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Noise Reduction in Industrial Environment: Case Study in Cement Factory Cilacap, Indonesia

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ABSTRACT: In this study characterization of noise reduction in industrial environment was contrasted with noise reduction on roadside. Many study determined noise reduction on highway, but very rare study on industrial environment. The aim of this study is to determine noise reduction of tree belt in an industrial environment at an urban forest of cement factory in Cilacap Indonesia. The study compares five different scenarios of tree height; 6-meter, 10-meter, 15-meter, 20-meter and 30-meter height. To determine the net noise reduction effect termed as relative attenuation, an amplifier was placed 1 meter in front of the trees, and the sound pressure level was placed behind the tree belts at four different distances; 5, 10, 15 and 20 meters. Relative attenuation from tree belts areas subtracted with relative attenuation at equal distances over open ground. Open ground is places without tree belt which taken as control. In this work, the important factors that affect the noise reduction were taken into account, i.e. species, height, a number of trees and distance. From the research, we found that noise due to industrial environment have different characterization with noise on the highway. Therefore further research is needed to determine the design of experiments in an industrial environment to analyse characterization of noise reduction with better accuracy.

KEYWORDS: environmental ergonomics, fruit tree, height of tree, industries activity, noise.

1 INTRODUCTION

The strategic location of Cilacap City and its natural resource have been attracted various sectors. Cilacap has dominant sector in agriculture, trade, and processing industry [1]. Consequently processing industry grow in Cilacap, such as cement factory, oil refinery plant, tuna canning plant, shrimp canning plant, flour mill food, sugar processing plant, wood processing plant and electric steam power plant. Therefore, demand for housing construction has forced people to live nearby industrial area which is exposed to noise for long periods of time. Yet there is a difference between the noise threshold of the environment. Noise level limit for housing environment is 55 dBA whereas for industrial environment is 70 dBA [2].

In 2013, Holcim Indonesia Cilacap plant was one of the only a few business in Indonesia to receive a Gold PROPER rating from the Indonesian Ministry of Environment, the highest award in Indonesia for environment and waste management and the fourth time the plant has achieved this result. In order to improve and make the ergonomic environment, Holcim

Indonesia Cilacap plant takes an active role in environment, including reducing noise in industrial environment and reduce noise pollution exposure. Nevertheless environmental ergonomics have been connected to sustainability that promote the wellbeing of the occupants and protect the environment through energy conservation and green buildings [3].

A lot of sources of noise pollution, such as communication, traffic, and industrial activities. Indonesian Labour Ministry defined noise as all the unwanted sound that comes from the tools or production processes, and working tools were at a certain level can result in hearing loss [4]. Based on data from the World Health Organization (WHO) noise pollution was the third most dangerous environmental pollution, after exhaust emissions pollution and water pollution [5; 6]. However, noise pollution tends to overlook because its effects were not sudden or striking [7]. This danger is not realized by most people in Indonesia.

Nevertheless excessive noise affects the human health both directly and indirectly. Physical health problems, heart disease, temporary or permanent hearing loss were the direct impact of noise [8]. Physiological responses that change in heart rate, blood pressure and the production of adrenal hormones, in addition to impact the mental health and emotional balance, impact on daily life, such as sleep disturbances both quantity and quality were the indirect impact of noise.

Furthermore, noise is not only danger for human health [9; 10] however also have an impact on human performance [11; 12]. Noise reduced comprehension, attention, and vigilance [13]. Noise also reduced reading comprehension, short and long term memory [14], job dissatisfaction and psychological disorders [15]. Noise interferes with our ability to communicate and to hear warning signals, noise interferes with our ability both to carry out and to learn complex cognitive tasks, and heart disease [8; 16]. Another noise impact is a loss of quality of life, nevertheless this aspect is important for citizens, government, and industry.

A lot of field surveys were conducted to evaluate the noise in the open environment in different countries. However, almost noise research, in general, was due to the noise of traffic, from aircraft, train, or vehicles on the highway [14; 6; 17]. Even noise pollution in national parks has also been investigated [18]. Only a little research found due to the noise of industrial environment [15; 19; 20]. Research which is determined noise-reduction of tree belt in industrial environment, which compare the different group of tree height has never been done before.

The natural way to reduced noise in the open environment is by planting vegetation. Vegetation types affected relative attenuation. Pinus sylvestris was better to reduced highway noise compared Populus nigra tree belts in Turkey [21]. Pithecellobium dulce was better to reduced highway noise compared to the other samples, which were Samanea saman, Pterocarpus indicus, Tectona grandis in Indonesia [22].

Whereas the important factors that affect the noise reduction were species, height, distance, wide and amount of trees. Height and width of the tree belt were positive correlated with relative attenuation [23]. The effectiveness of 10 bush turkey belts at a distance of 5m, 9m, and 20m that can grow in the condition of the city may play an important role in the noise reduction [24]. Multiple regression models for six tree belts determined that the relative attenuation was high when the distance, receiver and the noise source height were small, and the belt width/visibility was large [23].

The aim of this study is to determine noise reduction effectiveness of tree belt existing in industrial environment at urban forest of cement factory in Cilacap Indonesia. This study determined five different groups of tree height which were 6, 10, 15, 20 and 30 meters height.

The number of samples in each group were different according to the conditions on site. This study compare five different groups of tree height. Four samples of fruit trees with 6-meter height. Four types of wood tree, consist of one samples of 10-meter height, one samples of 15-meter height, three samples of 20-meter height, and five samples of 30-meter height. In this work, the important factors that affect the noise reduction were taken into account, i.e. type, height, distance and amount of trees. Result of this study shows the relationship between relative attenuation, distance and the trees height in industrial environment.

2 MATERIALS & METHOD

The city of Cilacap, at an average elevation of 6 meters is located between 108°04'30"-109°30'30" east meridian and 7°30°-7°45'20" south parallel has tropical climate feature, the widest region in the South of Central Java Province, Indonesia. The population of the city is 1.748.705 according to the census 2010. However, distribution of the population is generally concentrated in urban centers. Industrial processing sector dominated the Product Domestic Regional Bruto of Cilacap. The research place was the urban forest of Holcim Indonesia Cilacap plant as can been seen on Fig. 1.

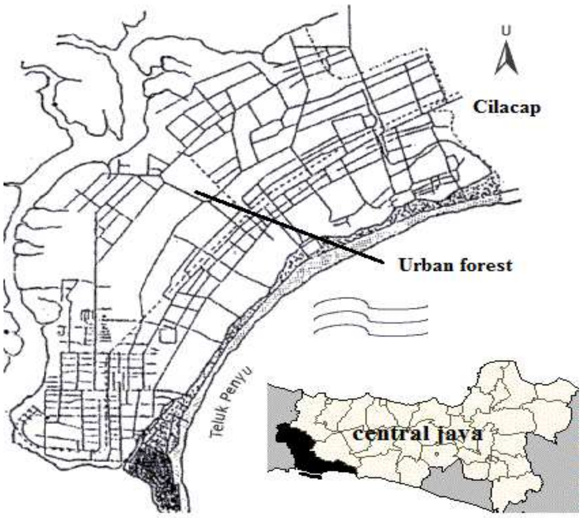

Fig. 1. Map of study area

Fig. 2. Urban Forest

Urban forest which are existing in the study area consist of common trees in Indonesia was chosen for study; they were grown on flat areas. The plants had been 10-12 years old and were around 1-2 m of length. The average height of fruit vegetation is 6 m, and the wood vegetation used as sample divided into four group height, 10m, 15m, 20m, and 30m, as can be seen on Table 1.

Table 1. Height, type, species and amount of group tree used in the experiment

Type	Height (meter)	Species	Sample Group
Fruit	6	Annona muricata Annona squamosa Artocarpus heterophyllus Gnetum Gnemon Mangifera indica L Manilkara kauki Psidium guajava L Syzygium aqueum Terminalia Cattapa	4
Wood	10	Canarium kipella Cassia siamea Glyrisidia sepium Lagerstromia sp Swietenium mahagoni	1
Wood	15	Albizzia falcataria Glyrisidia sepium Swietenium mahagoni	1
Wood	20	Albizzia falcataria	3
Wood	30	Albizzia falcataria Anthocephalus cadamba Canarium kipella Cassia siamea Glyrisidia sepium Lagerstromia sp Swietenium mahagoni	5

The experiment design used was based on previous research, where the noise source (TOA speakers, 50 Watt) produce a noise value of 90 dB(A) placed on each central line, within 1 meter in front of the tree and 1.2 meters from the ground [23; 24; 25], as can be seen in Fig. 3.

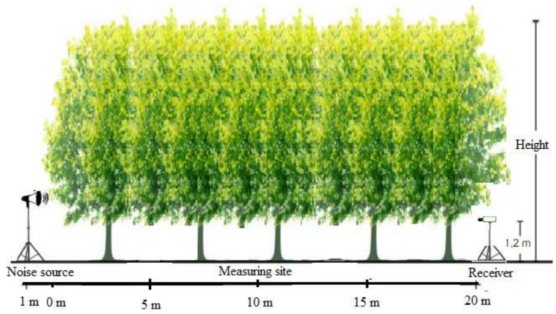

Fig. 3. The profile of experimental design

Measurements were made in August and September 2014. Noise meter used Precision Gold Environmental meter type N09AQ and Rion sound level meter type NA-24, placed on each transect line as can be seen in Fig. 4. Furthermore the noise meter and the amplifier operated more than 1 minute before the formal measurement conducted. Noise meter calibrated before use. The noise meter was set up using A-weight signal level. The noise was measured by noise meter 10 times every 30 seconds at each measurement points.

Measurements were taken three series, first series measurement are transect line A and B, furthermore second series measurement are transect line B and C, and the last or the third series measurement are transect line C and D. Relative value of sound pressure level at two transect lines are averaged to determine the mean value measurement.

One measurement series consists of eight measuring sites with four stage measurement as can be seen on Fig. 4. The first stage measurement at a distance of 5 meters, the second at a distance of 10 meters, the third measurement at a distance of 15 meters, whereas the fourth measurement at a distance of 20 meters.

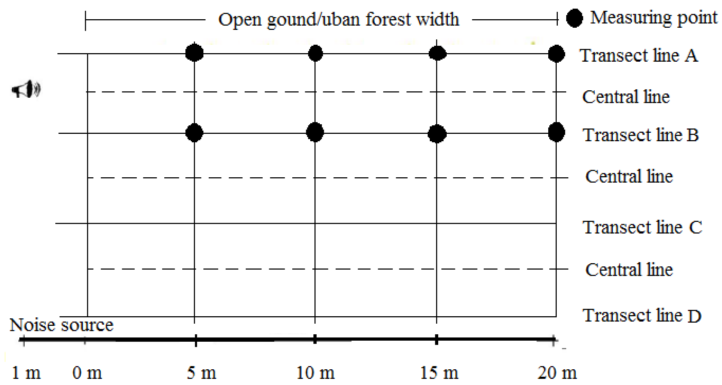

Fig. 4. The experimental design

Data carried out on the open ground at a distance of 5, 10, 15 and 20 meters measured as a control tests represents the effect of distance alone. Whereas data from the tree belt include effects of the distance and the trees. The difference between the two measuring site produces the net noise reduction effect termed as "relative attenuation" of every measuring site within the tree belt [25]. Measurements also recorded important factors that affect the noise reduction, species, distance, height and a number of trees.

3 RESULT & DISCUSSION

Noise control by vegetation remains grow therefore provides many other benefits besides reducing noise. Previous studies stating that the vegetation planted around the source of the noise can reduce the noise [6; 21; 22; 23; 24; 25]. The vegetation barriers judged the best aesthetically pleasing, although least effective at attenuating noise [26].

Furthermore the distance measurements used in this study refers to the effective distance that has been demonstrated in previous studies, which used four different distances; 5, 10, 15 and 20 meters. In conclusion, the barrier effect of noise is measured via relative attenuation [25]. Research in Taipei, Taiwan used multiple regression models for with 35 tree belts proved that distance gives big impact on the relative attenuation [25]. The relative attenuation declined slowly with increasing distance up to the turning point, but declined rapidly beyond the turning point; a turning point existed at a distance of approximately 40 meters. Vegetation exceeded 50 meters in length beyond has no effect on noise reduction [6; 25]. The effective vegetation length was less than 25 meter [21; 24] Research in Turkey indicating that at a distance of 0-25 meter noise reduction six times higher than at a distance of 25-50 meter and 50-75 meter [21]. The effective length of vegetation was less than 25 meter [24]. Therefore housing residents were further than 50 meters from the noise source and being away from the ground. Planting urban forest in the industrial environment does not have a significant effect on exposure to noise at the housing resident environment. An effective way for reducing the noise in the neighbourhood residents are by planting around the house.

Measurement in this research made with four different distances, 5, 10, 15, 20 meters which were made to compare the relative attenuation of five different group of tree height. The measurement results in the form of maximum relative attenuation from the different group of tree height in each distance are illustrated in Fig. 5. From the figure we can sort relative attenuation from the highest to the lowest value, 15m, 6m, 30m, 20m, and 10 m height of the tree. In conclusion the tree height do not have linear correlation to the relative attenuation. This result did not match to the previous research where tree height had positive correlation with relative correlation [23].

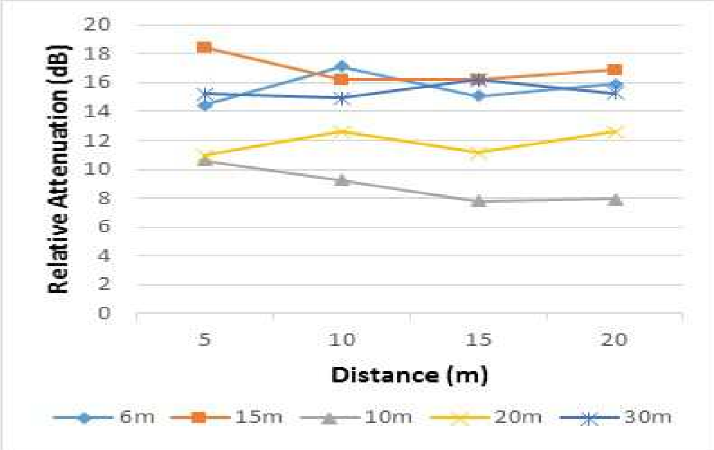

Fig. 5. Relative attenuation from various trees height

The results showed inconsistencies with the previous studies, vegetation planted around the source of noise can reduce the noise (6;21; 22; 23; 24; 25]. Furthermore the mixed stand more effective to reduce noise than uniform species [6]. In this research, wood trees with 15-meter height, which has mixed species, Albizzia falcataria, Glyrisidia sepium and Swietenium mahagoni proved to be more effective than the wood tree groups with 20 meters height, which has uniform species, Albizzia falcataria. In addition, noise reduction at a distance of 5 meters, had a big difference among all types of vegetation, while at a distance of 16, 18 and 20 meters the difference was almost the same [22]. Relative attenuation in this study at a 5-meter distance on all groups of tree height exceeded 10 dBA. The highest value of relative attenuation at a 5 meter distance achieved by 15 meter trees height.

The new discovery of this study was the correlation of tree height with the relative attenuation. The previous study concludes that tree height was positively correlated with the relative attenuation [23]. Whereas in this research, the tree height was not positively correlated with the relative attenuation. The tree height shows new pattern of affectivity to reduce noise, at the first the tree height were positively correlated, show the increases relative attenuation at height of 5 to 10 meters, and reached its peak at a height of 15 meters. However at height of 20 and 30 meters were negatively correlated, show the decreases relative attenuation.

In this study the noise source and receiver height refers to the effective measurement from the previous research of noise control study in Taiwan. Noise source placed 1 meter in front of the tree and 1.2 meters from the ground whereas the receiver placed at the measurement point and 1.2 meters from the ground [23]. That study concluded that the lower altitude of the receiver and noise source, the greater the relative attenuation. From the research, we found that noise due to industrial environment generated at different heights with noise on the highway. Therefore further research is needed to determine the design of experiments in an industrial environment to analyse affectivity of noise reduction with better accuracy.

4 CONCLUSION

Noise due to industrial environment different with noise on the highway. Therefore further research is needed to determine the design of experiments in an industrial environment to analyse characteristic of noise reduction with better accuracy. However, further research is needed to find an effective way to control noise in an industrial environment with noise source above 1.2 meters.

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