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RESEARCH ARTICLE

# Utilization of Remote Sensing and Geographic Information System to Identify Buffer Zones Area at Plumpang Fuel Depot

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**Abstract**. Plumpang is a national vital object surrounded by residential areas in its vicinity. This study aims to identify buffer zones at the Pertamina Plumpang BBM Depot. The method used in this research is Spatio Temporal Analysis with secondary data from the land-use map of Jakarta, Google Earth imagery from 2002 to 2022, and Landsat 4 imagery from 1990. The results show that at distances of 50 meters, 50-100 meters, and 100-250 meters, there are 503, 870, and 2554 buildings, respectively. Furthermore, these buildings are predominantly very dense residential areas. Due to the highly concentrated population and the proximity to the depot, the area faces a high risk of fire disasters given the flammable nature of the fuel. The proximity of the settlement to the fuel depot has a direct correlation with the heightened risk of a fire disaster. The buffer zone distance used in the range of 50 - 100 meters to ensure the safety of the population from potential fire disasters. The designated buffer zone can be effectively transformed into a hydrological flow or water channel serving as a separator and barrier between the fuel depot and residential areas.



## 1. Introduction

Disaster events have the potential to occur in any location and can be caused by natural hazards or human activities (Setiawan et al., 2020). Fire is one of the potential disasters that can occurs anytime, anywhere and cannot be predicted (Cvetkovi et al., 2022; Setiawan et al., 2020; Sutrisno et al., 2021). Fire is considered one of the most dangerous and destructive disasters due to its deadly impact, causing significant losses, extensive damage, severe environmental pollution, large economic losses and even casualties (Chaiklieng et al., 2020; Setiawan et al., 2020; Winandari et al., 2021; Zhou et al., 2016). Exposure to combustion pollutants is known to have the potential to cause short or long-term adverse health effects (Abdulsalam et al., 2016; Hoek et al., 2007). Fires can be attributed to various factors that contribute to their initiation and occurrence. Some of these factors include unstable stove, highly volatile fuels, damaged cables, electrical short circuits, and the combustion of flammable building materials (Twigg et al., 2017).

Petroleum, as a primary resource, holds immense importance in society and is widely recognized as one of the fundamental cornerstones for sustainable development (Ibrahim et al., 2019). Fuel, as another form of petroleum, plays a crucial role in various transportation industries, making it a crucial component to support mobility and economic activities. Oil or fuel depots have a lot of flammable petroleum products that can be potential causes of fires (Chaiklieng et al., 2020; Zavareh et al., 2022). The combination of fuel with the air has the potential to ignite and create a significant conflagration or explosion incident (Hoek et al., 2007; Zhou et al., 2016). Over the past decade, the world has consistently witnessed fires occurring in almost every country and has caused more than 300,000 deaths (Chang & Lin, 2006; Iglesias et al., 2022; L. Li & Dai, 2021; Thomas, 2018; Twigg et al., 2017; Zhou et al., 2016). There are several cases of catastrophic fires have occurred at fuel industry sites, such as the Buencefield Fuel Storage Depot (Unitied Kingdom), The Bayamon Storage Oil Facility (Puerto Rico, United States), and The Indian Oil Corporation Ltd (India) (Batista-Abreu & Godoy, 2013; Sharma et al., 2013; Thomas, 2018; Zhou et al., 2016).

The Buncefield oil depot experienced a catastrophic explosion on December 2005, accompanied by an extensive fire with more than 20 storage tanks were incinerated, leading to an inferno that raged for multiple days, Causing widespread devastation across the fuel storage site, included a significant office block, industrial and residential properties within 100 meters from the location (Atkinson, 2017; Hoek et al., 2007; Nicholas & Whitfield, 2013; Thomas, 2018). Nobody was killed but, over 40 people were injured and there was extensive property damage (Nicholas et al., 2013). In Another Case, The Bayamon Storage Oil Facility in Puerto Rico and The Indian Oil Corporation Ltd in Jaipur experienced a fire in October 2009 (Batista-Abreu & Godoy, 2013; Shristi Vidusha et al., 2018). A total of 21 fuel storage tanks in Bayamon, Puerto Rico, exploded and caught fire, with flames reaching of 30 meters. This incident caused significant damage to 50% of the storage facility area, the surrounding environment, residential homes, and resulted in substantial economic losses (Batista-Abreu & Godoy, 2013; Zhou et al., 2016). Indian Oil Corporation Ltd, located in Jaipur, India, faced a fire initiated by pipe malfunctions in the fuel delivery pipeline, led to 12 fatalities and injuries to 300 others. The fire engulfed all easily combustible materials, causing damage to facilities, including the administrative building, fire station, and emergency station, for over a week. Minor effects were also observed within a 2 km radius of the facility (Sharma et al., 2013; Shristi Vidusha et al., 2018; Zhou et al., 2016).

Indonesia has experienced numerous fire disasters, one of which occurred in the fuel and oil industry. Fires have occurred at the Balongan Oil Refinery, Cilacap Oil Refinery, Balikpapan Oil Refinery, Pertamina Dumai Oil Refinery, BBM Distribution Pipeline in Pertamina Cimahi, and the most recent incident at the Pertamina Plumpang Fuel Depot, located in Tanah Merah, Koja sub-district, North Jakarta. The fire at the Pertamina Plumpang Fuel Depot resulted in the tragic loss of 33 lives, with 11 people sustaining injuries and 639 people have been evacuated. In addition to the fire incident that occurred in 2023, the Pertamina Plumpang Depot experienced a fire in 2009, which, fortunately, resulted in only one fatality.

The Pertamina Plumpang Fuel Depot is classified as a National Vital Object in the Energy Sector and Mineral Resources of Indonesia that play a critical role due to their significant impact on the lives of many people, national interests, and strategic sources of state income within the energy and mineral resources sector. As one of the vital objects, the Pertamina Plumpang Fuel Depot should be located far from residential areas. Population dynamics exert a notable influence on societal growth, and consequently becomes palpable over time. One significant outcome of population dynamics is the alteration in land use patterns (Putri et al., 2019). The high number of residential areas around the Pertamina Plumpang Depot can be attributed to the increasing demand for residential area however, the available land is limited. Population growth indirectly increases the demand for the number of locations to be used for residential areas (Zhang, 2020). The conversion of land into residential areas signifies a surge in population, which contributes to a higher density within an area (Sagala et al., 2016; Setiawan et al., 2020).

Area with high population density increases the difficulty of fire prevention and safety management (Zhang, 2020). The high density of buildings coupled with the inadequate provision of fire hydrants and water supplies further complicates fire management. These conditions facilitate the rapid spread and escalation of fires, making them more challenging to control (Twigg et al., 2017). Therefore, when a given location possesses these determining factors, it is likely to manifest as an area susceptible to fire-related disaster. Fire disaster management is a process, method, action, or effort made in dealing with fire and overcoming the level of difficulty of control that can paralyze community activities and casualties(Atkinson, 2017; Turner et al., 2022). Fire safety is primarily concerned with the prevention and mitigation of fire, as well as smoke propagation and effective extinguishment (Cvetkovi et al., 2022). One of the security or preventive measures is to make a distance between national vital objects and residential areas.

A buffer or protective zone is an area used as a barrier or separation between one region and another (Hamatuli & Muchanga, 2021; Herbert & Butsic, 2022; Kurnianti et al., 2015; Ornai et al., 2020; Rasel et al., 2015), The geographic information system had the ability to process and analyze data spatially (Al-Dousari et al., 2023; Chhetri & Kayastha, 2015; H. Li & Huang, 2021; Setiawan et al., 2020). The geographic information system can be used to obtain data on the description of the location of the study carried out with image interpretation techniques, were used to obtain an idea the location of fire and the surrounding location (Setiawan et al., 2020). Based on the background of the problem exPlained, this study aims to identify buffer zones area between the Fuel Depot and residential areas.

## 2. Methods

This study is located at the Pertamina Plumpang Fuel Depot, Tanah Merah, Koja District, North Jakarta which has

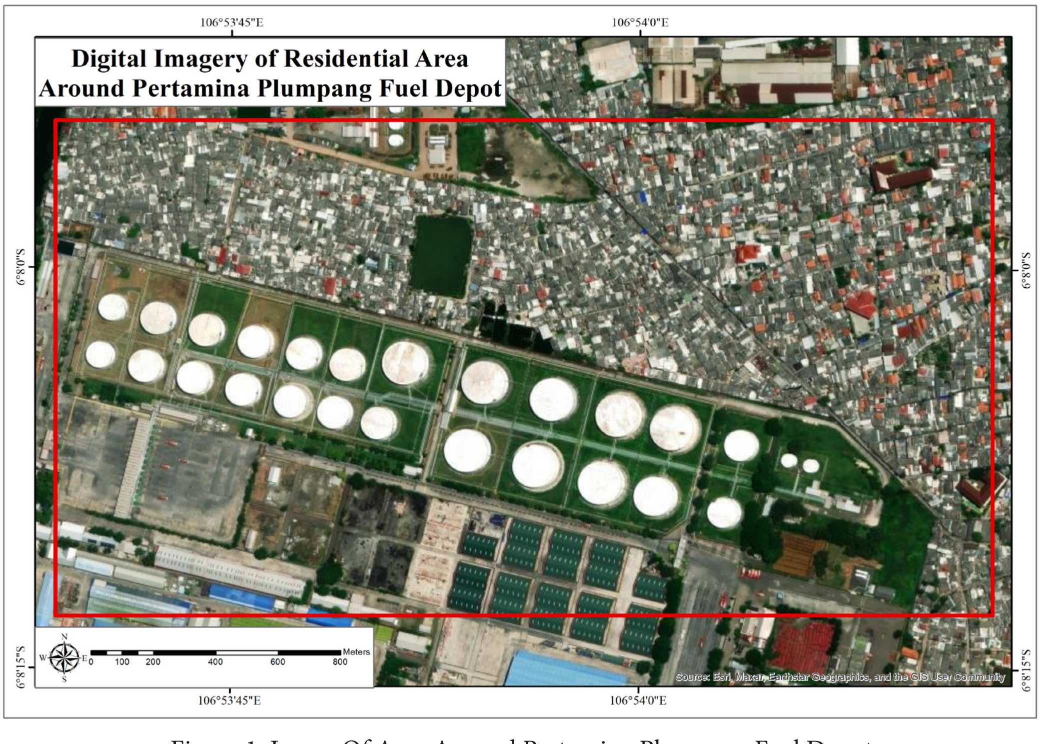


Figure 1. Image Of Area Around Pertamina Plumpang Fuel Depot

a Fuel Depot Area of 483920 square meters. The method used was Spatio Temporal Analysis. The data collection process was carried out through secondary data from the websites of relevant providers, namely the Jakartasatu.go.id, Google Earth Imagery of 2002 – 2022, Landsat 4 Imagery of 1990 from USGS. The data obtained through the website were building data and land use of Pertamina Plumpang Fuel Depot, and the data from Google Earth and Landsat 4 was the Imagery of Plumpang Fuel Depot in 1990 – 2022 (Figure 1) . Data analysis and interpretation of Landsat 4 and Google Earth imagery are performed using Geographic Information System (GIS) software because it can process and analyze data spatially (Setiawan et al., 2020). The data processing begins with buffering building and landuse data of Plumpang Fuel Depot. The land use data were used to obtain the distance between buildings in the vicinity of the depot and to identify areas that should be designated as buffer zones. The indicators to be used in determining buffering parameters refer to the (Singapore Civil Defence Force SCDF, 2012) guidelines. The anthropogenic buffer zones contained in Zambian Law No. 1 of 2000, concerning buffer zones, are 50 meters (Hamatuli et al., 2021), and (Chhetri et al., 2015) which increase the buffer zone of oil service station or fuel depot to 100 m and above 100 meters. Areas with distances up to 50 meters are characterized by high vulnerability levels, distances up to 100 meters exhibit moderate vulnerability levels, and distances exceeding 100 meters indicate low vulnerability levels.

## 3. Result and Discussion

Buffer zone can be used as a barrier or separation object between Pertamina Plumpang Fuel Depot and another land use such as residential area. Buffer zone can be concerned to prevention and mitigation of fire disaster (Herbert & Butsic, 2022; Ornai et al., 2020). The results of data processing using the analysis at the Pertamina Plumpang Fuel Depot, buffer zone can be classified into 3 zones, namely below 50 meters zones, 50 - 100 meters, and above 100 meters (figure 2). An analysis conducted utilizing the buffering technique have been determined based on specific indicators. The color-coded scheme employed assigns red, yellow, and green to the range of 0-50 meters, 50-100 meters, and 100-250 meters. The Distances up to 50, 100, and above 100 meters areas can be classified into high, medium, and low vulnerability levels. The classification determination can be linked based on explosions that have occurred at other fuel storage depots, such as in the cases of the Buncefield fuel depot fire and explosion in England, the Fuel Storage in Bayamon Puerto Rico, and the Oil Storage Facilities in Sitapura, Jaipur, India, where the minor impacts reached from 100 to 2000 meters from the explosion zone (Batista-Abreu & Godoy, 2013; Shristi Vidusha et al., 2018; Thomas, 2018).

The results are intersected with the building shapefile data to obtain the number of buildings at each distance, as shown in Table 1 below.

The buildings in the red zone are the most dangerous and very vulnerable to the effects of fires. As many as 503 building located in the High Level Vulnerabilities, that can causing a lot of losses and even the residents can be killed. Residential area locations in heightened vulnerability pose a significant risk due to the potential for extensive casualties. The yellow areas indicate a moderate level of vulnerability with 870 building in the area. The green areas represent zones with a low level of vulnerability, situated at a distance of 100 to 250 meters, with 2554 buildings located in that level.

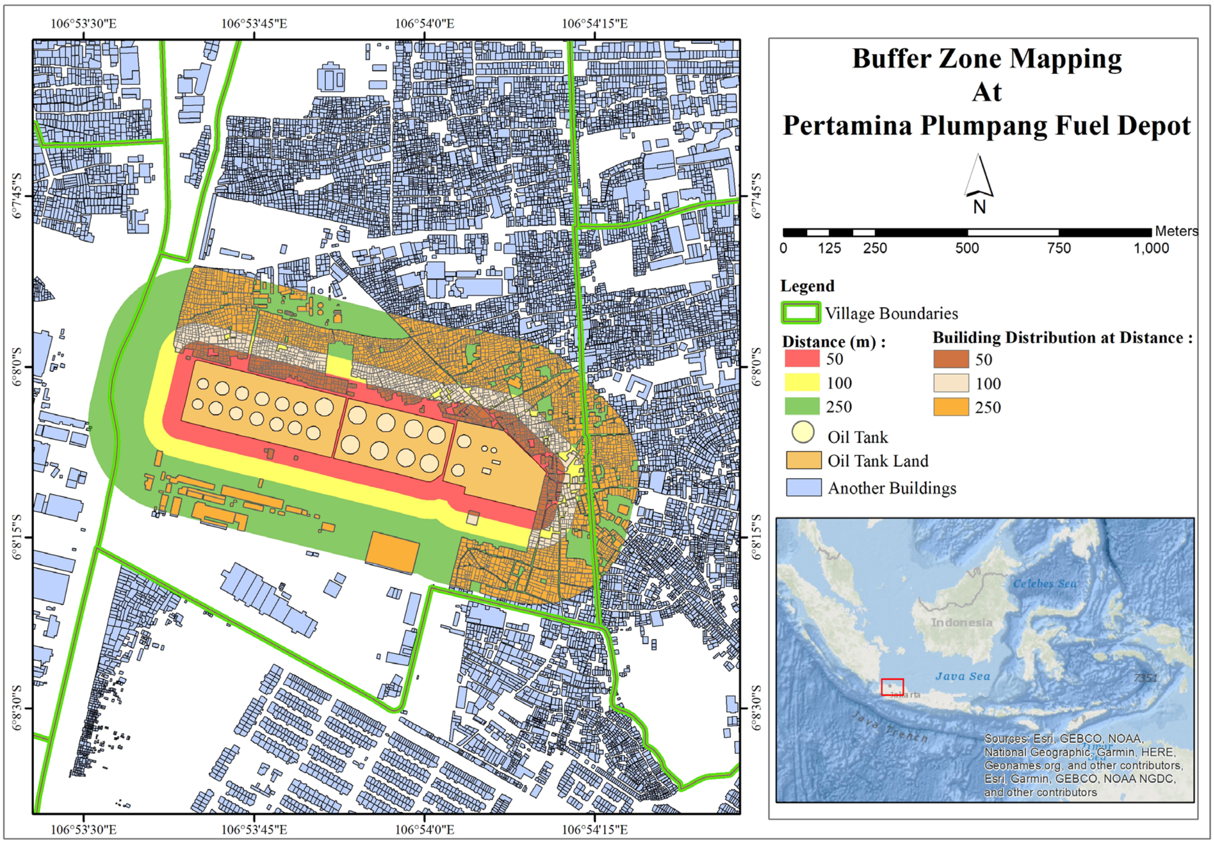


Figure 2. Image of analysis results at Pertamina Plumpang Fuel Depot using buffering techniques with distances of 50,100, and 250 meters.

Table 1 Buffer Zone Area With Amount of Buildings

| No | Distance From Fuel Depot | Number Of Buildings | Classification Of Vulnerabilities |
|---|---|---|---|
| 1 | 0 - 50 meters | 503 | High Level |
| 2 | 50 - 100 meters | 870 | Moderate Level |
| 3 | 100 - 250 meters | 2554 | Low Level |

Source: Data Processing

The Pertamina Plumpang Fuel Depot, has a cylindrical fuel storage tanks characterized by their cylindrical shape, with a movable roof that covers the liquid surface (Zavareh et al., 2022). The fuel depot has 24 cylindrical tanks containing various fuels, namely Solar, Pertamax, Pertamax turbo, and others. The cylindrical tank variant has the potential to present significant hazards in terms of fire outbreaks (Zavareh et al., 2022). The depot has capacity storage of 291.889 kiloliters, classified into three categories tank, 20,000 metric tons, 10,000 metric tons , and 5000 metric tons. The cylindrical variant with extensive storage capacities of tanks, pose a high risk of potential fire incidents, potentially leading to significant and substantial explosions that can escalate the severity of fires (Liu et al., 2021; Zavareh et al., 2022; Zhou et al., 2016). The oil or fuel industry is known to be highly vulnerable fire incidents due to several factors associated with liquid hydrocarbons, including oil and highly flammable fuels (Batista-Abreu & Godoy, 2013; Shristi Vidusha et al., 2018; Sutrisno et al., 2021). All oil product storage facilities are considered dangerous because they are prone to fire and explosion causing material losses (Zvyagintseva et al., 2021).

The fire at the Plumpang Fuel Depot can be classified as a minor incident when compared to the fires at the Buncefield Fuel Storage Depot that destroying most of the storage locations for more than 20 tanks with 40 people injured. The Bayamon Oil Storage Facility causing 21 tanks exploded and caught fire, have significant impacts by destroying 50% of the storage facility area, the surrounding environment, residential homes, and resulting in substantial economic losses, and Indian Oil Corporation Ltd with 12 tanks causing 12 casualties and injuries to 300 others with Minor effects observed within a 2 km radius of the facility (Atkinson, 2017; Hoek et al., 2007; Nicholas & Whitfield, 2013; Sharma et al., 2013; Shristi Vidusha et al., 2018; Thomas, 2018; Zhou et al., 2016). However, the Pertamina Plumpang Fuel Depot has a higher number of casualties compared with these incident, resulted in the tragic loss of 33 lives, 11 people sustaining injuries and 639 people have been evacuated.

As a national vital object, Pertamina's Plumpang fuel depot should be situated at a considerable distance from residential areas. The proximity of the Pertamina Plumpang Fuel Depot location to residential areas can be a primary cause of the significant number of casualties.. The fire that occurred at the Pertamina Plumpang fuel depot was caused by an error in the fuel delivery pipeline from the storage tank, leading to the outbreak of the fire, although none of the tanks exploded, causing substantial damage and posing a considerable danger. Fires that arise within oil tanks emit substantial radiation and demonstrate high intensity, the impact can extend beyond the immediate vicinity, potentially affecting even more distant areas. (Zhou et al., 2016).

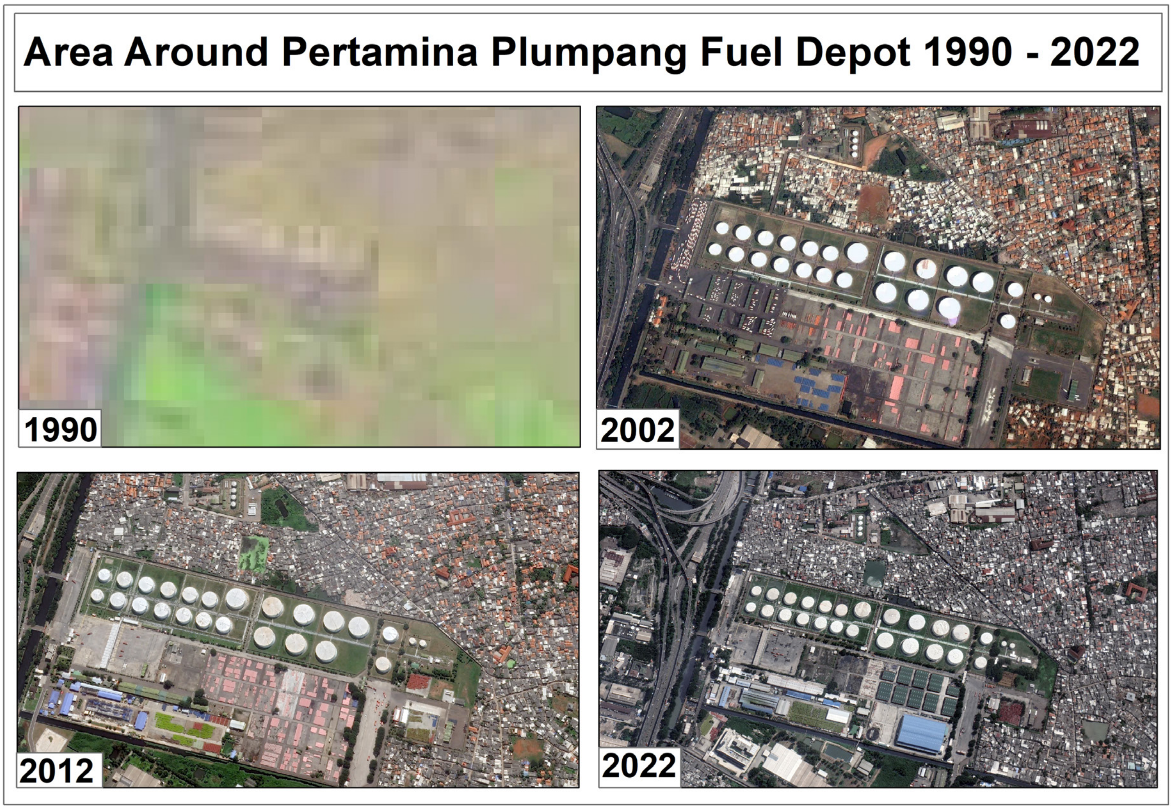


Figure 3. Identification Changes in The Area Around Pertamina Plumpang Fuel Depot from 1990 - 2022

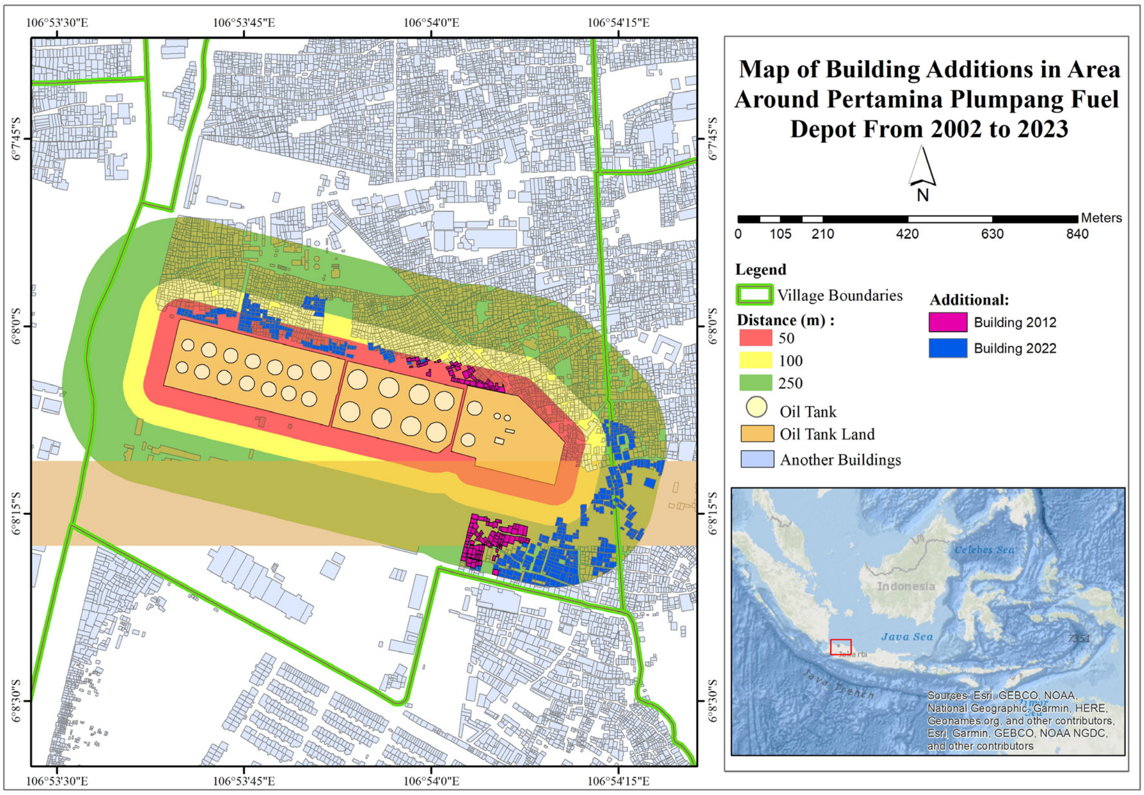


Figure 4. Identification of Building Additions in Area Around Pertamina Plumpang Fuel Depot

Table 2. Amount of Buildings Addition From 2002 - 2022

| No | Year | Number Of Buildings |
|---|---|---|
| 1 | 2002 – 2012 | 198 |
| 2 | 2012 - 2022 | 442 |

Source: Data Processing

The area around Pertamina's Plumpang fuel depot consists of residential areas associations with fuel depots can cause several problems such as fires spreading to residential areas, high road traffic, noise, emissions, and water pollution by fuel products (Iojă et al., 2012). The development of urban areas is not supported by the carrying capacity of the environment causing urban growth due to the existence of a buffer zone between residential areas and national vital objects (Taridala et al., 2017)

In 1990 (Figure 3) can be identified that the area around Pertamina Plumpang is still predominantly covered in light green, indicating vegetation. In 2002, several residential areas had been established, but they were not densely populated. In the northern area of the depot, green open spaces were still present, acting as a buffer between the depot and residential areas. In 2012 and 2022, it is evident that the northern area around the Pertamina Plumpang depot has undergone a complete transformation into a densely populated residential area. The density was particularly prominent in the northern and eastern parts of the Pertamina Plumpang depot, as evident from the proximity between the roofs of adjacent buildings (Figure 4). The density of rooftops can serve as an indicator of a high population residing in the area.

The results from Figure 4 are then processed to obtain the magnitude of each building addition classified within the range of the increasing years (Table 2).

From 2002 to 2012, there was an addition of 198 residential buildings located at various vulnerability levels, including high vulnerability. These buildings are situated in close proximity to the Pertamina Plumpang depot, specifically in the northern part of the fuel depot. From 2012 to 2022, there was an addition of 442 buildings, and some of them are located in areas with high vulnerability, specifically in the northern part of the depot's northern area. In the areas around the depot, there have been numerous changes in land use from vegetation and open land, transforming into densely populated residential areas. Densely populated residential areas near the fuel storage depot location can result in a significant loss of life in the fire event.

As a measure of handling and combating fires, the buffer zone has a very meaningful role because the fires in residents homes were caused by the spread of fires originating from the Pertamina fuel depot to residential areas. Buffer zones can be used as protective barriers between one location and another (Lv et al., 2022). However, a considerable number of structures were discovered that were intended to serve as a protective buffer zone between residential areas and the fuel depot. In essence, the designated buffer zone has been substituted by these buildings (Law et al., 2020). Areas at a distance of 0 - 50 meters and 50 - 100 meters can be affected when a fire disaster occurs with high vulnerability and danger.

According to the result, it is recommended to establish a buffer zone with a range of 0-100 meters from the present outer wall of the Pertamina Plumpang fuel depot to ensure adequate distance between the depot and residential areas. Based on (Chhetri et al., 2015) and (Atkinson, 2017), it is better to determine the buffer zone area at a distance of 0 - 100 meters from the outer walls of the current depot when referring to the outbreak at the BunceField fuel depot in England (UK). This determination is grounded in the aftermath of the incident at the Buncefield Fuel Depot, where the repercussions extended up to a distance of 100 meters from its initial position. Within this range, buildings designated for commercial and residential purposes experienced severe structural damage, necessitating the demolition of several structures.

The designated buffer zone can be effectively transformed into a hydrological flow or water channel, serving as a separator and barrier between the fuel depot and residential areas. By utilizing the land as a hydrological flow, the buffer zone inherently influences residents to construct areas on the opposing side of the fuel depot. In addition to constructing a canal, an alternative approach for the buffer zone area involves using vacant land and enclosing it with a boundary wall. Currently, the fuel depot and residential areas are merely separated by a border wall. Therefore, the establishment of a buffer zone significantly enhances the preventive measures against potential fire disasters, ensuring that any emergencies are addressed promptly and effectively. This proactive measure aims to minimize casualties and mitigate substantial damages caused by fires.

## 4. Conclusion

The proximity of residential areas to the Pertamina Plumpang Fuel Depot plays a crucial role in the increased vulnerability of these areas to fire disasters. The highly flammable nature of the fuel, even to the slightest spark, intensifies the risk significantly. With a storage capacity of 291.889 kiloliters, any fire outbreak within the depot has the potential to escalate in severity, consequently spreading to the surrounding area. Associations between residential areas and gas stations or fuel depots give rise to various challenges, including the heightened likelihood of fires. The determination of buffer zones is needed to regulate the safe distance between residential areas or other commercial buildings with fuel depots which are national vital objects. Based on the result, there are 503, 870, and 2554 buildings at a distance of 50, 50 – 100, and 100 – 250 meters. Buildings located at greater distances from fuel depots exhibit reduced vulnerability and tend to possess enhanced safety measures.

## References


Abdulsalam, A., Kabir, R., & Arafat, S. M. Y. (2016). Assessment of Fire Safety Preparedness in Selected Health Institutions in Niger State. *International Journal of Perceptions in Public Health*, *1*(11), 50–58.

Al-Dousari, A. E., Mishra, A., & Singh, S. (2023). Land use land cover change detection and urban sprawl prediction for Kuwait metropolitan region, using multi-layer perceptron neural networks (MLPNN). *Egyptian Journal of Remote Sensing and Space Science*, *26*(2), 381–392. https://doi.org/10.1016/j.ejrs.2023.05.003

Atkinson, G. (2017). Buncefield: Lessons learned on emergency preparedness. *Loss Prevention Bulletin*, *254*, 23–28.

Batista-Abreu, J. C., & Godoy, L. A. (2013). Thermal Buckling Behavior of Open Cylindrical Oil Storage Tanks under Fire. *Journal of Performance of Constructed Facilities*, *27*(1), 89–97. https://doi.org/10.1061/(asce)cf.1943-5509.0000309

Chaiklieng, S., Dacherngkhao, T., Suggaravetsiri, P., & Pruktharathikul, V. (2020). Fire risk assessment in fire hazardous zones of gasoline stations. *Journal of Occupational Health*, *62*(1). https://doi.org/10.1002/1348-9585.12137

Chang, J. I., & Lin, C. C. (2006). A study of storage tank accidents. *Journal of Loss Prevention in the Process Industries*, *19*(1), 51–59. https://doi.org/10.1016/j.jlp.2005.05.015

Chhetri, S. . K., & Kayastha, P. (2015). Manifestation of an Analytic Hierarchy Process ( AHP ) Model. *ISPRS International Journal of Geo-Information*, *4*, 400–417. https://doi.org/10.3390/ijgi4010400

Cvetkovi, V. M., Jankovi, B., Nikoli, N., & Milo, P. (2022). International Journal of Disaster Risk Reduction Fire safety behavior model for residential buildings : Implications for disaster risk reduction. *International Journal of Disaster Risk Reduction*, *76*(November 2021). https://doi.org/10.1016/j.ijdrr.2022.102981

Hamatuli, M., & Muchanga, M. (2021). Social Perspectives on the Effects of Buffer Zone Anthropogenic Activities on Mashili Reservoir of Shibuyunji District , Central. *International Journal of Humanities Social Sciences and Education (IJHSSE) Volume*, *8*(11), 102–109. https://doi.org/https://doi.org/10.20431/2349-0381.0811013

Herbert, C., & Butsic, V. (2022). Assessing the Effectiveness of Green Landscape Buffers to Reduce Fire Severity and Limit Fire Spread in California: Case Study of Golf Courses. *Fire*, *5*(2). https://doi.org/10.3390/fire5020044

Hoek, M. R., Bracebridge, S., & Oliver, I. (2007). Health impact of the Buncefield oil depot fire , December Study of accident and emergency case records. *Journal of Public Health*, *29*(3), 298–302. https://doi.org/10.1093/pubmed/fdm036

Ibrahim, H. ., & Syed, H. S. (2019). Hazard Analysis of Crude Oil Storage Tank Farm Hazard Analysis of Crude Oil Storage Tank Farm. *International Journal of ChemTech Research*, *11*(November 2018), 300–308. https://doi.org/10.20902/IJCTR.2018.111132

Iglesias, V., Stavros, N., Balch, J. K., Barrett, K., Cobian-Iñiguez, J., Hester, C., Kolden, C. A., Leyk, S., Nagy, R. C., Reid, C. E., Wiedinmyer, C., Woolner, E., & Travis, W. R. (2022). Fires that matter: Reconceptualizing fire risk to include interactions between humans and the natural environment. *Environmental Research Letters*, *17*(4). https://doi.org/10.1088/1748-9326/ac5c0c

Iojă, C. I., & Tudor, C. A. (2012). Temporal Analysis of Incompatible Land-Use and Land-Cover: The Proximity between Residential Areas and Gas Stations in Bucharest Suburban Area. *Procedia Environmental Sciences*, *14*, 49–58. https://doi.org/10.1016/j.proenv.2012.03.006

Kurnianti, D. N., Rustiadi, E., & Baskoro, D. P. T. (2015). Land Use Projection for Spatial Plan Consistency in Jabodetabek. *Indonesian Journal of Geography*, *47*(2), 124–131. https://www.researchgate.net/publication/310613079

Law, A., & Bisby, L. (2020). The rise and rise of fire resistance. *Fire Safety Journal*, *116*, 103188. https://doi.org/10.1016/j.firesaf.2020.103188

Li, H., & Huang, X. (2021). Gis-Based Fire Risk Spatial Assessment for Semiconductor Plant. *IOP Conference Series: Earth and Environmental Science*, *772*(1). https://doi.org/10.1088/1755-1315/772/1/012080

Li, L., & Dai, L. (2021). Review on fire explosion research of crude oil storage tank. *E3S Web of Conferences*, *236*, 1–7. https://doi.org/10.1051/e3sconf/202123601022

Liu, K., Wu, D., Xia, J., Chen, W., Chen, G., Liu, J., & Li, H. (2021). Risk Evaluation Indicator System for Lightning Disaster in Oil Storage Depots. *IOP Conference Series: Earth and Environmental Science*, *859*(1). https://doi.org/10.1088/1755-1315/859/1/012114

Lv, R., Liu, Y., Zhang, L., & Kong, D. (2022). Urban historic heritage buffer zone delineation: the case of Shedian. *Heritage Science*, *10*(1), 1–15. https://doi.org/10.1186/s40494-022-00702-9

Nicholas, M., & Whitfield, A. (2013). The Buncefield Accident and the Environmental Consequences for Fuel Storage Sites and other Sites in the UK , Regulated under the Seveso Directive The Buncefield Accident and the Environmental Consequences for Fuel Storage Sites and other Sites in the UK. *CHEMICAL ENGINEERING TRANSACTIONS*, *31*(January 2013). https://doi.org/10.3303/CET1331077

Ornai, A., Ne'eman, G., & Keasar, T. (2020). Management of forest fire buffer zones: Implications for flowering plants and bees. *Forest Ecology and Management*, *473*(August 2019). https://doi.org/10.1016/j.foreco.2020.118310

Putri, R. F., Wibirama, S., Giyarsih, S. R., Pradana, A., & Kusmiati, Y. (2019). Landuse change monitoring and population density analysis of Penjaringan, Cengkareng, and Cakung Urban Area in Jakarta Province. *E3S Web of Conferences*, *76*. https://doi.org/10.1051/e3sconf/20197603004

Rasel, Biswas, Khan, F., & Yang, M. (2015). Scenario based hazard identification of a gas Station in Arctic Region. *Proceedings of the National Academy of Sciences*, *3*(1), 1–15. http://dx.doi.org/10.1016/j.bpj.2015.06.056%0Ahttps://academic.oup.com/bioinformatics/article-abstract/34/13/2201/4852827%0Ainternal-pdf://semisupervised-3254828305/semisupervised.ppt%0Ahttp://dx.doi.org/10.1016/j.str.2013.02.005%0Ahttp://dx.doi.org/10.10

Sagala, S., Wimbardana, R., & Pratama, F. P. (2016). Behavior and Preparedness to Fire Hazard in High Density Settlements in Bandung. *Forum Geografi*, *28*(1), 1–20. https://doi.org/10.23917/forgeo.v28i1.433

Setiawan, C., Handawati, R., & Ermalia. (2020). Analysis of Influence Settlement Density on the Fire Hazards Settlement at Cengkareng Subdistrict, West Jakarta. *IOP Conference Series: Earth and Environmental Science*, *412*(1). https://doi.org/10.1088/1755-1315/412/1/012011

Sharma, R. K., Gurjar, B. R., Wate, S. R., Ghuge, S. P., & Agrawal, R. (2013). Assessment of an accidental vapour cloud explosion: Lessons from the Indian Oil Corporation Ltd. accident at Jaipur, India. *Journal of Loss Prevention in the Process Industries*, *26*(1), 82–90. https://doi.org/10.1016/j.jlp.2012.09.009

Shristi Vidusha, R., Sharath, D., Yadav, B. P., & Nandan, A. (2018). Case Study on Vapour Cloud Explosions (Buncefield and Jaipur Explosion)—A Review. In *Springer Transactions in Civil and Environmental Engineering* (pp. 135–147). https://doi.org/10.1007/978-981-10-7281-9_11

Singapore Civil Defence Force SCDF. (2012). *Singapore Fire Code 2007 : Fire Safety Requirements for Petroleum Service Station*. 1–13.

Sutrisno, H. H., Wibawa, B., Triyono, T., Amiruddin, J., Kusumohadi, C. S., Setyadi, P., & Yoga, N. G. (2021). The identification of fire potentials in oil mining area on Minas Sumatera Operations-Indonesia by manual assessment method. *IOP Conference Series: Materials Science and Engineering*, *1098*(6), 062093. https://doi.org/10.1088/1757-899x/1098/6/062093

Taridala, S., Yudono, A., Ramli, M. I., & Akil, A. (2017). Expert System Development for Urban Fire Hazard Assessment. Study Case: Kendari City, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *79*(1). https://doi.org/10.1088/1755-1315/79/1/012035

Thomas, G. O. (2018). Buncefield: A possible alternative multi-stage route to localised overpressure generation. *Process Safety and Environmental Protection*, *119*(August), 253–260. https://doi.org/10.1016/j.psep.2018.08.003

Turner, W. C., Périquet, S., Goelst, C. E., Vera, K. B., Cameron, E. Z., Alexander, K. A., Belant, J. L., Cloete, C. C., du Preez, P., Getz, W. M., Hetem, R. S., Kamath, P. L., Kasaona, M. K., Mackenzie, M., Mendelsohn, J., Mfune, J. K. E., Muntifering, J. R., Portas, R., Scott, H. A., … Kilian, J. W. (2022). Africa's drylands in a changing world: Challenges for wildlife conservation under climate and land-use changes in the Greater Etosha Landscape. *Global Ecology and Conservation*, *38*(February). https://doi.org/10.1016/j.gecco.2022.e02221

Twigg, J., Christie, N., Haworth, J., Osuteye, E., & Skarlatidou, A. (2017). Improved methods for fire risk assessment in low-income and informal settlements. *International Journal of Environmental Research and Public Health*, *14*(2). https://doi.org/10.3390/ijerph14020139

Winandari, M. I. R., Wijayanto, P., & Faradila. (2021). Fire risk based on building density in dense settlement. *IOP Conference Series: Earth and Environmental Science*, *780*(1). https://doi.org/10.1088/1755-1315/780/1/012053

Zavareh, R. D., Dana, T., Roayaei, E., Monavari, S. M., & Jozi, S. A. (2022). The Environmental Risk Assessment of Fire and Explosion in Storage Tanks of Petroleum Products. *Journal Sustainability (MDPI)*, 1–17. https://doi.org/https://doi.org/10.3390/su141710747

Zhang, H. (2020). Research on Building Fire Risk Management Based on BIM. *IOP Conference Series: Earth and Environmental Science*, *571*(1). https://doi.org/10.1088/1755-1315/571/1/012067

Zhou, Y., Zhao, X., Zhao, J., & Chen, D. (2016). Research on Fire and Explosion Accidents of Oil Depots. *CHEMICAL ENGINEERINGTRANSACTIONS*, *51*, 163–168. https://doi.org/10.3303/CET1651028

Zvyagintseva, A. V., Mezhova, L. A., Sazonova, S. A., Stenyukhin, L. V., & Chertkov, P. V. (2021). Prognostication of fire of oil and oil products storage tank farms and engineering and technical solutions. *Journal of Physics: Conference Series*, *2094*(5). https://doi.org/10.1088/1742-6596/2094/5/052030