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Research Article

The effect of motorized vehicle emission toward lead accumulation and rice productivity alongside the uphill of Paguyangan main road, Brebes Regency

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Abstract: This study that was carried out in paddy fields next to Paguyangan main road in Paguyangan Village, Paguyangan District, Brebes Regency, was aimed to find out the effect of the road slope position, and the distance between main road and field toward the lead accumulation and rice productivity. The study was conducted using a survey method of purposive random sampling that consisted of two factors. The first factor was the slope position which was determined based on the three slope levels, i.e. T1/starting slope (3.4º of slope at 300 m above sea level (asl) altitude), T2/mid slope (15.84º of slope at 315 m asl altitude), and T3/end slope (8.7º of slope at 330 m asl altitude). The second factor was the distance of sampling points from the road, i.e. 25 m (J1), 50 m (J2) and 75 m (J3). The results showed that the difference in slope position and distance between the road toward plants did not significantly affect lead accumulation in rice, lead accumulation in the soil, and rice productivity on paddy fields alongside Paguyangan main road, Paguyangan Village, Brebes Regency, although the lead concentrations in rice and soil were above the specified threshold.

Keywords: *lead, rice productivity, vehicle emission*

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Introduction

A side effect of country development progress is increasing infrastructure and transportation. These intensive activities resulted in increasing quantities of contaminants into the urban environment. Consequently, a variety of environmental problems have cropped up and toxic metal pollution has become a significant issue, especially in urban air, soils and road dust (Bilos et al., 2001; Madrid et al., 2002; Han et al., 2006).

Air pollution has been considered one of the significant environmental challenges because of its effect on ecosystems and human health. The concentration levels and sources of heavy metals contamination were studied in road dust samples collected from various locations including four different activity areas: industrial area, highways and residential both of urban and rural area in development country (Suryawanshi et al., 2016).

The primary source of air pollution comes from transportation activities, especially from motorized vehicles that use fuel containing 60% pollutants of mono-oxide carbon and about 15% consists of hydrocarbons (Wolf, 2003). In addition, another pollutant comes from combustion, industrial processes, waste disposal, etc. Most of a motor vehicle causes serious residual gas emission in the form of heavy metal, such as lead (Pb). Pb particles generated by motor vehicle are generally 0.02 - 0.05 µm large. The smaller its particle, the longer it stays in the air. At this size, Pb particle could be distributed about 100 –1,000 km far from its origin by the wind. Agricultural land, rice field in particular, which is located nearby road passed by the motor vehicle, is susceptible to the accumulation of Pb (Wati et al., 2015).

Rice is widely cultivated in rural areas, including Paguyangan village, Bumiayu, Central Java. Some of the rice fields are located on the side of Paguyangan main road. Every day various motorized vehicles, either motorbikes, cars, trucks or buses pass through this road. The amount of these vehicles has an impact on the emergence of pollutants in the air. On the uphill road, the aperture of the engine throttle is greater so that the fuel intake of the combustion chamber is increased to fulfil the needs of the vehicle. This will have an impact on the number of emissions produced by motorized vehicles (Wiguna et al., 2013).

Roadside plants usually get more exposure to Pb compared to plants in other locations. The high mobility of motorized vehicles as a result of the opened national roads will have an impact on the accumulation of pollutants (Pb) which are likely to be absorbed by rice cultivated next to the road. There is a tendency for plants to take toxic substances including heavy metals which are then transferred along the food chain. The use of polluted land or water for food crop cultivation causes a decrease in productivity and produces contaminated food grains and vegetables which adversely affects human health (Singh et al., 2011). This study was conducted to find out the effect of the road slope position and the distance of the rice field from the road on the lead accumulation and rice productivity.

Materials and Methods

The study was conducted from January to April 2018 in the fields of IR64 rice variety exposed to vehicle emission on the Paguyangan main road, Paguyangan Village, District Paguyangan, Brebes Regency Central Java Indonesia. A purposive random sampling of survey was carried out to collect data. Samples of rice and soil were collected from a field near the busy main road with slopes of 3.4-15º. Sampling points in this study were based on slope position (denoted T), and field distance from the road (denoted J). The position of the slope was determined based on the degree of slope and divided into 3 levels, consisted of T1/starting slope (3.4º of slope at 300 m above sea level (asl) altitude), T2/mid slope (15.84º of slope at 315 masl altitude) and T3/end slope (8.7º of slope at 330 masl altitude). The distances of sampling points from the road were 25 m (J1), 50 m (J2), and 75 m (J3). Overall there were nine sampling points (Figure 1). Three samples of rice and soil were collected from each sampling point. Physiological analysis of leaves and yield of rice plant was carried out at the Laboratory of Agroecology, Faculty of Agriculture, Universitas Jenderal Soedirman, while the analysis of lead accumulation in rice grain and soil, using method of Atomic Absorption Spectrophotometer (AAS), was carried out at the Laboratory of Agricultural Environment Research Institute (Balingtan), Jakenan, Pati.

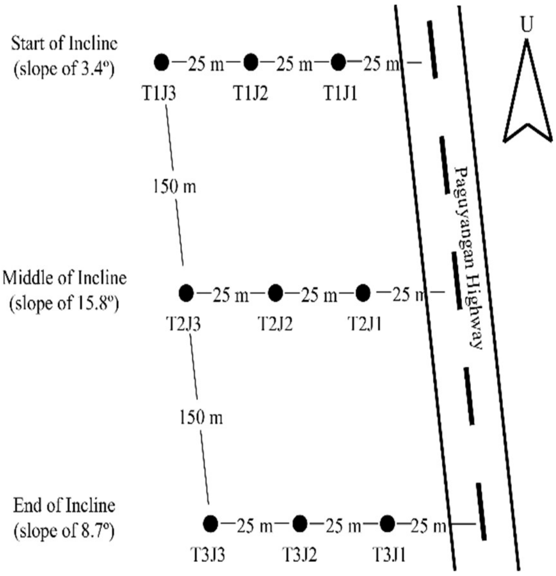

Figure 1. Plot sketch of the study

Data obtained were analyzed using a three-factor nested design ANOVA at p 0.05 to identify the different effects among factors. A stepwise Duncan Multiple Range Test (DMRT) was also conducted to find the most significant parameter. The data were processed manually using Microsoft Office Excel 2016 and DSTAT.

Results and Discussion

Data presented in Table 1 show that the traffic of motorized vehicles in the study area was busy as the main road connecting some districts in Central Java such as Banyumas, Bumiayu and Tegal. The number of vehicles gave high Pb emission to the air. This condition is an important environmental indicator of metal contamination from atmospheric deposition, that receives various inputs of anthropogenic metals from various activities, power plants, fossil fuel burning, waste incineration, construction and demolition activities (Bilos et al., 2001; Charlesworth et al., 2003; Bhanarkar et al., 2005, 2008; Gupta et al., 2012). The adverse effects of poor environmental conditions on human health are most evident in urban environments, particularly in developing countries where urbanization, industrialization and rapid population growth take place on an unprecedented scale (Duzgoren-Aydin, 2007).

Table 1. Number of vehicle and Pb emission on the study area

Vehicle Type	Number			Pb emission (g)		
	1 day	1 month	4 months	1 day	1 month	4 months
Motorcycle	32,229	966,880	3,867,520	696.15	20,884.61	83,538.43
Car	10,517	315,520	1,262,080	227.17	6,815.23	27,260.93
Bus	2,341	70,240	280,960	uk	uk	uk
Truck	4080	122,400	489,600	uk	uk	uk
Amount	49,168	1,475,040	5,900,160	923.32	27,699.84	110,799.36

Remark: uk = unknown, taken from primary data

The results of analysis of variance (Table 2) show that the slope position did not give different effect on lead accumulation in rice and in soil, leaf area, number of grains per panicle, and weight of 1000 seeds, but it affected the density of stomata, chlorophyll value, panicle number, fresh grain weight per clump and dry grain weight per clump. The distance of the road to the field only affected in fresh grain weight per clump and dry grain weight per clump.

Table 2. The result of observation variables

No.	Observation Variables	Treatment		
		T	J	T x J
1	Lead accumulation in rice (ppm)	ns	ns	ns
2	Lead accumulation in soil (ppm)	ns	ns	ns
3	Stomata density (mm^{-2})	*	ns	ns
4	Chlorophyll value (mg/L)	*	ns	ns
5	Leaf area (cm^2)	ns	ns	ns
6	Panicle quantity	*	ns	ns
7	Grain per panicle quantity	ns	ns	ns
8	1000 grains weight (g)	ns	ns	ns
9	Fresh grain weight per clump (g)	*	*	*
10	Dry grain weight per clump (g)	*	*	*

Remarks: ns= not significantly different, *= significantly different, based on ANOVA at p 0.05 T = slope position, J = distance of the road to the plants, T x J = interaction of slope position with a distance of the plants to the road

The interaction between slope position and the distance from the road gave significantly effect on fresh grain weight per clump and dry grain weight per clump. Data analysis of variables showed a diverse response. According to Sastrawijaya (1991), factors affecting the distribution of Pb in the air resulting in the varied Pb content of soil are climate factors (temperature, humidity, precipitation, wind direction, and wind velocity), and environmental factors (traffic velocity, distance of rice field to the roads, driving manners, and vehicle velocity).

Effect of the slope position on stomata density, chlorophyll value, panicle quantity, and Pb content in rice and soil

Stomata density

Table 3 shows that the highest stomata density on leaves was at the starting of the slope (T1), which was 292.44 per mm^2. This was because at the starting of the slope, the vehicle produced lower emissions, which meant that the Pb emissions were also lower. The decreased Pb concentration also indicated that CO_2 in the air decreased. Salisbury (1995) pointed out that stomata density is very dependent on CO_2 concentration, that is, if CO_2 falls or is low then the number of stomata in broad unity will be greater. Sembiring and Sulistyawati (2006) reported that stomata increased with decreasing of Pb concentration in leaves, but the correlation coefficient is very small so that it can be stated that Pb does not significantly affect the number of stomata in the leaves.

Chlorophyll value

The highest chlorophyll level (29.82 mg/L) was found at the plants grown beside the end of the slope. This was because at the end of the slope the vehicle's speed was increasing and relatively smooth. The smoother of traffic flow gave a lower effect of air pollution, which would affect the Pb level absorbed by the plant. Sembiring and Sulistyawati (2006) reported that decreasing Pb levels will be in line with the increase in total chlorophyll value. Changes in chlorophyll value due to Pb concentration are associated with damage to the chloroplast structure. The formation of chloroplasts is strongly influenced by mineral nutrients such as Mg and Fe. Excessive entry of heavy metals in plants, for example, Pb will reduce the intake of Mg and Fe, causing changes in the volume and amount of chloroplasts. Pb levels greatly affect the percentage of damage stomata and chlorophyll level in the leaves, which are caused by particles of vehicle emission and growth of the industrial sector in Langsa City as a source of impact towards decreasing the quality of the environment, especially the accumulation of air pollutants especially lead (Pb) particles (Suhaimi, 2017).

Table 3. Effect of the slope position on observation variables

Slope Position	KTB (ppm)	KTN (ppm)	KS (mm^{-2})	KK (mg/L)	LD (cm^2)	JM	JGM	BGS (g)
Start	26.75	25.52	292.44 a	23.36 ab	1818.74	21.22 a	96.48	26.82
Middle	24.65	26.73	272.89 b	20.15 b	1929.77	18.00 b	93.33	25.61
End	25.86	26.43	284.44 ab	29.82 a	1641.05	19.22 ab	89.7	28.34

Remarks: KTB = rice lead content, KTN = soil lead content, KS = stomata density, KK= chlorophyll content, LD = leaf area, JM = panicle quantity, BGS = 1000 grain weight, BB = fresh grain weight per clump, BK = dry grain weight per clump. The numbers followed by different letters in the same column are significantly different at *p* 0.05 of DMRT

Panicle quantity

The slope position gave a significant effect on the number of panicles. Panicle quantity was highest at the beginning of the slope which was 21.22. Gunawan (2015) reported that in addition to emitting Pb, the vehicle also emits SO_2 into the air, high rainfall will increase the washing of sulfur (S) elements. The starting position of the slope would undergo sulfur sedimentation due to a lower position than that of the middle and the end of the slope. Sulfur is a secondary macronutrient that plays a role in the formation of chlorophyll, protein and plant metabolism. Sondari (2009) reported that the number of panicles is influenced by the metabolic processes in rice plants which are supported by the availability of nutrients in the soil. When photosynthesis goes well, carbohydrate partition for the formation of panicles will increase.

Pb accumulation in rice and soil

Table 3 shows that the slope position did not show differences in lead accumulation in rice and soil. This is allegedly due to the influence of climate in the research location, including the speed and direction of the wind and rainfall. The direction of the wind in January until March was heading to the northwest in 189.6-192.2 km/day of speed, which means that the wind direction was in the opposite of the slope. Air pollution at the middle and the end of the slope is assumed to be higher than that at the starting point of the slope because in the mounting position the amount of exhaust gas increases which causes air pollutants to increase. However, the direction of the wind that is in the opposite direction of the slope makes Pb pollution spread evenly in various slope positions. According to Agus et al. (2014), the critical limit of lead in rice is 1 ppm, while the Pb threshold value in paddy fields is 12.75 ppm as suggested by the Soil Research Institute (2002). However, the results of the analysis of all treatments for the lead in rice and soil obtained exceeded the limits of the lead levels (Figure 2).

The active mechanism of roots absorbing nutrients and water in the soil also brings lead compounds into the plant. Lead enters the leaf tissue through a passive absorption mechanism through the stomata gap, due to the diameter of the Pb particle which is smaller than the size of the stomata gap. The lead that enters the plant tissue is then circulated to all parts of the plant to reach the grain (Winarna et al., 2015). According to Alloway (1995), there are several mechanisms of metal tolerance in plants, i.e. 1) selective absorption of ions by reducing membrane permeability or other differences in membrane structure and function, 2) ion immobilization of roots, leaves, and seeds, 3) ion transfer from metabolism by deposition (storage) in an insoluble form, 4) changes in metabolic patterns, increased inhibited enzyme systems, increased antagonistic metabolites or reduced metabolism that passes through obstructed sites, 5) releases ions from plant bodies through washing from leaves, gutations, abortion leaves and excretion from roots.

The lead accumulation in rice, in this study, was also thought to be influenced by the leaves of rice plants that have a rough-textured surface and dense canopy. Taihuttu (2001) stated that plants having coarse-textured leaves have a higher ability of particulate entrapping, than plants having leaves with slippery surfaces. Dense plant canopy absorbs more particulates than bare canopy plants because the chances of particulate capture will be greater. The ubiquity of Pb and its known toxicity to human and wildlife necessitates its continual determination in the environment.

Petrol is a petroleum-derived liquid mixture which is primarily used as a fuel in internal combustion engines, is also used as a solvent, mainly known for its ability to dilute paints (Weli et al., 2014).

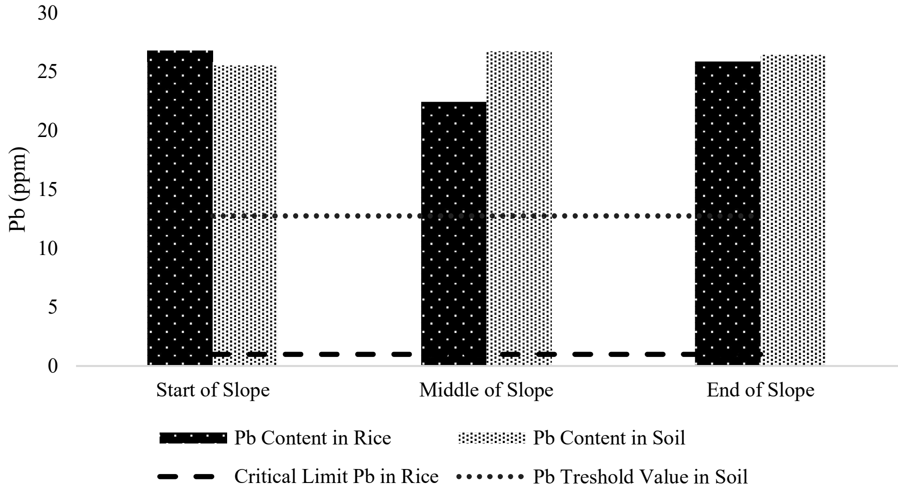

Figure 2. Effect of the slope position on lead accumulation in rice and soil

Effects of the distance between roads and plants on Pb accumulation in rice and soil

Table 4 shows that the distance between the road and plants does not show differences in lead accumulation both in rice and soil. Results that were not significantly different in this study were thought to be due to distance intervals that were too close (25 m, 50 m and 75 m). This is not in accordance with the results of research Fitrianah (2016) who get the lead accumulation in rice and soil are higher at the closest location to the road, with a studied distance is 100 m, 1000 m and 2000 m. The distance interval greatly affects the amount of Pb pollutants because the spread is more influenced by the wind. Mengel and Kirkby (2001) reported that the lead content in plants that grow on the roadside could reach 50 ppm, but the amount will be normal (2-3 ppm) at a distance of 150 m from the edge of the road. Although the lead accumulation in rice and soil obtained in this study was not significantly different, the Pb accumulation in rice and soil obtained exceeded the recommended Pb limit. The results of the analysis of lead in rice are presented in Figure 3. Winarna et al. (2015) pointed out that the distribution of Pb is influenced by the size of the particles, the state of the wind and the weather. Large particles fall in the form of dust around the source, while very small Pb floats in the air as an aerosol. Life period of Pb in the air released by motor vehicle emissions is 4-40 days. The Pb particles can be carried by the wind to reach a distance of 100-1000 km from the source. However, most of the Pb that floated in the air were deposited at a distance of 33 m from the edge of the road. Lead is difficult to dissolve and enter the soil and accumulates in the ecosystem where the lead settles, so lead is difficult to remove.

Effect of interactions between the slope position and the distance of the road to the plants

The effect of slope position on fresh weight of rice grain per clump was influenced by the distance of the road to the plant (Table 5). In the starting and middle of the slope positions, the highest fresh weight of grain per clump was reached at 75 m. However, at the end of the slope position, the highest fresh weight of grain per clump was reached at 25 m. The highest fresh grain weight per clump (49.51 g) was obtained at the initial position of the slope and at the distance of the road to the plant was 75 m.

Table 4. Effect of the distance between roads and plants on observation variables

Distance road to plants (m)	KTB (ppm)	KTN (ppm)	KS (mm^{-2})	KK (mg/L)	LD (cm^2)	JM	JGM	BGS (g)
25	25.54	25.87	282.22	24.85	1665.93	18.56	96.37	26.64
50	25.61	26.51	284.89	25.24	2085.66	19.11	92.52	27.79
75	26.11	26.3	282.67	23.25	1637.97	20.78	90.63	26.33

Remarks: KTB = rice lead content, KTN = soil lead content, KS = stomata density, KK= chlorophyll content, LD = leaf area, JM = panicle quantity, BGS = 1000 grain weight, BB = fresh grain weight per clump, BK = dry grain weight per clump. The numbers followed by different letters in the same column are significantly different at *p* 0.05 of DMRT

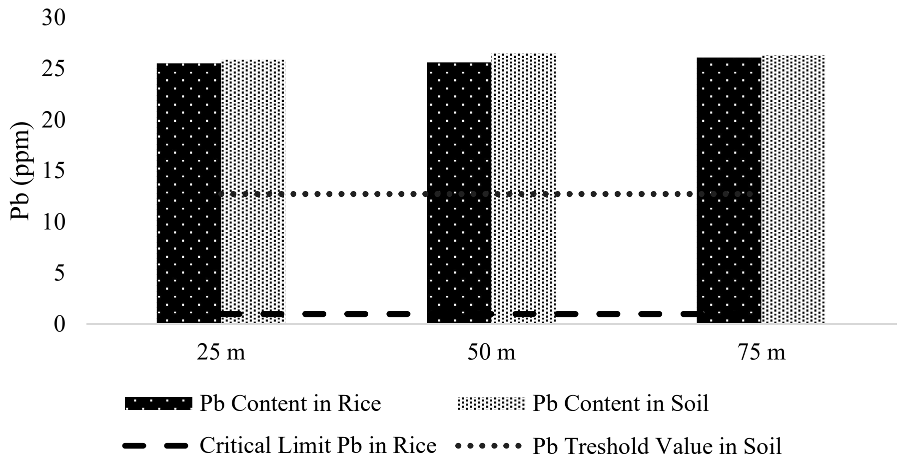

Figure 3. Effect of the distance between road and plants on lead accumulation in rice and soil

Fresh grain weight is influenced by photosynthesis that takes place in plants. Photosynthesis can be disrupted by an increase of the lead even with low concentrations. Pb pollution at the starting of the slope and the distance of 75 m of plants to the road is assumed to have a lower concentration than other sample points. At the starting of slope position, the aperture of the engine throttle is still normal so that emissions from motor vehicles are less.

Table 5. The interaction between the slope position and the distance of the road to the plants on the weight of fresh grain per clump

Slope Position	Distance of Road and Plant (m)		
	25	50	75
Start	36.35 Bab	30.50 Ba	49.51 Aa
Middle	27.47 Bb	33.15 ABa	38.43 Ab
End	38.07 Aa	31.45 ABa	28.98 Bc

Remarks: The numbers followed by capital letters (A-C) in the same row, and the numbers followed by lowercase letters (a-c) in the same column are significantly different at *p* 0.05 of DMRT

On the other hand, the distance of 75 m plants with roads is the longest distance in this study. Distance is inversely proportional to the Pb concentration, the farther distance from the source of the pollutant shows the lower concentration of lead in the air. Gunawan (2014) stated that Pb originating from the air would be deposited in the soil at a depth of less than 20 cm from the surface. The lead concentration in the soil on the edge of the road will decrease due to the increasing distance. Table 6 showed that the effect of slope position on dry grain weight per clump is influenced by the distance of the road to the plant. In the starting and middle positions of the slope, the highest dry grain weight per clump was reached at 75 m. However, the highest dry grain weight per clump at the end of the slope is reached at 25 m.

Table 6. The interaction between the slope position and the distance of the road and the plants on the weight of dry grain per clump

Slope Position	Distance of Road and Plant (m)		
	25	50	75
Start	32.74 Bab	27.39 Ca	44.19 Aa
Middle	24.82 Bb	28.95 ABa	33.48 Ab
End	34.42 Aa	27.90 ABa	25.63 Bb

Remarks: The numbers followed by capital letters (A-C) in the same row, and the numbers followed by lowercase letters (a-c) in the same column are significantly different at *p* 0.05 of DMRT

The highest dry grain weight per clump (44.19 g) was obtained at the starting position of the slope and 75 m distance from the road. This is presumed because dry grain weight per clump is directly proportional to fresh weight. Arifin et al. (2014) noted that the dry weight is the accumulation of carbohydrates, protein, vitamins and other organic materials. The amount of this accumulation is also related to stomata level.

Conclusion

The slope position has a significant effect on stomata density, chlorophyll value, panicle number, fresh grain weight and dry grain weight, The distance between road and plants significantly affected fresh grain weight and dry grain weight per clump. The differences in slope position and distance between road and plants did not significantly affect lead accumulation level in rice and rice productivity in paddy fields alongside the main road at Paguyangan Village, Brebes Regency. Lead accumulation in rice and soil in this study has reached over the threshold values.

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