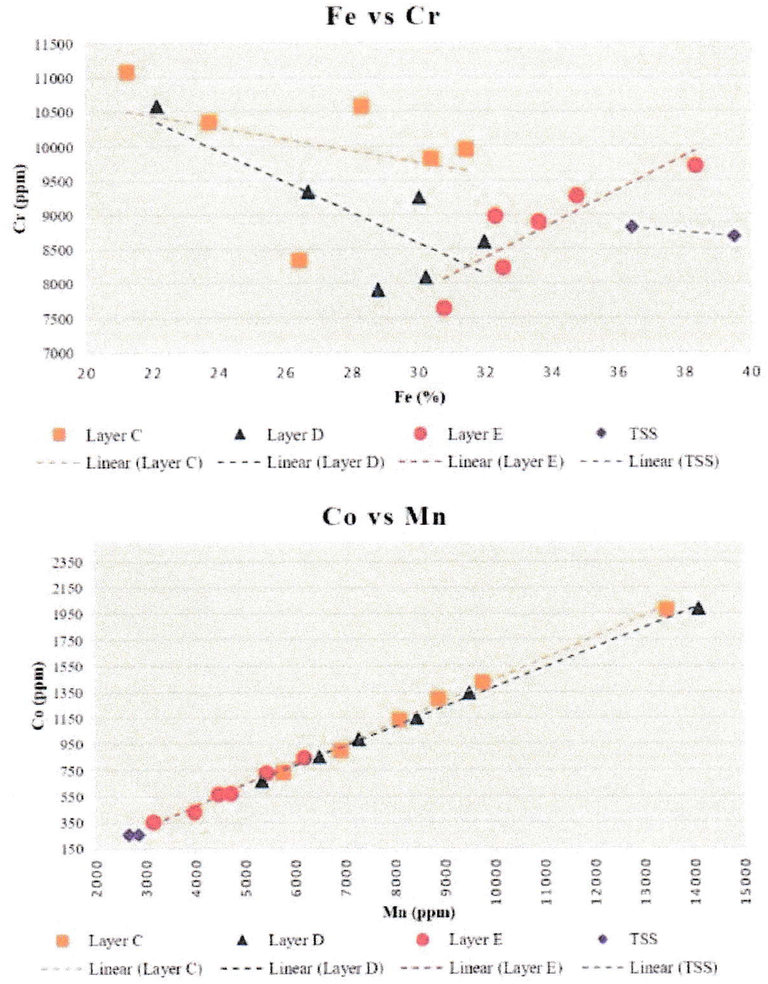

Figure 5. Fe vs Cr (upper) and Mn vs Co (lower) relationship diagram of the soil samples from waste dump profile and tailing sediments from Motui area.

Table 1. Geochemical concentration of soil sampling and tailing sediment from Motui area.

No	Sample No	Elements				Remark
		Co (ppm)	Fe (%)	Mn (ppm)	Cr (ppm)	
1	MC – C1	1137	26.38	8088	8343	Layer C
2	MC – C2	1422	23.7	9755	10360	
3	MC – C3	1300	28.25	8863	10588	
4	MC – C4	735	31.4	5748	9958	
5	MC – C5	1985	21.23	13428	11088	
6	MC – C7	905	30.35	6903	9825	
Mean	1247.33	26.89	8797.50	10027.00		
7	MC – D1	1342	26.65	9485	9335	Layer D
8	MC – D2	987	30	7278	9258	
9	MC – D3	1990	22.13	14085	10590	
10	MC – D4	852	28.75	6475	7913	
11	MC – D5	1150	31.95	8438	8605	
12	MC – D7	667	30.2	5338	8095	
Mean	1164.67	28.28	8516.50	8966.00		
13	MC – E1	430	34.73	3968	9273	Layer E
14	MC – E2	357	38.3	3148	9710	
15	MC – E3	727	32.28	5405	8988	
16	MC – E4	572	33.58	4703	8903	
17	MC – E5	845	30.73	6168	7643	
18	MC – E7	565	32.5	4458	8238	
Mean	582.67	33.69	4641.67	8792.50		
19	TSS - 1	255	39.48	2658	8683	Tailing
20	TSS - 2	255	36.4	2863	8820	
	Mean	255	37.94	2760.5	8751.5	

Conclusion

Chromite, magnetite, limonite, and hematite are the responsible metal-bearing minerals for heavy elements occurrence in soil samples from the waste dump profile in the Motui area. Variation in heavy metal concentration (Fe, Co, Mn dan Cr) in soil samples and tailing sediments were formed from chemical weathering processes. General element mobility trend display that Co, Cr and Mn exhibit an increasing trend toward the bottom of the layer, whereas Fe content shows a decreasing trend. The concentrations of Mn and Co are positively correlated in all layers and tailing sediments, whereas Fe and Cr shows a negative correlation in Layer C, D and tailing sediments but positively correlated in Layer E.

Acknowledgements

The authors would like to thank North Konawe Government for the support during the sample collection activity in Motui Area. This study was financially supported by Doctoral Dissertation Grant (Hibah Penelitian Disertasi Doktor) from Kemenristek/BRIN 2021 (Contract no. 7/E1/KP.PTNBH/2021).

References

Akane, I., Otake, T., Maulana, A., Sanematsu, K., Sufriadin, and Sato, T. 2021. Geochemical constraints on the mobilization of Ni and critical metals in laterite deposits, Sulawesi, Indonesia: A mass balance approach. *Resource Geology* 71(3):255-282, doi:10.[illegible]1/rge.12266.

Ale[illegible]ndre-Kwaterczak, U. and Helios-Rybicka, E. 2009. Contaminated sediments as potential source of Zn, Pb and Cd for a river system in the historical metalliferous ore mining and smelting industry area of South Poland. *Journal of Soils and Sediments* 9(1):13-22, doi:10.1007/s11368-008-0051-z.

Dublet, G., Juillot, F., Brest, J., Noel, V., Fritsch, E., Proux, O., Olivi, L., Ploquin, F. and Morin, G. 2017. Vertical changes of the Co and Mn speciation along lateritic regolith developed on peridotites (New Caledonia). *Geochimica et Cosmochimica Acta* 217:1-15, doi:10.1016/j.gca.2017.07.010.

Festin, E. S., Tigabu, M., Chileshe, M.N., Syampungani, S. and Ode'n. P. C. 2019. Progress in restoration of post-mining landscape in Africa. *Journal of Forestry Research* 30(2):381-396, doi:10.1007/s11676-018-0621-x.

Fu, [illegible] Yang, J., Yang, M., Pang, B., Liu, X., Niu, H. and [illegible]ang, X. 2014. Mineralogical and geochemical characteristic of serpentinite-derived laterite profile from East Sulawesi, Indonesia: Implication for the laterization process and Ni supergene enrichment in the tropical forest. *Journal of Asian Earth Sciences* 93:74-88, doi:10.1016/j.jseaes.2014.06.030.

Ilyas, A., Kashiwaya, K. and Koike, K. 2016. Ni grade distribution in laterite characterized from geostatistics, topography, and the paleo-groundwater system in Sorowako, Indonesia. *Journal of Geochemical*

Exploration 165:174-188, doi:10.1016/j.gexplo.2016.03.002.

Kierczak, J., Pietranik, A. and Pedziwiatr, A. 2021. Ultramafic geosystems as a natural source of Ni, Cr and Co to the environment: A review. *Science of The Total Environment* 755:142620, doi:10.1016/j.scitotenv.2020.142620.

Larondelle, N. and Haase, D. 2012. Valuing post-mining landscapes using an ecosystem services approach – An example from Germany. *Ecological Indicator* 18:567-574, doi:10.1016/j.ecolind.2012.01.008.

Lin, C., Tong, X., Lu, W., Yan, L., Wu, Y, Nie, C., Chu, C., Long. J. 2005. Environmental impacts of surface mining on mined land, affected streams and agricultural lands in Dabaoshan mine region, southern China. *Land Degradation & Development* 16:463-474.

Maulana, A., Sanematsu, K. and Sakakibara, M. 2016. An overview on the possibility of Scandium and REE occurrence in Sulawesi. *Indonesian Journal on Geosciences* 3(2):139-147, doi:10.17014/ijog.3.2.139-147.

Prematuri, R., Turjaman, M., Sato, T. and Tawaraya, K. 2020. The impact of nickel mining on soil properties and growth of two Fast-growing Tropical Tress species. *International Journal of Forestry Research* 19:1-9, doi:10.1155/2020/8837590.

Roca, N., Pasos, M.S. and Bech, J. 2008. The relationship between WRB soils units and heavy metals content in soils of Catamarca (Argentina). *Journal of Geochemical Exploration* 96(2-3):77-85, doi:10.1016/j.gexplo.2007.04.004.

Soltani, N., Keshavarzi, B. Moore, F., Sorooshian, A. and Ahmadi, M.R. 2017. Distribution of potentially toxic elements (PTEs) in tailing, soils, and plant around Gol-e-Gohar iron mine, a case study in Iran. *Environmental Science and Pollution Research International* 24(23):18798-18816, doi:10.1007/s11356-017-9342-5.

Vardaki, C. and Kelepertsis, A. 1999. Environmental impact of heavy metals (Fe, Ni, Cr, Co) in soils water and plants of triada in euboa from ultrabasic rocks and nickeliferous mineralization. *Environmental Geochemistry and Health* 21:211-226, doi:10.1023/a:1006648428381.

Wuana, R.A. and Okieimen, F.E. 2011. Heavy metal in contaminated soils: A review of sources, chemistry, risk and best available strategies for remediation. *International Scholarly Research Network Ecology*, Article ID 402647, doi:10.5402/2011/402647.

g_sediments_from_lateritic_nickel_post-mining_areas_in_Motui.pdf

ORIGINALITY REPORT

6%	4%	5%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	**Submitted to Universitas Diponegoro** Student Paper	1%
2	**coek.info** Internet Source	1%
3	**etd.repository.ugm.ac.id** Internet Source	1%
4	**discovery.researcher.life** Internet Source	1%
5	**eprints.lib.hokudai.ac.jp** Internet Source	1%
6	**Błażej Cieślik, Jakub Kierczak, Anna Pietranik. "Mineralogical and geochemical evidence for two-stage silicification of serpentinized peridotites from the Szklary Massif (NE Bohemian Massif)", Mineralogia, 2022** Publication	<1%
7	**Ciszewski, Dariusz, Urszula Aleksander-Kwaterczak, Agnieszka Pociecha, Ewa Szarek-Gwiazda, Andrzej Waloszek, and Elżbieta Wilk-**	<1%

Woźniak. "Small effects of a large sediment contamination with heavy metals on aquatic organisms in the vicinity of an abandoned lead and zinc mine", Environmental Monitoring and Assessment, 2013.
Publication

---

8 P. Byrne, P. J. Wood, I. Reid. "The Impairment of River Systems by Metal Mine Contamination: A Review Including Remediation Options", Critical Reviews in Environmental Science and Technology, 2012 <1%
Publication

---

9 Wei Fu, Yangyang Feng, Peng Luo, Yinmeng Zhang, Xiaorong Huang, Xiangwei Zeng, Qian Cai, Yongzhang Zhou. "Weathering of Ophiolite Remnant and Formation of Ni Laterite in a Strong Uplifted Tectonic Region (Yuanjiang, Southwest China)", Minerals, 2019 <1%
Publication

---

10 A Nur, A Reichelt-Brushett, P Howe. " Nickel uptake in spp. and host cnidarian - assessment using the model cnidarian ", IOP Conference Series: Earth and Environmental Science, 2019 <1%
Publication

---

11 Akane Ito, Tsubasa Otake, Adi Maulana, Kenzo Sanematsu, Sufriadin, Tsutomu Sato. "Geochemical constraints on the mobilization <1%

of Ni and critical metals in laterite deposits, Sulawesi, Indonesia: A mass - balance approach", Resource Geology, 2021

Publication

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		