Chemical Plant in the Downtown: Study of Ammonia Release Causative Factor and Its Negative Impact towards Workers and Communities at XYZ Fertilizer Factory

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Abstract. Ammonia gas exposure to the environment that mainly caused by certain factors has the potential to bring negative impacts, particularly to workers and the community in terms of health issues. This study aims to analyse the factors that cause ammonia gas release and its negative effects on the workers and the community that lives near the factory. This study will use Hazard Identification Methods i.e Likelihood and severity scale to strengthened that findings in field observation, key informant interviews, and questionnaire. Based on the study, it was found that certain conditions that often caused ammonia gas release are located in ammonia storage tanks, cooling water reservoirs, and pumps and valves with an incidence rate of at least once per day. Meanwhile, certain conditions such as clogging, negligence, maintenance, and start-ups are scarce where the incidence rate is once in a year or even more. The impacts of ammonia occur in humans through inhalation and directly cause irritation, and respiratory problems that differ in each depends on the exposure duration and concentration level.

Keywords: Ammonia Impact, Chemical Plant Hazard, Environmental Health, Fertilizer Plant

1. Introduction
The more complex processes and technology in an industry, the higher its possibility to involve a material that can cause accidents that threaten human life and the surrounding environment [1]. The release of ammonia gas in the air can cause serious health problems for humans and ecosystems, even in small concentrations ranging from tens of ppm [2]. Ammonia gas exposure occurs in workers in industries engaged in synthesis, formulation, transportation, along with the use of these substances [3]. Ammonia gas can be dangerous when contacted in tissues in living bodies that have moisture or contain water [4]. When contact with humans, ammonia gas reacts with water in the surface layer of the eyes, skin, and respiratory tract to form caustic ammonium hydroxide compounds [5], causing a sensation such as burning or irritation in the area [6].

This article presents a case in XYZ factory that engage in manufacturing ammonia and urea fertilizer which located near the Musi River, approximately 7 km from the centre of Palembang, which known as one of the big cities in Indonesia. The first plant was established in 1963 and now consist of 4 plants with a total production capacity of 1,149,000 tons per year of ammonia and 2,280,000 tons per year of

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urea. In the beginning, the factory location was built far from a residential area. However, since 1991, many people have built houses around the area that grew closer each year. This condition creates some disadvantages in both parties because ammonia gas is often released in the air during the manufacturing process that caused several environmental issues as follows:

In the study of Navianti [7] on 2002, it was analysed that ammonia exposures around 73.8% for exposure to high concentrations (2330 µg/m$^3$), and 43.9% for exposure to low concentration ammonia gas (174.5 µg/m$^3$). This value is quite high considering the quality standard for ammonia in ambient air according to PP. RI No.41 of 1999 is 1360 µg/m$^3$/24 hours.

On March 5th, 2014, tourists and residents were exposed to mild eye irritation and discomfort in breathing while crossing the area around XYZ factory due to ammonia gas exposure on their way to Kemaro Island. The last case has occurred on November 1st, 2018 at 8.00 pm where a big amount of ammonia gas was released due to a leakage in the urea synthesize reactor safety valve during the start-up plant. It reached the nearest residential area that surrounds the factory, causing nausea, eye and nose irritation, hard to breathe, and asthma, that forced the people to evacuate from the area. This article aims to analyse several factors that often cause ammonia gas to be released in the environment, and the negative effects of ammonia gas release on the environment, especially workers and communities around the plant.

2. Methods

This study focuses on the plant in XYZ factory that was operating since 2001, namely Urea and Ammonia Plant X-IB and X-III. Purposive sampling was carried out to determine the respondent that represents the workers for questionnaires, with the criteria of over 23 years old age and more than 3-years of working experience. The questionnaires distributed in the amount of 90 pieces, with the distribution of 22 pieces for workers of X-IB ammonia plant, 23 for workers of X-IB urea plant, 23 for workers at ammonia X-III plant, and 22 for workers at urea X-III. Key informant interviews were also conducted with a list of informants presented in table 1.

| No | Department                                      | Number of Informants (Person) |
|----|------------------------------------------------|------------------------------|
| 1. | Ergonomics and Health Company Hygiene           | 1                            |
| 2. | Ammonia and Urea Operation Plant X-IB           | 2                            |
| 3. | Ammonia and Urea Operation Plant X-III          | 2                            |
| 4. | Environmental, Health&Safety                    | 2                            |

For a comparison towards the community, the study was carried out with a limitation of an area that surrounding the XYZ factory with a distance of 500-1000 m. Hence, the area chosen was I-IIir Subdistrict with total resident 6,906 people that divided into 19 neighbourhoods and 4 hamlets. Using random cluster sampling, the sample location was reduced to 4 neighbourhoods and 1 hamlet, namely RT 19 RW 04, RT 16 RW 04, RT 12 RW 04, and RT 10 RW 04. Next, the sample selection was narrowed down by the addition of criteria in the form of people living with a distance between 500-1000 m from the factory with an age range of 25-40 years for more than 5 years. The questionnaires were distributed by 140 pieces, with the distribution of each RT numbering 35 questionnaires.

This study also uses the Hazard Identification method based on AS/NZS 4360 standard to analyse the findings from field observation, questionnaires, and interviews. Likelihood scale (shown in table 2) is used to state the most common factors and cause ammonia gas to be released.
Table 2. Likelihood scale based on AS / NZS 4360 standard [8].

| Level | Description | Explanation |
|-------|-------------|-------------|
| 5     | Almost Certain | There are ≥ 1 event in each shift |
| 4     | Minor        | There are ≥ 1 event each day |
| 3     | Moderate     | There are ≥ 1 event each week |
| 2     | Major        | There are ≥ 1 event each month |
| 1     | Catastrophic | There are ≥ 1 event every year or more |

For an analysis of the negative impact potential of ammonia release carried out with the same analysis using a severity scale by Hazard Identification AS/NZS 4360 standards shown in table 3 of the recorded accidental case data in the plant. To determine the possibility of the different negative impact of ammonia on each respondent, t-test analysis performed by SPSS version 23 will also be conducted in this study. If the significance value obtained is <0.05, then there are differences between the two data variables tested. Conversely, if the significance value obtained is > 0.05 then there is no difference between the two data variables tested.

Table 3. Severity scale based on AS / NZS 4360 standard [8].

| Level | Description  | Explanation |
|-------|--------------|-------------|
| 5     | Insignificant | No injuries have occurred |
| 4     | Minor        | Minor Injury |
| 3     | Moderate     | Moderate Injury, need medical attention |
| 2     | Major        | Severe injury ≥ 1 person, causing a disturbance in production |
| 1     | Catastrophic | Fatal ≥ 1 person, a wide range of impacts and cessation of all activities |

3. Result and Discussion

Based on field observations, it was found that ammonia gas released due to certain conditions, namely Mechanical Problems at the pump (mainly due to corrosion or the equipment lifetime that cause a leakage); Negligence on the distribution and shipping process of Ammonia; Clogging in Process Equipment that causes a burden to another section, resulting in an inefficiency in urea conversion that caused excess unconverted ammonia released from the stack; and Turn around and plant maintenance that requires to drain the excess material out the equipment. This is supported by Kidam & Hurme study which states that out of 364 total industrial work accidents, the main contributing factors were equipment problems in the piping system (25%), reactors and storage tanks (14%), and process vessels (10%) [9]. Gyenes & Wood has a similar opinion, where the main factor causing industrial workplace accidents is equipment problems which are 30% caused by the ageing equipment [10]. The ageing condition in question is a decrease in conditions and changes in equipment that are used over time [11]. Every equipment in the factory has a lifetime or usage period before experiencing depreciation, which usually ranges from 10 years and above [12]. In addition to equipment problems, a lack of knowledge of written work procedures, personal protective equipment, education, and work experience, work environment conditions and work safety management are also supporting factors for potential accidents in industrial workers [13]. Here are the summarise of each finding and the likelihood scale classification presented in table 4.
Table 4. Summary of Location and the Description of Ammonia Gas Release Cause.

| No | Plant          | Location                          | Causative Description                                                                 | Likelihood (L) | Description        |
|----|----------------|-----------------------------------|---------------------------------------------------------------------------------------|----------------|--------------------|
| 1  | Ammonia        | Ammonia Storage Tank             | Excessive pressure in the tank                                                        | 4              | Minor              |
| 2  | Ammonia        | Ammonia Storage Tank             | Leakage in the pump                                                                   | 2              | Major              |
| 3  | Ammonia        | Ammonia Recovery Unit            | Clogging in the piping system                                                          | 1              | Catastrophic       |
| 4  | Ammonia        | Loading Line Ammonia to the ship  | Spilt ammonia residue in the host after loading to the ship                           | 1              | Catastrophic       |
| 5  | Urea           | Ammonia Pump to Urea Synthesis    | Leakage due to old equipment usage                                                    | 4              | Minor              |
|    |                | Reactor                          |                                                                                        |                |                    |
| 6  | Urea           | Cooling Water Tank               | Accidentally carried ammonia in cooling water during the cooling process              | 4              | Minor              |
| 7  | Urea           | Synthesis, Purification and       | errors in reading the process (ratio of raw materials, pressure, and temperature     | 2              | Major              |
|    |                | Recovery Unit                     |                                                                                        |                |                    |
| 8  | Urea           | Purification and Recovery Unit    | Clogging in one equipment that caused an overburden to another equipment              | 1              | Catastrophic       |
| 9  | Ammonia and    | All Unit                          | Entrapped ammonia in the equipment that released when it was opened or drained during  | 1              | Catastrophic       |
|    | Urea           |                                   | the maintenance                                                                        |                |                    |
| 10 | Ammonia and    | All Unit                          | When the plant is starting up                                                          | 1              | Catastrophic       |
|    | Urea           |                                   |                                                                                        |                |                    |
| 11 | WWTP           | Equalisation Column              | The excess ammonia is carried away from the plant and then evaporates due to contact  | 2              | Major              |
|    |                |                                   | with air                                                                               |                |                    |

From the causative description seen in table 4, it can be analyzed that most of the ammonia release was an accidental case which categorised as catastrophic (occurs at least more than 1 event every year) and major case (more than 1 event each month). This is also stated by the informant that some of the ammonia cases that released in a high concentration, dispersed in the air, reached all the way through the settlement area were accidental which mainly caused by mechanical trouble such as clogging, overburden, and clogging, and caused a negative impact both to the workers and the communities in the affected area. Thus, table 5 presented several cases found involving ammonia exposure in XYZ Fertilizer Factory that impacted on human.

In comparison to table 4, on the case description of accidental contact to ammonia, most of them caused by a "frequently-happened factor" or described as minor in Hazard Identification, ie. Pipe and valve leakage that spilt the ammonia directly towards the victim. Even though there was another case that in Table 4 described as catastrophic (see the case year 2018 in table 5), however, all of the impacted features have some similarities on each victim.
Table 5. Several cases of accidental ammonia release in XYZ fertilizer plant from 2015-2018.

| Year of Case | Location | Case Description | Impacts | Severity Scale (S) |
|--------------|----------|------------------|---------|-------------------|
| 2015 Ammonia pipeline (Urea Plant) | A (Urea Plant Worker), accidentally splashed by liquid ammonia in his face during a draining process in the leakage ammonia pipeline valve | Heavy pain in the outer eyelid, Inability to breath normally, Required a medical attention (2 days hospitalization) | 3 (Moderate) |
| | B (Welder), was exposed to a high concentration of ammonia gas from a leaking pipe during a quality check of welding result on ammonia pipeline | Suffering chemical burn on the neck and thighs, Breathing difficulties, Required a medical attention (> 2 days hospitalization) | 3 (Moderate) |
| 2016 Urea Plant | C (Urea Plant Worker), was exposed to an ammonia gas that suddenly burst from one of the urea valve (due to a leakage) | Swollen eyes, Breathing difficulties, Minor burn (10%) on the cheeks and left arm, Required a medical attention (2 days hospitalization) | 3 (Moderate) |
| Port | D & E (Ammonia Transport Ship Crew); were exposed to a sudden ammonia residue that spilt from the ammonia storage tank hose due to a miscommunication between the field ammonia and control room operator | Breathing difficulties, Burning sensation in eyes, unconscious, A sudden panic attack causing leg injuries | 4 (Minor) |
| 2018 Urea Plant | Communities were exposed to a sudden release of ammonia due to a leakage in urea reactor safety valve during start-up that reached the residential area | Breathing difficulties (particularly infants and women), Eye and nose irritation, Nausea, Asthma (occurring to certain people), Unconcious, Required medical attention (for certain people, 1 day of hospitalization) | 3 (Moderate) |

Based on table 5, it can be seen that the similar features upon the victim of ammonia exposure describe that they have difficulty breathing, severe irritation of the eyes, nose, and throat, and minor burns. However, upon deeper analysis, there were different symptoms suffered by the victim, depending on who the victim was and how high the level of ammonia concentration that they accidentally contacted. Even in the severity scale, most of the cases described as moderate (in which required a medical attention), if we compared the case of urea worker that directly splashed with the community that indirectly affected (the ammonia was released from the source first, dispersed in the air, and reached the community area), both of them inquired almost similar symptoms even though the ammonia concentration on the workers might be higher than in the communities. Thus, it can be inferred that the impact of brief exposure depends on the individual's ability to adapt through the circumstances. This is also shown in Pratiwi et al. where the impact of the ammonia occurs in 5 minutes with a concentration of 20-25 ppm [14]. This is different from Sekizawa&Tsubone and Fedoruk et al., namely disorders in individuals who have not adapted to occur in 10-15 minutes with a concentration of 20-30 ppm [16,17].
Lessengger study states that exposure to ammonia concentrations reaching 32-35 ppm for 5 minutes will have an impact on dryness in the nasal cavity [18]. Thus, it can be inferred that the difference in the description of the symptoms that was felt was different for each individual. This is also in line with the t-test analysis with variable symptoms of disturbances in ammonia and urea plant workers presented in table 6.

Table 6. T-Test Results on the Disorders symptoms experienced by Ammonia and Urea Plant Workers in XYZ Factory.

|                     | Paired Differences | 95% Confidence Interval of the Difference | t  | Df | Sig. (2-tailed) |
|---------------------|--------------------|------------------------------------------|----|----|----------------|
|                     | Mean               | Std. Deviation                           | Std. Error Mean | Lower | Upper |
| Health problems of ammonia workers - Health problems of Urea workers | -2.89 | 5.96 | 0.89 | -4.68 | -1.09 |

Based on the results of the t-test in table 4, the sig value (2-tailed) is obtained 0.002 <0.005. So based on its decision making, it was concluded that there was a significant difference between the health problems experienced by ammonia plant workers and the urea plant. To strengthen the t-test results, the following are the percentage of symptoms experienced by workers which presented in table 7.

Table 7. Symptoms of disturbance experienced by workers when contacted to ammonia.

| No | Symptoms                                      | Percentage of the workers having a disturbance |
|----|-----------------------------------------------|-----------------------------------------------|
|    |                                              | Ammonia unit workers (%)                      |
|    |                                              | Urea unit workers (%)                         |
| 1. | Eye Irritation                                | 31.82                                         |
| 2. | Nasal Irritation                              | 18.18                                         |
| 3. | Dry Throat                                   | 15.91                                         |
| 4. | Nausea                                       | 2.27                                          |
| 5. | Irritations in eyes, nasal, and dry throat   | 11.36                                         |
| 6. | Eye irritation and Dry throat                 | 9.09                                          |
| 7. | Eyes and Nasal Irritations                   | 4.44                                          |
| 8. | Eye irritation and nausea                     | 2.27                                          |
| 9. | Nasal irritation and dry throat               | -                                             |
|10. | Dry throat and nausea                         | 6.67                                          |
|    |                                              | 2.22                                          |

Based on table 7, there are differences in the symptoms experienced by respondents when exposed to free ammonia. The largest percentage is 31.11% (14 of 45 respondents) experienced irritation to the eyes with painful and dry eye characteristics, 17.78% (8 out of 45 respondents) experienced irritation to the nasal with the characteristics of feeling around the cavity when breathing, and 15.56% (7 out of 45 respondents) experienced throat dryness with characteristics of a burning sensation and dryness in the throat. Unlike the ammonia plant workers, the largest percentage of the disturbances experienced by urea plant workers is dry throat by 24.44% (11 out of 45 respondents). About 20% (9 out of 45 respondents) experienced irritation to the nasal, while 17.78% (8 out of 45 respondents) experienced dry eye, nasal, and throat irritation in the same sequence of eye irritation and nasal cavity, then the throat felt burn when trying to breathe. Communities also showed different responses. Based on the results of the questionnaire given to 140 people from 4 different RTs, 85.7% of respondents stated that the first thing felt when exposed to ammonia gas was breathing discomfort, followed by eye irritation (92.9%), difficulty breathing in third place (22.9%), Dry nose and throat irritation ranks fourth (4.29% and
5.71%), and feeling nauseous is fifth (3.57%). Thus, it can be inferred that the impacts of ammonia occur through inhalation, directly cause irritation and respiratory problems [19]. Ammonia gas will be absorbed directly by the eyes, nose, skin, and respiratory tract. However, disturbance reaction would not occur to the respiratory tract to the lungs immediately, unless if the person were exposed to very high concentrations of ammonia. Moreover, most of the experienced disorder symptoms only appeared in the short term. Therefore, a response regarding the potential for a long-term disorder caused by ammonia gas inhalation based on the respondent was conducted and presented in table 8.

| No | Respondent                        | Long-term Health Complaints due to the Ammonia Exposure |
|----|-----------------------------------|--------------------------------------------------------|
|    |                                   | Yes | No          |
| 1  | Ammonia Plant X-IB                | 5   | 17          |
| 2  | Ammonia Plant X-III               | 6   | 17          |
| 3  | Urea Plant X-IB                   | 14  | 9           |
| 4  | Urea Plant X-III                  | 12  | 10          |
|    | **Total**                         | **37** | **53** |

**Workers**

| No | Respondent       | Yes | No |
|----|------------------|-----|----|
| 1  | RT 19 RW 04      | 18  | 17 |
| 2  | RT 16 RW 04      | 16  | 19 |
| 3  | RT 12 RW 04      | 29  | 6  |
| 4  | RT 10 RW 04      | 10  | 25 |
|    | **Total**        | **73** | **67** |

**Communities**

| No | Respondent       | Yes | No |
|----|------------------|-----|----|
|    | **Grand Total**  | **110** | **120** |

Based on Table 8, only 47.83% of the total respondents stated that there were health complaints due to periodic exposure to ammonia. From the 37 workers who experienced health issues, the disorder experienced by ammonia workers was the differences in skin color (9.09%) and sinusitis (45.45%), while the disorder experienced by urea workers was the differences in skin colour (17.86%), 32.14% experience sinusitis and 50% experience changes in breathing patterns. The difference in skin colour in question is chemical burns due to high concentrations of ammonia exposure. Sinusitis, in this case, is under the description in the Brautbar study, namely irritation of the mucous membrane in the nasal region due to exposure to ammonia and changes in breathing patterns according to the Sundblad et al. study are symptoms such as wheeze and asthma [2,20]. Workers exposed to these gases and suffer the health issues need a recovery time of at least 1-4 days a week. The same thing was found in the respondents of the community. Of the 140 total respondents, 73 people (52.14%) complained of symptoms of the disease such as nausea, dizziness, and shortness of breath, while 67 (47.85%) people have no complaints. Based on the percentage of complaints, 94.52% (69 out of 73) respondents stated temporarily, and 5.88% (4 out of 73) respondents stated permanently. The complaints of permanent disruption by community respondents are lung and asthma. However, this cannot be ascertained because of the possibility of other factors (such as the community's lifestyle or hereditary disease records).

4. Conclusion

Ammonia gas release that potentially causes a negative impact was due to a particular condition in the factory, mainly located in ammonia storage tanks, cooling water reservoirs, pumps, and valves. The particular condition occurs due to leakage, clogging, maintenance, and negligence. This event has the potential to release ammonia in higher concentrations than other problems and has the potential to hurt workers to the community. The impacts of ammonia occur in humans through inhalation, directly cause
irritation and respiratory problems, which differs on each person. Ammonia gas will be absorbed directly by the eyes, nose, skin, and respiratory tract to the lungs. However, reactions to the skin and lungs do not occur suddenly, unless exposed to very high concentrations. Ammonia exposure strongly impacts on short-term diseases such as skin discolouration, sinusitis, wheeze and asthma symptoms that last 1-4 weeks, while long-term disease that caused by ammonia still debatable due to a possibility of other factors such as lifestyle and genetic disease records.

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