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Heavy Metal Contamination on Shallot Fields In Bantul Regency, Yogyakarta

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ABSTRACT

Shallot cultivation usually uses very intensive agrochemicals that could affect the soil's chemical properties and contaminate agricultural land by increasing the content of heavy metals. The use of agrochemicals is closely related to the behavior of farmers. The research aimed to study the heavy metal contamination and soil chemical properties in shallot fields and analyze the relationship between farmer behavior in using fertilizers and pesticides with a heavy metal concentration in agricultural land. The research was conducted in Srigading Village, Batul, Yogyakarta. Soil samples as many as 30 samples were taken from the shallot fields before harvest using a purposive sampling method and were analyzed for heavy metal concentrations of Pb, Cd, Ni, Co, Cr, and other soil chemical properties. Interviews were also conducted with landowners or farmers at the soil sampling location. Analysis of interview data was carried out by scoring each qualitative data into quantitative data through a questionnaire and testing the correlation between farmer behavior and heavy metal content. The results found that the shallot fields in the Srigading Village, Bantul contain heavy metals Pb, Cd, Cr, Co, and Ni with concentrations below soil quality standard. The soil organic carbon content in shallot fields has a low value. Farmer behavior has a weak negative correlation with heavy metal content in the soil.

Keywords: Heavy metal, shallots, field

INTRODUCTION

The excessive use of agrochemicals is one of the causes of agricultural land degradation to be unproductive land called critical land (Wahyunto and Dariah 2014). Horticultural and secondary cultivation activities are the most intensive agricultural activities using agrochemicals (Abadi *et al*. 1993). In the shallots cultivation at Brebes District, Brebes Regency, the farmers apply excessive pesticides with very high concentrations, up to 25 times during 50 planting days. The applied pesticide contains 16 active insecticide ingredients and nine fungicidal active ingredients, including mankozeb and propineb (Maizul 2016). The functional, active ingredients are propineb and mancozeb that contains heavy metal Pb of 12.48 mg kg^{-1} and 19.37 mg kg^{-1} (Setyorini *et al.* 2003).

Accumulation of heavy metals in the soil can decrease soil fertility, especially soil microbial activity and plant yields, and also those toxic materials can enter the food chain (Kurnia *et al*. 2009). So, heavy metal contamination on agricultural land is a significant problem; not only could it damage the plants or even die, but rather the accumulation of heavy metals in agricultural products (Leepar 1978). The contamination of heavy metals in soil or agricultural products can also be harmful to human health through the food chain either directly or indirectly (Cai *et al.* 2019). Heavy metals accumulating in the human body will cause tissue damage, especially the detoxification and excretion of tissues (liver and kidney). Heavy metals are harmful to humans because they are carcinogenic (cancer-forming) and teratogenic (misformed organs) (Darmono 1995).

Srigading village is the center of shallot farming in Bantul Regency. Shallots plants are very susceptible to being attacked by plant pest organisms, so, in overcoming product damage from pest attacks and obtaining optimal yields, farmers in the area continue to use agrochemicals intensively 2 to 3 times a week regularly. In addition to agrochemicals, the shallot farmers in the Srigading Village also use inorganic fertilizers during the planting period to increase shallot yields, especially those grown on sandy soil. Sandy soil is porous, making it easier for water and air to circulate, and the roots penetrate easily so that water and nutrients are easily lost from the soil.

The research aimed to determine heavy metal contamination of Pb, Cd, Ni, Co, and Cr, and other soil chemical properties in the shallot field in Srigading Village, Bantul, and examine the farmers' behavior using fertilizers and pesticides. Fertilizers and pesticides are strongly related to farmers' behavior. It is expected that the farmers have good behaviors in using fertilizers and pesticides. Socialization, education, and training can affect farmers' awareness about the dangers of agrochemicals to the environment and are the main determinants of environmentally friendly behavior in controlling plant-disturbing organisms (Khan and Damalas 2015; Talukder *et al*. 2017). Farmers who receive training on pesticide management will tend to pay more attention to the environment in choosing agrochemicals to be used and in their use compared to farmers who do not follow training (Sharifzadeh *et al.* 2018).

MATERIALS AND METHODS

Study Location and Data

The research was conducted in the shallot field of Srigading village, Bantul Regency, Yogyakarta. The data collected in this study is primary data, in which the data is obtained directly both through direct observation in the field with interviews and analysis in the laboratory. The primary data sources of this research include heavy metal content in the soil and the farmers' behavior regarding the use of inputs (fertilizers and pesticides).

Soils Sampling and Analysis

The sampling location was determined using a purposive sampling method on ready-to-harvest shallot cultivation land. The soil samples were taken in a composite manner, with each sample consisting of 5-10 individual samples (subsamples) set diagonally on each plot of land. There are 30 points of sampling.

The soil samples obtained from the field were prepared by drying the soil sample to obtain a constant moisture content, then pulverized using a mortar pestle to make a powder (diameter 0.5 mm). Then, the soil samples were analyzed for the total heavy metal concentration Pb, Cd, Cr, Co, and Ni and the chemical properties, the method of analysis can be seen in the Table 1. The method of analyzing heavy metals in soil samples was carried out using the Atomic Absorption Spectrophotometer (AAS), which refers to Eviati and Sulaeman (2009) and Sisay *et al.* (2019) with modifications to the volume of the analyzed sample, the volume of administration of concentrated nitric acid solution and the stages of destruction. The observations of heavy metal parameters and soil chemical properties (pH, soil organic carbon, CEC, exchangeable cations) were carried out at the Integrated Laboratory of the Indonesian Agricultural Environmental Research

Table 1. The analysis method of soil sampling.

Type of analysis	Unit	Method
pH H_2O and KCl	-	pH meter
Soil Organic Carbon (SOC)	%	Walkley and Black
CEC	cmol(+)kg^{-1}	Extract NH_4OAC pH 7
Exchangable cations (K, Na, Mg, Na)	cmol(+)kg^{-1}	Extract HCl 25%
Total heavy metal	mg kg^{-1}	Extract HNO_3:$HClO_4$

Table 2. Critical limits for heavy metal in soil.

Heavy metal type	Critical limit (Alloway 1995) (mg kg^{-1})
Pb	100-400
Cd	3-8
Co	25-50
Cr	75-100
Ni	100

Institute (IAERI), Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture. The data on heavy metal content in shallot fields were compared with critical limits for heavy metal in soil (Table 2).

Famer Sampling Techniques and Analysis of the Relationship between Farmer's Behavior and Heavy Metals in Shallot Field

The data collection related to farmers' behavior using fertilizers and agrochemicals was through interviews with respondents. Respondents were determined based on sampling soil ready to harvest in 30 location points. In each point of the soil sample, one sample of farmers was considered a respondent. Therefore, there were 30 respondents. The respondents could be landowners or shallots farmers. The information collected were (1) the identity of farmers/respondents (name, age), socio-economic conditions of farmers (education level, how long they have worked as farmers, and the harvest); (2) the area of agriculture; (3) the agricultural activities (planting patterns, types of fertilizers and pesticides used, types of planted varieties); (4) and the behavior of farmers in using fertilizers and pesticides (the doses of fertilizers and

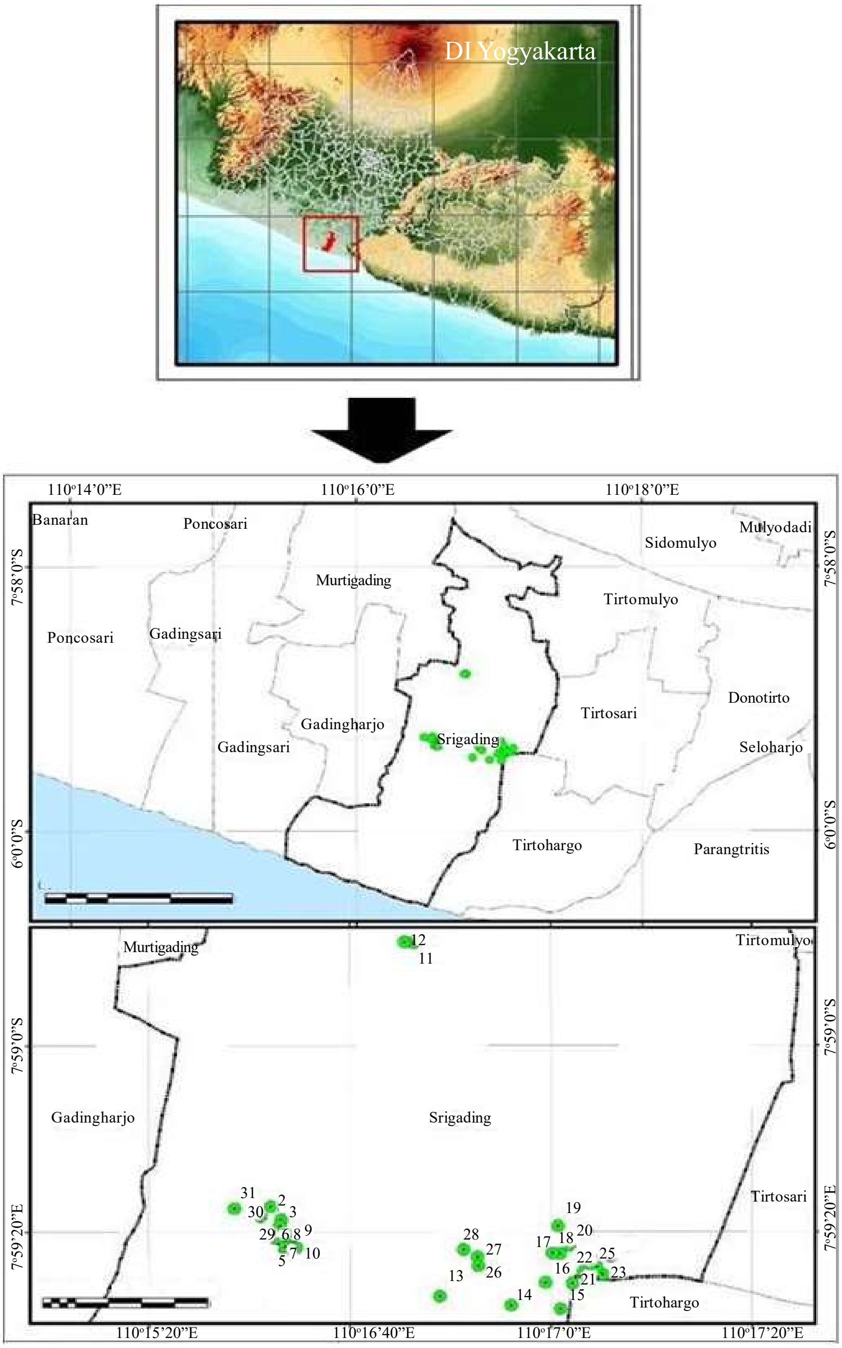

Figure 1. The Location Point Map of Soil Sampling.

pesticides, the application frequency of fertilizers and pesticides, the sources of information on instructions for the use of types of fertilizers and pesticides, reasons for using fertilizers and pesticides, how to mix pesticides and the willingness of farmers to stop using chemical pesticides and switch to vegetable/organic pesticides). The relationship between farmers' behavior and heavy metal concentration on shallot fields was tested correlation analysis with the SPSS program.

RESULTS AND DISCUSSION

Srigading Village is an area that has fertile agricultural land so that it is possible to develop agricultural products. Agricultural products developed in the Srigading Village; apart from paddy fields, the community also uses sandy beach land for agricultural cultivation activities. The sand land used for cultivation is along the coast of Samas Beach, precisely in Ngepet Hamlet, Tegalrejo, Srigading village, which is usually used to cultivate shallots. Shallots are generally cultivated in paddy fields, but after a breakthrough by utilizing marginal land for farming activities, some farmers began to be interested in changing the land functions. Most shallot farmers in the Srigading Village are still using paddy fields even though there have been breakthroughs to increase farming yields. The change happens because rice fields and sand fields have their respective advantages and disadvantages, so they become considerations for farmers in shallot farming activities.

The Soil Chemical Properties in Shallot Agriculture

The soil conditions on agricultural land in Srigading Village or the location of soil sampling were carried out several tests of several soil chemical properties including CEC, pH, soil organic carbon (SOC), and exchangeable cations (Na, K, Ca, Mg), which can be seen in Table 3.

Shallot plants require a soil pH that is not too acidic, the availability of suitable bases, moderate to high cation exchange capacity. Thus the nature of the soil on agricultural land in the Srigading village is very suitable for onion cultivation. One of the obstacles to optimizing the cultivation and sustainability of shallot productivity in this soil is the low level of soil organic matter. The soil in the agricultural land of the Srigading village contains mostly sand. Soil with sand content has properties that quickly pass water so that aeration is excellent and organic matter decomposition is fast (Tewu *et al.* 2016).

The low content of soil organic matter can be overcome by applying fertilizer. Provision of compost such as cow dung compost, chicken manure, Gamal leaves, and Angsana leaves can improve soil physical properties (soil moisture, soil porosity, and volume weight) and soil chemical properties (soil pH and soil organic carbon) (Surya 2015).

Soil organic carbon and soil grain size positively correlate with the concentration of heavy metals Pb, Cd, and Cu present in the soil (Maslukah 2013). The organic materials are divided into two, which are high-quality organic materials and low-quality organic materials based on their N, P, and lignin content (Sismiyanti *et al.* 2018). Chicken manure is one of the high-quality organic materials that can increase the concentration of heavy metals in the soil (Wan *et al.* 2020) because chicken manure contains heavy metals such as Cd, Co, Cr, Pb, and Ni (Setyorini *et al.* 2003). Biochar results from processing low-quality organic materials such as corn cobs, oil palm empty fruit bunches, sawdust, and others that can reduce heavy metals in soil because biochar can adsorb heavy metals (Li *et al.* 2021).

Table 3. The Soil chemical properties in shallot field in Srigading Village.

Soil Properties	Value	Unit	Information
pH H_2O	6.46-7.33	-	A bit sour -neutral
SOC	0.49-1.14	%	Very low
CEC	16.07-29.36	cmol(+) kg^{-1}	medium-high
Exchangeable cations			
K	0.25-0.50	cmol(+) kg^{-1}	low-medium
Na	0.22-0.83	cmol(+) kg^{-1}	low-high
Ca	4.22-9.41	cmol(+) kg^{-1}	low-medium
Mg	0.62-1.94	cmol(+) kg^{-1}	low-medium

Source: Lab Analysis 2020

Table 4. Descriptive statistics of heavy metal concentrations in the Agriculture Land of Srigading village.

	Pb	Cd	Co	Cr	Ni
			mg kg^{-1}		
Mean	27.38	1.87	12.73	6.26	8.92
Median	27.59	1.91	13.14	6.31	9.10
Standard Deviation	2.20	0.21	1.41	0.86	0.90
Minimum	19.14	1.03	8.58	4.35	6.00
Maximum	30.04	2.21	15.08	7.97	10.09
CV (%)	8.03	11.45	11.08	13.75	10.09
Count	30	30	30	30	30
Critical limit	100.00	3.00	25.00	75.00	100.00

Heavy Metal Content in Shallot Agriculture Land

The agricultural land in the Srigading Village has been cultivated for decades with shallots with a cropping pattern of 2 times a year with the intensive use of chemical fertilizers and chemical pesticides. The use of agrochemicals for an extended time continuously can contaminate agricultural land, such as heavy metals in agrochemicals accumulated in the soil. The details of the total heavy metal content in agricultural land in the Srigading Village can be seen in Table 4. The heavy metal concentration of Pb, Cd, Co, Cr, and Ni was detected at all soil sampling points, but none exceeded the heavy metal quality standard set by Alloway (1995).

Based on interviews with shallot farmers, the main fertilizer trademarks used by farmers include Mutiara, Saprodap, and Phoskaplus. NPK Mutiara fertilizer contains 5 nutrients, which are 16% nitrogen, 16% P_2O_5 (phosphate), 16% K_2O (potassium), 0.5% MgO or magnesium and 6% CaO or calcium. Saprodap fertilizer contains 16% N (nitrogen), 20% P_2O_5 (phosphate) 12% S (sulfur). Phoskaplus fertilizer contains 15% N (nitrogen), 15% P_2O_5 (phosphate), 15% K_2O (potassium). According to Alloway (1995), the concentration of Cd in phosphate fertilizers ranged from 30-60 mg kg^{-1}. Pb is found in phosphate fertilizers at 7 – 225 mg kg^{-1} and compost at 1.3 – 2240 mg kg^{-1}. The fertilizer dose ranged from 1 Mg ha^{-1} – 2.8 Mg ha^{-1} depending on the condition of the agricultural land. The high application of phosphate fertilizers causes the accumulation of heavy metals in shallot fields because phosphate fertilizers contain heavy metals Pb and Cd (Alloway 1995). Moreover, the phosphate rock contains heavy metals that can pollute the environment, so it must remove the heavy metal content if it is used as fertilizer (Javied *et al.* 2009) The application of agrochemicals by farmers based on the results of interviews is made chiefly three times a week; even if there are many pests, it can be done once a day. Types of agrochemicals that farmers often use include insecticides and fungicides. Fungicides are often used with the trademark remazole P 490 EC with prochloraz 400 g l^{-1} and propiconazole 90 g l^{-1}, antracol 70 WP with the active ingredient propinep 70%, rovral 50 WP with the active ingredient iprodion 50%. An insecticide often used under the trademark vayego 200 SC contains the active ingredient tetraniliprol 200 g l^{-1}. Antracol fungicide contains heavy metal Pb of 12.48 ppm (Rasman and Hasmayani, 2018). The dose used by shallot farmers in the Srigading Village for powdered agrochemicals is around 1-3 spoons for 14 liters of water, and for liquid agrochemicals, it is also around 1-3 spoons for 14 liters of water. These doses are without any volume weighing and are only based on farmers' estimates. The dosage listed on the label for the fungicide anthracol is 2 g l^{-1} (300-800 l water ha^{-1}). The frequency of pesticide application on shallot plants with high enough doses, especially on agrochemicals containing heavy metals such as anthracol, can accumulate heavy metals in soil and shallots.

The distance between plants and roads is one factor that affects the presence of heavy metals in plants and the application of fertilizers and agrochemicals. A survey conducted at shallot production centers in Brebes and Tegal regencies showed a decrease in Pb levels in the soil the farther from the road, from four soil sampling sites with a distance of 500, 1000, 1,500, and 2,500 respectively from the road. In the main, the concentration of heavy metal Pb was 17.69, 16.14; 15.05; and 14.49 mg kg^{-1}, respectively (Nurjaya *et al.* 2003).

The soil sampling points on shallot farms in Srigading Village are <500 m from the road; it is pretty busy, although not the main road. Heavy

Tabel 5. The Analysis Result of the Correlation between the Farmers Behavior and Heavy Metal Contents in Shallots.

		Farmers' Behavior	Pb	Cd	Co	Cr	Ni
Farmers' Behavior	Pearson Correlation	1	-.278	-.213	-.266	-.261	-.27
	Sig. (2-tailed)		.137	.258	.156	.164	.14
	N	30	30	30	30	30	3
Pb	Pearson Correlation	-.278	1	.966**	.720**	.680**	.787*
	Sig. (2-tailed)	.137		.000	.000	.000	.00
	N	30	30	30	30	30	3
Cd	Pearson Correlation	-.213	.966**	1	.738**	.698**	.815*
	Sig. (2-tailed)	.258	.000		.000	.000	.00
	N	30	30	30	30	30	3
Co	Pearson Correlation	-.266	.720**	.738**	1	.777**	.924*
	Sig. (2-tailed)	.156	.000	.000		.000	.00
	N	30	30	30	30	30	3
Cr	Pearson Correlation	-.261	.680**	.698**	.777**	1	.803*
	Sig. (2-tailed)	.164	.000	.000	.000		.00
	N	30	30	30	30	30	3
Ni	Pearson Correlation	-.270	.787**	815**	.924**	.803**	
	Sig. (2-tailed)	.148	.000	.000	.000	.000	
	N	30	30	30	30	30	3

**. Correlation is significant at the 0.01 level (2-tailed). Source: Primer Data processed in SPSS 20

metals such as Pb released by motor vehicle fumes will accumulate in the surrounding soil (Frazer and VD Touw 2014). Therefore, the distance of soil from roads (highways, primary roads, and secondary roads) has a relatively significant impact on heavy metal concentrations in its surrounding (Wang *et al.* 2021).

The Correlation between the Heavy Metal Content in the Shallots Agriculture Land and the Farmers' Behavior

Based on the correlation test results, it was shown that between the heavy metal content in the soil and the farmers' behavior in using fertilizers and agrochemicals, all of them had a weak correlation, although not significant. The correlation test results of heavy metal content in the soil and the farmers' behavior are shown in Table 5.

The direct correlation between the farmers' behavior and heavy metal contents in the soil for all heavy metals has a negative direction even though the correlation is weak, which means that the better the farmers' behavior in using fertilizers and agrochemicals, the smaller the heavy metal content in the soil. Efforts to improve agricultural land by reducing agrochemicals, especially chemical pesticides, can be done by providing information and education aimed at farmers and sellers of agrochemical materials (Pan *et al.* 2021).

CONCLUSIONS

The shallot agriculture in Srigading Village contains heavy metals Pb, Cd, Co, Cr, and Ni, which are low or below the critical limit set by Alloway (1995) in which the heavy metal values of Pb, Cd, Co, Cr, and Ni below 100-400, 3-8, 25-50, 75-100 and 100 mg kg^{-1} respectively. Heavy metals concentration in the shallot field in Srigading Village is in a tolerable stage. The heavy metal concentration of Pb, Cd, Co, Cr, and Ni was spread at all soil sampling points. Moreover, soil organic carbon in shallot agriculture land is deficient. The farmers' behavior in fertilizers and pesticides has a weak and insignificant relationship with the heavy metal content in the soil of Srigading Village.

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