POLLUTION OF SOIL BY AGRICULTURAL AND INDUSTRIAL WASTE

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ABSTRACT

Soil contaminated by heavy metals from agricultural and industrial wastes will produce unhealthy food. Heavy metals enter the food chain and are consumed by human beings. Phosphate fertilizer which contains small amounts of cadmium and lead is widely applied in lowland areas of West Java. However, both these heavy metals remain below toxic levels. In contrast, contamination of lowland rice fields by sewage sludge from textile plants and gold mining has increased the heavy metal content of the soil and reduced rice yields. Remediation of polluted soil is being carried out, using plants such as Vetiveria zizanioides and Eichornia crassipes, plus applications of zeolite. These treatments were able to reduce the concentration of lead and cadmium in the soil.

INTRODUCTION

In modern economies, various types of activity, including agriculture, industry and transportation, produce a large amount of wastes and new types of pollutants. Soil, air and water have traditionally been used as sites for the disposal of all these wastes. For example, beef cattle in the United States are estimated to produce 92 million mt/year of manure, while dairy cattle produce 27 million mt/year (Tan 1995). Some of this manure may wash into nearby streams, and pollute rivers, lakes and soil.

The most common kinds of waste can be classified into four types: agricultural, industrial, municipal and nuclear (Alloway 1995). Agricultural wastes include a wide range of organic materials (often containing pesticides), animal wastes, and timber by-products. Many of these, such as plant residues and livestock manure, are very beneficial if they are returned to the soil. However, improper handling and disposal may cause pollution.

Industrial waste products may be in gas, liquid or solid form. The most important gases are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). They are produced by combustion in industry and by automobiles, and they pose a hazard to the environment.

Food processing plants produce both liquid and solid wastes. Another urban waste is municipal garbage. This is made up of materials discarded by homes and industry. It contains paper, plastic and organic materials. Some of these can be recycled by composting or they may be burnt or disposed of in landfills.

Sewage sludge is the product of treatment plants. The materials processed in the treatment plants are domestic and industrial wastes. They are usually liquid mixtures, composed both of solids, and of dissolved organic and inorganic materials. The water is separated from the solid part by a number of treatments before it is environmentally safe for discharge into streams or lakes.

The content of major nutrients and micronutrients in sewage sludge varies depending on the source. Data indicates that the nitrogen content of textile sludge is generally high. However, the heavy metal content is also high. Some trace elements are required in small amounts by plants and animals, whereas others are hazardous to

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human health.

This Bulletin discusses the contamination of soil by agricutlural and industrial wastes in agriculture areas of West Java, Indonesia. The pollution of agricultural areas in Indonesia is mainly caused by the overuse of fertilizers and pesticides. Another cause of pollution is sewage sludge or municipal garbage that is in irrigation water and flows into lowland rice fields, or is disposed of in landfills. These wastes reduce soil quality, and are a potential cause of environmental degradation.

CONTAMINATION FROM INDUSTRIAL WASTES

A study was conducted of industrial pollution in lowland rice areas in the district of Rancaekek, West Java. These areas are being polluted by heavy metals from sewage sludge produced by the textile industry. This waste is disposed of directly into three rivers, all of which are used to irrigate lowland rice. About 720 ha of lowland rice fields were polluted in this way.

Soil surveys by Kurnia (1999) revealed that there were very high concentrations of boron, cadmium and lead in three villages in the Rancaekek district. Falling soil productivity in these areas caused a reduction in rice yields and farmers' incomes. After 20 years of contamination, the average rice yield had decreased by about 80%. The initial rice yield of about 4-6 mt/ha had become 1 mt/ha. However, the heavy metal content in the soil had increased by about 18% - 98%, compared to unpolluted soil.

A greenhouse study using polluted soil from this area showed that high concentrations of lead, cadmium, copper, chromium and boron were found in the plant tissue, roots and grain of rice. Most of the pollutants had accumulated in the root system.

CONTAMINATION FROM AGRICULTURAL WASTES

A study carried out by Adiningsih *et al.* (1998) in an area of intensive lowland rice farming in West Java found that the levels of lead and cadmium in the soil were fairly low. Lead was present in soil samples in a range of 10 - 43 ppm, while the levels of cadmium were 0.19 - 0.49 ppm.

The content of lead and cadmium which were present may have originated in applications of phosphate fertilizer. The cadmium content of phosphate fertilizer in Indonesia is 35 - 255 g/mt (Alloway 1995).

Phosphate fertilizer is essential in intensive agriculture, especially in Indonesia with its high rainfall and rapid leaching. These conditions result in a low soil pH and high levels of iron and aluminum oxide. These in turn immobilize the phosphorus in the soil solution, and hinder its uptake by plants.

Based on the levels of lead and cadmium in rice, Kasno *et al*. (2000) found that intensive lowland rice areas in two districts of West Java could be divided into three categories: Highly polluted soils, soils with medium pollution, and unpolluted soils (Table 1). Only 7% of the total lowland areas studied were polluted by lead, and about 4% by cadmium. These results indicate that after 30 - 40 years of phosphate application, the productivity of these soils could still be sustained.

Another study was conducted in tea plantations in an area of West Java which is important for agroforestry and tourism (Sofyan *et al.* 1997). The aim of the study was to see the effect of air pollution by automobiles on soil quality. The result of the soil survey showed that the lead content of the soil in the plantations increased near main roads (Table 2). The level of soil pollution by lead, most of which was produced by petrol combustion, depended on the distance from the main road. However, the cadmium content in soils was not influenced by the distance from the main road. This indicates that the cadmium content in the soil was not the result of air pollution, but may have resulted from the application of high levels of phosphate fertilizer in these areas.

CONTAMINATION FROM GOLD MINING AND SMELTING

Gold mining is carried out by individuals rather than companies in Junung Pongkor, West Java. They use traditional methods for separating the gold from the raw material. The main waste product from this process is mud and rubble which contain a high concentration of mercury. These wastes are disposed of directly in the Cikaniki river, which is also used as a source of irrigation water in the

Table 1. Total area of intensive paddy rice contaminated by lead and cadmium in Kawarang and Bekasi district, West Java, Indonesia

Lead and cadmium content in rice grain	Level of pollution	Total area (ha)	Percentage (%)
Lead (ppm)			
< 0.5	Unpolluted	63,300	60
0.5 - 1.0	Slightly polluted	35,000	33
> 1.0	Polluted	7,200	7
Total		105,500	
Cadmium (ppm)			
< 0.12	Unpolluted	83,300	79
0.12 - 0.24	Polluted	18,500	17
> 0.24	Polluted	3,700	4
Total		105,500	

Source: Kasno *et al.* 2000

Table 2. Heavy metal content in two tea plantations, West Java, Indonesia

Distance from main road (m)	Lead		Cadmium	
	Plantation A	Plantation B	Plantation A	Plantation B
0	37	55	0.6	0.4
50	24	30	-.8	0.4
100	23	28	0.7	0.4
200	19	27	0.6	0.4

Source: Sofyan *et al.* 1997

Table 3. Mercury content of soil, rice straw and rice grain in area contaminated by gold mining

Villages	Distance from traditional mining location (km)	Mercury content (ppm)		
		Soil	Rice straw	Rice grain
A, B	< 0.1	6.7	5.3	0.43
C	0.8 - 1.0	5.6	1.8	< 0.0005
D	1.2 - 1.5	1.8	0.8	< 0.0005
E	7.0 - 7.5	2.4	-	< 0.25
F	11.5 - 12.0	1.3	-	< 0.0005

Source: Kurnia *et al.* 2000

lowland rice areas around the mining areas.

A soil survey conducted by Kurnia *et al.* (2000) in this area found that the soil surrounding the traditional mining was polluted by mercury. The pollution covered the land around six villages (Table 3). The concentration of mercury in soil near the mining was higher than in more distant soils. A high concentration of mercury was found in rice straw and rice grain. All of the values were higher than the maximum permitted level of mercury in soils (0.5 ppm).

REMEDIATION AND REHABILITATION OF SOILS CONTAMINATED BY HEAVY METALS

Soil contaminated by heavy metals may pose a threat to human health if the heavy metals enter the food chain. Remediation should be carried out to ensure that agricultural produce from such areas can safely be eaten.

Remediation can be achieved in several ways: physical, chemical and biological. A study has been carried out by Roechan *et al.* (2000) on the use of vetiver grass (*Vetiveria zizanioides*) and zeolite to remediate contaminated soils in Bekasi, West Java.

The results showed that vetiver grass could grow well on soils contaminated with high concentrations of lead and cadmium. By concentrating the contaminants in its roots, the vetiver grass reduced the concentration of lead in soil by as much as 38 - 60%, and cadmium by 35 - 42% (Table 4). The heavy metals accumulate in the root system (Table 5).

The application of 500 kg/ha zeolite increased the growth and yield of rice growing in contaminated soils, and decreased the total concentration of lead and cadmium by up to 1.5 times. Zeolite reduced the level of available lead and cadmium by half. In addition, the application of zeolite reduced the lead content of rice straw by 56%, and of rice grain by 69%. It reduced the cadmium content of the rice grain by up to 67%, compared to the control.

Another experiment by Adiningsih *et al.* (1998) was conducted in a greenhouse, uisng water hyacinth (*Eichornia crassipes*) to remediate soil polluted by lead and cadmium. The results showed that these plants grew well in contaminated soil, and were able to accumulate lead and cadmium taken up from the soil (Table 7). The content of lead and cadmium in the plants (on a dry matter basis) reached as high as 400 ppm.

Table 4. Lead and cadmium content in soil before and after remediation by vetiver grass

Treatment	Site A		Site B	
	Before	After	Before	After
		Lead (ppm)		
Vetiver	38	15	14	8
Vetiver + 80 ppm lead	118	48	94	58
		Lead (ppm)		
Vetiver	1.2	0.7	0.6	0.4
Vetiver + 20 ppm cadmium	21.1	12.7	20.6	13.4

Source: Roechan *et al.* 2000

Table 5. Levels of lead and cadmium in vetiver grass after remediation by vetiver

Treatment	Site A			Site B		
	Straw	Root head	Root	Straw	Root head	Root
			Lead (ppm)			
Vetiver	4.6	13.6	9.1	3.2	8.3	5.4
Vetiver + 80 ppm lead	6.2	18.2	12.1	4.2	11.0	8.8
			Cadminum (ppm)			
Vetiver	0.07	0.25	0.19	0.00	0.20	0.11
Vetiver + 20 ppm cadmium	0.12	0.98	0.42	0.08	0.54	0.27

Source: Roechan *et al.* 2000

Table 6. Lead amd cadmium content of soil after remediation by vetiver

Treatment	Site A		Site B	
	Total	MV-Morgan	Total	MV-Morgan
		Lead (ppm)		
Control	33.9	2.8	11.0	2.9
Zeolite (500 kg/ha)	26.1	1.8	9.5	6.1
Zeolite (500 kg/ha + 80 ppm lead)	30.4	6.4	20.0	10.3
		Cadmium (ppm)		
Control	3.2	0.27	0.38	0.15
Zeolite (500 kg/ha)	1.8	0.14	0.22	0.08
Zeolite (500 kg/ha + 20 ppm cadmium)	1.8	0.67	2.34	0.83

Source: Roechan *et al.* 2000

Table 7. Uptake and levels in water hyacinth of lead and cadmium under different application levels

Application (ppm)	Level in plant (dry matter basis)	Uptake (ppm)	
		Lead	Cadmium
Lead			
0	156	2	-
50	155	13	-
100	155	24	-
200	160	45	-
400	150	126	-
Cadmium			
0	130	-	0.3
50	27	-	5.4
100	25	-	9.2
200	27	-	15.5
400	27	-	30.5

Source: Adiningsih *et al.* 1998

CONCLUSION

After 30 - 40 years of intensive use of fertilizer in lowland areas of West Java, including rock phosphate, the concentration in the soil of heavy metals such as lead and cadmium still remains below toxic levels. However, these elements are sometimes present naturally in rock phosphate, so that continuous monitoring is needed.

Sewage sludge from the textile industry contains high concentrations of elements such as boron, lead, cadmium, copper and chromium. Disposal of these wastes into rivers decreased rice production and was a potential cause of environmental degradation.

Air pollution from the exhaust of cars driving through tea plantation areas increased the lead content of the soil. The concentration of the lead was highest in the soil nearest the main road.

Traditional gold mining and smelting in Gunung Pongkor was a significant cause of pollution for lowland rice around this area, and increased the mercury content of rice.

The remediation of soil contaminated by lead and cadmium by growing water hyacinth or vetiver grass, with an application of zeolite, significantly reduced the level of these two heavy metals in the soil.

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