Revisit the green barrier development for ammonia exposure preventive countermeasure at urea fertilizer Z Factory in South Sumatera, Indonesia

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Abstract The release of large-scale ammonia in the air by urea fertilizer plants Z has caused negative impacts on the environment, particularly to environmental pollution and human health. Some actions have been taken as a countermeasure, one of them is the development of Green Barrier, a living filter consist of various plantation that design based on its ability to absorb certain pollution substances in the ambient air. This article aims to analyze the development of the green barrier construction and its effectiveness as an effort to prevent the spread of ammonia gas around the urea fertilizer plant Z environment. Sequential explanatory with comparative analysis of data obtained from questionnaires using Spearman Coefficient Correlation, interviews, and data on green barrier construction processes used to achieve research objectives in this study. Based on the results of the study it was found that the existence of the green barrier was more effective in reducing noise than reducing the ammonia odour. This is also supported by field observations where the construction of a green barrier is still not fully optimal due to land acquisition problems, damage to several plants on the green barrier, and many green barrier areas that have not been planted by plants which are mainly bordered by community land.

Keywords: Ammonia Exposure, Fertilizer Plant, Green Barrier, Pollution Prevention Strategy

1. Introduction
Air pollution will have a harmful impact both on living things and materials [1]. Generation of pollutants that exposed to ambient air, has the potential to cause a negative impact on building, animals and vegetation, humans, whether in a short and long term [2]. The air pollution impact generally causes health problems with different types and levels, depending on the pollutants size and their chemical composition [3]. Therefore, a countermeasure strategy to manage the air pollution is essentially needed with a consideration of durability, efficiency, and most importantly, environmental friendly and sustainable [16]. In regards to increasing the level of environmental concern, green barriers are often recommended as an environmental management strategy to mitigate air pollution that primarily caused by chemical industries [4]. The Green Barrier (also known as Green Belt) is a “natural filtration” equipment that consist of plantations that minimize air pollution by absorption, adsorption,
detoxification, accumulation, and metabolization without having a decline in growth while improve the air quality by providing oxygen to the atmosphere [17]. This is based on the philosophy of the plant's ability to absorb pollutant gases from the environment as well as absorb carbon dioxide and oxygen gases [5]. Khan and Abbasi [6] state that various tree arrangements can change wind profiles or form local inversions to trap pollutants in such a way so it can reduce the percentage of the pollutant in the air. Therefore, several indicators are needed in determining which plants are suitable for the construction of the green barrier in the chemical industry [6,7].

This study presents a case of the green barrier development by Urea Fertilizer Factory Z located in South Sumatera, Indonesia. This factory located very close to the residential area, so in case of accident or disruption happened in the factory will directly impact to the nearest residential area. On September 14, 2001, in accordance with the Palembang Mayor's Decree Number 208/Kpts/Bapeldalda/2001, stated that the Urea Fertilizer Factory Z must overcome the spread of ammonia and noise to the community around the factory, especially at a 700m radius from the factory, due to a disruption of noise that reached 78 dB (A), and ammonia exposure that prone to reach 12 ppm which resulted from the factory activity. The form of this response is the development of the Green Barrier as the boundary between factories and residents, which has been carried out from 2002 to the present. However, in the event of a disruption of the ammonia gas release at the plant, it still has an impact on the surrounding community until now. This article aims to analyze the development of the green barrier construction and its effectiveness as an effort to prevent the spread of ammonia gas around the urea fertilizer plant Z environment.

2. Methods
This study was conducted in 1-Illir Urban Village, Illir Timur II Subdistrict with the distance of 500-1000 metres from the factory boundaries. This Urban Village consists of 19 neighbourhood and 4 hamlets, and by using the cluster random sampling, reduced to 4 selected neighbourhood and 1 hamlet namely RT 19 RW 04, RT 16 RW 04, RT 12 RW 04, dan RT 10 RW 04. By the total population of 6,906 people, 108 people were counted as the representation using the Slovin formulation with 10% error factor. The questionnaire was divided evenly into each neighbourhood, and the result was analyzed using the Spearman Correlation Coefficient Test method with SPSS software version 23. The basis for decision making determined based on the significance value if the sig value < 0.05 means that there is a relationship between the variables and vice versa. The criteria for the correlation coefficient between variables have a range of ± 0.00-1.00 presented in table 1.

| No | Correlation Coefficient Value | Description         |
|----|-------------------------------|---------------------|
| 1. | 0.00-0.20                     | Almost no correlation |
| 2. | 0.21-0.40                     | Low Correlation      |
| 3. | 0.41-0.60                     | Medium Correlation   |
| 4. | 0.61-0.80                     | High Correlation     |
| 5. | 0.80-1.00                     | Perfect Correlation  |

The analysis then carried out descriptively by comparing the results of field observations, informant interviews, and processed questionnaires.

3. Result and Discussion
Tree Plantation as an effort to control air pollution around the factory, particularly ammonia (NH₃) pollution in some work areas, both in the form of lanes and following the availability of land shape and the land area. In case of the fertilizer industry that located close to the settlement area, the green barrier has several functions, including a dust absorber, noise reducer, along with the pollutant gas absorber and the odour that it caused [9]. Therefore, table 2 presents an alternative proposed by Susanto and
Komarawidjaja [9] study regarding the appropriate plantation for the green barrier development in the fertilizer industry.

**Table 2.** Alternative Plant Composition for Green Barrier Development in Fertilizer Industry [9].

| No | Plant Name           | Latin Name                     | Compound Absorption |
|----|----------------------|--------------------------------|---------------------|
| 1  | Burmese rosewood     | *Pterocarpus Indicus*          | Carbon Dioxide      |
| 2  | Flamboyant           | *Delonix regia*                | Carbon Dioxide      |
| 3  | Puspa                | *Schima wallichii*             | Carbon Dioxide      |
| 4  | Ylang-Ylang          | *Canangium odoratum*           | Odour               |
| 5  | Bullet wood          | *Minusops elengi*              | Odour               |
| 6  | Mahogany             | *Swietenia mahagoni*           | Nitrogen            |
| 7  | Coral Cockspur tree  | *Erythrina variegata*          | Nitrogen            |
| 8  | Tamarind             | *Tamarindus indica*            | Nitrogen            |
| 9  | Jackfruit            | *Arthrocarpus heterophillus*    | Sulphur             |
| 10 | Banyan Tree          | *Ficus benyamima*              | Sulphur             |
| 11 | Acasia               | *Acasia auriculiformis*        | Sulphur             |
| 12 | Candlenut            | *Alleurites molucanna*         | Sulphur             |
| 13 | Guava                | *Psidium guava*                | Sulphur             |
| 14 | Silk tree            | *Albizia chinensis*            | Dust                |
| 15 | Madras Thorn         | *Phitecelobium dulce*          | Carbon Dioxide, dust|

In the southwestern part of factory Z, a Green Barrier area was built, which is a green area that was used as a conservation area by the factory in allocating waste from plant operations. This Green Barrier area is 13 hectares, planted by various types of trees to reduce noise and ammonia odour resulted along the manufacturing process. Table 3 presents several types of plantation found in the green barrier area.

**Table 3.** Plant species found in the fertilizer Factory Z Green Barrier [10]

| No | Plant Type         | Latin Name                     | Quantity (plant) |
|----|--------------------|--------------------------------|-----------------|
| 1  | Teak               | *Tectona grandis*              | 625             |
| 2  | Blackboard Tree    | *Alstonia scholaris*           | 527             |
| 3  | Mahogany           | *Swietenia mahagoni*           | 512             |
| 4  | Burmese rosewood   | *Pterocarpus indicus*          | 430             |
| 5  | Rain Tree          | *Samanea saman*                | 345             |
| 6  | Acacia             | *Acasia auriculiformis*        | 342             |
| 7  | Bamboo             | *Phyllostachys edulis*         | 103             |
| 8  | Fern Tree          | *Filicium decipiens*           | 86              |
| 9  | Coconut and Palm   | *Cocos nucifera and Arenga pinata* | 67              |

There is some similarity found in table 3 in comparison to table 2, including mahogany and acacia. However, to determine the effectiveness of the green barrier, a questionnaire was made to see the green barrier project and advantages in the community perspective. Based on the questionnaire, table 4 presents the percentage of respondents perspective toward the effect of Green Barrier development in Urea Fertilizer Factory Z.
Table 4. Percentage of community’s perspective towards the development of the Green Barrier

| No | Green barrier Effects                          | Percentage (%) |
|----|------------------------------------------------|----------------|
| 1  | Reduce the ammonia odour                      | 21.43          |
| 2  | Reduce the noise                              | 32.14          |
| 3  | Make the surrounding environment cooler       | 15.71          |
| 4  | No particular effects                         | 30.71          |

It can be inferred from table 4 that the respondent opinion of green barrier more effective as the noise reducer more than the odour, even though the green barrier was built mainly for two purposes. In comparison, table 5 presents the respondent opinion towards the green barrier effect in reducing the ammonia exposure.

Table 5. Percentage of Community Perspective towards the green barrier effect for reducing ammonia exposure odour in ambient air

| No  | Effectiveness Level | Percentage (%) |
|-----|---------------------|----------------|
| 1.  | No Effect           | 41.43          |
| 2.  | A little bit Effective | 46.43        |
| 3.  | Quite Effective     | 10.71          |
| 4.  | Very Effective      | 1.43           |
| 5.  | Perfectly Effective | 0.00           |

Based on table 5, it can be inferred that the green barrier did not achieve its other purposes for reducing the ammonia exposure, proven by only 1.43% respondents feel very effective, while 46.43% said that it only a little bit effective and 41.43% stated that it does not affect. This is contradicting to Khan and Abbasy [6] study. Therefore, two assumptions based on the findings in the field observation and the questionnaire, which are the area was not fully maximised its potential or the ability for the plantation to absorb the ammonia has been decreased. The first assumption was built based on the green barrier realisation programme data presented in table 6.

Table 6. Percentage of Green Barrier Program Realization in the Area around Urea Fertilizer Factory Z Environment

| No  | Description     | Plan Land (m²) | Plan Building (m²) | Realisation Land (m²) | Realisation Building (m²) | Percentage (%) |
|-----|-----------------|----------------|-------------------|-----------------------|--------------------------|----------------|
| 1.  | Green Barrier II| 36,523         | -                 | 36,523                | -                        | 100            |
| 2.  | Green Barrier III | 57,834      | 22,480.68        | 13,378                | 11,068                   | 23.13          |
| Total |                | 94,357         | 22,480.68        | 49,901                | 11,068                   | 52.89          |
| Grand Total |                | 116,837.7     | 60,696            | 52.18                 |

Based on table 6, it was found that the development realisation only reaches 52.18 of 100%. This was due to some problem that occurs during land acquisition. This was stated by the informant during the interview:

"Urea Factory Z try to buy the land from the community based on Tax Object Selling Value (NJOP), meanwhile the community feels that the selling price for their land and building is much lower than the market price. Another solution has emerged which is replacing the building and land with the same
quantity in another area. But the community reject the offer by stating that the replacement is not fit to their requirements (not a strategic and far from the centre of the city), so they prefer to stay”

Another particular reason is the land area for the green barrier was a graveyard area and the family were reluctant to sell it because they required to dismantle the tomb and it considered as a taboo act. Therefore, the green barrier was not fully implemented as seen in figure 1 (a) and (b).

![Figure 1](image1.jpg)

**Figure 1.** (a) Green Barrier area that has not yet planted and fully acquired by the factory; (b) the area between the factory border that has a deceased family’s tomb

The second assumption emerge based on another informant who stated that in 2013, almost 75 species of plants in Green barrier area was damaged due to the constant exposure of ammonia gas. This statement was in –line with the field observational findings as seen in figure 2 (a) and (b).

![Figure 2](image2.jpg)

**Figure 2.** Some dry and damaged plantation found in the green barrier located: (a) near the settlement area and (b) near the border between the factory and the settlement area.

However, compared to the other countermeasure methods of Urea Factory Z in regards of ammonia exposure (i.e. spraying and burning), the best countermeasures to be applied to the area around the plant are indeed the development of Green Barrier. This is due to the environmental concern that caused by the other method. The burning method is proven as efficient to reduce the ammonia exposure, however, created another compound such as Nitrogen Oxide, that widely known as one of the Greenhouse gas [11]. Meanwhile, the other method which is spraying (binds the ammonia with water and separate it in wastewater treatment unit) would potentially harmful if the amount of the ammonia absorbed in the water exceeds the wastewater treatment unit ability to manage, causing a high amount of ammonium hydroxide (NH$_4^+$), an irritant chemical compound that affect biological balance, such as damaging plant life, causing excessive fertilization of soil and plants, increasing the growth of algae on the surface of
the water, and damaging the water life [12]. This is also supported by the Spearman test to see a relation between the influence of the green barrier existence and the community response as presented in table 7.

Table 7. Correlation and the correlation direction between the Influencing Variables and the Community Response with Spearman Test

| Correlation                                                                 | Sig. (2-tailed) | Correlation Coefficient | Amount of Data | Description       |
|----------------------------------------------------------------------------|-----------------|--------------------------|----------------|------------------|
| The prevalence of ammonia exposure per day with the green barrier influence on changing the air quality | 0.006           | -0.232                   | 108            | Correlated       |
| The time of ammonia exposure per day with the green barrier influence on reducing the ammonia odour | 0.008           | -0.222                   | 108            | Correlated       |

It can be analyzed from table 7 that the green barrier around the factory area indeed correlated with the level of community prevalence of being exposed to ammonia odour and the term of ammonia being exposed. The strength of the correlation in the variable above is low, with a correlation coefficient of 0.232 and 0.222. The correlation direction of the tested variable is negative, interpreting that the traits were not in the same direction. Therefore, it can be interpreted that if the prevalence rate of people in smelling the ammonia odour decreases, then the effect of the green barrier on air quality increases. The increasing of the influence of the green barrier will also cause a decrease in ammonia odour in the air around the factory. However, some weaknesses that must be considered by the factory, namely the plant vulnerability level and the damage that used as pollution absorbers, as well as uneven planting in the green barrier area.

In addition to the above criteria, the plant tolerance level or other words the sensitivity level of a plant that can adapt as pollution protection must be considered in the development of the Green Barrier [13]. In the application of the green barrier to the fertilizer industry, the researchers agree with Aruninta's study [13], which is supported by Lukman et al. [14] regarding the resistance of several types of plants to air ammonia levels. The study concluded that all of the studied plantation (seen in table 8) could absorb ammonia, but had different levels of absorption, sensitivity, and damage due to the pollutants absorption.

Table 8. The Plant’s ability to absorb ammonia, their sensitivity and damage [14]

| No | Plant Type       | Latin Name                | Absorption Ability | Sensitivity | Damage Percentage (%) |
|----|------------------|---------------------------|--------------------|-------------|-----------------------|
| 1  | Tropical Almond  | Terminalia catappa        | 3,0                | 1,8         | 12,4                  |
| 2  | Burmese rosewood | Pterocarpus indicus       | 3,4                | 1,4         | 8,8                   |
| 3  | Mahogany         | Swietenia mahogany        | 2,5                | 2,0         | 20,6                  |
| 4  | Green Champa     | Polyalthia longifolia     | 3,3                | 2,6         | 41,5                  |
| 5  | Bullet wood      | Mimusops elengi           | 1,4                | 1,2         | 7,1                   |

Based on table 8, Burmese rosewood and Green Champa have the hight ammonia absorption ability, however, Green Champa has a higher level of sensitivity and damage than Burmese Rosewood. Meanwhile, mahogany has a lower level of absorption but has a higher level of sensitivity and damage percentage compared to Burmese Rosewood. This strengthened the second assumption, due to the amount of mahogany plantation in green barrier Urea Fertilizer Z is more compared to Burmese Rosewood (as seen in table 2). Thus, it can be assumed that the plantation in green barrier was damaged, as in line with Lukman et al. [14] study which stated that plants which absorb too much nitrogen
concentration would disrupt its physiological balance and increase sensitivity to the environment in the form of drought, low temperatures, pests, and diseases. This is also in-line with Roziaty [15] study which stated that excessive absorption of ammonia will cause damage to the chloroplast and palisade, causing a decrease in the ability of plants to absorb water and the imperfection in opening the stomata.

4. Conclusion
Development of green barrier as a countermeasure is believed to be environmental friendly approach in handling ammonia exposure compared to other method such as burning or water spraying that potentially arising some environmental issues in the after process. Based on the result, it can be analyzed that the green barrier indeed correlated with the prevalence of being exposed to ammonia odour and the term of ammonia being exposed, with correlation coefficient of 0.232 and 0.222 and negative direction. Thus, it were interpreted that if the prevalence rate of people in smelling the ammonia odour decreases, then the effect of the green barrier on air quality increases. The increasing of the influence of the green barrier will also cause a decrease in ammonia odour in the air around the factory. However, only 21.43% of the community believed that green barrier was effective against the ammonia, while the others (32.14%) believed that it was more effective as the noise reducer. Upon further investigation, it was found the development was stagnant due to some several problems including the unreached agreement between the factory and the community in terms of buying and selling the land, and the unwillingness of the community to migrate due to privacy reason. Other emerging issues are the uneven planting of plants and the high amount of damaged plants due to an excessive amount of pollution absorption. Therefore, related stakeholder has to regularly check the plantations in green barrier area (i.e replacing the overused/ damaged plantations with the new ones, calculating or forecasting the limit of each plantations based on its absorption abilities, etc). Moreover, further studies regarding the high level of ammonia absorption as well as high resistance plant are needed, as well as the plantation arrangement for the green barrier is necessary for better management in preventing the ammonia exposure pollution.

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