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Short communication

Nickel accumulating plants in the post-mining land of Sorowako, South Sulawesi, Indonesia

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Abstract

Twenty-three plant species from three post-mining sites in Sorowako, South Sulawesi, Indonesia were collected and their nickel concentrations in the dried leaf samples determined. Most species had a concentration below the threshold for nickel hyperaccumulation, with the exception of *Sarcotheca celebica* Veldk. (Family Oxadilaceae), which recorded a concentration of 1039 mg Ni kg^{-1} dry weight. However, all collected species would be suitable for remediation of the post-mining lands.

Keywords: Hyperaccumulation, Phytoremediation, *Sarcotheca celebica.*

Nickel mining has been going on in Sorowako, South of Sulawesi, Indonesia for many decades. Nickel mining activities, through stripping of overburden to extract nickel ore and disposal of tailings, provide obvious sources of metal contamination. Unlike organic compounds, metals cannot be degraded and the cleanup usually requires physical or chemical removal (Diels et al., 2002). A promising technology to clean up heavy metal contaminated sites is phytoremediation in which plants remove organic and inorganic contaminants from the soil, and convert them into non-toxic forms, or stabilize into less soluble forms. Several shrubs and trees such as *Melastoma* sp., *Crotalaria* sp., *Weinmannia fraxinea* (D. Don) Miq., *Dillenia serrata* Thunb., *Garcinia* sp., *Sarcotheca celebica* Veldk., *Colona scabra* Burr. Merr. & Perry, *Casuarina equisetifolia* L., *Vitex cofasus* Rein., *Calophyllum soulatri* Burm.F., and *Metrosideros petiolata* Kds. survive and reproduce on soils heavily contaminated with nickel (Sorowako International Nickel Company, 2005). On metalliferous soils, however, most plants accumulate low concentrations of metals in their shoots, while a few species, usually the metallophytes (species endemic to metalliferous sites) accumulate distinctly high amounts (Baker et al., 2000). The capacity to specifically accumulate high amounts of metals in shoots makes such hyperaccumulators suitable for phytoremediation. The present study aims to elucidate information on Ni accumulating indigenous plant species growing in the post-mining lands of Sorowako, South Sulawesi, Indonesia, which may help revegetation of contaminated sites.

Three sites (Rante, Petea, and Butoh) in the Ni post-mining areas located in the vicinity of Verbeek Mountain of Sorowako, South Sulawesi (120° 45' to123° 30' E and 06°30' to 05°30'S), where mining is still active, were selected for the study based on the condition of vegetation (total extent 218,000 ha; Fig. 1). The sites experienced a precipitation of about 3000 mm during the period from November 2010 to March 2011. Annual temperature ranged

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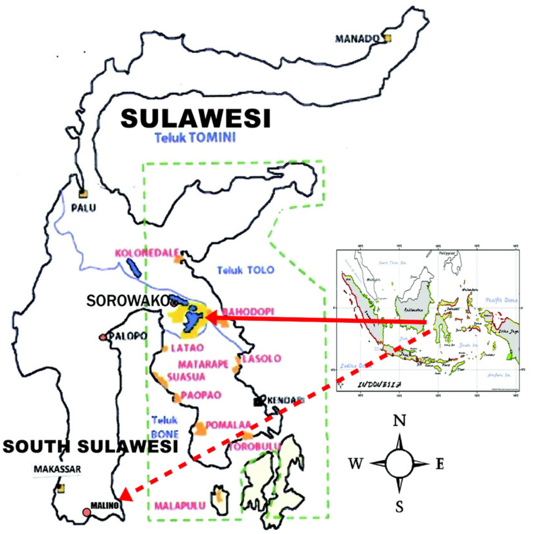

Figure 1. Study area in nickel post-mining land of Sorowako, South Sulawesi, Indonesia.

from 25 to 26°C and humidity ~80%. Predominant soils types are Ultisols and Oxisols, and the altitude ranges from 300 to 900 m. Vegetation is tropical and includes bushes, shrubs, and trees. Butoh site (121^{o}20' 46.8"E and 02^{o} 31'36"S), about 100 ha in extent, has an altitude of 436 m. It was rehabilitated in 1979 and is dominated by plants such as *Weinmannia fraxinea* Smith, *Dillenia serrata* Thunb., and *Garcinia* sp. (Sorowako International Nickel Company, 2005). Rante site (121^{o} 21' 17.7" E and S 02^{o} 32' 04" S) covering 5 ha, has an altitude of 434 m. This area was revegetated in 2005 and is dominated by herbs and shrubs such as *Mimosa pudica* L., *Nephrolepis* sp. and *Imperata cylindrica* L. Petea site (121^{o} 30' 22.2" E and 02^{o} 30'37" S) has an altitude of 843 m (138 ha). Some parts of this site were rehabilitated in 2010. Plants that exist in this site include herbs, shrubs, and trees. For comparion of soils, a normal site (Oxisol), non-nickel mining area (Milano; 119^{o} 34' 30"E and 05^{o} 20' 41"S) was also included. Malino is 700 km from Sorowako, with and altitudinal range of 500 to 2500 m, and having mean temperature of 21 to 24°C.

Three composite soil samples were taken from each site (0 to 20 cm depth) during the period from November 2010 to March 2011. The samples were air dried, sieved, and analyzed for pH (H_2O and KCl), organic C (Walkley and Black), N (Kjeldahl), P (Olsen), Ca, Mg, Na, K (1 N NH_4OAc pH 7.0), and nickel (Inductively-Coupled Plasma, Optical Emission Spectroscopy (ICP-OES) using a Perkin Elmer Optima 2000 DV) contents and soil texture (hydrometer method). Samples of dominant naturally growing plant species were collected from the Butoh, Rante, and Petea sites. Leaf fragments were screened for Ni accumulation by a semi-quantitative test using filter paper impregnated with dimethylglyoxime (1% solution in ethanol, Reeves, et al., 1996). A negative result generally indicates Ni content below 1000 mg g^{-1} (dry matter). To obtain quantitative results, leaf samples were analyzed using Inductively-Coupled Plasma, Optical Emission Spectroscopy (ICP-OES). For this, 500 g of fresh leaf of each plant species was washed with 3% HCl, rinsed with deionized water 2 to 3 times, and dried for analysis. The soil samples were dried in an oven for 6 h at 105^{o}C. The dried samples were crushed, and 100 mg dissolved in 2 ml of HNO_3 (65%). This solution was heated in an oven at 200^{o}C for about 14 h, until the sample dissolved completely; the extract was made up to 50 ml, which was used to determine Ni concentrations. Triplicate of soil and plant samples were analyzed and their means with standard error (SE) are presented. The ability of plants to accumulate heavy metals was determined by calculating the Bioconcentration Factor (BCF), the ratio between metal concentrations in plant aboveground and the concentration of metals in the soil. BCF values 1 to 10 indicates hyperaccumulator plants, 0.1 to 1 moderate accumulators, 0.01 to 0.1 low accumulators, and <0.01 non-accumulators (Wei et al., 2008).

Soil Ni concentrations at Rante, Petea and Butoh sites were 5356, 3150, and 2465 mg kg^{-1}, respectively; the unpolluted Malino site (51 mg kg^{-1}) had 40 to 100 times less Ni (Table 1). There were 23 plant species belonging to 12 families inhabiting these sites. Foliar Ni accumulation of most plants at Petea site was higher than that at other sites (Table

2), regardless of the intermediate soil Ni concentration at this site. Most of the colonizing species were low accumulators with BCF values ranging from 0.01 to 0.33. High metal uptake capacity and

Table 1. Soil physical and chemical characteristics in three-nickel post-mining sites at Sorowako and an unpolluted site (Malino) in South Sulawesi, Indonesia.

Soil Properties	Sites			
	Rante	Petea	Butoh	Malino
Mean of Total Ni (mg kg^{-1})	5356	3150	2465	51
Standard Error	±154	±135	±270	±3
Clay (%)	62	52	62	70
Silt (%)	28	32	28	24
Sand (%)	10	16	10	6
pH (H2O)	6.5	6.39	6.59	6.05
Organic matter content (%)	1.77	1.8	1.58	1.64
CEC (me 100 g^{-1} soil)	22.45	24.10	23.52	22.53
N-Total (%)	0.20	0.13	0.14	0.15
P2O5 (mg kg^{-1})	11.10	11.25	11.13	11.24
Ca (me 100 g^{-1} soil)	3.85	3.25	3.54	3.64
Mg (me 100 g^{-1} soil)	2.61	2.52	2.84	2.45
Na (me 100 g^{-1} soil)	0.48	0.42	0.32	0.47
K (me 100 g^{-1} soil)	0.12	0.22	0.21	0.14

Table 2. Prominent plant species, their foliar Ni concentration, and Bioconcentration Factor (BCF) values from three-nickel post-mining sites in Sorowako, South Sulawesi, Indonesia.

Sites	Species	Family	Ni Concentration (mg kg^{-1})	BCF
Butoh	*Hyptis capitata* Jacq.	Lamiaceae	102.36±10.31	0.056*
	Lantana camara L.	Verbenaceae	39.43±5.79	0.031*
	Leucaena leucocephala (Lam.) de Wit.	Fabaceae	24.29±3.48	0.010*
	Mimosa pigra L.	Fabaceae	138.89±8.99	0.016*
	Sesbania rostrata Bremek. & Oberm.	Fabaceae	31.43±4.89	0.013*
	Wedelia biflora L.	Asteraceae	76.67±6.61	0.042*
Rante	*Chromolaena odorata* L.	Asteraceae	117.79±11.67	0.010*
	Crotalaria juncea L.	Fabaceae	28.64±4.66	0.005 na
	Cynodon dactylon (L.) Pers.	Poaceae	147.62±15.99	0.024*
	Imperata cylindrica L.	Poaceae	38.10±10.38	0.022*
	Mikania cordatum L.	Asteraceae	44.34±7.49	0.008 na
	Nephrolepis (L.) Schott	Polypodiaceae	130.58±13.05	0.028*
	Tephrosia sp.	Fabaceae	55.29±16.77	0.006 na
Petea	*Celtis occidentalis* L.	Ulmaceae	129.17±7.22	0.041*
	Crassocephalum rubens (Jacq.) S. Moore	Asteraceae	132.69±36.34	0.042*
	Hyptis capitata Jacq.	Lamiaceae	100.00±12.85	0.032*
	Knema celebica Wilde	Myristicaceae	330.56±10.37	0.105**
	Knema plumulosa Sincl.	Myristicaceae	520.83±4.29	0.165**
	Melastoma malabathricum L.	Melastomataceae	105.24±5.47	0.033*
	Melochia umbellata (Houtt) Stapf	Sterculiaceae	76.61±13.31	0.024*
	Sarcotheca celebica Veldk.	Oxalidaceae	1039.25±22.56	0.330**
	Trema orientalis L.	Ulmaceae	112.50±4.02	0.036*
	Weinmannia fraxinea Smith	Cunoniaceae	113.21±5.14	0.036*

na= non-accumulator; * low accumulator, ** moderate accumulator high biomass production are needed to extract metals from soils within a reasonable period (Ebbs and Kochian, 1997). As can be seen from Table 2, none of the plants belonged to the category of hyperaccumulator (BCF>1) and there were three non-accumulators (BCF < 0.01). However, *Knema celebica* de Wilde, *K. plumulosa* Sincl. and *Sarcotheca celebica* from the Petea site had BCF values more than 0.1, which can be classified as moderate accumulators. According to Reeves et al. (2008), hyperaccumulator is a plant that can accumulate more than 1000 mg Ni kg^{-1} on dry matter basis in the aboveground plant tissues. As *S. celebica* accumulated 1039.3 mg Ni kg^{-1}, this species can be classified as a hyperaccumulator, although the BCF value was less than 1. *S. celebica* roots absorb the metal, translocate in to the shoots and store it there (Baker et al., 2000) at concentrations considered toxic to normal plants. *Knema celebica* and *K. plumulosa* also survive under elevated metal conditions, despite relatively lower foliar Ni concentrations than *S. celebica.* Thus, *K. celebica*, *K. plumulosa* and *S. celebica* have the potential for phytoremediating and phytomining Ni from contaminated sites.

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References

Baker, A. J. M., McGrath, S.P., Reeves, R.D., and Smith, J.A.C. 2000. Metal hyper-accumulator Plants: A review of the ecology and physiology of a biological resource for phytoremediation of metal-polluted soils. In: Terry, N. and Banuelos, G (eds), *Phytoremediation of Contaminated Soil and Water.* Lewis Publishers, Boca Raton, FL., pp 85–107.

Diels, L., van der Lelie, N., and Bastiaens, L. 2002. New development in treatment of heavy metal contaminated soils. Rev. Environ. Sci. Biotech., 1: 75–82.

Ebbs, S.D. and Kochian, L.V. 1997. Toxicity of zinc and copper to *Brassica* species: implications for phytoremediation. J. Environ. Qual., 5: 1424–1430.

Sorowako International Nickel Company, 2005. Development of local vegetation types (Native Species Development) as the former regional mine reclamation efforts in the development of mining regions ecosystem of Inco Sorowako, in cooperation between Inco Sorowako and the Research Institution of the Hasanuddin University, Makassar, Indonesia.

Reeves, R.D. and Adiguzel, N. 2008. The nickel hyperaccumulating plants of the serpentines of Turkey and adjacent areas: A review with new data. Turk. J. Biol., 32: 143–153.

Reeves, R.D., Baker, A.J.M., Borhidi, A., and Berazain, R. 1996. Nickel accumulating plants from the ancient serpentine soils of Cuba. New Phytol., 133:217–224.

Wei, S., Zhou, Q., and Mathews, S. 2008. A newly found cadmium accumulator-Taraxacum mongolicum. J. Hazard. Materials, 159:544–547.