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RESEARCH ARTICLE

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PHYSICAL CONTAINMENT OF THE MAIN LIQUID FUELS THAT CIRCUIT ON ROADS IN FRONT OF SOME CONTAINERS

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ABSTRACT

Liquid fuels like ethanol, diesel oil, and vegetable oil, are getting around more and more in tank trucks, leading the increment of fleets of trucks and their possible involvements in fuel spill accidents, whose require promptly actions in order to avoid leaks to minimize Ambiental damage to animals and human beings. The fire department, besides having legal competence it’s also the first and usually the only organ standing against this type of occurrence, with the objective of utilizing containment physical fuel resources that are efficient. Combining The existing demand with empirical knowledge, tests were made in order to analyze the efficiency of four different types of containers, taking into consideration weight, volume, and acquisition value for the containers: fine-washed sand, quicklime, and cement. Concluding that cement containers and quicklime are the most efficient for the main goal.

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INTRODUCTION

The fuel is a product that takes many risks to the people who work with it due to its own inflammability and chemical health risk, especially in the safety of workers. These risks have been increasing due to Brazil being a big consumer of fuels in the world, with an expectation of consumption reaching more than 4 million oil barrels per day (Ernst; Young Terco, 2011). The risk of occurring accidents involving vehicles transporting fuel is intense due to numerous trucks on highways carrying fuels and dangerous products, such as gasoline, ethanol, diesel oil, vegetable oil, and more. This condition allows analyzing that accidents involving the road transport of these fuels can cause serious risks of contamination. In cases of accidents with dangerous products, as addressed by Pedro (2006), it’s able to put at risk the safety and health of people due to the environment being subject to the possibility of hazardous products reaching water courses, contaminating the soil, atmospheric air, and even the water table by infiltration.

For the Ministry of Environment (2009), the main polluting chemical agents that cause damage to the environment and that expose people to diseases are petroleum derivatives. About the contamination of the environment, especially the soil and water table, resulting from fuel leakage, Queiroz et al. (2008), teach us that this occurs from the rupture of containers, packaging, or storage tanks which will lead to the occurrence of leaks, spills, releases, disposal, accumulation or ponding, infiltration, emission of pollutants, substances, gasses or vapors, fires, explosions, etc., resulting in serious risks and consequences for people. The problem faced with so many risks and accidents involving dangerous products, especially liquid fuels, it is essential that there’s a fast and efficient action to contain leaks or even decrease their effects when they occur. The main public aid agency that usually makes the first intervention is the Fire Department, either the State Military Firefighter or even the Civil Defense Community Brigades, where the second is under the operational coordination of the first one. The Constitutional Letter of 1988 in your article.

144, § 5º makes clear the mandatory attribution of intervening in these occurrences to the Fire Departments of the federative entities. With regard to the Paraná Fire Department, we have the State Constitution of 1989, article 46, which reinforces the competence to act promptly in the face of this type of occurrence. Still, in this analysis of competence, we have the Standard Operating Procedures that guide and support the legal action of the Firefighter. The present research aimed to analyze some materials that are used empirically, seeking to evidence this condition of physical containment scientifically. Against liquid fuel leaks that occur daily on the roads where thousands of vehicles transport the most diverse types of fuels. Trying to analyze the action of some containers with the best performance when the ability to contain a fuel spill to avoid the consequences from spills that may occur, reducing the risk to people and the environment.

Containment forms for liquid fuels: According to Ernst and Young Terco (2011), Brazil is a big consumer of fuels in our world, the Oil and Gas sector represents around 13% of the GDP, moving 2.1 million barrels of oil per day, with expectations of doubling this value until 2025. The fuel is a product that causes many risks to those who work with it, as it is a flammable liquid and chemically harmful to health, it is necessary to pay great attention to the safety of workers. Every day, countless trucks travel around highways and cities carrying diverse types of fuels and dangerous products, among them, the most consumed are gasoline, ethanol, diesel oil, and vegetable oil. In this context, the risk of an accident involving these vehicles transporting such fuels is intense. In this analysis, accidents involving road transport of dangerous products can affect the population, being a serious threat due to the serious risks of contamination Becker et al. (2000, *apud* Oliveira, 2017). Accidents with dangerous products are not only putting people's safety and health at risk, but the environment becomes subject to this situation due to the possibility of dangerous products reaching water courses, contaminating the soil, atmospheric air, and even the water table by infiltration (Pedro, 2006). According to the Ministry of the Environment (2009), the main polluting chemical agents that cause damage to the environment and that expose people to diseases are petroleum derivatives.

The Characteristics of Fuels: The most dangerous products transported on highways are those used by the automobile fleet, which are ethanol, gasoline, diesel oil, and even vegetable oil. Gasoline and diesel fuel are made of hydrocarbons and, to a lesser extent, oxygenated products and by sulfur, nitrogen, and oxygen, respectively (Carvalho, Filho, 2014). According to Abiquim (2015), the gasoline is drained into sewers, its vapors can cause explosions, in addition to the possibility of causing risks to human health. Diesel oil, despite having medium toxicity and low volatility, is very flammable. And, in case of spillage of this type of fuel, it must be absorbed by sand or other non-combustible absorbent material. Vegetable oil is biodiesel, in other words, it is a fat obtained from plants, predominantly by the seeds of oleaginous plants, such as cotton, peanuts, palm oil or palm, sunflower, corn, soybeans, beans of castors. Its greatest risk is the fact that such product leaks into rivers, lakes, and seas, causing an imbalance in our ecosystem where it is estimated that one liter of oil into a watercourse can contaminate one million liters of water (Salles, 2010). Through the processing and fermentation of some sugars and starches, such as sugar cane, corn, beets, cassava, and potatoes, among others, Ethanol is extracted through the action of a microorganism called Sacchromyces cerevisiae (Francisco, 2020). The ethanol presents a danger of inflammation by its low point of glow being too malefic for human health, to the environment, contaminates water courses, making them unsuitable for use for any purpose, and may destroy the fauna and flora of the spill site. When there is a spillage of this fuel, it must be absorbed with sand or other non-combustible absorbent material (Abiquim, 2015).

Risk of Contamination of Soil and Groundwater Resulting from Fuel Leakage: Occurrence of transit accidents involving fuel or dangerous products could occur in countless situations and incidents, potentially and adversely modifying the environment from the rupture of containers, packaging, or storage tanks which will lead to the occurrence of leaks, spills, releases, disposal, accumulation or ponding, infiltration, emission of pollutants, substances, gases or vapors, fires, explosions, etc (Queiroz et al., 2008). Regarding groundwater contamination by fuel spills, Corseuil and Marins (1997) state that:

In a gasoline spill, one of the main concerns is the contamination of aquifers that are used as a source of water supply for human consumption. Because it is very slightly soluble in water, spilled gasoline, containing more than a hundred components, will initially be present underground as a non-aqueous phase liquid. (NAPL). In contact with underground water, the gasoline will partially dissolve. The Hydrocarbons monoaromatics, benzene, toluene, ethylbenzene, and the three xylenes ortho, meta, and called BTEX compounds, are the constituents of gasoline that have greater solubility in water and, therefore, are the contaminants that will first reach the water table (Corseuil, Marins, 1997). Studies show that BTEX compounds are benzene, toluene, ethylbenzene, and xylenes, these hydrocarbons being present in the fuels derived from petroleum, which are more soluble and more toxic than the others, are highly harmful to human health and which, in the event of a spillage in aquifers, may make the exploitation of these for human consumption (Oliveira, Loureiro, 1998).

Still in the behavior of petroleum-derived fuels when these are released into the soil, the above authors pointed out that they are conditioned to a series of transport processes through the subsurface system, highlighting the following:

- Penetration through the soil until reaching the water table, forming a layer of the supernatant product;
- Horizontal mobilization of fuel on the ground, in his free stage whose may reach foundations, garages, galleries, and other underground structures;
- Retention in soil pores, forming a perennial source of long term contamination;
- Partial dissolution of soluble components within the aqueous phase of the soil contaminating aquifers and compromising the quality of water courses and supply water extraction wells;
- volatilization of components with accumulation of explosive vapors in some structures and causing atmospheric pollution (which may only be temporary);
- biodegradation of hydrocarbons resulting from physical-chemical and biological processes (Oliveira, Loureiro, 1998).

Firefighter's Assignment in Responding to Fuel Leakage: It is up to the Fire Departments of the federative entities to carry out civil defense activities (Federal Constitution, 1988, Art. 144, § 5), understanding the care for the environment and the safety of people with regard to the leakage of fuel as a major civil defense action. With regard to the Military Fire Brigade of the State of Paraná, the State Constitution of 1989 provides in article 46, combined with item V, that the body must preserve the safety of people and property. In the Infra, we have constitutionally other provisions that guide and support the Firefighter's performance, such as the Standard Operating Procedure (POP-27) of 2006, amended and improved with POP-210 of 2018 published in the Bulletin of the Fire Brigade Command no. 236 of 2018 (Trach, Bortolassi, Oliveira, 2018). POP-210 says that the expected result of the Fire Department is to contain it in case of leakage, avoiding or minimizing secondary damages, especially those that harm life and the environment, and avoiding any type of contamination or unnecessary exposure for those involved. It also emphasizes that its procedure should be based on making containment dikes and seeking ways to stop the leak.

MATERIAL AND METHODS

The methodology whose was used in this investigation was based on the process of measuring fuel against physical containers in terms of water-tightness.

To carry out the experiment, the following materials were used:

- 04 gallons of mineral water with a capacity of 20 liters each;
- Cotton fabric cap;
- Graduated bowls with a capacity of 5 and 10 liters, respectively;
- Stopwatch;
- Bucket for measuring solid/liquid volume;
- 16 gallons with a cap with a capacity of 5 liters each for fuel;
- Fuels: 20 liters of gasoline, 20 liters of ethanol, 20 liters of diesel oil and 20 liters of vegetable oil, divided into 4 portions of 5 liters each, respectively;
- Container material: 40 liters of cement, 40 liters of fine washed sand, 40 liters of common quicklime and 40 liters of fine sawdust, divided into 4 portions of 10 liters each respectively;
- 1 drum for disposing of materials/fuels with a minimum capacity of 80 liters.

The methodology adopted for conducting the experiment was the subdivision of actions into eight stages for better management of the process, as well as:

- **Step 1:** Partial cut of the bottom of the 20-liter gallon so that the bottom would serve as a lid, not allowing the fuel to evaporate. The gallon was positioned inverted, with the gallon nozzle facing the bottom, and the cotton fabric plug was placed at the outlet of the nozzle to prevent the solid part of the container material from draining.
- **Step 2:** Below the gallon nozzle, the graduated container with a capacity of 5 liters was positioned to receive the fuel drained from the gallon and enable its measurement.
- **Step 3:** To measure the 10 liters of each type of container material, a graduated container was used, and then this container material was poured into the gallon, which was previously prepared to receive this material and later the fuel.
- **Step 4:** To measure the 5 liters of each type of fuel, a gallon with a maximum capacity of 5 liters was used.
- **Step 5:** The fuel from the 5-liter gallon was poured into the 20-liter gallon, where the containing material was, the stopwatch was simultaneously activated to record the time, the fuel content of the 5-liter gallon was poured into at this moment, the stopwatch was activated, and the lid (bottom) of the 20-liter bottle of mineral water is closed in order to avoid the evaporation of the fuel due to its volatility rate.
- **Step 6:** A digital timer was used to record the time of 10 and 20 minutes, respectively, of the fuel leak drained by the container material. The 10-minute simulation refers to the approximate response time of the assistance provided by the Fire Brigade Corporation on the perimeter within the urban area and 20 minutes to the response to a call on the highway. After reaching the first 10-minute split, the graduated vessel was removed to measure the amount of fuel drained and replaced by another vessel with the same characteristics and empty so that the measurement process could continue. At the end of the 20-minute period, the second stage of the process was completed, where the second vessel was removed to measure the amount of fuel drained.
- **Stage 7:** Both the drained fuels and the container materials used were sent for correct disposal, with the fuels being sent to a gas station that already has the routing, proper disposal, and authorized by environmental agencies, as well as the content material that was sent to the landfill.
- **Step 8:** To tabulate the types of fuels, containment materials, partial times, and amounts of fuel drained at each step of the process, a free Microsoft Excel Office 365 Spreadsheet (Microsoft, 2019) was used. To analyze the collected data and generate the graphs, the statistical software The R Project for Statistical Computing version 3.6.1 (The R Foundation, 2019) and the integrated environment software for development for the R Language, the IDE RStudio Desktop version 1.2 (RStudio, 2019), both free software, as shown in Figure 1.

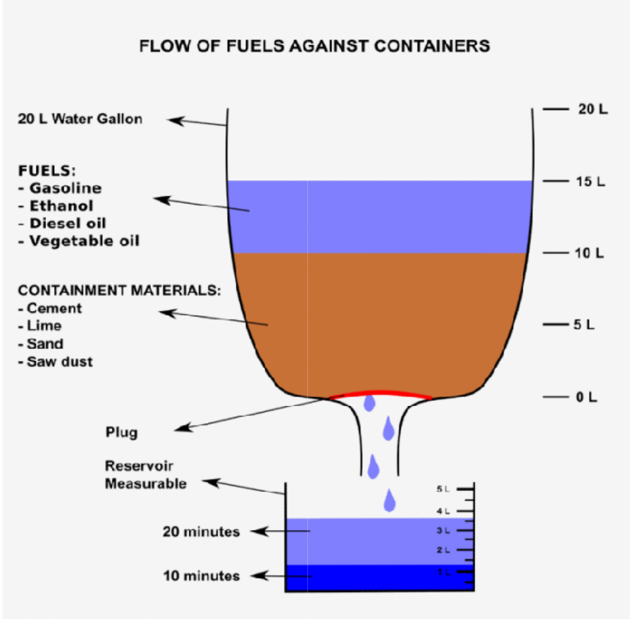
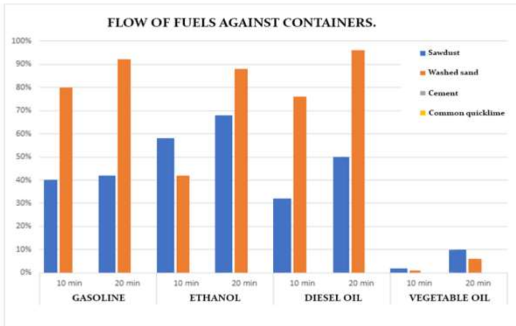


Figure 1. Schematic for measuring liquid fuels against the action of the containing materials

RESULTS

The evaluated fuels had their behavior in relation to the measured containers, being possible to conclude which container had a better performance in terms of the ability to contain a fuel spill. It should be noted that the experiment sought to evaluate the containment capacity and not the absorption capacity purely and simply, that is, it was not intended to measure how much the containers are capable of absorbing the residue of fuel spilled on a runway, for example. The results of the tabulation of the data obtained during the experiment can be seen in Table 1. The obtained results in Table 1 allow us to conclude that among the fuels observed against the washed sand container, gasoline presents greater fluidity in the first 10 minutes (4.0l) than the other fuels, followed by diesel oil (3.8l), ethanol (2.1l) and vegetable oil (0.05l). When analyzing for a longer observation time of 20 minutes, the increase of fluid volume occurs with diesel oil (4.8l), followed by gasoline (4.6l), ethanol (4.4l), and vegetable oil (0.3l). When analyzing the sawdust container, we saw that in the first 10 minutes, ethanol showed greater fluidity (2.9l), while gasoline flowed 2.0l, followed by diesel oil (1.6l) and vegetable oil (0.1l). When analyzing the fluidity of the fuel in front of the analyzed container in 20 minutes, we have that ethanol had the highest flow rate (3.4l), followed by diesel oil (2.5l), gasoline (2.1l) and vegetable oil (0 .5l). Another analysis that deserves to be highlighted is that at the times evaluated (10 and 20 minutes) there was no flow to be measured for gasoline, ethanol, diesel oil, and vegetable oil compared to the containers of cement and common quicklime. The percentage of fuel flow in front of the containers is shown in Table 2 and Figure 2.



*Note: The higher the percentage of flow, the lower the fuel retention capacity will be by the analyzed container.

Figure 2. Measurement of the flow of liquid fuel dammed by types of containers and varying times

Table 1. Process of measurement of fuels against physical containers, regarding watertightness.

TIME	TYPES OF FUELS AND PHYSICAL CONTAINERS			
Fuel: **GASOLINE**				
	fine saw dust	fine washed sand	Cement	Common quicklime
10 minutes	2.0	4.0	0	0
20 minutes	2.1	4.6	0	0
Fuel: **ETHANOL**				
	fine saw dust	fine washed sand	Cement	Common quicklime
10 minutes	2.9	2.1	0	0
20 minutes	3.4	4.4	0	0
Fuel: **DIESEL OIL**				
	fine saw dust	fine washed sand	Cement	Common quicklime
10 minutes	1.6	3.8	0	0
20 minutes	2.5	4.8	0	0
Fuel: **VEGETAL OIL**				
	fine saw dust	fine washed sand	Cement	Common quicklime
10 minutes	0.1	0.05	0	0
20 minutes	0.5	0.3	0	0

Observation: the values are expressed in liters, in times between 10 and 20 minutes respectively.

Table 2. Measurement of the flow of fuels in front of the containers.

CONTAINER	GASOLINE				ETHANOL				DIESEL OIL				VEGETAL OIL			
	10 min	%	20 min	%	10 min	%	20 min	%	10 min	%	20 min	%	10 min	%	20 min	%
Fine sawdust	2.0	40.0	2.1	42.0	2.9	58.0	3.4	68.0	1.6	32.0	2.5	50.0	0.1	2.0	0.5	10.0
Fine washed sand	4.0	80.0	4.6	92.0	2.1	42.0	4.4	88.0	3.8	76.0	4.8	96.0	0.1	1.0	0.3	6.0
Cement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common quicklime	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3. The average cost of the product on March 12, found in the city of Paranavaí

	Net weight for 10L volume	Average value found on the market	Spent value in the volume searched
Cement	10,210 kg	BRL 31.90 per 50 kg bag	BRL 6.51
Quicklime	9,250 kg	BRL 15.60 per 25 kg bag	BRL 5.77
Sand	11,480 kg	BRL 120.00 per m^3	BRL 1.20
Sawdust	2,070 kg	BRL 20.00 per m^3	BRL 0.02

Table 4. Change in percentage when comparing containers.

Cement	Δ%	Quicklime	Δ%	Sand	Δ%	Sawdust
6.51	12.82	5.77	380.83	1.20	5,900.00	0.02

The analysis of Table 2 makes it possible to determine the following behaviors related to the types of fuels and containers:

Gasoline Fuel: In the first 10 minutes, gasoline showed higher fluidity if compared to fine-washed sand (80.0%), followed by sawdust (40.0%) and cement (0.0% and quicklime (0.0 %) There weren't significant changes in the fluidity behavior at 20 minutes. Figure 3 illustrates the division of gasoline fuel into four equal portions of 5 liters intended for the development of the sample analysis process.

Figure 3. The type of fuel of Gasoline, divided into four portions of 5 Lt each, referring to samples 1, 2, 3, and 4

Ethanol Fuel: In the first 10 minutes, the ethanol showed greater fluidity if compared to sawdust (58.0%), followed by fine-washed sand (42.0%), cement (0.0%), and quicklime (0.0%). In the fluidity behavior at 20 minutes, there was an inversion in regard to washed sand (88.0%) and sawdust (68.0%) due to waterlogging and saturation of the sand by the fuel. Figure 4 illustrates the division of Ethanol into four equal portions of 5 liters, which is intended for the development of the sample analysis process.

Figure 4. Fuel type Ethanol, divided into four portions of 5 Lt each, referring to samples 1, 2, 3, and 4

Fuel Diesel Oil: In the first 10 minutes, the diesel oil showed greater fluidity compared to the fine-washed sand (76.0%), followed by sawdust (32.0%) and cement (0.0% and quicklime (0.0%). 0%) There were no significant changes in the fluidity behavior at 20 minutes. Figure 5 illustrates the division of the Diesel Oil fuel into four equal portions of 5 liters, which is intended for the development of the sample analysis process.

Figure 5 – Fuel type Diesel oil, divided into four portions of 5 Lt each, referring to samples 1, 2, 3, and 4

Fuel Vegetable Oil: In the first 10 minutes, the vegetable oil showed greater fluidity if compared with sawdust (2.0%), followed by fine-washed sand (1.0%), cement (0.0%), and quicklime (0.0%). There were no significant changes in the fluidity at 20 minutes. Figure 6 illustrates the division of Vegetable Oil fuel into four equal portions of 5 liters intended for the development of the sample analysis process.

Figure 6. Type of fuel Vegetable Oil, divided into four portions of 5 Lt each one, referring to samples 1, 2, 3, and 4

The containers chosen to analyze the containment capacity against the main fuels already mentioned were: quicklime, cement, sawdust, and fine-washed sand, respectively, as addressed in Figure 7. These were chosen because they are the most empirically used.

Figure 7. The type of containers used in the experiment: Quicklime, Cement, Sawdust, and Fine washed sand

It's important analyzing the cost of each product involved in fuel containment by analyzing each container material individually. The analysis revealed that the amounts spent in Reais for the experiment were BRL 6.51 for cement, BRL 5.77 for quicklime, BRL 1.20 for washed sand, and BRL 0.02 for sawdust, as shown in Table 3. Table 4 allows us to visualize the percentage variation in the comparison of containers. Therefore, we can notice there is a low variation between cement and quicklime (12,82%) When comparing sand against sawdust (5900,00%).

CONCLUSION

The Studies show that some materials are more efficient than others when trying to measure the quantity of fuel passing through them. In such context, we try to understand how much of the main fuels that pass by our highways, being transported by trucks, such as gasoline, diesel oil, ethanol, and vegetable oil, are contained in case of leaks. From the analysis, we saw that cement and common quicklime are way more efficient than sawdust and fine-washed sand. These last ones have the advantage of being economically more viable, however, with much more low resolution in terms of water-tightness. Cement and quicklime represent some cost factors that organizations such as the Fire Department that wish to use this product in their emergency care must consider this cost and provide in a budget or through partnerships resources for the acquisition. Washed sand can be purchased at a lower price in building materials depots or even in extraction ports. Sawdust can be purchased from lumber companies or furniture and joinery factories. We do not intend to exhaust the seek for methods trying to improve the empirical and scientific knowledge emphasizing that other forms of interaction between products can help in the containment works aimed at reducing costs. From the observation and analysis of applicated tests was possible to conclude which container had better performance in relation to the capacity of containing a fuel spill. We observed cement and common quicklime are more efficient than sawdust and fine-washed sand. Sawdust and washed sand are economically more viable but of much lower resolution than cement and quicklime in water tightness.

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