

**Research Article**

**The effect of motor vehicle emission towards lead (Pb) content of rice field soil with different clay content**

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**Abstract:** Motor vehicle gas emission contains lead (Pb) which is a hazardous and toxic substance. Agricultural land, especially rice field, which is located nearby roads passed by many motor vehicle, are susceptible to the accumulation of Pb. If Pb is permeated by plants cultivated in the rice field, it will be very hazardous for humans as they are the final consumers. Hence, it is essential to identify Pb content of rice-field soil initiated by motor vehicle gas emission. This study was aimed to identify the effects of motor vehicle density, the distance between rice-field and road, and the clay content of soil towards Pb content of soils in Blitar and Ngawi Regencies of East Java. The method used for the study was survey method managed by using three-factor nested design with three replicates. The results of this study showed that motor vehicle density and the distance of rice field to road provide significant affected the total of Pb content of soil. However, the dissemination pattern of Pb in the soil was irregular due to the factors of climate and environment. Before Pb reached soil surface, Pb was spread out in the air due to the effect of temperature, wind velocity, vehicle velocity, size of vehicle, and road density. Consequently, the location with low motor vehicle density and positioned faraway to the road had higher total rate of Pb than the location with high motor vehicle density and positioned nearby the road. Clay content affected the total rate of Pb content as much as 37%, every 1% increase of clay content increased the total rate of Pb as much as 0.08 mg/kg.

**Key words:** *clay content, lead, motor vehicle gas emission, rice field soil*

**Introduction**

The advancement of human civilization is the effect of developing era and the increase of population. One issue confirming the advancement of human civilization is the increase of variety and quantity of transportation vehicle. The data retrieved from Police Office of Indonesia as cited in BPS (2012) showed that, in 2012, the total number of motor vehicle in Indonesia increased to 94,373,324 units and the data reported by Traffic Corps of Indonesian Police as cited in Kurniawan (2014) showed that in 2013, the total number of motor vehicle increased as much as 11% to 104,221 million units. The majority of that motor vehicle causes serious residual gas emission in the form of heavy metal, Lead (Pb) in particular. Pb generated by motor vehicle is generally 0.02- 0.05  $\mu\text{m}$  large, the smaller the size of Pb is, the longer the time of Pb

hanging in the air. This condition happens to make Pb particle disseminated as far as 100 – 1,000 km far from its initial position by wind. Agricultural land, rice field in particular, which is located nearby road passed by motor vehicle, is susceptible to the accumulation of Pb. If Pb is permeated by plants cultivated in the rice field, it will be very hazardous for humans as they are the final consumers. Hence, it is essential that Pb content of rice-field soil initiated by motor vehicle gas emission be identified.

**Materials and Method**

This study was conducted in rice fields located in Blitar Regency, covering Wlingi, Kesamben, and Doko Sub-Regencies, and Ngawi Regency, covering Padas and Pangkur Sub-Regencies, from June to October 2013. The method used for this study was survey method managed by using three-

factor nested design with three repetitions. Those three nested factors were the different locations with different clay content (Blitar Regency has low clay content and Ngawi Regency has high clay content), the rate of motor vehicle density (high, moderate, and low), and the distance of the rice fields to the roads (50 m, 100 m, and 150 m).

The samples of soil were collected when the soil was not sunken (during the phase of rice plant dike) and within the depth of the topsoil ( $\pm 20$  cm beneath the soil) which was in the form of disturbed soil. These samples were analyzed for total rate of Pb, soil texture, C-organic-C, CEC (Cation Exchange Capacity), and pH of soil. The data were tested using three-factor nested design ANOVA with 5% rate of F test to identify the different effects among factors. To identify the relationship among the observational parameters, correlation and regression tests were conducted. A stepwise regression test was also conducted to find the most significant parameter. The data were processed manually using Microsoft Office Excel 2007, while correlation, regression, and stepwise regression analyses were performed using SPSS 17.0.

## Results and Discussions

### *Pb content of soils within the different rates of motor vehicle density*

In Blitar and Ngawi Regencies, the roads with high motor vehicle density are the artery roads, while the roads with low motor vehicle density are the local roads. The measurement results of motor vehicle density rate in Blitar and Ngawi Regencies presented in Table 1 show that 66% of the motor vehicle was dominated by motorcycles, and the rests were 20% of cars, 10% of trucks, and 4% of busses. Motor vehicle density rate in Ngawi Regency was very high because the roads are the provincial highways interconnected East Java Province and Central Java Province. Generally, motor vehicle density in Ngawi Regency was higher than in Blitar Regency, however the average density per minute was considered similar.

Motor vehicle density causes Pb initiated by gas emission accumulated on the surface of soil of Blitar and Ngawi Regencies (Figure 1). Pb content was very low within the area with high motor vehicle density; while, Pb content was high within the area with low motor vehicle density.

Table 1. Motor vehicle density in Blitar and Ngawi Regencies

| Location | Sub-Regency | Motor Vehicle Density<br>(per minute) | Type of Motor Vehicle (unit) |       |     |            |
|----------|-------------|---------------------------------------|------------------------------|-------|-----|------------|
|          |             |                                       | Bus                          | Truck | Car | Motorcycle |
| Blitar   | Wlingi      | High                                  | 4                            | 8     | 17  | 49         |
|          | Kesamben    | Moderate                              | 0                            | 2     | 6   | 15         |
|          | Doko        | Low                                   | 0                            | 0     | 1   | 6          |
| Ngawi    | Padas       | High                                  | 5                            | 10    | 16  | 53         |
|          | Padas       | Moderate                              | 0                            | 2     | 6   | 21         |
|          | Pangkur     | Low                                   | 0                            | 0     | 3   | 9          |

In Ngawi Regency, however, the highest Pb content was identified in the area with moderate motor vehicle density and the lowest Pb content was in the area with low motor vehicle density. Pb content in the area with high motor vehicle density was lower than that in the area with moderate motor vehicle density by the range of 0.47 mg/kg. Results of this study showed that Pb content in the study locations did not meet the proposed hypothesis, i.e. the higher the density of motor vehicle is the higher Pb content of that area will become. The motor vehicle density affected Pb content of soil by its irregular pattern. Results of ANOVA revealed that the difference of motor vehicle density in these two study locations provided significant effect towards Pb content of rice-field soil.

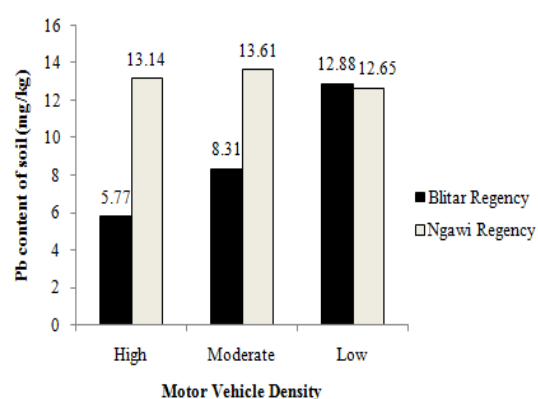


Figure 1. Pb content of rice field soil within the different rates of motor vehicle density in Blitar and Ngawi Regencies.

The fuel of motor vehicle contains Pb in the form of tetraethyl lead or TEL ( $(\text{CH}_3\text{CH}_2)_4\text{Pb}$ ). TEL is an additive substance used in the process of producing fuel which is used to increase octane value and to stand as anti-knocking preventing explosion during ignition process; therefore, it is not only  $\text{CO}_2$ , but also Pb particle which is released to the air. When Pb is exposed to the air, it travels through the air due to several particular factors until it reaches the surface of soils.

According to Sastrawijaya (1991), factors affecting the dissemination of Pb in the air that resulting in the varied Pb content of soil are climatology 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). The average wind velocity for the last five years to the time of sampling ranged from 3.54 to 6.11 knot. This significantly determined the dissemination course of Pb from its initial area.

Besides the environmental factors of road and motor vehicle that contributed to the dissemination of Pb in the air of the two locations, there were many long-haul transportation vehicles passing by with high velocity. If the traffic velocity, vehicle velocity, and motor vehicle density are considerably high, the air condition will turn to be irregular due to wind movement and Pb particle will have a tendency to be disseminated to many directions. Furthermore, large vehicles passing the artery roads with high velocity have a higher tendency to put the wind in motion compared to the small vehicles. Hence, Pb content of soil is lower within the rice field located nearby roads with high motor vehicle density than that within the other areas with different motor vehicle density. In local roads, the majority of vehicles were dominated by local transportation vehicles characterized by its short-haul route and low average velocity.

Wind movement of the areas with moderate and low motor vehicle density was relatively stable. Since Pb has a very great mass density by  $11.35 \text{ g/cm}^3$  or 9,458 times greater than the mass density of air ( $\rho_{\text{air}} = 0.0012 \text{ g/cm}^3$ ) and by the existence of gravity force, Pb particle will attach to the surface of soil when the wind movement are relatively stable. This condition is believed to cause Pb content of soil in Blitar Regency within the area located nearby the road with low motor vehicle density is considerably high, while Pb content of soil in Ngawi Regency was the highest within the area located nearby the roads with moderate motor vehicle density. According to Soehodho and Taufick (2005), if motor vehicle moves the wind rapidly towards a particular

direction, the distribution area of pollution will be broader and the concentration tends to be small.

#### ***Pb content of rice field soil within the various distance of the rice field to the road***

The distance of rice field to the road is one of the factors affecting the rate of Pb content of soil (Figure 2). Pb content in Blitar was relatively low ranging from 4 to 15 mg/kg (Figure 2a). Pb content was low within the rice fields located 50 m away from the roads and the rate of Pb content increased within the rice fields which were located 100 m and 150 m away from the roads. In Ngawi Regence, however, the Pb content ranged from 11 to 15 mg/kg (Figure 2b). The highest Pb content of soil was found in the rice fields located 50 m away from the road with low motor vehicle density, and the lowest Pb content of soil was found in the areas located 150 away from the roads with low motor vehicle density.

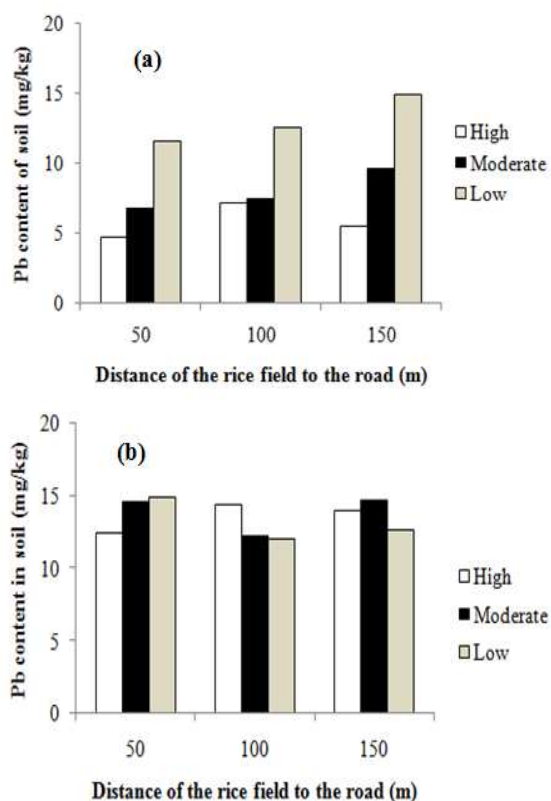


Figure 2. Pb content of soil in the rice field of Blitar (a), and Ngawi (b) Regencies

The hypothesis of this study referred to the study of Manurung (2005) and Parsa (2001) that the more distant the locations of rice fields to the roads are, the lower the content of Pb is. Although the results did not fulfill the hypothesis, the

distance of the rice fields to the roads still affected the rate of Pb content of soil. Pb content of soil was affected by the distance of the rice fields to the roads with the irregular pattern. Rice fields located quite far from the roads with high motor vehicle density had higher tendency of being exposed to Pb. It was proven by the result of ANOVA test confirming that the distance of the rice fields to the roads provided significant effect towards Pb content of soil. The distance of the rice fields and the rate of motor vehicle density affected the rate of Pb content. According to Fergusson (1990), Pb particle generated by the smoke of motor vehicle will stay for 4 to 40 days in the air. This quite long period causes Pb particle to be disseminated to 100-1,000 m away from its initial position by wind.

#### ***The effect of clay content and chemical properties of soil on the rate of Pb content in soil***

The soil textures of both study locations are different due to the different types of soil. The type of soil in Blitar Regency is Inceptisol (Layli, 2012) that makes the soil textures to be dominated by sand and dust fractions, while the type of soil in Ngawi Regency is Vertisol (Prasetyo, 2007) that is dominated by clay fraction. The results of ANOVA analysis showed that the factor of locations interpreting clay fractions of soil provides a very significant difference towards the rate of Pb content of soil. However, the structure of this significant difference was vague; hence, a follow-up test was conducted to know the relationship of clay content with Pb content of soil. In the soil, clay content did not affect Pb content by itself, some other factors contributed to it as well; the factors were C-organic, pH, and CEC of soil.

The relationships of each parameter and the total of Pb content of soil were positioned at different correlation classes. The factors of clay fractions, pH, and CEC were at the classes of strong correlation by the correlation coefficients ( $r$ ) of 0.61; 0.55; and 0.53; while C-organic was at the correlation class of medium by the correlation coefficients ( $r$ ) of 0.33. Based on those results of correlations, clay fraction, C-organic, pH, and CEC, were all correlated with Pb content of soil. Then, to understand the extent of effect provided by each factor toward Pb content of soil, multiple-regression analysis was conducted by  $y$  factor = the total of Pb content of soil and  $x$  factor = clay content, organic-C, pH, and CEC. The result of variety of all variables of  $x$  towards  $y$  was as much as 42% ( $R^2$ ). The result of multiple regression representing the levels of effect provided by each factor of  $x$  towards  $y$  exhibited

in Table 2 show that the form and the extent of effects of those four distinct factors towards the total of Pb content were different.

Table 2. The similarities and the levels of effect of clay content and soil chemical properties on the rate of Pb content of rice field soil

| Regression Equation                                 |           |                 |                  |
|---|-----------|-----------------|------------------|
| $y = 0.996 + 0.11x_1 - 2.74x_2 - 0.05x_3 + 1.64x_4$ |           |                 |                  |
| No.   | Factors   | Forms of Effect | Extent of Effect |
| 1   | Clay      | Positive        | 0.11             |
| 2   | C-organic | Negative        | 2.74             |
| 3   | CEC       | Negative        | 0.05             |
| 4   | pH        | Positive        | 1.64             |

Notes:  $y$  = the total of Pb content (mg/kg),  $x_3$  = CEC (me/100 g),  $x_1$  = Clay fraction (%),  $x_4$  = pH,  $x_2$  = C-organic (%)

Clay content and pH provided positive effects towards the total of Pb content of soil; it indicates that in every increase of clay fraction (%) and pH, total of Pb content (mg/kg) will increase as well. On the contrary, organic-C and CEC provided negative effects towards the total of Pb content of soil. This indicates that in every increase of C-organic (%) and CEC (me/100g), the total of Pb content of soil (mg/kg) will decrease. Every 1% increase of clay fraction increased 0.11 mg/kg of Pb content and 1% increase of pH increased 1.64 mg/kg of Pb content. While, every 1% increase of C-organic and 1 me/100 g CEC would decrease 2.74 mg/kg and 0.05 mg/kg of Pb content, respectively.

Generally, the rate of Pb content in Blitar Regency was relatively similar to that of Ngawi Regencies although the rate of Pb content in Ngawi Regency was higher than that of Blitar Regency. This condition occurred due to the effect of the other dominant soil parameter; i.e. pH. pH level of soil in Blitar Regency that ranged from 5.6 to 6.0; while, pH level of soil in Ngawi Regency ranged from 6.3 to 7.1. The exchange of cation occurs effectively in the soil with acidic pH level to neutral pH level in which Pb tends to be insoluble and thus its contents in the soil is considerably high (Rieuwerts et al., 1998). When the factors in the soil interact with one and another, there must be the most dominant factor affecting the rate of Pb content. To find out the most dominant factor affecting the factor of  $y$  (the total of Pb content of soil) among all factors of  $x$ , stepwise regression test was conducted. The result of stepwise regression test showed that among those factors of  $x$ , clay fraction was the most dominant factor affecting the total of Pb content of soil by 37% ( $R^2$ ) within the equation of  $y =$

$6,636 + 0,08x$ , where  $y$  is the total of Pb content and  $x$  is the clay fraction). Thus, it can be concluded that every 1% increase of clay fraction would increase 0.08 mg/kg of Pb content of soil. Clay fraction became quite dominant in this study because C-organic level of the rice field soil was relatively low. Alumaa et al. (2001) reported that Pb which touches the surface of soil will be strongly permeated by the first component making contact with that heavy metal. Due to the low organic substances and the high distribution coefficient value of Pb, clay fraction is the dominant factor which forcefully binds Pb.

Distribution coefficient ( $K^0$ ) which is defined as the concentration of metal within its solid phase towards its liquid phase, demonstrates the mobility and the distribution of heavy metal in the soil (Wahba and Zaghloul, 2007). The higher the value of  $K^0$  of metal is, the harder the distribution of Pb will become (immobile). The average level of Pb content was low in locations with low level of clay fraction. On the contrary, the average level of Pb content was high in locations with high level of clay fraction. This occurred because  $Pb^{2+}$  would be attached to the negative charge of clay. The study locations in Blitar Regency had low clay fraction because the soil texture was dominated by sand and dust fraction that resulted in the small area of absorption surface and the little amount of Pb permeated. The high rate of sand fraction caused Pb to be easily carried away into the deeper layer

through percolation process due to the low ability of sand fraction to restrain water. On the other hand, the higher the level of clay fraction is, the wider the surface area and the higher Pb content will become. The study of Ponizovsky and Mironenko (2001) indicated that Pb content of light-textured soil is lower than Pb content of heavy-textured soil. This proves that the types of clay mineral affect the binding of heavy metal within soil. According to Elfattah and Wada (1981), the selectivity coefficient of  $Pb^{2+}$  ion exchange decreases along with the increase of affinity of Pb towards mineral surface in the form of adsorbed-Pb(II). The above explanations clarify the rationales of the higher Pb content of soil in Ngawi Regency than in Blitar Regency.

#### ***The tolerable value of Pb content for rice field soil in Blitar and Ngawi Regencies***

The Pb content of soil in Blitar Regency that had low clay content ranged from 4.5 mg/kg to 15.07 mg/kg, while that in Ngawi Regency soil having high clay content ranged from 11.39 mg/kg to 14.99 mg/kg. Based on the indicators of soil quality parameters proposed by Soepardi (1983), Pb content in both locations was at the level of moderate. The threshold value of Pb in rice field soil is as much as 12.75 mg/kg as suggested by Balit Tanah (2002). Derived from this value, the threshold values of Pb in rice field soils in Blitar and Ngawi Regencies are presented in Table 3.

Table 3. Pb content in the study locations based on the tolerable threshold value for rice field soil

| Location       | Motor Vehicle Density | Distance (m) | Pb (mg/kg) | Based on the Threshold Value (12.75 mg/kg) |
|----------------|-----------------------|--------------|------------|--|
| Blitar Regency | High                  | 50           | 4.15       | safe                                       |
|                |                       | 100          | 7.65       | safe                                       |
|                |                       | 150          | 5.50       | safe                                       |
|                | Moderate              | 50           | 7.12       | safe                                       |
|                |                       | 100          | 7.62       | safe                                       |
|                |                       | 150          | 10.20      | safe                                       |
|                | Low                   | 50           | 10.86      | safe                                       |
|                |                       | 100          | 12.71      | safe                                       |
|                |                       | 150          | 15.07      | polluted                                   |
| Ngawi Regency  | High                  | 50           | 11.80      | safe                                       |
|                |                       | 100          | 14.44      | polluted                                   |
|                |                       | 150          | 13.92      | polluted                                   |
|                | Moderate              | 50           | 14.77      | polluted                                   |
|                |                       | 100          | 11.63      | safe                                       |
|                |                       | 150          | 14.44      | polluted                                   |
|                | Low                   | 50           | 14.99      | polluted                                   |
|                |                       | 100          | 11.58      | safe                                       |
|                |                       | 150          | 11.39      | safe                                       |

## Conclusion

Motor vehicle density provides a significant impact towards the total of Pb content of soil; however, the distribution pattern is irregular due to the factors of climate and environment. The distance of rice field to the roads provides significant effect towards the total of Pb content; the rice field located far away from the road is exposed to higher rate of Pb than the rice field located nearby the road; it is so since Pb is disseminated into many directions before it touches the soil. Clay content is the most dominant factor affecting Pb content of soil by 37% in which every 1% increase of soil clay fraction increases 0,08 mg/kg of Pb.

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