Ambient concentration of soil heavy metals in Indonesian tertiary and quaternary geologic formations: an explorative study

Iskandar¹,², Darmawan¹, U Sudadi¹ and Budi Mulyanto¹
¹Department of Soil Science and Land Resources, IPB University

E-mail: issi_iskandar@apps.ipb.ac.id

Abstract. In natural conditions, heavy metals in soils are inherited from rocks and minerals weathering. This study aims to determine the ambient concentration of heavy metals in soils developed from several rock types from tertiary and quaternary geological formations and their relationships. Composite soil samples were taken at 0-30 cm depth in sites far away from anthropogenic contamination of heavy metals, roads, and lands where solid and liquid wastes were probably discharged. Total concentrations of Aqua Regia extracted soil Cd, Cr, Cu, Ni, Pb and Zn were determined by AAS. Soil mineral types and amount in sand fraction were determined by polarization microscopy. The overall ambient total concentrations of soil Cd, Cr, Cu, Ni, Pb, and Zn in mg.kg⁻¹ were 2.0-19.7; 0.4-5.3; 1.1-73.3; 0.9-30.5; 17.8-62.9; and 8.1-419.5, respectively. The relationship between soil minerals and ambient concentrations of these metals was unclear. However, among the soil samples analysed, high concentrations in mg.kg⁻¹ of Cd (10.5-19.7) were found in soils developed from clay and sand sedimentary and intermediary volcanic tuff rocks, Ni (15.0-30.5) in soils on andesitic-basaltic and volcanic tuff rocks, Pb (57.4-62.9) in soils on granitic rocks, and Zn (119.6-419.5) in soils on andesitic-basaltic rocks, while for Cr and Cu was spread evenly across all parent rock types.

Keywords: andesitic-basaltic, granitic, heavy metal, sedimentary, volcanic tuff

1. Introduction
As one of the non-renewable natural resources, soil must be utilized according to its carrying capacity. Utilization that exceeds carrying capacity will cause soil degradation. Soil degradation is the loss of actual or potential productivity or utility as a result of natural or anthropogenic factors. Essentially, it is the decline in soil quality or a decrease in its productivity and environmental regulatory capacity [1]. According to [1,2] the processes that cause this soil degradation involve physical, chemical and biological processes. Among the physical processes is a decrease in soil structure stability, which in turn leads to crust formation, compaction, erosion, desertification, anaerobiosis, environmental pollution, and unsustainable use of natural resources. Chemical processes involve acidification and leaching, salinization, decreasing cation exchange capacity and losing fertility. Associated with environmental pollution, soils contaminated by heavy metals, such as Ni, Zn, Cd, Cu, and Pb have dramatically increased during the last decades due to the use of agricultural fertilizers and pesticides, municipal waste, mining, traffic, smelting, manufacturing, emissions, and industrial effluents.

²To whom any correspondence should be addressed (issi_iskandar@apps.ipb.ac.id)
Thus, for Indonesia as a country whose land is mostly used for agriculture and plantations, the determination of the standard criteria for soil degradation related to the concentration of heavy metals in the soil is very important.

Regulations concerning soil quality standards that have been issued in Indonesia are Government Regulation (GR) No. 150/2000 concerning Control of Soil Damage for Biomass Production. In the GR, soil damage is defined as “changes in the nature of the soil, i.e. the physical, chemical and biological properties of the soil, which exceeds the standard criteria for soil damage”. In this GR it is described: (1) standard criteria for soil damage due to water erosion, (2) standard criteria for soil damage in dry land, and (3) standard criteria for soil damage in wetlands as a basis for prevention, mitigation and restoration of soil damage for activities agriculture, plantations and plantation forests. Soil degradation due to pollution by heavy metals has not been regulated in GR No. 150/2000. In fact, with increasing industrial activities, the potential for soil pollution by heavy metals is increasing as well.

The absence of soil quality standards regarding heavy metals is presumably due to the lack data of background concentration of various heavy metals in various types of soil in Indonesia. This data is very necessary as a basis for determining quality standard criteria of heavy metal pollution. On the other hand, the criteria for soil quality standards regarding heavy metals that have been developed in various developed countries, including the Netherlands, Germany, the United Kingdom, Australia, Japan, Canada, the United States and others can only be used as references but cannot be adopted directly by Indonesia because of the fundamental differences in the types of parent rocks which are natural sources and ambient determinants of heavy metals in the soils. The proposed maximum limits on the levels of heavy metals allowed in soil in various countries according to [8] are presented in table 1.

| Heavy metal | Austria | Canada | Poland | Japan | G. Britain | Germany |
|-------------|---------|--------|--------|-------|------------|---------|
| Cd          | 5       | 8      | 3      | -     | 3          | 2       |
| Co          | 50      | 25     | 50     | 50    | -          | -       |
| Cr          | 100     | 75     | 100    | -     | 50         | 200     |
| Cu          | 100     | 100    | 100    | 125   | 100        | 50      |
| Ni          | 100     | 100    | 100    | 100   | 50         | 100     |
| Pb          | 100     | 200    | 100    | 400   | 100        | 500     |
| Zn          | 300     | 400    | 300    | 250   | 300        | 300     |

This study aims to determine ambient concentration of heavy metals in soils developed from several rock types from tertiary and quaternary geological formations and their relationships. These rock types are the main parent rocks of the main Indonesian soils. We hope that this research can show how to collect large amounts of heavy metals data over a large area with high variability in soil types, quickly and at a low cost budget.

2. Materials and Methods

2.1. Sampling locations

The determination of soil sampling location is based on consideration of the age of the geological formation and rock type. In tertiary-aged geological formations soil samples were taken from soil developed from andesitic-basaltic and granitic igneous rocks, while in quaternary geological formations soil samples were taken from clay and sand sedimentary rocks, and intermediary volcanic tuff rocks. Soil samples were taken composite at a depth of 0-30 cm. Another criterion for determining location of soil sampling was never or has not experienced heavy metal pollution. Therefore, the
location of soil sampling was determined away from anthropogenic sources of heavy metal pollution, far away from roads and land for solid and liquid waste disposal.

Soil samples in the andesitic-basaltic geological formation were taken at: 1). Desa Citepus, Pelabuhan Ratu, at an altitude of 95 m above sea level with the coordinates of 06°57.951’ SL, 106°31.756’ EL. Land use was for mixed gardens. According to the geological map of Bogor Quadrangle, Java, on a scale of 1:100,000 this location includes the Citepus Tpv formation composed of breccias, limestone tuff breccia, lava flows and tuffaceous sandstones; generally layered less well, conglomerates with andesitic and basaltic composition[9], 2). Sadu Village, Soreang District, Bandung, at an altitude of 814 m above sea level with coordinates of 07°01.959’ SL, 107°30.618’ EL. Land use was for cassava gardens. According to the geological map of the Garut and Pameungpeuk Quadrangle, Java, on a scale of 1:100,000 this location includes the Soreang Tmb formation (Besar Formation) composed of tuffaceous and lava breccia, andesitic to basaltic composition[10], and 3). Suka Baru Village, Penengahan District, South Lampung, at an altitude of 103 m above sea level with coordinates of 05°47.494’ SL, 105°43.034’ EL. Land use was for mixed gardens and reeds. According to the geological map of the Tanjungkarang Quadrangle, Sumatra, on a scale of 1:250,000 this location includes the Tpv Bakauhuni (Andesite) formation composed of andesite lava with sheet jointing [11].

Soil samples that developed in granitic geological formations were taken from three locations in Lampung Province, namely in: 1). Kertasari Village, Tanjung Bintang District, South Lampung, Afdeling I Business Unit Bergen plantation, PTPN VII at an altitude of 80 m above sea level with coordinates of 05°20.03’ SL, 105°26.5’ EL. Land use was for rubber plantations. According to the geological map of the Tanjungkarang Quadrangle, Sumatra, on a scale of 1:250,000 this location includes the Tejg formation (Jatibaru Granite) composed of pink granite [11], 2). Granit Indah Tourism Park, Afdeling I Business Unit Bergen plantation, PTPN VII at an altitude of 100 m above sea level with coordinates of 05°22.7’ SL, 105°26.8’ EL. Land use was for huma rice field. According to the geological map of the Tanjungkarang Quadrangle, Sumatra, on a scale of 1:250,000 this location includes the Kgdsn formation (Sulan Granodiorite) composed of granodiorite and tonalite, and 3). Kertasari Village, Tanjung Bintang District, South Lampung, Afdeling I Business Unit Bergen plantation, PTPN VII at an altitude of 61 m above sea level with coordinates of 05°19.40’ SL, 105°26.60’ EL. Land use was for oil palm plantations. According to the geological map of the Tanjungkarang Quadrangle, Sumatra, on a scale of 1:250,000 this location includes the formation of Kds (Diorite) composed of diorite and quartz diorite.

Soil samples in the geological formation of clay sedimentary rocks were taken at: 1). Citepus village, Pelabuhan Ratu, at an altitude of 34 m above sea level with coordinates of 06°58.174’ SL dan 106°31.797’ EL. Land use was for irrigated rice fields. According to the geological map of the Bogor Quadrangle, Java, on a scale of 1:100,000 this location includes the Qa Citepus (Alluvium) formation composed of clay, silt, pebbles and gravel; especially river deposits including sand and coastal sand deposits along Pelabuhan Ratu Bay, 2). Gintung Village, Mauk Sukagiri District, Tangerang, at an altitude of 33 m above sea level with coordinates of 06°06.229’ SL, 106°33.724’ EL. Land use was for rice fields. According to the geological map of the Jakarta and Thousand Islands Quadrangle, Java, on a scale of 1:100,000 this location includes the formation of Qa Mauk (Aluvium) composed of clay, silt, sand, pebbles, and rock fragments[12], and 3). Tanjung Sari Village, Cangkuang District, Bandung, at an altitude of 705 m above sea level with coordinates of 07°02.410’ SL, 107°34.576’ EL. Land use was for cucumber fields. According to the geological map of Garut and Pameungpeuk Quadrangle, Java, on a scale of 1:100,000 this location includes the Qd/QI formation (Lake Deposition) composed of clay, silt, fine sand to coarse, gravel, generally tuffaceous.

The locations of soil samples in the geological formation of sand sedimentary rocks were in Serang Village, South Cikarang Subdistrict, Karawang at an altitude of 81 m above sea level with coordinates of 06°21.817’ SL, 107°06.759’ EL. Land use was for mixed gardens. According to the geological map of Karawang Quadrangle, Java, on a scale of 1:100,000 this location includes the Qoa Karawang formation (Sandstone, Conglomerate and Silt) composed of conglomerate sandstones, siltstones and sandstones[13].
Soil samples in the geological formation of a volcanic tuff rock were taken at: 1). Cimayasari Village, Cipeundeuy District, Subang, at an altitude of 95 m above sea level with coordinates of 06° 30.683' SL, dan 107° 34.098’ EL. Land use was for mixed gardens. According to the geological map of Bandung, Java, on a scale of 1:100,000 this location included the formation of Qos Subang (tuffaceous sandstone, clay and conglomerate) composed of tufa sandstones, sometimes containing pumice, clay containing plant remains, conglomerates, breccia and fine sand[14], and 2). Bungursari village, District of Bungursari, at an altitude of 111 m above sea level with coordinates of 06° 29.009° SL, 107° 28.898’ EL. Land use was for mixed gardens. According to the geological map of the Karawang Quadrangle, Java, on a scale of 1:100,000 this location includes the Qav formation (Tuffaceous Sandstone and Conglomerate) which is composed of tuffaceous sandstone, conglomerate, tuff and breccia.

2.2. Method of Analysis
Soil samples were air dried and sieved with a 2 mm sieve. The total concentration of heavy metals analyzed included Cd, Cr, Cu, Ni, Pb and Zn using Aqua Regia as extractor (a mixture of concentrated HNO₃ and concentrated HCl ratio of 1:3) as described in ISO standard 11466 and then measured by Atomic Absorption Spectrophotometer. In addition to heavy metals, mineral analyses were also carried out on the sand fraction contained in each soil sample. The soil sample is washed with water until a sand fraction is obtained which is free of clay and silt. The sand fraction of 100-210 μm was analysed by the count line method under a polarization microscope.

3. Results and discussions
3.1. Minerals composition in soils
The results of mineral analysis of sand fraction presented in table 2 show that the mineral composition of each soil sample generally reflects the type of rock from the geological formation where each of these soils is derived. The composition of soil minerals that develop from andesitic-basaltic igneous rock (Citepus, Soreang, Penengahan) shows a high proportion of easily weathered minerals, consisting of olivine, amphibole, augite, hypersthene, labradorite, andesine and oligoclase. Among these three soil samples, soil samples from Soreang show mineral compositions that reflect the origin of more basaltic rocks, indicated by the presence of olivine, green amphibole and higher augite content. Soil samples that developed from granitic rock types in the Tejg and Kds formations in Tanjung Bintang and the Kgdn formation in Granit Indah Tourism Park, South Lampung are dominated by quartz minerals, both turbid and clear quartz, and contain significant plagioclase minerals, such as oligoclase, andesine and albite.

| Rock type                  | Geologic Formation | Location       | Gr. Amph. | Br. Amph. | Augite | Hypersthene | Lab. | Andesine | Oligo | Orbo. | Mag. | Hypersthene | Turr. | Gr. Conc. | Iron Conc. | Weat. Min. | Weat. V. Gl. | Volc. Glass | Turr. Gl. | Volc. Gl. | Turb. Qt. | Clear Qt. |
|----------------------------|--------------------|----------------|-----------|-----------|--------|--------------|------|-----------|-------|-------|------|--------------|------|-----------|-------------|------------|-------------|-------------|----------|----------|---------|--------|---------|-----------|
| Andesitic-basaltic         | Tpv                | Citepus, Pelabuhan Ratu | -       | 6         | -      | 3           | 5    | -         | -     |       | 40   | 6            | 5    | 7         |
|                           | Tmb                | Soreang, Bandung     | 2       | 2         | 2     | 5           | 2    | 1         | 7     | 1     | -    | sd            | df 40 | 1         | 11          | 17        | 8         | 11       | 11       | 5         | 9        |
| Granitic                   | Tpv                | Panengahan, South Lampung | -       | 1         | -      | 1           | 3    | 1         | 11    | 2     | -    | sd            | 6    | 2         |            |           | 3         | 11        | 1         | 5        | 9        | 6        |
|                           | Tjej               | Tgj Bintang, South Lampung | -       | -         |       | 1           | 1    | 7         | 7     | 1     | -    | 15           | -    | 2         | 5            | 20        | 1         | 6        | 3        | 29       |
|                           | Kgdn               | Granit Indah, South Lampung | -       | -         |       | 2           | -    | sd        | -     | 1     | 3    | -            | -    | 5         | 23           |           |           |          | -        |          |
| Sedimentary clay           | Qa                 | Citepus, Pelabuhan Ratu | -       | 11        | 4     | 18          | 9    | 7         | 2     | -     | 24   | -            | -    | 8         | 1            | 6        | 1         | 8        | 3        |          |
|                           | Qd                 | Mank, Tangerang      | -       | -         |       | 5           | 8    | 11         | 9     | 2     | -    | 35           | -    | 2         | 19           | 2         | 2         | 5        | -        |          |
| Sedimentary sand           | Qoa                | South Cikarang, Karawang | -       | 2         | 6     | 5           | 19    | 12        | -     | 20    | -    | 36           | -    | 1         | 16           | -        | -         | 7        |          |          |
| Volcanic tuff              | Qox                | Cipeundeuy, Subang   | -       | -         |       | -           | -    | 3         | -     | -     | 24   | 64           | 14   | 9         | -            | 6        | 4        |          |          |          |
|                           | Qov                | Bungursari, Purwakarta | -       | 1         | -      | 1           | 1    | 1         | -     | -     | 33   | 25           | 27   | 1         | -            | 6        | 4        |          |          |          |

Note: Gr. Amph.=green amphibole; Br. Amph.=brown amphibole; Hyper.=hypersthene; Lab.=labradorite; Oligo=oligoclase; Orbo=orthoclase; Mag.=magnetite; Turm.=tournelite; Iron Conc.=iron concentration; Weat. Min.=weathered mineral; Weat. V. Gl.=weathered volcanic glass; Volc. Glass=volcanic glass; Turb. Qs=turbid quartz; clear Qs=clear quartz.
Samples from soil that develop from clay sedimentary rock types (Citepus, Mauk, Cangkuang) are generally characterized by a high number of minerals: green amphibole, augite, hypersthene, labradorite, andesine, oligoclase, and unidentified weathered minerals. This mineral composition shows that the sediment material contains many easily weathered minerals, which means that the level of weathering of the material in the original area is not yet advanced. Likewise, the level of weathering after this material has been deposited in its current position.

Samples taken from soil developed from sand sedimentary rocks in South Cikarang, Karawang do not show the typical composition of sandstone minerals, but rather resemble the composition of minerals contained in the soil from andesitic igneous rocks. This shows the possibility that the coarse sedimentary material that composes this formation is the result of the sedimentation of pyroclastic material derived from the closest volcanic activity.

Samples of soils developed from volcanic tuff materials were taken from two locations, i.e. Cipeundeuy and Bungursari. The mineral composition of the sand fraction in these soils is dominated by magnetite, iron concretion and weathered minerals. The small amount of easily weathered minerals in these soils indicates that the soil has undergone further weathering. Soil samples that developed from granitic rock types are dominated by quartz and contain significant plagioclase minerals.

3.2. Heavy metals concentration in soils

The results of measurements on the total concentration of Cd, Cr, Cu, Ni, Pb and Zn in each soil samples that developed in various types of parent rock are presented in table 3.

| Rock type          | Geologic Formation | Location                  | Cd   | Cr   | Cu   | Ni   | Pb   | Zn   | Total EWM* |
|--------------------|--------------------|---------------------------|------|------|------|------|------|------|------------|
| Andesitic-basaltic| Tpv                | Citepus, Pelabuhan Ratu   | 7.5  | 3.0  | 24.6 | 15.0 | 33.1 | 119.6 | 67         |
|                    | Tmb                | Soreang, Bandung          | 5.4  | 5.3  | 39.2 | 30.5 | 32.7 | 92.5  | 44         |
|                    | Tpv                | Panengahan, South Lampung | 7.3  | 2.6  | 15.8 | 15.6 | 34.4 | 419.5 | 70         |
| Granitic           | Kds                | Ttg, Bintang, South Lampung | 3.1  | 3.0  | 24.9 | 10.1 | 62.9 | 90.1  | 47         |
|                    | Teig               | Ttg, Bintang, South Lampung | 2.0  | 0.4  | 5.2  | 2.6  | 60.7 | 34.5  | 11         |
|                    | Kgdsn              | Granit Indah, South Lampung | 3.0  | 0.6  | 1.1  | 0.9  | 57.4 | 8.1   | 10         |
| Sedimentary clay   | Qa                 | Citepus, Pelabuhan Ratu   | 6.4  | 3.1  | 23.8 | 12.2 | 24.6 | 41.7  | 66         |
|                    | Qa                 | Mauk, Tangerang           | 16.3 | 1.0  | 30.4 | 5.6  | 27.1 | 39.4  | 56         |
|                    | Qd                 | Cangkuang, Bandung        | 19.4 | 3.6  | 73.3 | 13.1 | 34.5 | 38.9  | 59         |
| Sedimentary sand   | Qoa                | South Cikarang, Karawang  | 10.5 | 3.7  | 49.4 | 5.5  | 17.8 | 66.0  | 70         |
| Volcanic tuff      | Qos                | Cipeundeuy, Subang        | 19.7 | 1.5  | 29.1 | 15.3 | 36.1 | 35.0  | 12         |
|                    | Qav                | Bungursari, Purwakarta    | 10.5 | 2.5  | 39.9 | 29.4 | 29.4 | 55.7  | 32         |

*EWM= easily weathered minerals: Olivine, Amphibole, Augite, Hypersthene, Labradorite, Andesine, Oligoclase, Albite, unidentified weathered minerals, weathered volcanic glass

Table 3 shows that among the six metals measured, the average total Zn in the soil was the highest (8.1-419.5 mg/kg), followed by Pb (17.8-62.9 mg/kg) and Cu (1.1-73.3 mg/kg), then Ni (0.9-30.5 mg/kg) and Cd (2.0-19.7 mg/kg) and the lowest is Cr (0.4-5.3 mg/kg). The total Zn content in the soil developed from igneous rocks, both andesitic-basaltic or granitic, ranges from 90.1 to 419.5 mg/kg, except for the soils developed from granitic igneous rocks of Teig and Kgdsn formation ranging from 8.1 to 34.5 mg/kg. The total levels of Cr, Cu and Ni in soil derived from granitic igneous rocks Teig and Kgdsn formations, in general, are also lower than those in the soil from other rocks. The total concentration of Cd is generally greater in soils developed from Quaternary-aged geological formation compared to those from Tertiary-aged geological formation.

Table 3 also shows that among the soil samples analyzed, high concentrations in mg/kg of Cd (10.5-19.7) were found in soils developed from clay and sand sedimentary and intermediary volcanic tuff rocks, Ni (15.0-30.5) in soils on andesitic-basaltic and volcanic tuff rocks, Pb (57.4-62.9) in soils...
on granitic rocks, and Zn (119.6-419.5) in soils on andesitic-basaltic rocks, while for Cr and Cu was spread evenly across all parent rock types.

3.3. Relationship between minerals in sand fraction and concentration of heavy metals in soils

Naturally, the heavy metals in the soil system derived from mineral constituents of the parent rock of the soils. In descending order, ultramafic, basaltic and some sedimentary rocks contain higher amounts of heavy metals than brightly coloured acid rocks [15]. According to [3] rock-forming minerals containing heavy metals are olivine (Co, Cu, Mn, Ni, Zn), augite (Co, Cu, Mn, Ni, Pb, Zn), biotite (Cu, Co, Mn, Ni, Zn), apatite (Pb), anorthite (Cu, Mn), andesine (Cu, Mn), oligoclase (Cu), albite (Cu), garnet (Cr, Mn), orthoclase (Cu), muscovite (Cu), ilmenite (Co, Cr, Ni) dan magnetite (Co, Cr, Ni, Zn). Olivine, hornblende, augite, biotite, apatite, anorthite, andesine, oligoclase and albite are classified as easily weathered minerals. As a result, the higher the amount of easily weathered minerals, the higher the levels of heavy metals in the soil.

In relation to the geological formation and rock type at each location of soil samples, it is generally seen that the total levels of heavy metals in the soil that develops from granitic igneous rocks tend to be lower than those from other rock types, except for Pb which it shows the highest value (57.4-62.9 mg/kg). The results of mineral analysis of sand fraction (table 2) and levels of total heavy metals in the soil (table 3) show that the soil developed from granitic rocks in the Tejg formation in Tanjung Bintang and Kgdsn in the Granit Indah Tourism Park, both in South Lampung, contains relatively lower Cr, Cu, Ni, Pb and Zn compared to the soils developed from other rocks. This seems to be related to the low content of easily weathered minerals (10-11%) and the high content of resistant mineral of quartz (84-86%). Other soil which also developed from granitic rocks in the Kds formation in Tanjung Bintang, South Lampung, contained relatively higher amounts of Cr, Cu, Ni, Pb and Zn. This soil contains higher easily weathered minerals (47%), and the remain is 15% magnetite and 31% quartz.

Soils that develop from clay sediments (sampling site in Mauk and Cangkuang), sand sediments and volcanic tuffs (Cipeundeuy and Bungursari), contain higher amounts of Cd than those that develop from other rock types. However, high levels of Cd in these soils cannot be correlated to the dominance of one or a group of minerals.

4. Conclusion

a) Heavy metals content of Zn (8.1-419.5 mg/kg) and Pb (17.8-62.9 mg/kg) in the soil is higher than Cu (1.1-73.3 mg/kg) and Ni (0.9-30.5 mg/kg), followed by Cd (2.0-19.7 mg/kg) and the lowest Cr (0.4-5.3 mg/kg).
b) The overall ambient total concentrations of soil Cd, Cr, Cu, Ni, Pb, and Zn in mg.kg⁻¹ were respectively 2.0-19.7; 0.4-5.3; 1.1-73.3; 0.9-30.5; 17.8-62.9; and 8.1-419.5.
c) Soils that develop from andesitic-basaltic igneous rock types, clay sediments and sand sediments are characterized by sand fraction minerals which contain more easily weathered minerals than those that develop from granitic igneous types and intermediary volcanic tuff.
d) The relationship between the type of soil parent material rock or the type of mineral sand fraction in the soil with ambient heavy metal content is unclear. But in general, soils containing high easily weathered minerals will contain higher amounts of heavy metals, while soils with a sand fraction dominated by quartz will contain less heavy metals.

5. References

[1] Lal R 1997 Degradation and resilience of soils Phil. Trans. R. Soc. Lond. B. 352 997-1010
[2] Lal R 2015 Restoring soil quality to mitigate soil degradation Sustainability 7 5875-95
[3] Alloway B J 1995 The origin of heavy metals in soils Heavy metals in soils ed B J Alloway (London Glasgow Weinheim: Blackie Academic & Professional) chapter 3 pp 38-57
[4] Rayment G E, Jeffery A J and Barry G A 2002 Heavy metals in Australian sugarcane Comm. Soil Sci. and Plant Anal. 33 3203-12
[5] Kaur M, Soodan R K, Katnoria J K, Bhardwaj R, Pakade Y B and Nagpal A V 2014 Analysis of physico-chemical parameters, genotoxicity and oxidative stress-inducing potential of soils of some agricultural fields under rice cultivation. *Trop. Plant Res.* **1** 49-61

[6] Bhatti S S, Kumar V, Singh N, Sambyal V, Singh J, Katnoria J K and Nagpal A K 2016 Physico-chemical properties and heavy metal contents of soils and kharif crops of Punjab, India *Int. Conf. on Solid Waste Management. Procedia Environmental Sciences* **35** 801-8

[7] Ali S M, Ahmed H A M, Emara H A A, Janjua M N and Alhafez N 2019 Estimation and bio-availability of toxic metals between soils and plants *Pol. J. Environ. Stud.* **28** 15-24

[8] Kabata-Pendias A 1995 Agricultural problems related to excessive trace metal contents of soil *Heavy metals - problems and solutions* ed W Salomons *et al* (Berlin: Springer Verlag) chapter 1 pp 3-18

[9] Effendi A C, Kusnama and Hermanto B 1998 *Geological map of the Bogor Quadrangle, Jawa scale* 1:100,000 (Bandung: Geological Research and Development Center)

[10] Alzwar M, Bachri S and Akbar N 1992 *Geological map of the Garut and Pameungpeuk Quadrangle, Jawa scale* 1:100,000 (Bandung: Geological Research and Development Center)

[11] Mangga S A, Amirudin, Suwarti T, Gafoer S and Sidarto 1993 *Geological map of the Tanjung Karang, Sumatera scale* 1:250,000 (Bandung: Geological Research and Development Center)

[12] Turkandi T, Sidarto, Agustiyanto D A and Purbo Hadiwidjoyo M M 1992 *Geological map of the Jakarta and Thousand Islands, Jawa scale* 1:100,000 (Bandung: Geological Research and Development Center)

[13] Achdan A and Sudana D 1992 *Geological map of the Karawang Quadrangle, Jawa scale* 1:100,000 (Bandung: Geological Research and Development Center)

[14] Silitonga P H 1973 *Geological map of the Bandung Quadrangle, Jawa scale* 1:100,000 (Bandung: Geological Research and Development Center)

[15] Schimming C G 1992 Belastung mit Metallen *Handbuch des Bodenschutzes* ed H P Blume (Landsberg: Ecomed) chapter 2.7 pp 277-317