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Study of Dispersion Hazard Potential of The LPG Stations Around The RDE Site in Rainy and Dry Season

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ABSTRACT

STUDY OF DISPERSION HAZARD POTENTIAL OF THE LPG STATIONS AROUND THE RDE SITE IN RAINY AND DRY SEASON. There are two LPG station (SPPBE) which are the depot of filling, storage and distribution of Liquid Petroleum Gas (LPG) namely PT. BM and PT. ISR which the distance each are 2,995 and 4,141 km from Experimental Power Reactor (RDE) site with capacity 15 and 30 tons. LPG station is a stationary source, which is one aspect of the external human induced events that need to be analyzed in the preparation of site evaluation reports to obtain site permits. Hazard potential that may occur from the depot LPG are fire, explosion and dispersion of hazardous and toxic gas. The release of LPG due to valve leakage which is then dispersed at a certain dose has potentially harmful to health, even death to the population around the RDE site. The purpose of the study was to know the effect of seasons (rainy and dry) to the potential hazard of LPG dispersion from LPG truck tank valve to the around RDE site. The method of study are collection the atmospheric data such as wind direction and speed, temperature and humidity, collection the station LPG characteristic, such as mass of gas, diameter and length of tank, and valve diameter, etc. The atmospheric data was obtained from Pondok Betung Climatology Station, in dry, transition, and rainy seasons, furthermore data was analyzed using ALOHA software version 5.4.5. The results show dispersion from LPG release due to valve leakage from PT. BM and PT. ISR around the RDE site, in the dry season (April), the transition (January and July) as well as the rainy season (October) does not hazardous to the RDE site. Maximum threat zone occurs in dry season at April (wind speed 1.54 m/s), which reaches radius 179 m with airborne LPG concentration 5500 ppm, radius 111 m with concentration 17000 ppm and radius 71 m with concentration 53000 ppm.

ABSTRAK

STUDI POTENSI BAHAYA DISPERSI DARI STASIUN LPG DI SEKITAR TAPAK RDE PADA MUSIM HUJAN DAN KEMARAU. Terdapat dua stasiun LPG (SPPBE) yang merupakan depo pengisian, penyimpanan dan distribusi *Liquid Petroleum Gas* (LPG) yaitu PT. BM dan PT. ISR yang jaraknya dari tapak RDE (Reaktor Daya Eksperimental), masing-masing 2.995 dan 4.141 km, dengan kapasitas masing-masing 15 dan 30 ton. Depo LPG adalah sumber stasioner, yang merupakan salah satu aspek kejadian eksternal akibat ulah manusia yang perlu dianalisis dalam penyusunan laporan evaluasi tapak untuk mendapatkan izin tapak. Potensi bahaya yang dapat terjadi dari depo LPG adalah kebakaran, ledakan dan dispersi lepasan gas berbahaya dan beracun. Lepasan LPG karena kebocoran katup yang kemudian terdispersi, pada dosis tertentu mempunyai potensi yang membahayakan kesehatan, bahkan kematian pada populasi di sekitar tapak RDE. Tujuan penelitian adalah mengetahui pengaruh musim (hujan dan kemarau) terhadap potensi bahaya dispersi lepasan LPG dari tangki truk LPG ke sekitar tapak RDE. Metode penelitian meliputi pengumpulan data atmosferik seperti arah angin dan kecepatan angin, temperatur dan kelembaban, serta data karakteristik depo LPG, seperti massa gas, diameter dan panjang tangki, diameter katup, dll. Data atmosferik pada musim hujan, transisi dan kemarau diperoleh dari stasiun klimatologi Pondok Betung. Selanjutnya dilakukan analisis menggunakan software ALOHA versi 5.4.5. Hasil penelitian menunjukkan bahwa dispersi dari lepasan LPG akibat kebocoran katup dari PT. BM dan PT. ISR di sekitar tapak RDE, di musim kemarau (April), transisi (Januari dan Juli) serta musim hujan (Oktober) tidak membahayakan tapak RDE. Maksimum zona ancaman terjadi pada musim kemarau di bulan April (kecepatan angin 1,54 m/s), yang mencapai radius 179 m dengan konsentrasi LPG di udara 5500 ppm, radius 111 m dengan konsentrasi 17000 ppm dan radius 71 m dengan konsentrasi 53000 ppm.
Kata kunci: LPG, tapak RDE, potensi bahaya, dispersi, musim hujan dan kemarau

1. INTRODUCTION

Fires, explosions and toxicities are the three potential hazards of LPG station (gas filling, storage and distribution). The problem is at a distance of about 3-4 km from the LPG

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station is planned to be built RDE by the National Nuclear Energy Agency (BATAN). One of the requirements for obtaining a nuclear reactor site permit is the site evaluation data for human induced event aspects.

External events caused by human activities are one factor that can affect the determination of the site candidates for Nuclear Power Plant among other RDE. This is because either directly or indirectly, facilities and human activities on around the area where nuclear installations are built, under certain conditions may affect the safety of nuclear installation.

LPG station is an industrial plant which is one of human facilities and activities. In LPG station, there are devices and pieces of equipment used, such as e.g. gauges, valves, pumps, compressors, storage vessels, etc. Each piece of equipment used in a process line of LPG station has the potential to leak, especially if service routines are not maintained. Each joint or connection point can also be a potential source of release, which can develops into a major hazard[1]. Therefore, the IAEA makes Safety Standards Series No. NS-G-3.1, which is a guideline for site evaluation, so that potential sources of external human induced events for nuclear installations should be identified and some of the possibilities that produce hazard phenomena must be evaluated[2].

LPG station can be act as a source of external events against nuclear installations, as they store and distribute hazardous and toxic chemicals. The previous research stated that in the site vicinity (less than 5 km from the RDE site) there is a LPG station that is suspected to have a potential hazards[3]. The potential hazards from LPG stations other than explosions and fires, is the release of hazardous and toxic fluids. Analysis of the potential for explosion hazard from LPG station on around the site RDE has been done, and it is known that in case of leakage 2.5 inch[4].

In depot filling, storage and distribution of fuel gas, the tank truck will refuel LPG (Liquefied Petroleum Gas) in the tubes and distribute the tubes to the distributor. LPG is gaseous at atmospheric pressure, but LPG is marketed in liquid form in pressurized metal tubes because the volume in liquid form is less than in the form of gas for the same weight. The LPG tube is also not fully charged, only about 80-85% of its capacity, due to the possibility of thermal expansion[5].

LPG is a mixture of various hydrocarbon elements, especially propane and butane, and small amounts of propylene, butylene and other hydrocarbons, depending on the source[6]. LPG is produced from natural gas extraction or oil refining, and which is produced from oil refineries containing unsaturated hydrocarbons (propylene and butylene). Market statistics show that 75% of LPG comes from natural gas and 25% of the oil refining process[7]. In addition, the content of LPG also depends on the purification process unit, the operating conditions of the process[8], use and weather. Countries with relatively cold climates tend to use a high percentage of propane, but countries with warmer climates use a high percentage of butane. For example, Italy uses the percentage of propane-butane (25-75% volume), France (35-65% Volume) and Germany (90-10% by volume)[9]. While in Indonesia, based on the LPG specification issued by the Directorate General of Oil and Gas. No. 26525.k /10/DJM.T/2009, the composition of LPG products containing at least 97% of the mixture of propane (C_3H_8) and butane (C_4H_{10}) and a maximum of 2% is a mixture of pentane (C_5H_{12}) and heavier hydrocarbons[10]. LPG used as fuel in Indonesia, has a composition ratio of propane: Butane is 30:70[11]. The mercaptan is usually added to the LPG to give a distinctive odor, so leaks can be detected quickly.

LPG has a low boiling point, when released to the environment will evaporate quickly and will quickly dispersed into the atmosphere, resulting in potential exposure to the population and the environment. Liquid LPG, if vaporized to form gas with a volume of 250 times and LPG vapor is heavier than air [12]. The vapor can flow near the soil surface and down to the lowest level of the environment. In the still air, the vapor will spread slowly.

Leak of fuel tanker truck is one of hazards which are likely to occur. The potential hazard of release of LPG gas dispersed into the atmosphere, can lead to health problems to workers and visitors around the depot area, because they inhale air-mixed hydrocarbons. The release of LPG gas can also lead to greenhouse gas emissions[13]. This research aims to determine the potential hazards to RDE site from LPG release which then dispersed in air at the dry and rainy seasons.

The rainy season is a condition when an area has a lot of rain, with average rainfall in a month can reach 150 mm or more[14]. The dry season is a condition when an area does not receive rain, but if it receives rain, the average amount of rainfall is less than 150 mm per month. Among the rainy and dry seasons there is an intermediate season, which is the period of transition from the rainy season to the dry season or vice versa. In the transition season, weather conditions have not stabilized, air temperature, wind direction, or irregular rainfall. When the hot air, suddenly there can be heavy rain.

The potential hazards to RDE site are seen from the range distance of the threat zone from the source and value (airborne concentration) of the threat zone. The method used in the study is the collection of primary and secondary data which is then analyzed using ALOHA software version 5.4.5.

2. THEORY

LPG (Liquefied Petroleum Gas) is a clean fuel fluid that has many uses namely in the chemical industry, household needs, transportation and other economic sectors[15]. LPG used for household necessities as a fuel fluid is a mixed-type LPG, whose main components are propane and butane. LPG is a highly flammable, odorless, pure, colorless, non-corrosive liquid, which can cause some hazard when released to the atmosphere, although in the process important parameters have been determined to ensure safety. The release of LPG gas which is then dispersed, which is inhaled and contact with the eyes or skin can have health effects. The dispersion of the gas release among other is affected by the wind speed.

LPG can cause frostbite and irritation if contact with eyes or skin. Exposure to high amounts of LPG in the environment, can reduce the amount of oxygen in the air, causing weakness in humans around with symptoms of headache, dizziness, nausea and vomiting[16]. Minimum oxygen levels in air are 19.5% by volume. Larger gas exposures can also cause shortness of breath, supress central nervous system function, brain damage, hallucinations, unconsciousness and liver failure or death[17]. Long-term gas exposure can cause thirst, lethargy, fatigue, weight loss, central nervous system damage, nosebleeds, rhinitis, halitosis, ulceration of the mouth and nose, conjunctivitis, anorexia[18]. Publications in 1996 and 2004 also reported the occurrence of sudden deaths due to LPG inhalation, which shows that the liver and kidneys were among the major organs where high concentrations of LPG accumulated[16]. Two mechanisms to be considered for death after LPG inhalation are asphyxia and depress central nervous system[19]. Levels of creatinine and uric acid from workers exposed to LPG will be significantly higher. LPG can cause increased red blood cells, haemoglobin and platelet counts on people who are exposed, based on the national library of medicine. Exposure can cause the value of liver function increases[20].

According to The National Standardization Agency (BSN), the LPG threshold value in the air at workplace for 8 per day working hours is 1000 ppm[21]. This is also confirmed by The New Jersey Public Employees Occupational Safety and Health Act (PEOSHA) and The American Conference of Governmental Industrial Hygienists (ACGIH), which has established workplace health and safety standards, that the limit of exposure for LPG allowed in the air averaged 1000 ppm for 8 hours of work[22].

To identify and interpret the toxicology of hazardous chemicals has been established Acute Exposure Guideline Levels (AEGL). AEGL identification is one method to help protect the surrounding community when hazardous chemicals are released within a certain perode. AEGL represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes to 8 hours, are developed for five exposure periods (10 and

30 minutes, 1 hour, 4 hours, and 8 hours)[23]. The severity of toxic effects due to exposure is divided into three levels of AEGL i.e. AEGL-1, AEGL-2 and AEGL-3.

AEGL-1 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration (expressed as ppm or mg/m) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.

AEGL-3 is the airborne concentration (expressed as ppm or mg/m) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

ALOHA (Areal Locations of Hazardous Atmospheres) software version 5.4.5 is a computer program, designed for modeling chemical release/spills, for emergency response and planning due to chemical release/spillage by assessing the risks to the surrounding human populations related to the hazard of toxic air, heat radiation from fires and the effects of explosives[24,25]. In this research, ALOHA is used for analyzing the LPG dispersion. A threat zone is the area within which ALOHA predicts the hazard level to exceed level of concern (LOC) at some time after a release begins, with a 60-minute exposure duration as the default toxic LOCs. A Level of Concern (LOC) is a threshold value of a hazard (in this study is toxicity); the LOC is usually the value above which a threat to people may exist.

In this research we will discuss potential hazards to RDE site from LPG release which then dispersed in the dry and rainy seasons, where wind speeds in both seasons are different.

3. METHODOLOGY

The method used in this research is secondary data collection, primary data retrieval and analysis. The primary data from two LPG stations, namely PT BMU and PT ISR is located near RDE site (radius ± 5 km), Puspiptek Serpong, in South Tangerang, Indonesia. Analysis of LPG dispersion by simulation using ALOHA software version 5.4.5, July 2015 using data input i.e. coordinates and elevation of LPG station location, atmospheric data (wind direction and speed, temperature, humidity) and source data (mass of gas), diameter and length of tank, and valve diameter. The atmospheric data (2016 year), i.e., wind direction and speed, temperature, humidity are obtained from Climatology Station of Pondok Betung, South Tangerang. The Climatology Station of Pondok Betung is a regional zone in the meteorological hazard analysis. Data of wind speed, wind direction and humidity are in accordance with the conditions of temperature at the time of data collection. Case studies were taken meteorological conditions one day with maximum temperature and are an extreme condition in January, April, July and October. In Indonesia, April in 2016 is the dry season, January and July is the transition season, and October is the rainy season. The atmospheric data shown in Tables 1 while the location and source data (mass of gas), diameter and length of tank, valve diameter shown in Table 2. In this research used LPG scenario containing 100% butane.

Table 1. Atmospheric Data from Pondok Betung Station in 2016[26,27,28]

Month	Wind Speed (m/sec)	Wind Direction (°)	Max. Temp (°C)	Humidity (%)
January (transition season)	2,57	270	34.8	80
April (dry season)	1,54	260	34	84
July (transition season)	2,06	240	33.4	82
October (rainy season)	9,77	250	24	75

Table 2. Location and Source Data[29]

Parameter	PT BM	PT ISR
Location:		
- Coordinates	6°20'03.99"S 106°40'27.47"E	6°45'45.82"S 106°41'03.71"E
- Elevation (masl)	52	56
Source data:		
- mass in tank (kg)	15 000	30 000
- Tank diameter (mm)	2 140	2 890
- Tank length (mm)	10 020	11 070
- Valve diameter (inch)	3	3

4. RESULTS AND DISCUSSION

LPG station is stationary source type. Stationary sources are the source which the location of the initiating mechanism (explosion centre, point of release of explosive or toxic gases) is fixed[2]. On screening stage, if the source of the hazardous fluid is within a distance of more than 5 km from the site then it is not necessary to analyze. This is because if there is release of the hazardous fluid at a distance of more than 5 km, the air will reduce and disperse the gas to a tolerable extent before reaching the site. Based on the confirmation in the field, it is found two depots LPG station with the distance to RDE site respectively 2,995 and 4,141 km, so it is necessary to analyze the its potential hazard.

The release of gas from LPG tank owned by PT. ISR and PT. BM comes from a skid tank. The leakage scenario is from the valve in the horizontal cylinder tank. Although LPG is a flammable chemical, but in this study, LPG only escaping from tanks (not burning). The LPG is released from the valve will vaporize and then disperse in an open environment escaped as a mixture of gas and aerosol (two phase flow). Aerosols are small droplets in the air move freely. Seen in Table 1, the wind direction of the transition season, the dry season or the rainy season is almost the same, but the humidity and temperature, in the rainy season is very different.

Result of calculation by using ALOHA obtained the range distance and airborne concentration of LPG release from PT. BM (case study in January-October), shown in Figure 1-4.

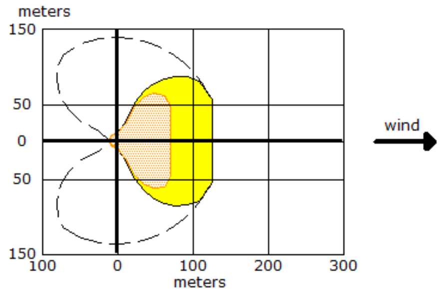

Figure 1. The Range Distance and Airborne Concentration of LPG Release of PT. BM in Transition Season (January 2016).

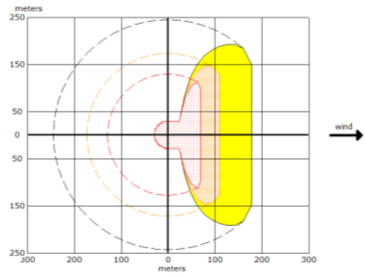

Figure 2. The Range Distance and Airborne Concentration of LPG Release of PT. BM in Dry Season (April 2016).

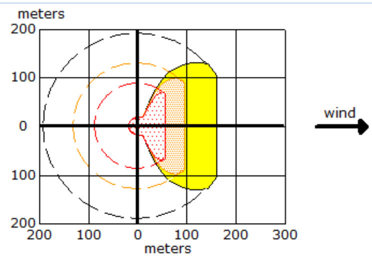

Figure 3. The Range Distance and Airborne Concentration of LPG Release of PT. BM in Transition Season (July 2016).

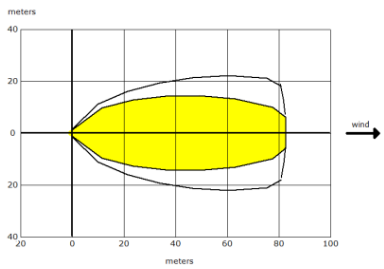

Figure 4. The Range Distance and Airborne Concentration of LPG Release of PT. BM in Rainy Season (October 2016).

Explanation :

greater than 53000 ppm (AEGL-3 [60 min])
greater than 17000 ppm (AEGL-2 [60 min])
greater than 5500 ppm (AEGL-1 [60 min])
wind direction confidence lines

While the range distance and airborne concentration of LPG release from PT. ISR is shown in Figure 5-8.

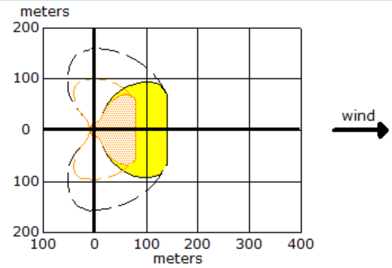

Figure 5. The Range Distance and Airborne Concentration of LPG Release of PT. ISR in Transition Season (January 2016).

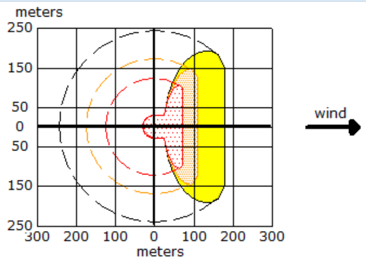

Figure 6. The Range Distance and Airborne Concentration of LPG Release of PT. ISR in Dry Season (April 2016).

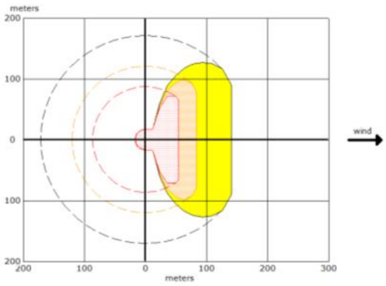

Figure 7. The Range Distance and Airborne Concentration of LPG Release of PT. ISR in Transition Season (July 2016).

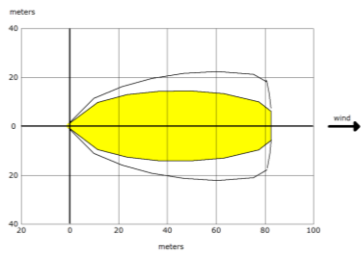

Figure 8. The Range Distance and Airborne Concentration of LPG Release of PT. ISR in Rainy Season (October 2016).

The value of AEGL-1, AEGL-2, and AEGL-3 are the forecast of the threat zone where yellow, orange, and red zones indicate predicted areas exposed after the release of the chemicals. The first tier (AEGL-1) shown in the yellow zone is a mild threshold effect, the second tier indicated by the orange zone (AEGL-2) is an escape-impairment threshold, and the third tier with red zone (AEGL-3) is a life-threatening threshold effect. The red threat zone shows the worst hazard. In Figure1-8, it is seen that the highest concentration release that could experience life-threatening health effects or death (red zone) is 53000 ppm. While the amount of airborne concentration that could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape is 17000 ppm (orange zone). At airborne concentration 5500 ppm (yellow zone) could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects.

Distance of toxicity threat zone from source PT. ISR and PT. BM in dry, transition and rainy season are shown in Table 3.

Table 3. Distance of Threat Zone from LPG Dispersion in Dry and Rainy Season of PT. ISR & PT. BM

Source	Season	Dispersion Zone		
		Red	Orange	Yellow
PT. ISR	Transition season in January	46 m	80 m	142 m
	Dry season in April	71 m	111 m	179 m
	Transition season in July	54 m	83 m	141 m
	Rainy season in October	21 m	41 m	83 m
PT. BM	Transitionseason in January	42 m	71 m	126 m
	Dry season in April	71 m	111 m	179 m
	Transition season in July	57 m	95 m	161 m
	Rainy season in October	21 m	41 m	83 m

Table 3 show that at PT. ISR and PT. BM, during the rainy season in October, where wind speed is higher (9.77 m/sec) than the transition period (January and July) and the dry season (April), the distance from the threat zone is the lowest covering 83 m for LPG concentration in air 5500 pm (yellow zone), 41 m for concentration 17000 ppm (orange zone) and 21 m for concentration

53000 ppm (red zone). The higher the wind speed, the distance from the toxicity threat zone is shorter, either for threat zone red, orange or yellow. This is because high wind speeds increase dispersion[30], so the spread of toxicity does not go further. At lower wind speeds, the mixing speed of pollutant clouds with the surrounding air is also lower, so the distance of the LPG threat zone is further away. However in addition to wind speed, temperature and humidity also affect the dispersion. Low humidity means the amount of moisture contained in the air is low, so it becomes one of the causes of dispersion to become faster because the air can move without being inhibited by water vapor. Higher air temperatures cause lower air densities, thus increasing the flow of gas convection, so the distance of the threat zone is lower[30].

The RDE site is at a distance of 2.995 km from PT. BM and 4.141 km from PT. ISR. The maximum distance of the threat zone from PT. ISR and PT. BM is occurs in dry season at April (wind speed 1.54 m/s), which reaches 179 m with airborne LPG concentration 5500 ppm, at 111 m with concentration 17000 ppm and 71 m with concentration 53000 ppm. During the dry, transition and rainy season, the RDE site is categorized as safe from potential hazard of LPG dispersion from PT. ISR and PT BM. This is because the maximum distance of the threat zone is only reaches 179 m, it lower of distance PT. BM and PT ISR to RDE site.

The study of both LPG depots with a capacity of 15-30 tons and a distance of about 3-4 km from the RDE site shows the threat zone distance of airborne LPG concentration that is not much different. This is because based on modeling with ALOHA software the Max Average Sustained Release Rate of two LPG depots equal reach 662 kilograms/min.

5. CONCLUSION

LPG dispersion from gas release due to valve leakage from PT. BM and PT. ISR in the dry season (April), transition season (January and July) and rainy season (October) are categorized as not hazardous to RDE site. This is because the maximum distance of the threat zone is only reaches 179 m, it lower of distance PT. BM and PT ISR to RDE site, respectively 2,995 and 4,141 km.

Maximum threat zone occurs in dry season at April (wind speed 1.54 m/s), which reaches 179 m with airborne LPG concentration 5500 ppm, at 111 m with concentration 17000 ppm and 71 m with concentration 53000 ppm. The higher the wind speed (9.77 m/sec) in rainy season, the distance from the toxicity threat zone is shorter, the distance from the threat zone is the lowest covering 83 m for airborne LPG concentration 5500 pm. This is because high wind speeds increase dispersion, so the spread of toxicity does not go further.

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REFERENCES

[1]. Drager, "Gas Dispersion", Drager Safety AG & Co. KGaA, Germany, www.draeger.com, access July 2017.

[2]. IAEA, "External Human Induced Events In Site Evaluation For Nuclear Power Plants", IAEA NS-G-3.1, Vienna, 2002.

[3]. June Mellawati, Siti Alimah, "The Potential Hazards of Human Activity Around The Nuclear Plant Site: Case Study of Nuclear Plant Site at Puspiptek Serpong", Conference Proceedings; Enhancing Quality of Life Through Human Well Being and Environmental Sustainability In Social Science. September 12-14, 2017, Bogor City, Indonesia. Bogor International Conference for Social Science. Djuanda University, Bogor. 2017.

[4]. Siti Alimah, Dedy Priambodo, June Mellawati, "Analisis Potensi Bahaya Ledakan SPPBE di Sekitar Calon Tapak RDE", Majalah Ilmiah Pengkajian Industri BPPT, Vol. 11 No. 1, April, 2017.

[5]. L. Rosmayati, "Kajian Komposisi Hidrokarbon dan Sifat Fisika-Kimia LPG untuk Rumah Tangga, Lembaran Publikasi Minyak dan Gas Bumi", Lembaran Publikasi Minyak dan Gas, Vol. 46. No.2, Agustus, 2012.

[6]. New Jersey Department of Health, "Righ to Know Hazardous Substance Fact Sheet Liquefied Petroleum Gas", May, 2010.

[7]. M.S.B. Ishak, "Secermination of Explosion Parameter of LPG-Air Mixtures in The Closed Vessel", A Thesis Submitted in Fulfillment of the

Requirements for The Awards of The Degree of Bachelor of Chemical Engineering (Gas Technology), University Malaysia Pahang, November, 2008.

[8]. The Minister of The Environment and Health Canada, "Liquefied Petroleum Gases", Draft Screening Assessment Petroleum Sector Stream Approach. October, 2014.

[9]. M. Masi, "Experimental Analysis on a Spark Ignition Petrol Engine Fuelled With LPG (Liquefied Petroleum Gas)", Journal Energy, 21 June, 2011.

[10]. Tribunnews, Jakarta, Pertamina Rilis Spesifikasi dan Komposisi LPG, Jumat, 1 Oktober 2010, http://www. tribunnews. com/bisnis/2010/10/01/perta mina-rilis-spesifikasi-dan-komposisi-lpg?page=1, accessed June 2016.

[11]. D. Sartika K., "Analisis Konsekuensi Dispersi Gas, Kebakaran dan Ledakan Akibat Kebocoran Tabung LPG 12 Kg Di Kelurahan Manggarai Selatan Tahun 2012 Dengan Menggunakan Breeze Incident Analyst Software", Skripsi Fakultas Kesehatan Masyarakat, UI, Jakarta, Juni, 2012.

[12]. Ministry of ESDM, "Study of Gas Substitution with Other Energy in The Industrial Sector", Center of Data and Technology for Information of Energy and Mineral Resources, Ministry of Energy and Mineral Resources, 2013.

[13]. Siddiqui, NA., "Study of Release of Hydrocarbon in The Atmosphere While LPG and Propane Tankers Loading and Its Occupational Health Effects", International Journal of Scientific & Technology Research Volume 1, Issue 11, December 2012.

[14]. Afriyas Ulfah, Widada Sulistya, "Penentuan Kriteria Awal Musim Alternatif di Wilayah Jawa Timur", Artikel Kedeputian Bidang Klimatologi BMKG. Desember 2015

[15]. Bariha, N., et.al., "Fire and Explosion Hazard Analysis During Surface Transport of LPG", A Case Study of LPG Truck Tanker Accident In Kannur, Kerala, India, Journal of Loss Prevention in The Process Industries, 25 January. 2016.

[16]. Sirdah, M.M, et.al., "Possible Health Effects of Liquefied Petroleum Gas on Workers at Filling and Distribution Stations of Gaza Governorates", Eastern Mediterranean Health Journal, March, 2013.

[17]. US. Department of Health and Human Services, "Occupational Health Guideline for LPG", Public Health Service Centers for Disease Control National Institute for Occupational Safety And Health, September, 1978.

[18]. Broussard L.A., "Inhalant : Classification and Abuse, Levine B., Ed. Principles of Forensic Toxicology", Washington DC, 1999.

[19]. Fukunaga, T., et.al., "Liquefied Petroleum Gas (LPG) Poisoning", Forensic Science International, 82, 1996.

[20]. _____, What are The Health Effect of Liquefied Petroleum Gas?, https://www. reference.com/science/health-effects-liquefied-petroleum-gas-1d50970b3853 ccf#, access 27 February 2017.

[21]. National Standardization Body, "Threshold Value (NAB) Chemical In Air Workplace", Indonesian National Standard, SNI 19-0232-2005, 6 November, 2003.

[22]. New Jersey Department of Health, Righ to Know Hazardous Substance Fact Sheet Liquefied Petroleum Gas, May, 2010.

[23]. _______, "N-Butane Interim Acute Exposure Guideline Levels", NAS/COT Subcommittee for AEGLS, 2009.

[24]. Jone, R., et.al., "ALOHA (Aloha Locations of Hazardous Atmospheres) 5.4.4", Technical Documentation, Washington, November (2013).

[25]. NOAA'S National Ocean Service, "ALOHA", Office of Response and Restoration, US. Department of Commmerce, July, 2015.

[26]. BMKG, "Data Iklim Harian", Station Klimatologi Pondok Betung, 2016.

[27]. BMKG, "Prakiraan Musim Hujan Tahun 2016/2017 di Indonesia", Badan Meteorogi, Klimatologi, dan Geofisika, 2016.

[28]. BMKG, "Rapat Pembahasan Prakiraan Musim Kemarau Tahun 2016", http://www.bmkg.go.id/berita/?p=rapat-pembahasan-prakiraan-musim-kemarau-tahun-2016&lang=id, 10 Feb 2016, diakses 30 Januari 2018.

[29]. PKSEN, "Laporan Evaluasi Tapak RDE Revision 0", BATAN- PKSEN, 2015.

[30]. ANTHIKA, dkk., "Pengaruh Suhu, Kelembaban Udara dan Kecepatan Angin Terhadap Akumulasi Nitrogen Monooksida dan Nitrogen Dioksida", Karya Ilmiah Jurusan Fisika, Fakultas MIPA, Universitas Riau 2014.