APPLICATION AND INFLUENCE OF FIRE RISK REDUCTION RULES ON FIRE SAFETY AT PETROLEUM DISPENSING STATIONS IN KISUMU COUNTY, KENYA

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Application and Influence of Fire Risk Reduction Rules on Fire Safety at Petroleum Dispensing Stations in Kisumu County, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

Signature..... Date .....

Carolyne Jepchirchir Kebut

This thesis has been submitted for examination with our approval as the University Supervisors

Signature ..... Date .....

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Signature..... Date .....

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JKUAT, Kenya

DEDICATION

I dedicate this thesis to my daughter Jewel.

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This thesis is a result of support from several sources, and I wish to acknowledge them all. First my success in completing this project is due to the Almighty God for the courage, strength, knowledge, wisdom, and gift of life.

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LIST OF ABBREVIATIONS

ATEX	Atmosphere Explosible
BPDS	Branded petroleum dispensing stations.
CO_2	Carbon dioxide
CO	Carbon monoxide
DCP	Dry chemical powder
DOSHS	Directorate of Occupational Safety and Health Services
DSEAR	Dangerous substances and explosive atmosphere regulations
EL	Explosive limit.
EMCA	Environmental Management and Coordination Act
FRRR	Fire Risk Reduction Rules
FPC	Finite population calculation
GOK	Government of Kenya
GDP	Gross Domestic Product
H_2S	Hydrogen sulfide gas
ILO	International Labour Organization

IPDS	Independent petroleum dispensing stations
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KNBS	Kenya National Bureau of Statistics
KMTC	Kenya Medical training College
KM	Kilometer
KNUST	Kwame Nkrumah University of Science and Technology
LEL	Lower explosive limit
NGO'S	Non-Governmental Organizations
OHS	Occupational Health and Safety
OSHA	Occupational Safety and Health Act, 2007
O_2	Oxygen
PDS	Petroleum dispensing stations
SPSS	Statistical package for social sciences
US	United States
UN	United Nations

ABSTRACT

Fire safety is an essential aspect in each workplace, its efforts are geared to preservation of life and protection of property. Petroleum dispensing stations handle highly flammable and combustible substances that ignite at any given time at a conducive condition. The government of Kenya has instituted various laws and legislation to alleviate the fire safety status of such workplaces which should be adhered to. This thesis presents a qualitative and descriptive study on assessment of the application and influence of Fire Risk Reduction Rules (FRRR) on the status of fire safety in petroleum dispensing stations in Kisumu County. Questionnaires, interviews, and observation methods were used in this study to collect the data. Forty-seven (47) petroleum dispensing stations (PDS) were sampled of which sixteen (16) were independent PDS (IPDS) and the other thirty-one (31) being the branded PDS (BPDS). One hundred and seventy-six respondents were interviewed. The study found out that 83% of the respondents were aware of the safe storage of highly flammable substances;16.8% of the PDS carried out audits. Measurement of presence explosive vapors at the PDS's using an explosimeter indicated an average of 3.0% and 2.4% at day and night respectively at the fueling pump site and fuel offloading storage site. 425 near misses and unsafe acts were reported collectively at the PDS's. The study concluded that none of the PDS had fully implemented the FRRR, there wasn't guarantee on status of fire safety at the PDS's. However, BPDS had a better performance in awareness, implementation of FRRR and status of fire safety. This study recommends; regular Audits, workplace inspections and awareness creation on fire risk reduction rules should be done by the occupier and enforcing authorities.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The Kenyan Energy Act (2019) defines retail dispensing site as premises where petroleum is stored in bulk in one or more tanks and dispensed to consumers for their own use and includes filling and service stations. Petroleum dispensing stations are categorized as hazardous workplaces where flammable substances, including gasoline, diesel and illuminating kerosene are stored either underground or above ground. Implementation of established fire risk reduction rules at any workplace is key to attainment of a safe workplace, petroleum dispensing stations handles highly flammable substances which categorizes the workplace as highly hazardous. This poses potential risk to personnel, public, property, and the environment, hence the need to have stringent rules regarding fire safety in place. Mismanaging safety matters in such workplaces could cause catastrophic disasters. Zhou . et al, (2016), The flammability hazard of fuel is quantified by its flash point, that is the lowest temperature at which the fuel can vaporize to form an ignitable mixture with air. Gasoline has a flash point around -43º C whereas Diesel fuel flash points vary between 52°C and 96°C (126°F to 204°F) depending on the standard method used in measurement.

The Kenya Energy Regulation Commission categorizes petroleum dispensing stations into branded firms and independently owned oil marketers. In Kisumu County the branded petroleum dispensing stations are thirty-eight in number while twenty-four are independently owned stations obtained from a physical count.

According to a study on Flash points and volatility characteristics of gasoline/diesel blends carried out by Al-Abdullah (2015), The flammability hazard of the fuel is measured according to a standard method such as the IP 170 (EN ISO 13736). For European diesel fuel, the EN 590 specification requires the flash point to be at least 55°C. This means that if the temperature is below 55°C, as it would be in Europe even in summer, the vapor above the liquid in a vehicle fuel tank would be too lean

to be flammable and there would not be a fire hazard. Adding a more volatile liquid like gasoline to diesel fuel can depress the flash point and dramatically increase the flammability hazard.

Fire risk reduction rules, 2007 LN 59, being a subsidiary legislation derived from the Factories and other places of work Act (cap 514), apply to every workplace. The main objective of the provision is to give guidelines on prevention of fire incidents at the workplace and means of protection of property and injury to persons at the workplace and its surroundings in case of any eventuality. According to (Rohini S. et al., 2016) fire is a dominant hazard in the workplace. Human factors such as carelessness, negligence and lack of fire safety awareness are some of the leading causes of fire outbreaks. Despite the technological advancement in fire safety, fire remains the leading cause of lives and property loss at commercial and industrial facilities worldwide and fire could lead to the premature winding up of an organization no matter how big it is. An effective fire prevention strategy is an essential feature of fire protection. However, it must be kept in mind that regardless of the efficiency of a fire prevention strategy, some fires inevitably occur.

The effects of a fire to a business can be devastating, not only to the business affected by fire and water damage, but also to the community served by the business. The lasting effects can extend far beyond the fire-related damage that can affect the local economy and visual appearance of the neighborhood. Depending on the extent of damage, many employers simply cannot continue business operations. This, of course, can have a negative rippling effect on tax revenues generated for the county government, as well as the impact to surrounding property values. The ripple effect of a fire, like a pebble cast into a pond, can even affect outside companies that once supplied the business with goods and services. "Unwanted fires have a monetary impact on communities because fires remove businesses from the tax rolls while the damaged building is rebuilt and reconstructed. Statistics confirm that over 40% of the businesses that experience a fire never reopen because they lose their customer base" (Stookey, 2010,).

According to the study carried out by Sam et al, 2009 on safety in oil and gas industries in Qatar it was established that the oil and natural gas industries in Qatar have a very good safety record. Yet this performance was achieved without any government agency that was the equivalent of the UK Health and Safety Executive or the US Occupational Safety and Health Administration. Neither availability of any legislation that was analogous to the Health and Safety at Work Act, or to Control of Substances Hazardous to Health, Control of Major Accident Hazards, Dangerous Substances and Explosive Atmospheres Regulations, Atmospheres explosive or Registration, Evaluation, authorization, and Restriction of Chemicals. There wasn't an organization like the Chemical Safety Board that disseminates information and lessons that can be learned from specific industrial accidents. Despite this the safety performance of the process industries was a commendable success story. It was an excellent example of how responsible project partners can self-regulate their activities and how meticulous, and almost obsessive, attention to safety training can lead to spectacular safety performance.

In Kenya, OSHA Legal Notice No. 59 of 2007 of the Laws of Kenya, 2007, stipulates the requirements to be adhered to in respective workplaces in ensuring the safety and health of workers. This role is bestowed on the occupier in the workplace to ensure the fire Risk reduction rules which are a basic guide to achieving a safe workplace from occurrence of fire incidents. Implementation of the requirements should be audited annually by certified auditors as provided by the Directorate of occupational safety and health department.

1.2 Statement of the Problem

Petroleum dispensing stations are workplaces handling highly flammable and combustible materials at any given time, the lack or partial implementation of stipulated rules and regulation on handling highly flammable and combustible petroleum products at petroleum dispensing stations increases the magnitude of fire hazard occurrence. Taking this into consideration, all works being undertaken in such workplaces should be under clear instructions and regulations to ensure the safety of

the workplace, these regulations have been stipulated in the fire risk reduction rules, 2007 as instituted by the government of Kenya.

The Annual assessed report from Kisumu County fire brigade indicated to have responded to eleven reported cases of fire incidents of which five were in petroleum dispensing stations in the year, 2015, which caused huge losses as a result of destruction of workplaces. It is on this basis that the study seeks to assess the application and influence of fire risk reduction rules on the fire safety status in petroleum dispensing stations while exploring possible remedial measures using the Fire risk reduction Rules, 2007 as the point of reference.

1.3 Justification of the Study

Fires cause huge losses globally ranging from loss of life, injuries to loss or/and destruction of property, especially those of highly flammable substances which result to explosion hence risk a high spread if not controlled within a limited time. It is therefore necessary to assess the application and influence of fire risk reduction rules and perceive its contribution in promoting fire safety in petroleum dispensing stations in Kisumu County.

This study is important in the following ways: by addressing the fire safety status in petroleum dispensing stations, the findings will be used to ascertain the gaps within the available fire risk reduction rules and either improve on them or introduce new ones which can improve the fire safety standing within the petroleum dispensing stations. Government establishments will use the findings to formulate policies on their enforcement.

Finally, this analysis will add to existing knowledge on fire safety measures in fuel dispensing stations in Kenya and the way to boost on the prevailing fire risk reduction rules and different legislation concerning fire safety in places of work.

1.4 Objectives of the Study

1.4.1 Main Objective

The main objective of the study was to assess the application and influence of fire risk reduction rules and fire safety status in petroleum dispensing stations in Kisumu County, Kenya.

1.4.2 Specific Objectives

(i). To establish the level of awareness of the fire risk reduction rules in the petroleum dispensing stations.

(ii). To determine the extent of implementation of the Fire Risk Reduction Rules in petroleum dispensing stations

(iii). To identify the fire safety status in petroleum dispensing stations

1.5 Research Questions

The study was guided by the following research questions.

(i). What is the level of awareness of the fire risk reduction rules in the petroleum dispensing stations?

(ii). What is the level of implementation of Fire Risk Reduction rules in petroleum dispensing stations?

(iii) What is the fire safety status in the petroleum dispensing stations in Kisumu County?

1.6 Scope of the Study

The study focused on the application and influence of fire risk reduction rules on the fire safety status in petroleum dispensing stations in Kisumu County, Kenya. This study covered petroleum dispensing stations in Kisumu County, Kenya. Factor identification was done on prior knowledge upon which emphasis was based on the implementation of the FRRR. The fire safety status of the stations and correlating the

influence of the FRRR to fire safety status in the petroleum filling as stipulated in the Fire Risk Reduction Rules, LN. 59 of 2007.

1.7 Conceptual Framework

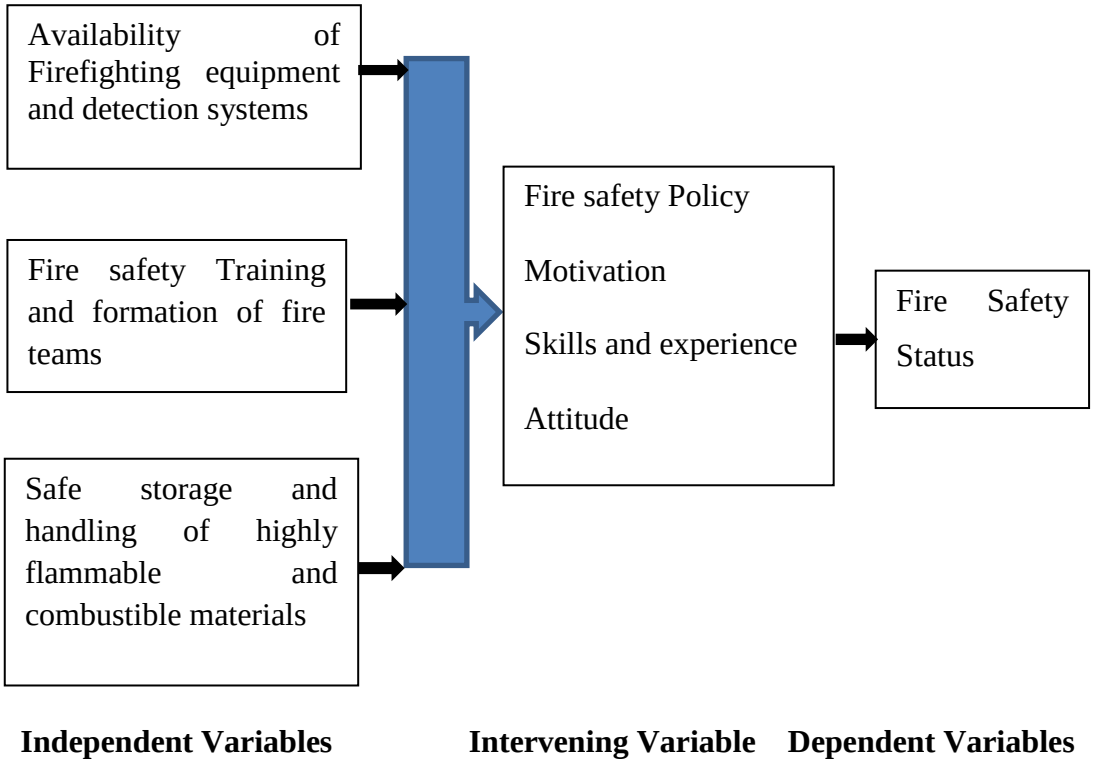

Figure 1.1: Conceptual Framework

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Principles.

2.1.1 Petroleum Dispensing Stations Fire Safety

Petrol stations are categorized as hazardous workplaces where flammable substances including petrol, diesel and illuminating kerosene are stored either underground or above ground. it a place where various modes of transportation fueling and refueling take place all day long. Due to the existing flammable substances, petrol stations pose potential hazard to the staff, public, property and the environment. Mismanaging safety matters in such workplaces could cause catastrophic disasters. Khalid et al, (2017).

According to Zhou et al. (2016), there are many sources of aspects which can cause ignition of fuel – air mixture or stored fuel in an oil depot. From the collection of various causes of fire and explosion accidents, the ignition sources could be divided into eight groups, namely electric spark, static electricity, lightning, open fire, smoking, heat sources (such as engine hot surfaces or heat generated by electric equipment), welding, and other types of sources such as impingement or friction.

2.1.2 Science of Fire

According to (Garson 2013) a fire is a chemical reaction in which a carbon-based material (fuel), mixes with oxygen (usually as a component of air) and is heated to a point where flammable vapors are produced. These vapors do come into contact with something that is hot enough to cause vapor ignition resulting into a fire.

Figure 2.1 shows a fire triangle of these factors involved to start and sustain a fire. Prevention of fires therefore focuses on eliminating the occurrence of one or all the three components Gairson (2013).

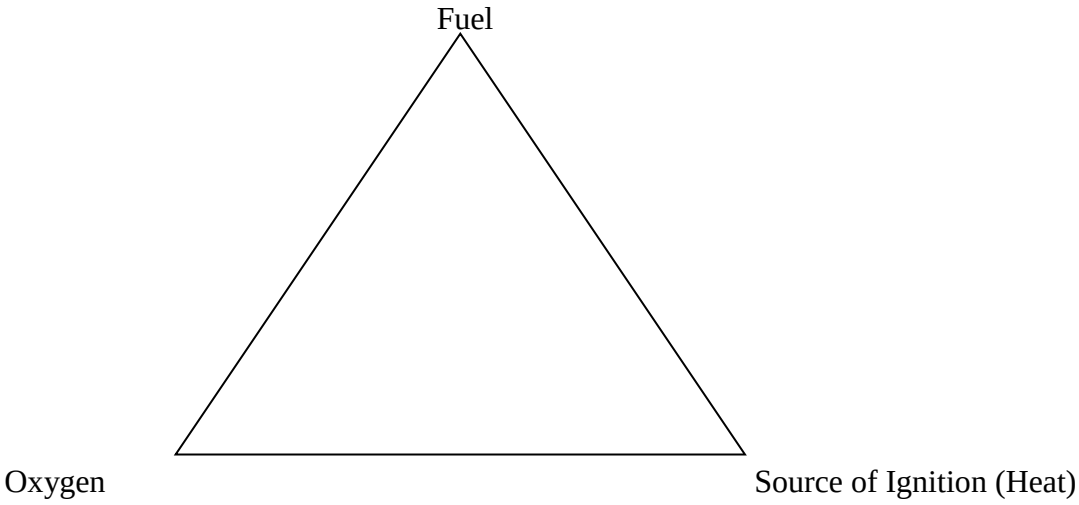

Figure 2.1: Fire Triangle (Source, Garson 2013.)

2.1.2.1 Classes of Fire

According to (FRRR, 2007) states the classes of fire as follows.

“Class A fire” fires involving normal combustible like paper, wood cloth, rubber, or plastic material.

“Class B fire” fires involving ignitable or flammable liquid, ignitable gases, or grease.

“Class C fire” fires involving energized electrical instrumentation where safety to the employee needs the utilization of electrically nonconducting extinguishing media.

“Class D fire” fire involving flammable metals like magnesium, zirconium, sodium, lithium, or potassium.

2.1.2 Fire Prevention

Zhang (2014) in his study noted that the safest way to deal with fire is to prevent it, proposing appropriate fire prevention measures in refueling stations, poses a great significance in reducing fire losses and ensuring safety of the station and surrounding

environment. Fire prevention strategies include, Proper housekeeping, safe systems of work, risk assessment, prohibition of smoking and sources of ignition, personnel training and maintenance of plant and equipment.

2.1.2.1 Plant and Equipment Maintenance

Zhang (2014) established that plant and equipment which its maintenance is not carried out properly have been the major causes of fire in most industries. Planned maintenance programme should deal with any suspected cause of friction heat due to loose drive belts, bearings which aren't properly lubricated and nay other moving parts. Leaking valves or flanges which could allow seepage of flammable liquids or gases are curbed prior to causing a disaster and static sparks due to inadequate earthing. All electrical equipment and installations should be installed, maintained, and inspected by a qualified contractor. Regular inspection and checks be carried out to remove defective equipment, ensure cords are in good condition, plug appliances and lights are in separate electrical outlets and used extension cords in the workplace are done safely.

2.1.2.2 Workplace Fire safety Inspection and Audits

Safety inspections are carried out to identify hazards, risks, and any other activity within the workplace, which is potential fire risk or unsafe practices, observe work practices to identify unsafe acts which could be rectified, eliminated, or accounted for. Firefighting Equipment inspection determines the availability, adequacy, and check of serviceability (Furness, 2010).

Safety audits are carried out to evaluate the safety programs and practices within the organization. This has been found to be the effective tool for assessing fire safety standards of an organization and assists in identifications of areas for improvement and evolve an action plan. It is done by carrying out field inspections using checklists i.e., inspection and by checking critical safety parameters of each building using level of compliances for measuring implementation of safety procedures (Siddiqui et al., 2014).

2.1.3 Fire Protection and Suppression

Fire protection and suppression systems of petroleum facilities follows the same philosophy of protection principles that is applied to any building or installation. The basic requirements are personnel evacuation, containment, isolation, and suppression of which these requirements are designed features that cannot be immediately brought in at the time of an incident, they must be adequately provided as part of the original facility design. Any organization should have a well thought out protection design philosophy that is understood and accepted by the management, these standards or guidelines form the basis from which the safety of the facility can be audited against. Organizations that do not provide such information do not have any accountability standards to meet or achieve, and therefore, the safety of the facility suffers accordingly (Gairson, 2013).

Barker (2018) reports that fires in buildings have resulted in loss of lives and property due to lack of adequate passive and active fire protection systems installation. The gap between standard/ regulation and the condition of fire protection systems in a building are based on lack of knowledge about the essence of the building management system and standard fire protection and these are not practiced according to the international and local standards and regulation.

According to (Spitzenberger et aly., 2016) when designing an effective and appropriate fire protection system, the engineers should implement both passive and active fire protection systems.

2.1.3.1 Active Fire Protection System

Active fire protection systems are designed to manage and mitigate the process of fire which require either automatic or manual intervention for actuation. These systems involve the application of fire extinguishing and other protective media to surfaces that are on fire or exposed to heat during an emergency. The fire extinguishing media include foam, powders, gases, and cooling agents. Active fire protection systems are intended to extinguish a fire, protect equipment in the vicinity from various damaging effects of fire, and reduce the risk of escalation of the

incident. However, these systems cause the smoke layer to stratify, which reduces visibility and increases the risk of smoke inhalation (Spitzenberger et al., 2016).

2.1.3.2 Fire Detection and Alarm System

According to Zhang (2009), a key aspect of fire protection is to identify a developing fire emergency in a timely manner, and to alert the building's occupants and fire emergency organizations. This is the role of fire detection and alarm systems. Depending on the anticipated fire scenario, building and use type, number and type of occupants, and criticality of contents and mission, these systems provide several main functions. They provide a means to identify a developing fire through either manual or automatic methods then alert building occupants to a fire condition and the need to evacuate. Another function is the transmission of an alarm notification signal to the fire department or other emergency response within the organization. These systems also shut down electrical, air handling equipment or special process operations, and initiate automatic suppression systems according to the design and set up intended by the organization.

Manual fire detection is the oldest method of detection where the simplest form, a person yelling can provide fire warning. However, in buildings a person's voice may not always transmit throughout the structure hence manual alarm stations are installed. The general design philosophy is to place stations within reach along paths of escape, that is near exit doors in corridors and large rooms. Thermal detectors are known to be the oldest type of automatic detection device, having origin in the mid 1800's, with several styles still in production today, most of its common units are fixed temperature devices that operate when the room reaches a predetermined temperature (usually in the 135°–165°F/57°–74°C). The second common type of thermal sensor is the rate-of-rise detector, which identifies an abnormally fast temperature climb over a short time. Both units are "spot type" detectors, which means that they are periodically spaced along a ceiling or high on a wall. The fixed temperature line type detector consists of two cables and an insulated sheathing that is designed to breakdown when exposed to heat. Whose advantage over spot detection is that thermal sensing density can be increased at lower cost (Frank, 2013).

Saylee et al. (2014) noted that Smoke detectors are a much newer technology, having gained wide usage during the 1970's and 1980's in residential and life safety applications. These devices are designed to identify a fire while in its smoldering or early flame stages, replicating the human sense of smell. The most common smoke detectors are spot type units, that are placed along ceilings or high on walls like spot thermal units. Smoke detectors operate on either an ionization or photoelectric principle, with each type having advantages in different applications. For large open spaces such as galleries and atria, a frequently used smoke detector is a projected beam unit which consists of two components, a light transmitter and a receiver that are mounted at some distance (up to 300 ft/100m) apart. As smoke migrates between the two components, the transmitted light beam becomes obstructed and the receiver is no longer able to see the full beam intensity which is interpreted as a smoke condition, and the alarm activation signal is then transmitted to the fire alarm panel.

Flame detectors represent the third major type of automatic detection method which imitate the human sense of sight. They are line of sight devices that operate on either an infrared, ultraviolet or combination principle. As radiant energy in the approximate 4,000 to 7,700 angstroms range occurs, as indicative of a flaming condition, their sensing equipment recognizes the fire signature and sends a signal to the fire alarm panel. Its advantage is that it is extremely reliable in a hostile environment. They are usually used in high value energy and transportation applications where other detectors would be subject to spurious activation. Common uses include locomotive and aircraft maintenance facilities, refineries and fuel loading platforms, and mines. Whereas the disadvantage is that they are awfully expensive and labor intensive to maintain. Flame detectors must be looking directly at the fire source, unlike thermal and smoke detectors which can identify migrating fire signatures (Accosta, 2014).

2.1.3.3 Automatic Sprinkler System

Water represents the ideal extinguishing agent in most fires. Sprinkler systems utilize water by direct application onto flames and heat, which causes cooling of the combustion process and prevents ignition of adjacent combustibles. They are most

effective during the initial flame growth stage where the fire is relatively easy to control. A carefully selected sprinkler will detect the fire's heat, initiate alarm, and begin suppression within moments after flames appear. These will control fire advancement within a few minutes of their activation in most instances, which will in turn result in significantly less damage than would have happened without sprinklers. Sprinkler systems are essentially a series of water pipes that are supplied by a reliable water supply. At selected intervals along these pipes are independent, heat activated valves known as sprinkler heads. These sprinkler heads are responsible for water distribution onto the fire. Some sprinkler systems design also include an alarm to alert occupants and emergency forces when sprinkler activation (fire) occurs (Barker, 2018).

Automatic fire sprinkler systems are designed to activate if a fire develops in their area of protection and limit or suppress the further development of the fire. when evaluating a building design that incorporates a sprinkler system for fire safety, knowledge of the effectiveness of sprinkler systems in reducing the risk from fire is important. The development of codified approaches to the design of systems (e.g. sprinkler standards) benefit from the knowledge of the effectiveness of the systems currently in use, Different methods of analyzing risk to fire safety in buildings have been developed (Frank, 2013).

2.1.3.4 Fire Extinguishers

A fire extinguisher is an active fire protection device which is used to extinguish or control small fires, often in emergency situations. A typical portable fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire. The two main types of fire extinguishers being the stored pressure and generated pressure. Stored pressure type is where the expellant is stored in the same chamber as the firefighting agent itself, depending on the agent used and different propellants used. The dry chemical type of extinguishers, nitrogen is used as the expellant whereas water and foam are pressurized with air. Cartridge-operated extinguishers contain the expellant gas in a separate cartridge that is punctured prior to discharge which exposes the propellant to the agent. Fire

extinguishers are further divided into handheld and cart-mounted type, also called wheeled extinguishers (Dey et al., 2014).

2.1.3.5 Hydrants

Fire hydrants are important municipal installations, placed at strategic positions to assist in putting out fires during an outbreak. This are above-ground connections that provide access to water supply primarily for the purpose of fighting fire. Every hydrant has one or more outlets to which a fire hose may be connected which provide sufficient water for firefighting, hydrants are sized to provide a minimum flow rate of about 945 liters per minute though varies according to pressure availability. The need for fire hydrants developed with the advent of underground water systems in the 1600‟s after installation of hollowed-out log pipes in England. As cities grew, so did their water systems and the need for a more effective fire management system. Water is the most cost-effective fire suppressant, and the fire hydrants gained more importance as fire departments and taxpayers alike realized that strategically placed, high-capacity hydrants can significantly reduce the impacts of fire hazards (Inah, 2018).

2.1.3.6 Foam Installations

Foam is used as a fire-fighting substance and is widely used for protection of industrial works, Storehouses, petroleum installations and other objects. The effect of fire suppression by foam is explained by the fact that the foam smothers the burning liquid hence cutting off the supply of oxygen, the water quantity in the finished foam also acts as a cooling agent to the fire. These provides a much faster knock off of the fire compared to the use of water only. Foam is majorly used in fires involving highly flammable substances for example petrol, diesel and illuminating kerosene. Because of this, the best foams are those that have a high resistance and provide a large reserve of water, i.e., have a comparatively small ratio (6–8), as well as the close-meshed foams, in which out rigged to the hydrant points at the time of need and are usually stored appropriately (Kachanov *et al.,* 2013).

2.1.3.7 CO_2 Suppression System.

According to (Siddiqui 2014) Carbon dioxide is one and half times heavier than air, colorless, odorless, non-combustible, electrically nonconductive inert gas. It is used to extinguish fires because it reduces the amount of oxygen in the atmosphere to the point where combustion cannot be supported. Its advantage is that no cleanup is required after use since it does not leave behind a residue. Carbon dioxide suppression systems have some disadvantages compared to other suppression systems because itis discharged as a gas for which its concentration is affected by the air movement around the dispensers which reduces the efficiency of extinguishment, and the cylinders require recharging. Carbon dioxide cylinders usually require to be installed in controlled temperature area where the temperature should not exceed 608C (NFPA-12, 2003).

2.1.4 Passive Fire Protection Systems

Passive fire protection systems are meant to contain fires or slow their spread in order to limit damage to the facility and give occupants more time to escape, evacuate, or gather in a safe area, they do not require energized initiation or any motion to activate it, only an effective barrier to prevent escalation. Spitzenberger et al, (2016)

2.1.4. 1 Fire Doors and Windows

Fire escape doors should be wide enough to allow people to pass through in the event of an evacuation. Fire doors protect persons escaping from heat, and more importantly, from the smoke generated from a developing fire. Signage indicating escape routes to the fire doors should be in place and installed with illuminating light to provide direction even in the event of a power failure in the given building. They should always be kept closed; however, because of their other function, they always open outward. Ismail, (2014)

2.1.4.2 Compartmentation

Another key strategy is to correctly design building compartments to keep the fire from spreading quickly. This entails placing barriers in the building such as fire-resistant doors and walls which confine the fire to a local area, or at least slow the speed at which it can spread. Compartments are designed based on the function of the buildings by architects, so residential and commercial buildings will have different compartment design strategies in order to ensure that occupants can remain safely, adequate compartmentation must be provided in support of the evacuation strategy. Feng (2018).

2.1.5 Explosive Atmospheres

An explosive atmosphere is formed when dangerous substances mix in the air. The fire spreads to the rest of the unburned mixture after ignition occurs once an explosive atmosphere is formed. There are many areas where conventional hazardous area classification is not applicable and yet “dangerous substances” are present. There is also a degree of confusion within many industries over what constitutes a dangerous substance and therefore confusion over where hazardous area classification is an applicable Basis of Safety. The use and limitations of hazardous area classification are discussed, where high flashpoint materials are present and where it is impossible to eliminate ignition sources. Dangerous substances are defined within the Dangerous Substance and explosive Atmosphere Regulations, 2002 (DSEAR, 2002) as flammable materials (liquids, gases, vapours, and dusts), compressed gases where an explosion hazard exists and acids where contact with metal may liberate hydrogen (Tony, 2015)

2.2 Legal Framework

2.2.1 Energy Act, 2019.

The energy act is an act of Parliament which is meant to consolidate the laws relating to energy, to provide for National and County Government functions in relation to energy, to provide for the establishment, powers, and functions of the energy sector

entities; promotion of renewable energy; exploration, recover, and commercial utilization of geothermal energy; regulation of midstream and downstream petroleum and coal activities; regulation, production, supply and use of electricity.

According to the Kenyan Energy Act, 2019, on Compliance with environmental, health and safety standards; require someone engaged in petroleum business to comply with the relevant Kenya standard and in the absence of such standard, the other standard approved by the commission from time to time on surroundings, health, and safety in consultation with the relevant authorities and in conformity with the relevant authorities concerning surroundings, health, and safety standards. In the event of a fire, explosion, oil spill, injury or fatality occurring while operating a petroleum facility or transportation of petroleum, either unintentionally or through negligence, the operator or person transporting petroleum shall immediately clean up the contaminated or damaged surroundings at his own expense, to the satisfaction of the commission and other relevant authorities.

2.2.2 Fire Risk Reduction Rules, 2007, LN59

The fire Risk Reduction Rules 2007, on handling of flammable substances, it is required of every occupier to ensure that the quantity of any highly flammable substance present at any one time in a workplace, shall be as small as is reasonably practical, having regard to the processes or operations being carried on. where highly flammable substances are to be conveyed within a workplace, the substances shall be conveyed through a totally enclosed system incorporating pipelines and pumps of similar appliances, but where conveyance of the substances within a workplace through a totally enclosed system is not reasonably practical, the substance shall be conveyed in vessels that are so designed and constructed as to avoid spilling of the substance.

In the process or operation, any highly flammable substance liable to be spilled or leaked all reasonable practical steps have been taken to ensure that the substance is contained or immediately drained off to a suitable container or to a safe place or otherwise treated to make it safe.

Regarding presence of flammable vapor in the workplace, there shall be no means likely to ignite vapour from any highly flammable substances, present where a dangerous concentration of vapour from flammable substances may reasonably be expected to be present. Continuous monitoring of the workplace with a view to assessing any possible fire risks and mitigate against them should be done and ensure that housekeeping is always maintained, dirt and refuse shall be removed at least once a day which should be kept in a receptacle. Every store shall have a marked gangway of at least one meter wide for the movement of persons; and where mobile equipment for transportation of material is in a store, a marked gangway shall be provided to accommodate the size of the equipment and for the use of persons working therein.

Regarding electrical safety, all electrical machines, equipment and hand tools in a workplace are properly earthed or double insulated and all electrical motors, fittings, attachments and switches shall be sparking proof in the workplaces where flammable liquids, vapors, dusts and gases are likely to be present. Fire safety audits being very essential to all workplaces should be carried out annually by a certified fire safety auditor. Firefighting equipment and detection system should be provided and distributed as the anticipated type of fire and magnitude. Firefighting equipment and installation should be maintained and inspected regularly to ensure availability and workability. Training in fire safety and formation of firefighting teams at each workplace is key to first and correct response to any given fire incident. The rule requires training to be conducted to employees and the occupier to ensure that at any given time a trained person is available at the workplace. The occupier should ensure fire drills are carried out annually. This is to gauge the response and capability to handle real incident by personnel and assisting agencies in the event of a real fire incident.

2.2.3 Occupation Safety and Health Act, 2007.

The Kenyan OSHA, 2007, is an act of Parliament to provide for the safety, health and welfare of workers and all persons lawfully present at workplaces, to provide for

the establishment of the National Council for Occupational Safety and Health and for connected purposes.

According to the OSHA, 2007, it is the responsibility of every occupier to ensure the safety and health of all persons working in his workplace. Each employee should also ensure his own safety and health and that of other persons who may be affected by his acts or omissions at the workplace and co-operate with his employer or any other person in the discharge of any duty or requirement imposed on the employer. He should always wear or use any protective equipment or clothing provided by the employer for the purpose of preventing risks to his safety and health and comply with the safety and health procedures, requirements and instructions given by a person having authority over him for his own or any other person's safety. All stocks of highly inflammable substances shall be kept either in a fire-resisting store, or in a safe place outside any occupied building Provided that no such store shall be so situated as to endanger the means of escape from the workplace or from any part in the event of a fire occurring in the store. In the case where highly flammable liquids are to be conveyed within a workplace they shall be conveyed through a totally enclosed system incorporating pipe-lines and pumps or similar appliances but where conveyance of highly flammable liquids within a workplace through such a totally enclosed system is not practicable, they shall be conveyed in vessels which are so designed and constructed as to avoid any risk of spilling and where in any process or operation any highly flammable liquid is liable to be spilled or to leak, all reasonably practicable steps shall be taken to ensure that any highly flammable liquid, which is spilt, or leaks shall be contained or immediately drained off to a suitable container or to a safe place. No means likely to ignite vapours from highly flammable liquids shall be present where a dangerous concentration of vapours from flammable liquids may reasonably be expected to be present and no person shall smoke, light, or carry matches, lighters or other flame producing articles, or smoking materials, in any place in which explosive, highly flammable or highly combustible substances, are manufactured, used, handled, or stored. The occupier shall take all practicable steps to ensure compliance with the foregoing provisions of this subsection, including the display at or as near as possible to every place in which this subsection applies, a clear and bold notice indicating that smoking is prohibited in that place. No plant,

tank or vessel which contains or has contained any explosive or inflammable substance shall be subjected to any welding, brazing, or soldering operation or to any cutting operation which involves the application of heat, until all steps have been taken to remove the substance and any fumes arising there from, or to render them non-explosive or non-inflammable and, if any plant, tank, or vessel has been subjected to any such operation, no explosive or inflammable substance shall be allowed to enter the plant, tank or vessel until the metal has cooled sufficiently to prevent any risk of igniting the substance all working hours.

2.2.4 Environmental Management and Coordination Act, 2015 (EMCA, 2015)

Kenya, EMCA 2015, is an act of parliament to provide for the establishment of an appropriate legal and institutional framework for the management of the environment and for matters connected therewith and incidental thereto.

According to (EMCA 2015), every person in Kenya is entitled to a clean and healthy environment and has the duty to safeguard and enhance the environment, no person shall discharge any hazardous substance, chemical, oil or mixture containing oil into any waters or any other segments of the environment contrary to the provisions of this Act or any regulations thereunder. A person who discharges a hazardous substance, chemical, oil or a mixture containing oil into any waters or other segments of the environment commits an offence and shall pay the cost of the removal of the hazardous substance, chemical, oil or a mixture containing oil including any costs which may be incurred by any Government agency or organ in the restoration of the environment damaged or destroyed because of the discharge.

2.2.5 Dangerous Substance and Explosive Atmosphere Regulations, 2002 (DSEAR, 2002)

The regulation sets minimum requirements for the protection of workers from fire and explosion arising from dangerous substances and potential explosive atmospheres. Employers are required to control the risks that fire, explosive atmospheres, and dangerous substances pose to people's safety while at work.

According to the regulations, dangerous liquids include petrol, solvent, paints, adhesives, and cleaning chemicals. These emit flammable vapours which could be set alight or explode in air. Gases include liquefied petroleum gas and methane that are stored in pressurized cylinders, when this escape, the gas could ignite and explode.

Chemicals include cleaning chemicals, which are unstable and could violently react with other materials or under certain conditions.

Dusts that are produced by work activities and materials including coal, woodworking, sugar and flour in the food industry, animal feed, and metal powders in factories. Clouds of dust raised by these could explode violently if ignited.

Zone classification according to DSEAR are as follows: zone 0 is a place which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is continuously present or for long periods or frequently.

Zone 1 is a place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is likely to occur in normal work operation.

Zone 2 is a place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is not likely to occur in normal work operation but if it does will only persist for a short period.

The zone identification will assist the employer to carefully select and install apparatus that will be safe for use in the explosive atmospheres, come up with measures to curb ignition sources from accessing the zones and several measures to ensure safety of the persons in the workplace.

2.3 Previous Works Relevant to the Study

In a study carried out in Minna Metropolis of Niger state in Nigeria by Abdulrahman (2014), to determine the level of awareness of hazards and safety measures among Petrol Filling Stations and assess the prevailing safety Practices in Petrol Filling

Stations, it was discovered that 65% of the Station Attendants were not properly trained on safety , forty five of Minna Petrol Filling stations didn't conform to Department of Petroleum Resources citing rules as setbacks from the road and residential areas were less than 30 meters. Independent Petroleum Marketers showed no concern on people selling Petroleum products in gallons, right in front of their Stations. Conglomerate owned Stations like the Nigeria National Petroleum Cooperation. Retail Outlets- (State owned), had better safety measures and orientations compared to those owned by independent marketers.

Rohini (2016) in his study on Knowledge and practices regarding fire safety amongst health care workers in tertiary care teaching hospital in Marathwada region of Maharashtra, India, established that Out of the 202 participants, majority 61.39% were females, 43.56% were in the age of 18-27 years, 28.21% were GNM, 34.16% were staff nurse, and 85.15% had 1-4 years of work experience. 96.4% had correct knowledge about what to do when there is fire accident, 81.68%, had correctly answered the question about DCP fire extinguishers can be used for A, B, C classes of fire. 87.13% had correct knowledge about where the evacuation map was displayed whereas 77.72% health care workers had knowledge about one type of firefighting equipment available in institution and only 27.72% knew fire emergency number. Only 48.2% of the respondents had adequate knowledge on fire safety preparedness. Most (83.3%) documentary items were missing across the institutions (i.e., fire safety preparedness policy document, copies with staff responsibility on fire management, evacuation plan, evacuation priority list, annual fire audit reports and fire drill reports). 93.07% respondents knew that important cause of death in fire accident was smoke and suffocation, and 77.72% had correctly mentioned that B class of fire does not cause by electric equipment, it is C class of fire cause by electric equipment. The study employed a cross sectional design where the date collected was analyses and presented in percentages. It was concluded that Majority of health care workers had significant knowledge though to achieve the role of every employee in fire accident there was need to give fire safety training for all health care workers on timely interval.

A study carried out on the Safety Practices in Filling Stations in Ile-Ife, Southwestern Nigeria by Olusegun et al, (2011), established that 94% were aware of safety measures with fire extinguisher being the most common safety measure known (54%). Fire hazard was the most common hazard known (94%). Setbacks from the road and residential areas were less than 30 meters in 90% and 48% of the filling stations respectively. Stations owned by conglomerates had better safety measures compared to those owned by independent private marketers. The study employed a descriptive cross-sectional type of methodology, this was carried out in filling stations located in Ife Central Local Government Area of Osun State between the months of April and May 2010.The list of all approved filling stations and their boundaries were obtained from the Town Planning office and all filling stations in this local government area were included in the study. Data was collected with the use of an interviewer-administered questionnaire. A walk-through survey was also done with the aid of a checklist which assessed the dimensions of the filling station, number of dispensers, fire extinguishers and their functionality, environmental parameters, and practices of attendants during fuel dispensing. Majority (92.6%) of the respondents were aware of safety measures in filling stations. Of these, only 55.5%, 25.9% and 37% are aware of the use of fire extinguishers, switching off the ignition before fueling and displaying of' No Smoking' labels in conspicuous places within filling stations, respectively.

In another study carried out on the Safety and health assessment in Kenyan petrol stations: Case study of Thika-Nairobi highway stations, Mutua (2012), it was established that, although the employees in all the identified stations were aware of the risks to safety and the health surrounding their work environment, the level of importance attached to this by the multinational dealers was higher than for independent stations. Training on employment and continuous sensitization was only done by multinationals. The study was carried out on petrol stations along the Nairobi- Thika superhighway, the then Nairobi-Thika highway where a total of twenty service stations were along the highway. However, four of them could not be classified because they were not registered by the energy regulatory commission. The results were recorded and analysed; the study sample entailed 100% of the total number of stations due to their small number. The research tools used were

Assessment where each service station was assessed individually, and an average score calculated before comparing the results with those of the other companies. A structured questionnaire was administered by guiding the interviewees (workers and managers) and the feed- back put down as understood by the researcher.

In a study carried out on Evaluation of Fire Protection Systems in Commercial Highrise Buildings for Fire Safety Optimization a Case of Nairobi Central Business District by Maina (2015) where a multi-attribute evaluation model/approach was applied to establish sufficiency and/or suitability of fire protection systems in the light of the national regulations and approved standards. The study findings show that, save for the facilities of the disabled and the firefighting/evacuation lifts, other fire protection systems were mainly provided in the buildings. However, insufficient maintenance and/or unsuitable elements rendered their safety performance low. The results of the analysis showed that portable fire extinguishers had the highest performance with 78.57% of the buildings sufficiently and suitably in terms of number, locations, servicing etc., while 0% of the building was sufficiently and/or suitably installed with a sprinkler system i.e., they all exhibited some deficiency in terms of coverage and maintenance issues. This could be associated with the cost factor. The results of other systems were as follows: Fire detection and alarm (14.29%); Escape route (50%); Emergency lighting (64.29%); Smoke control System (50.00%); Compartmentation (64.29%), Riser mains, hose reels and hydrants (64.29%); Fire Brigade access and facilities (64.29%); Safety signs and notices (7.14%); Portable fire extinguishers and Fire assembly points (28.57%). In view of the findings, it was recommended that increased efforts in inspection and maintenance of fire protection systems are considered to address the identified shortfalls throughout the project life. Provision for firefighting/evacuation lifts and facilities for the disabled persons should be considered during design of the commercial high-rise buildings.

In a study carried out by Qonono (2019) on Analysis of the fire hazard posed by petrol stations in Stellenbosch and the extent to which planning acknowledges risk,

aimed to investigate land-use planning in Stellenbosch, South Africa, it was observed that petrol stations pose a high fire risk for public safety therefore need for preparedness to handle large fires or explosions. To achieve this, the study first identified the land-use types around petrol stations in Stellenbosch and determined the extent to which their locations comply with the international and national planning regulations. Petrol stations within a six-kilometer radius from Stellenbosch's Centre were used as study sites. Second, the study examined the risk of fires/explosions at petrol stations. Third, the study investigated Stellenbosch Municipality's institutional preparedness to respond in an event of a fire/explosion at a petrol station. These results established that the siting of petrol stations does not comply with the international and national good practices, thus exposing the surrounding developments to fires and explosion and land-use planning does not consider hazards created by petrol stations. Preparedness to respond to petrol station fires by the Stellenbosch municipality appeared to be extremely low.

A study carried out on assessment of fire prevention and protection measures in group " C " buildings of Dehradun City, (2014) by Siddiqui et al. indicated that, Fire in any occupancy has potential to cause harm to people and severe damages to property. Part IV; hospitals and nursing homes had been classified under group "C" buildings. Fire safety audit was found to be the effective tool for assessing fire safety standards of an organization. It helped the people to identify the areas for improvement and evolve an action plan. In addition to this the project titled, "Assessment of Fire Prevention and Protection Measures in Group 'C' Buildings of Dehradun City" had been carried out to study, analyse, and assess the level of implementation of critical safety parameters by conducting Inspection and to suggest ways and means for improving the level of implementation of critical safety parameters. It was done by carrying out field inspections using checklists i.e., inspection and by checking critical safety parameters of each building using level of compliances for measuring implementation of safety procedures. This thesis presents an overview of the features and advantages of assessment, its findings and level of implementation of critical fire safety parameters of hospitals and nursing homes in the Dehradun city. It was concluded that most of the hospitals having fire extinguisher equipment fail to do the periodic checks and review of same at least

once in six month or year. It all depends on the firm how much importance is given to it. In many working firms it is mandatory to provide training to employees from each department from the expert and for that they get certificate as well also. In the wake of growing fire incidents, fire department must take up huge campaign tie up with celebrities and NGO's to creating awareness among all the employees about fire protection and prevention measures. Government should bring amendment to existing policies and made it mandatory to have fire prevention and protection measures, also employees should have the training from authorized agencies and should keep review and renewal of fire safety measures. This is the only way to prevent indiscriminately happening fire accidents.

Agyekum et al. (2016) on fire safety awareness and management in multi-storey students' hostels in Ghana, established that majority of the respondents didn't attach seriousness to the issue of fire safety in the various hostels surveyed, as such, fire safety awareness and management was low amongst most of the hostel occupants. The results further showed that 'storage of flammable materials in safe areas', 'provision of clear signage indicating exit routes and location of fire safety equipment', regular inspection and maintenance of electrical installations', 'regular inspection and maintenance of fire safety equipment', and 'accessibility to fire hydrants' are key practices which if implemented by management could control the outbreak of fire in the hostels. Although this study focuses on multi-storey students' hostels around the campus, the findings should be relevant to other hostels located within and around the campuses of other universities in Ghanaa. It was concluded that fire safety awareness was low amongst most of the hostel occupants. Similarly, fire disaster preparedness was obviously low and the likelihood of extreme danger to life and property in any fire incidence was high. Evidently, hostel management who were responsible for fire safety management had ineffectively executed their responsibilities to keep the students safe. The situation at hand in most hostels was alarming and pragmatic steps needed be taken to reduce to the barest minimum, the possibility of fire outbreaks.

According to an Assessment of Fire Safety and Evacuation Management in Nursing Homes in Dulbin by Moore (2012), it was established that None of the seventeen

nursing homes showed an adequate ability to prevent fire or evacuate residents to a place of safety neither of the nursing homes carried out adequate fire risk assessments. All the fire doors were kept closed hampering accessibility of exit in the event of a fire. Only one nursing home fully complied with relevant codes of practice in terms of construction and required fire safety facilities and had a sufficient standard of compartmentation to allow the movement of residents to a relatively safer part of the building to await rescue. There were however positive results such as the fact that all the homes had adequate automatic fire detection and alarm and emergency lighting systems installed and had carried out tests and maintenance on these systems to some extent. One home had routinely carried out all these required tests. Escape routes were found to be clear of obstructions and the standard of storage was high. Staff had received training in fire safety, and they were found to be motivated and receptive to improving fire prevention and evacuation. This was achieved where Seventeen nursing homes in Ireland were recruited to take part in this research. Ownership varies with seven private homes and ten health service executive administered homes involved. The homes were surveyed between May 2007 and November 2008. The methodology consisted of the following three elements: A building survey to establish fire safety facilities, an analysis of fire related documentation, Interviews with staff to establish existing fire safety procedure.

A Study carried out on the Awareness of Fire Safety Measures for Users and Staff of shopping malls: The Case of Mlimani City and Quality centre in Dar es Salaam by Kikwasi (2015) established that shopping malls were accessed by people from all walks of life and, therefore, provision of adequate fire safety measures was equally important. In Dar es Salaam, Tanzania, at large, use of shopping malls is a relatively new experience, and risks associated with use of shopping malls, such as fire outbreak, were not evident to frequent users. The main purpose of the study was to assess awareness of fire safety measures for users and staff of two shopping malls located in Dar es Salaam. The research adopted a case study strategy, and 100 respondents were involved in the study. Both random and purposive sampling methods were used to select respondents for the study. Multiple sources of evidence were used in data collection, namely literature review, observations, questionnaires,

and interviews. Findings indicate that both shopping malls have in place fairly fire prevention measures with varying degrees. Majority of staff and users indicated that they know fire safety measures, but their poor knowledge was reflected in assessing them on different equipment and installations, such as foam, hose reel, sprinklers, and drenchers. Results indicate that majority of respondents (71%) could not use firefighting equipment. It was evident that majority of respondents (88%) had never received any training on fire safety measures. The paper concluded that awareness of fire safety measure of users and staff of the two shopping malls was relatively low also the provision of fire safety training and instructions, such as posters for users and seminars for staff of shopping malls, shall be a focus of shopping malls owners and responsible authorities.

According to a study carried out by Danso et al, (2012) on the safety practices in oil and gas industries in Ghana, the study revealed several aspects of safety that, there are indeed peculiar safety hazards inherent in the operations of oil, gas and related energy industries that had the potential to cause danger to life, property, and the environment if not controlled and managed. It was observed that whereas pockets of regulation exist that address aspects of occupational health and safety in oil industry in Ghana, there was no national policy on occupational health and safety to guide the operations of the very industry. This leaving each of the companies investigated adopting its own safety regulations to guide its operations.

Some of the companies fared badly in the provision of safety education and training to visitors to their plants. This practice was dangerous in that when there was an accident, the visitors would be found wondering on how to conduct themselves. Furthermore, without safety education the visitor's self-conduct at the plant could be hazardous and pose a risk to his safety and health and indeed the safety of the plant and employees of the plant. In general, 22.9% of the companies were rated poor in the manner OH&S is practiced at their plants while they were rate excellent in 54.2% of the cases. The oil, gas and related energy industries must do better to improve safety at the workplace. The company that was found to be doing well in the manner safety was practiced at the plants, was the thermal power plant who scored excellent in 62.5% of the assessable areas and scored poor in only 12.5% of areas. The

company with the worst performance was the petroleum products storage company which scored excellent in only 50.0 % of the cases and scored poor in 31.3% of the cases. It was concluded that even though there were several legislative instruments whose area of coverage included aspects of safety in the oil, gas and related energy industries, no legislation exits that exclusively caters for the unique safety practices of that sector of industry. Further, it was found that the provisions of the Factories, Shops and Offices Act were inadequate to provide guidelines to ensure safety and healthy work environment in the industry. In spite the absence of specific national safety standards for the industry, the organizations studied had adopted varied international safety guidelines for the operation of their plants. Fire prevention and control was observed to be taken very serious by all the companies investigated. The thermal power company was identified to have the best safety practices amongst the companies investigated. Finally, it was observed that until the FID-Ghana is adequately resourced to effectively perform its monitoring and enforcement role in the industry, accidents will continue to occur in these industries.

Muindi (2014) in a study carried out on the assessment of workplace fire safety preparedness on KMTC campuses in eastern Kenya, established that Knowledge of staff on fire safety preparedness against OSHA, 2007 guidelines was low. Only 48.2% of the respondents had adequate knowledge on fire safety preparedness. A statistically significant association between staff knowledge level and cadre was noted ($\chi 2=34.565$; $p = 0.000$). Electrical faults were the most perceived fire hazard by 90.8% of the respondents. Majority (86.5%) of the respondents expressed the need for a basic training on fire safety preparedness. More than 60% of the respondents rated their fire safety preparedness level as below average. Most (83.3%) documentary items were missing across the institutions (i.e., fire safety preparedness policy document, copies with staff responsibility on fire management, evacuation plan, evacuation priority list, annual fire audit reports and fire drill reports). Most (84%) of the respondents had never been trained on fire safety preparedness. Fire safety committees as well as firefighting teams were also absent across the institutions studied. None of the colleges performed fire and safety drills. Majority (75.0%) of the buildings did not comply with the OSHA, 2007 building requirements on means of escape. Further, there was a statistically significant difference between

the institutions and the availability of fire extinguishers ($\chi 2$=10.791; p= 0.005), the availability of evacuation plans in the workplaces ($\chi 2$= 10.146; p=0.006) and the availability of sand buckets ($\chi 2$= 10.401; p=0.006).

A quantitative risk analysis for explosion safety of oil and gas in services stations carried out by Yimiao fluang (2017) established that many onshore and offshore oil and gas explosions have been occurring over years globally. Among them the piper alpha oil production, the Ghana petrol station explosion, and Kaohsiung underground pipeline explosions which are some of the most disastrous incidences.

According to a study by Zakya et al. (2021). on Determination and classification of explosive atmosphere zones while considering the height of discharges in hydrocarbon industry, it was noted that Prevention and protection of explosions are two notions often used subjectively, and to transform them into operative terms of decision support, it is indispensable to develop quantitative or semiquantitative approaches to determine the hazardous zones. The "classical and point-source" approaches that determine ATEX (explosive atmospheres) zones are semiquantitative methods that can meet the requirements of the ATEX directives (Directives 99/92/EC and 94/9/EC). The methodology's principle in determining ATEX zones consists in making a comparison with typical examples "classical approach" and to identify the source points, determine the degree of discharge, identify the type of the zone, determine the radius of the zone and ultimately the extent and shape of this zone "source point approach." The aim of this work is, on the one hand, to propose and present a classification methodology of the ATEX zones and, on the other hand, to apply the proposed methodology in a hydrocarbon separator.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Design

Qualitative and cross-sectional descriptive studies were employed in the research. Cross sectional descriptive design provides a wide range of variables without manipulation as direct response from the respondents is received.

3.2 Study Area and Population

The study was undertaken in Kisumu County which has total Population of 968,909; it covers an area of 2,085.9Km^2. The Population density was 465 Person per Km^2, according to the 2009 Census. By the year 2017, the projected population was 1,145,747. The average population density was 482 persons per square kilometers. (KNBS, 2015). The population according to the 2019 national census was 1,155,574, indicating a population density of 550 persons per Km^2.

The study area consisted of seven Sub Counties, namely, Kisumu East, Kisumu West, Kisumu Central, Muhoroni, Nyando, Nyakach, and Seme.

The major economic activities include fishing, agriculture, industry, services, and tourism. Its elevation is 1,131m above sea level.

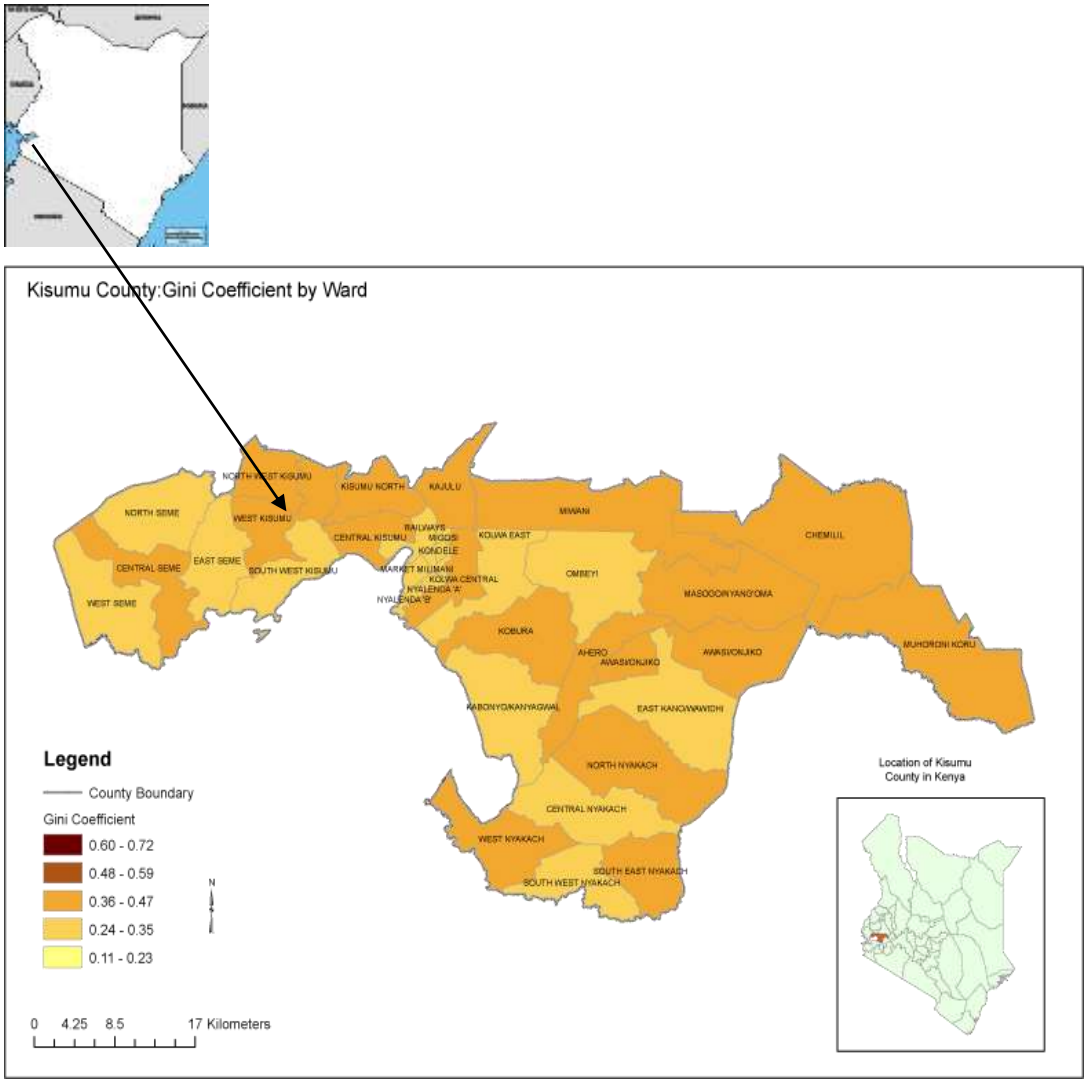

Figure 3.1: Map of Kisumu County. (Source: Google maps)

3.4 Target Population

The target population for the study comprised of petroleum dispensing stations distributed in the seven Sub Counties in Kisumu County and the petroleum station workers being the respondents. The target population was divided into two groups: the petroleum dispensing stations which were categorized independent petroleum marketers and branded petroleum companies as defined by the Energy Petroleum Regulatory Authority and the workers in the petroleum filling station formed the other target population.

Table 3.1: Target Population

Sub County	Independent Marketers stations	Branded companies' stations	Total
Kisumu Central	3	16	19
Kisumu East	4	8	12
Kisumu West	6	2	8
Nyando	3	3	6
Muhoroni	3	5	8
Seme	2	2	4
Nyakach	3	2	5
TOTAL	24	38	62

Source: author- physical count.

3.5 Sampling Method

Multi - stage sampling method was employed in the study, whereby from the seven sub counties that form Kisumu County, Four Sub Counties were selected, these being Kisumu east, Kisumu west, Kisumu central, and Muhoroni were purposefully selected as the sample. This was due to the concentration of number of the petroleum dispensing stations to make an effective representation.

All the petroleum dispensing stations in the four sub counties formed the target population from which respondents were selected. For each petroleum dispensing station, simple random sampling was used to select respondents.

3.6 Sample Size Determination

Mugenda and Mugenda (1999), stated that where time and resources allow, a researcher should take as big a sample as possible. The study took a sample of 50% of the total targeted sub counties which was four sub counties. All the petroleum dispensing stations in the four sub counties were sampled which makes 100% sample. The consideration was made because of the high concentration of petroleum dispensing stations in the given sub counties which could form a reliable

representation. In each petroleum dispensing station, the total number of workers was tabulated in table 3.2, after carrying out an interview with the station supervisors to establish the population of respondents in all the selected petroleum dispensing stations.

Table 3.2: Sample Size

Sub county	**Number of PDS**		**Number of employees**	
	IPDS	**BPDS**	**IPDS**	**BPDS**
Kisumu Central	3	16	20	112
Kisumu East	4	8	16	35
Kisumu West	6	2	27	10
Muhoroni	3	5	15	40
TOTAL	16	31	78	197

For determination of the sample size for questionnaire administration, the Fisher Formula, given by equation 3.1 was applied:

$$n = Z^2Pq/d \quad \text{..... Equation 3.1}$$

where:

n = sample size

Z = 1.96 (reliability coefficient at 95% confidence interval)

P = 50% estimate of the proportion under study

q = 1 – P

d = margin of error (0.05 degree of precision)

using the formula above the sample size was calculated as follows:

$n= (1.96)^2\ 0.5(1-0.05)/\ 0.05^2$

Finite population calculation (FPC) was further used since the population (N) was less than 10,000.

$$nf = n/(1 + \frac{n}{N})$$ ..... Equation 3.2

$$nf = 384/(1 + \frac{384}{275}) = 160$$

The sample size, n = calculated sample size + 10% nf to cover for the non-response.

Therefore n = 176

Respondents were selected proportionally in the 47 petroleum dispensing stations, after achieving the sample size to be used in questionnaire administration.

3.7 Research Instrument

Structured questionnaires, interviews, photography, measurements, and observation method was used with a guide of a preformulated checklist. The questionnaire was designed in four Parts. Part A covered the general information of the respondents capturing the petroleum filling station and duration worked. Part B aimed to get information about the awareness of the FRRR in the petroleum dispensing station. Part C covered the level of implementation of the FRRR in the workplace and the duration of operation of the PDS, whereas Part D covered the fire safety status of the PDS. A guide checklist was used to record observation on application of the FRRR within the workplace with the guide of the officer in charge. The questionnaire was pretested by administering four petroleum dispensing stations in Uasin Gishu County, of which two were BPDS and IPDS respectively. Ten number questionnaires were administered of which eight were successfully filled.

Explosive atmosphere Measurements were carried out using an explosimeter gadget which is a portable or stationary instrument that measures the concentration of the combustible gases in the atmosphere. The gadget is a gas warning device that indicates the content of explosive gases in the atmosphere by showing the percentage of explosive limit. This is according to the appropriate calibration gas for the intended application.

A Gas alert model MAX XTII was used for the study. This gas detector monitors up to four hazards: H2S, O2, CO and other combustible gases. The combustible sensor is calibrated at 50%LEL. To operate the gas detector: all connections were ensured to have been done and calibration confirmed. The activation button was pressed, then wait for the buzzer and indication on the screen. Detection was allowed for the identified area, if explosive atmosphere is detected, an alarm will go off to alert the user. Readings were obtained from the gadget screen.

3.8 Data Processing and Analysis

The filled questionnaires from the respondents were scrutinized for accuracy, consistency, and completeness. Only completed questionnaires were coded and analyzed. The data collected was analyzed with the aid of SPSS computer program. The data was analyzed using descriptive statistics and the results presented using frequencies and percentages. The results were then presented using charts, tables, frequencies, and percentages.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Response Rate

The questionnaires were administered to 176 respondents, of which 155 were successfully filled. This represented 88% response rate. Mugenda (2003) argues that a rate of 50 percent or higher is adequate for data analysis. This implies that 88% percent response rate was quite appropriate for data analysis.

4.2 Demographic Information of Respondents

The study sought to find out the gender of the respondents at the petroleum dispensing stations, indicated in figure 4.1.

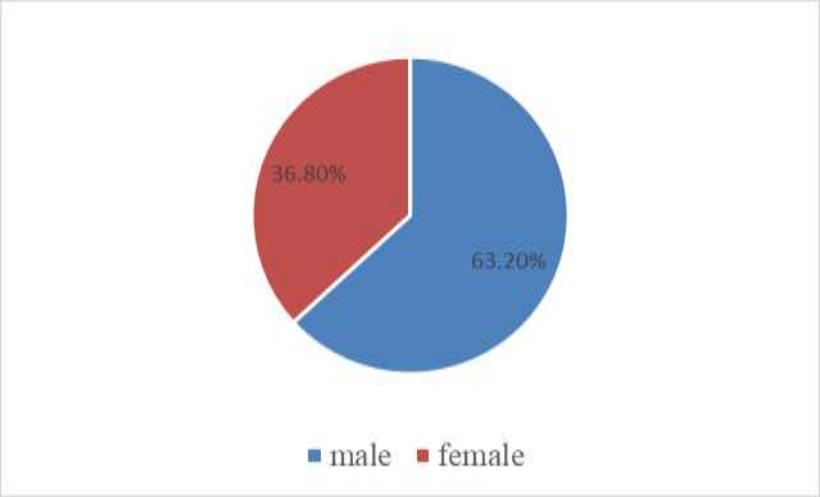

Figure 4.1: Gender of Respondents

The study found out that most of the respondents working in the petroleum dispensing stations were male 98(63.2%.) while female were 36.8%.

In figure 4.2, data on age of the respondents was collected and tabulated.

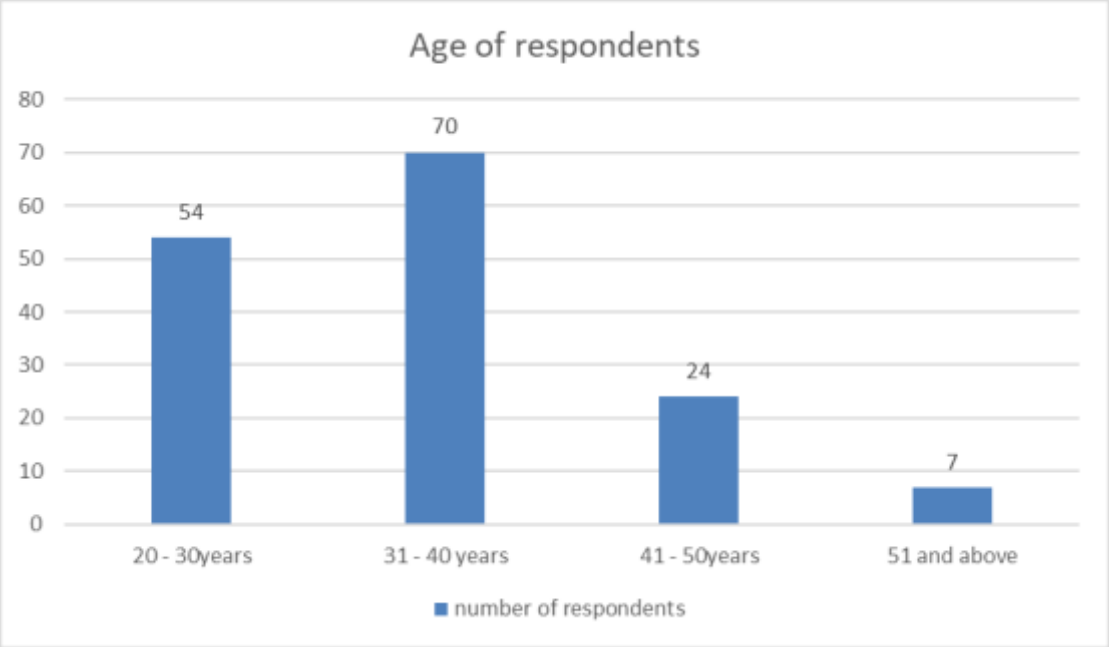

Figure 4.2: Age of Respondents

The age of the respondents indicated majority were of 31 – 40 years being 70(45.2%) while the minority were 7(4.5%) above 51 years of age. The study mainly deals with questionnaires regarding aspects of rules and regulations, which requires quite an understanding, the age of respondents would highly impact on achieving relevant information considering a young and youthful age would easily understand, hence achieving relevant response.

The data on level of education by the respondents was obtained during the study as tabulated in figure 4.3.

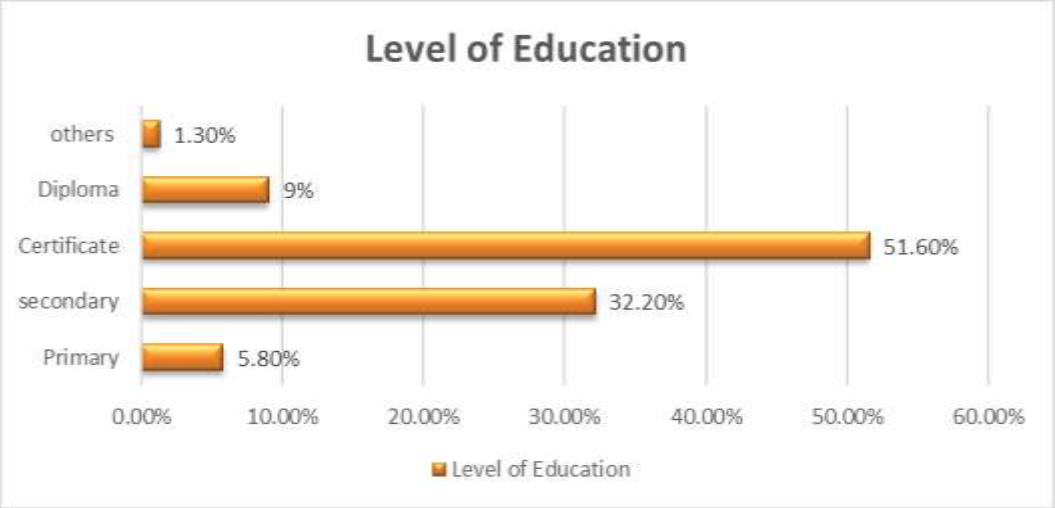

Figure 4.3: Level of Education

The level of education is a determinant on the understanding of the questions and response, from the results most of the respondents had undergone secondary education and above implying a positive understanding of the questionnaires. From the study most of the respondents had attained from certificate level at 51.6% while the least were the ones who couldn't state their level of education at 1.30%.

Respondents were asked how long they had worked in the particular workplace to determine their work experience which was established as indicated in figure 4.4.

Figure 4.4: Respondents Work Experience.

Most respondents had a work experience of one to five years at 62.6% while those who worked above 10years being 3.90%.

The duration the petroleum dispensing station had been in operation was established as shown in figure 4.5.

Figure 4.5: Duration Workplace has been in existence and operational.

It was established that most of the petroleum stations had been in existence for five to ten years while the least which were seven stations had been operational for less than five years.

4.3 Level of Awareness on the Fire Risk Reduction Rules in the PDS.

The level of awareness on the fire risk reduction rules was sought in both the branded and independently owned petroleum dispensing stations. Questionnaires were administered, to ascertain the awareness by respondents to the fire risk reduction rules which were implemented in their workplaces. Table 4.1 indicates the results on awareness of the fire risk reduction rules obtained from both the Branded and independent petroleum dispensing stations.

Table 4.1: Safe Storage and Handling of Highly Flammable Substances

Variable	Aware	Not aware
Fixed Storage tanks in safe position away from direct sunlight	126(81.3%)	29(18.7%)
Fire resistant storage structure	96(61.9%)	59(38.1%)
Availability of tank breathers.	38(24.5%)	117(75.5%)

The response on awareness of safe storage and handling of petroleum products indicated that 126(81.3%) of the respondents were aware that the highly flammable substances should be stored in fixed storage tanks which should be in safe positions and away from direct sunlight which increase the expansion of the substances raising the fire hazard risk. Availability of tank breathers being the least on awareness level in which only 38 respondents were aware, these breathers act as thermal relief points when the flammable substance expands, lack of point of breathing can easily result in explosion. According to Zhou (2016) it was established that over half of the accidents (51.03 %) took place in the loading and unloading operation area where large amount of fuel-air mixture evaporates from the loading and unloading operation area during the ritual oil filling or off-loading works from oil tank trucks. The second most dangerous area was discovered to be the oil storage area of which the proportion reaches 23.68 %. Storage tanks are the major equipment to store the flammable fuel in oil depots. When the fuel in the storage tanks is ignited by lightning, electric spark, or static electricity, it will cause some serious pool fire, surface burning or deflagration within the protective fire dike.

Chi- square test was used to determine the association between the categorical variables of demographics and level of awareness. P value = 0.05, whereby when the p-value is greater than 0.05, the significant association doesn't exist.

Table 4.2: Awareness of Safe Storage and Handling of Highly Flammable Substances by Demographics

Variable	Category	Level of awareness		Chi – square
		Aware	Not aware	
Gender	Male	68.3%	31.7%	$\chi 2$=6.02,df=3, p=.002
	Female	57.4%	42.6%	
Age	20 -29years	58.9%	41.9%	$\chi 2$=9.02,df=4, p=.050
	30- 39 years	86.9%	13.1%	
	40 – 49 years	97.5%	2.5%	
	50 years and above	87.3%	12.7%	
Highest level of Education	Secondary	72.6%	27.4%	$\chi 2$=11.702, df=6, p=.250
	Certificate	69.5%	30.5%	
	Diploma and above	67.3%	32.7%	
Work experience	1 – 5 years	50.6%	49.4%	X^2=5.762, df=2 p=.017
	5 -10 years	86%	14%	
	Above 10 years	90.8%	9.2%	

The relationship on the level of awareness on safe storage and handling of highly flammable petroleum products and work experience varied from the various aspects under the requirements expected. The relationship between work experience and awareness on storage of highly flammable product in safe positions and away from the sunlight was statistically significant at 95% confidence level x^2 (df=2) =4.03since p = .030 most of the respondents who had worked longer in the stations were aware of this requirement than those less than five years. Awareness on availability of storage tank breathers was however not statistically significant a confidence level of 95% x^2 (df=4) =6.702 and p=.150, the longer the experience could not establish automatic knowledge on the requirement.

It was further established that there was no significant association between the level of education and awareness of fire risk reduction rules where p-value was .250. However, there was a significant association between the level of awareness and age

of the respondents, the p-value was 0.002, this was largely attributed to the number of years the respondent had input on the work.

The study sought to find out the level of awareness on availability of adequate firefighting equipment and fire detection systems in both BPDS and IPDS. The results are as indicated in the table 4.3.

Table 4.3: Level of Awareness on Firefighting Equipment and Detection Systems

Variable	Aware	Not aware
fire detectors	45(29%)	110(71%)
Fire alarm system	82(52.9%)	73(47.1%)
Dry powder extinguishers	100(64.5%)	55(35.5%)
Water type extinguishers	96(61.9%)	59(38.1%)
Carbon dioxide type extinguishers	76(49%)	79(51%)
Automated foam sprinkler system	35(22.6%)	120(77.4%)

The findings from the above results indicate that 100(64.5%) of the respondents were aware of availability of dry powder type fire extinguishers in the station while 35 respondents were aware of availability of automated sprinkler systems within the work place this concurred with the study on the Safety Practices in Filling Stations in Ile-Ife, South Western Nigeria by Olusegun et al, (2011), established that 94% were aware of safety measures with fire extinguisher being the most common safety measure known (54%).

Another study by Muindi (2014) indicating that more than half (55.1%) reported that they knew how to use a fire extinguisher. Further analysis of the individual colleges revealed that about seventy percent (70%) and fifty-six (56%) of the respondents in Meru and Kitui Campuses respectively knew how to use fire extinguishers. However, in Embu Campus, 60.8% of the respondents had no idea of how to use the extinguishers. Firefighting equipment are quite crucial at any given workplace as

they provide with means of dealing with fire in the initial stages as external assistance is being sought determining on the magnitude of the fire.

Fire detectors raise alarm on the onset or before fire begins which assists in tackling an incident before it gets massive. The absence of this systems, response team might not easily to control a fire if it's discovered in the event it has already spread. This indicates the importance of such installations in the workplace. The study discovered that most of the respondents were not aware of the installation of fire detection systems in the workplace at 29% however a good number could indicate being aware of the alarm systems.

The study sought to find out the level of awareness on availability and display of signage in the petroleum dispensing stations, the results are as presented in figure 4.6.

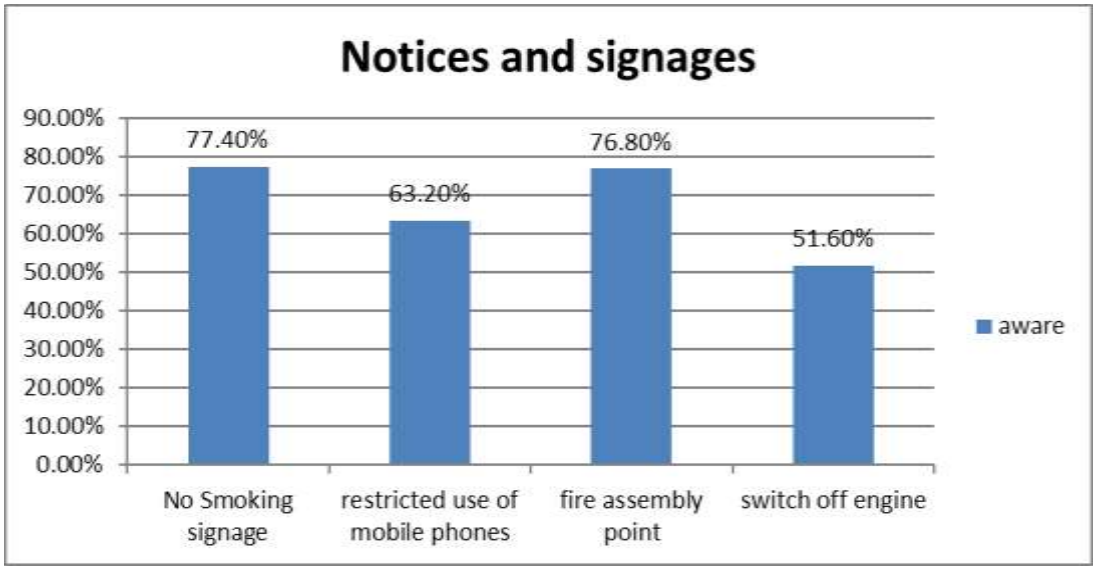

Figure 4.6: Level of Awareness on Availability and Display of Signage

According to the Fire risk reduction rules section 27. (1) clearly indicates that no person shall smoke, light, or carry matches, lighters or other flame producing articles or smoking materials, in any place where highly flammable or highly combustible substances are manufactured, used, handled, or stored. For this requirement to be enforced signage should be installed in both writing and drawing in the workplace,

especially the petroleum dispensing stations. The study established that an average number of respondents were aware of all the signage placed in their workplace with all the questions response being above 50% awareness. The most being aware of the NO smoking signage display and availability of fire assembly points at 77.40% and 76.80% respectively.

Table 4.4: Level of Awareness on Availability and Display of Relevant Signage in the Petroleum Dispensing Stations by Demographics.

Variable	Category	Level of awareness		Chi – square
		Aware	Not aware	
Gender	Male	78.4%	20.6%	$\chi 2$=4.02, df=2, p=.030
	Female	82.7%	17.3%	
Age	20 -29years	51.5%	48.5%	$\chi 2$=5.02, df=2, p=.050
	30- 39 years	76.9%	23.1%	
	40 – 49 years	93.5%	6.5%	
	50 years and above	92.3%	7.7%	
Highest level of Education	Secondary	87.7%	12.3%	$\chi 2$=6.702, df=4, p=.150
	Certificate	88.9%	11.1%	
	Diploma and above	72.7%	27.3%	
Work experience	1 – 5 years	67.9%	32.1%	X^2=9.762, df=2 p=.036
	5 -10 years	89%	11%	
	Above 10 years	97.1%	2.9%	

The study established a significant relationship on level of awareness of the NO smoking signage and the restricted use of mobile phones at the pump sites, this was confirmed by the p value being 0.03 and 0.05, respectively. Most of the respondents who had worked for less years could not consistently indicate knowledge on the availability and enforcement of the relevant signages. However, some of the aspects did not have statistical significance with p value being 0.150.

The study sought to establish the level of awareness on carrying out of fire safety audits in the workplace. The results are as indicated in figure 4.7:

Figure 4.7: Level of Awareness on Fire Safety Audits

Fire safety Audits should be conducted annually in all workplaces to ascertain the compliance level to fire safety provisions which would assist in improving the safety status of the workplace. The findings from the study indicated that most respondents were not aware of the provision and importance to carryout fire safety audits, only 16.8% were aware. This was contrary to a study carried out by Siddiqui et al. (2014) where Fire Safety audit was found to be the effective tool for assessing fire safety standards of the organization. It helped the people to identify the areas for improvement and evolve an action plan.

The study sought to establish the level of awareness on training and formation of fire teams in the petroleum dispensing stations, the results are as indicated in figure 4.8.

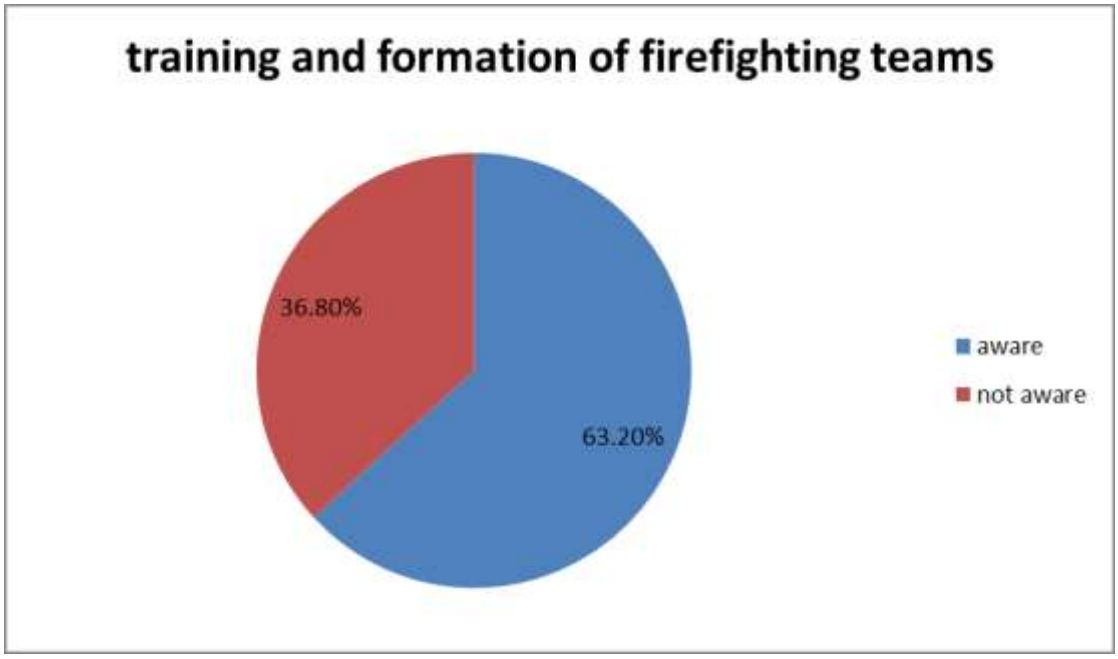

Figure 4.8: Level of Awareness on Training and Formation of Fire Teams

It was established that 63.2% of respondents were aware of the need to train in firefighting and have teams to respond in the event of a fire incident occurrence. It is a requirement stipulated in the fire risk reduction rules to ensure firefighting teams are trained conducted and refresher conducted annually by the occupier. Despite this regulation several respondents were still not aware of the provision. According to the study carried out on the Safety Practices in Filling Stations in Ile-Ife, Southwestern Nigeria by Olusegun et al, (2011), Majority (92.6%) of the respondents were aware of safety measures in filling stations. Of these, only 55.5%, 25.9% and 37% are aware of the use of fire extinguishers, switching off the vehicle ignition before fueling and firefighting training.

Chi-square test was employed to find out the statistical association between work experience of the respondents and the level of awareness, where p-value is ≤ 0.05. indicates significant association of the two variables. The results are indicated in table 4.5.

Table 4.5: Association between Work Experience and Level of Awareness on Training and Formation of Fire Teams by Respondents' Demographics

Variable	Work experience	Level of awareness		Chi Square
		Aware	Not Aware	
Awareness on training and formation of fir teams	1 day – 5 years	45(46.3%)	52(53.7%)	$\chi 2$=6.122, df=4, p=.035
	5 – 10 years	49(94.3%)	3(5.7%)	
	10 years and above	6(100%)		

Fire safety training and formation of fire teams in any workplace ought to be mandatory and each worker be aware as is a requirement by law. The study however established that most of the workers with work experience between 1 day to 5 years most of them were not aware of the fact that it is the responsibility of the occupier to ensure they undergo training. Awareness on this was statistically tested and a found significant association established between experience years and level of awareness, with 95% confidence level with $\chi 2$(df=4) =6.122, with p=.035. This concurred with a study carried out by Chung et al (2015) on the relationship between age, work experience, cognition and work ability in older employees working in heavy industry in korea, indicated that as age increases, work experience also increases ($p<0.01$, correlation coefficient: 0.31). Further, the higher the level of experience an employee ($p<0.05$, correlation coefficient: 0.21) indicated presence of significance.

The study sought to find out the level of awareness on installation of spark proof electrical equipment. The findings were as indicated on figure 4.9.

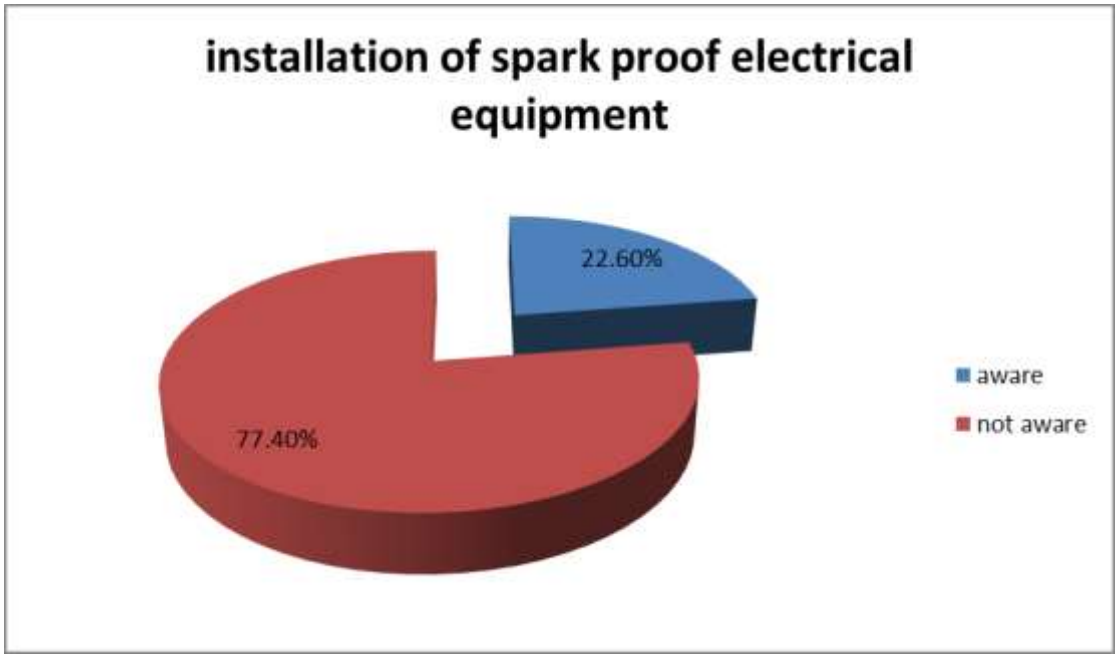

Figure 4.9: Level of Awareness on Installation of Spark Proof Electrical Equipment

It was established that most of the respondents were not aware of spark proof equipment in the workplace, 22.6% were aware of this requirement while the remaining 77.4% were not aware. According to the fire risk reduction rules, any workplace handling highly flammable substances, the equipment in the presence of this flammable vapors should be of spark proof material, this will curb the occurrence of fire because of flash points of this flammable substances. Gasoline having a flash point of -40 degrees and diesel 55 degrees can pose a massive fire hazard in the event of a spillage within the workplace.

In figure 4.10, Comparison on level of awareness on safe storage and handling of highly flammable and combustible substances was carried out between the IPDS and BPDS. The study explored their disparity despite the rules being equally applicable.

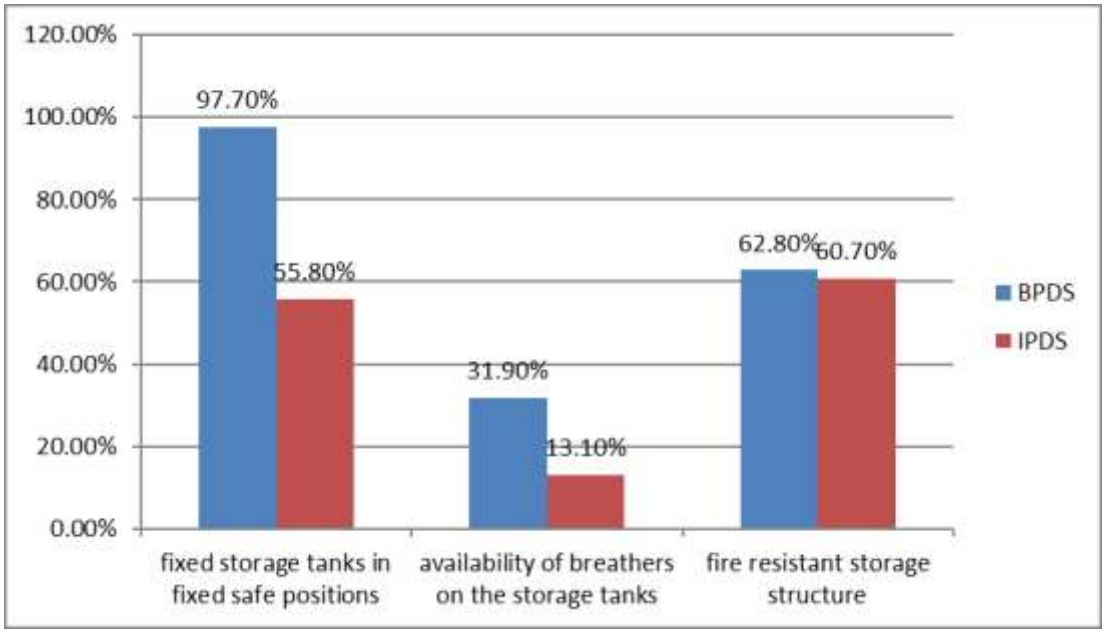

Figure 4.10: Comparison on Level of Awareness of Safe Storage and Handling of Highly Flammable Substances in BPDS and IPDS

The findings indicated most of the branded petroleum dispensing station respondents were aware of the storage of petroleum products in fixed storage tanks in safe positions. This was indicated by 97% respondents who were aware in the BPDS as compared to 55.8% of the respondents in the independent petroleum stations. This could be attributed to the fact that most of the branded petroleum dispensing stations are owned by multinational companies with standards operating procedures as compared to independent petroleum dispensing stations which are individually owned and operating without standard operating procedure. This concurred with a study carried out on the Safety and health assessment in Kenyan petrol stations: Case study of Thika-Nairobi highway stations, Mutua (2012), it was established that, although the employees in all the identified stations were aware of the risks to safety and the health surrounding their work environment, the level of importance attached to this by the multinational dealers was higher than that for independent stations.

A Comparison on level of awareness on availability of adequate firefighting equipment and fire detection systems in IPDS and BPDS was carried out as tabulated in figure 4.11.

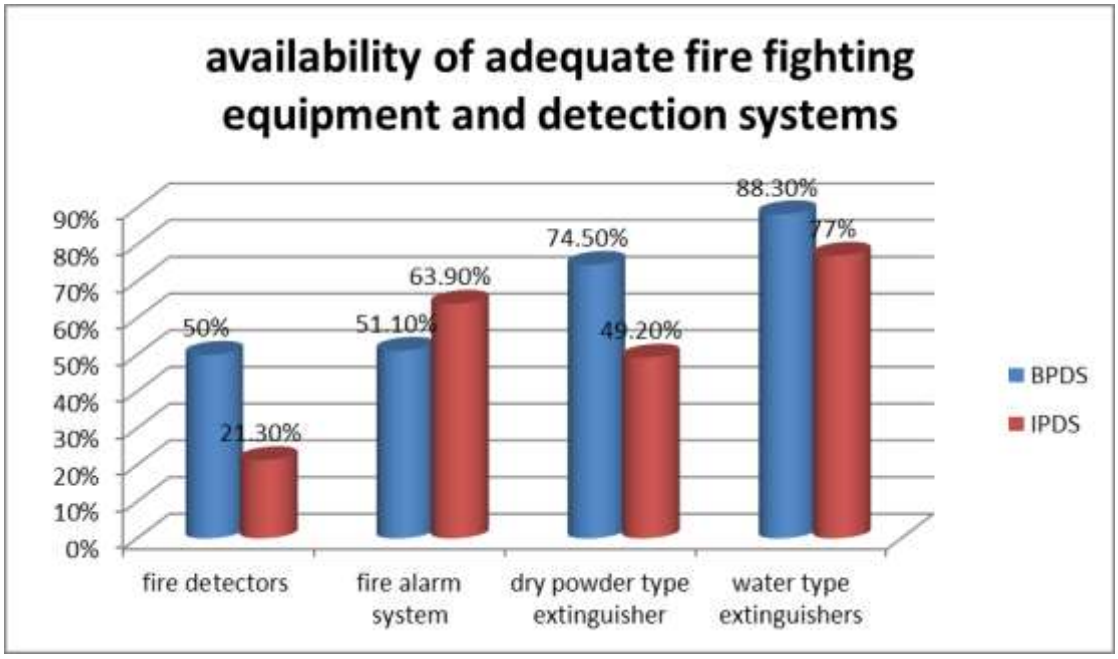

Figure 4.11: Comparison of Level of Awareness on Availability of Adequate Firefighting Equipment and Fire Detection Systems.

Firefighting equipment and detection systems in the workplace are crucial aspects which require each employee to be aware of their existence and operation. This would assist in the response to fire incidents by employees rather than waiting up for a third party for initial response which could safe an entire workplace. The findings indicated a good number of respondents both in Branded and independent petroleum dispensing stations having knowledge on existence and operation of dry powder type and water type portable firefighting equipment.

4.4 Implementation of the FRRR.

The extent of implementation of FRRR in both branded and independent petroleum dispensing stations was sought. This was established with a guide of an observation check list and interviewing of petroleum dispensing station supervisors on duty in both BPDS and IPDS.

The PDS supervisors were interviewed on available mode of storage of the petroleum products to determine compliance with the FRRR, observation was also conducted. The results were as indicated in table 4.6.

Table 4.6: Implementation of Safe Storage and Handling of Highly Flammable Substances

VARIABLE	BPDS				IPDS			
	YES		NO		YES		NO	
	Freq	%	Freq	%	Freq	%	Freq	%
Fixed Storage tanks in safe position away from direct sunlight	27	90.3	4	9.7	11	68.8	5	31.2
Fire resistant storage structure	26	83.9	5	31.1	9	56.2	7	43.8
Availability of vent pipes on storage tanks.	10	32.3	21	67.7	4	25	12	75

The study established that 90.3% of the BPDS and 68.8% of the IPDS had fixed storage tanks in a safe position while 9.7% of the BPDS and 31.2% of the IPDS had not implemented this requirement. This was attributed to the keenness on safe storage of petroleum products in underground tanks and ensuring implementation by the occupiers especially the branded petroleum dispensing stations who operate with standard procedures as compared to the independently owned petroleum dispensing stations. The study also established that 83.9% of the BPDS and 56.2% of the IPDS had installed fire resistant storage structures while 31.1% of the BPDS and 43.8% of the IPDS had not implemented the requirement.

Fire resistant storage structures are key priorities to any petroleum dispensing station as it will determine the fire safety of the workplace and its neighborhood, most branded petroleum dispensing stations had implemented this requirement as compared to the independently owned stations who had some of its petroleum

products stored in temporary drums which are not fire resistant due to minimal storage spaces provided for storage and ignorance on its consequences. Only 32.3% of the BPDS and 25% of the IPDS had installed vent pipes on the storage tanks, this was because of lack of awareness on the importance of provision of the vents as had been established during awareness interview done in the study and ignorance by the occupiers, as most of the occupiers had prioritized the security of the petroleum products hence safety being secondary regarding the provision of the vents.

The study sought to establish the implementation of the installation of firefighting equipment and detection systems in both the BPDS and IPDS, the results are as indicated on table 4.7.

Table 4.7: Installation of Firefighting Equipment and Detection Systems Installation

Variable	BPDS				IPDS			
	YES		NO		YES		NO	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
fire detectors	9	29	22	71	2	12.5	14	87.5
Fire alarm system	12	38.7	19	61.3	1	6.2	15	93.8
Dry powder extinguishers	20	64.5	11	35.5	6	37.5	10	62.5
Water type extinguishers	19	61.3	12	38.7	7	43.7	9	56.3
Carbon dioxide type extinguishers	15	48.4	16	51.6	2	12.5	14	87.5
Automated foam sprinkler system	0	0	31	100	0	0	16	100

Fire risk reduction rules section 29(1,2) requires every occupier to provide means of extinguishing fire at the workplace and ensure that the position is distinctively and

conspicuously marked. Most petroleum dispensing stations had installed portable fire extinguishers though not adequate considering the hazards within the workplace, none had fixed firefighting installation which could be more appropriate for the fires involved in such workplaces. It was established that most of the petroleum dispensing stations had installed portable extinguishers as the main firefighting equipment, most being dry powder type of fire extinguisher at 64.5% in BPDS and 37.5% of IPDS. Most PDS has not installed the fire alarm system, however the BPDS had performed better than the IPDS at 38.7% and 6.2% respectively.

Fire detectors raise alarm on the onset of fires, thus assist in tackling an incident before it gets massive, in the absence of this systems it might not be easy to control a fire if it is discovered at the event, it has already spread, this indicates the importance of such installations in the workplace. The study established that most of the PDS had not implemented the rule at 71% and 87.5% in BPDS and IPDS respectively.

The study sought to find out through interviews and analyzing available records of installation of electrical equipment within the PDS'S, the results on installation of the spark proof electrical equipment are as indicated on table 4.8.

Table 4.8: Installation of Spark Proof Electrical Equipment

Variable	**BPDS**				**IPDS**			
	Implemented		**Not Implemented**		**Implemented**		**Not Implemented**	
	Freq	**%**	**Freq**		**Freq**	**%**	**Freq**	**%**
Bonding provision on pumps and offloading site	15	48.4	16	51.6	5	31.2	11	68.8
Spark proof electrical equipment	20	64.5	11	35.5	7	43.8	9	56.2

According to the FRRR, section 13, any workplace dealing with highly flammable and combustible substances should install spark proof electrical equipment especially in the sites where flammable vapors are likely to be concentrated. In the case of petroleum dispensing stations, all fittings on the fueling pumps and offloading areas should comply with this requirement. It was established that 64.5% of BPDS and 43.8% of IPDS had installed spark proof electrical equipment. Spark proof electrical fittings curb causes of fire and explosion due to exposure of electrical fittings and equipment to flammable vapors in the right proportions. It was also established that 48.4% of BPDS and 31.2% of IPDS had provided bonding facilities at offloading and loading points while 51.6% of BPDS and 68.8% of IPDS had not implemented the requirement. The importance of bonding of loading and offloading trucks was overlooked at most of this workplace. This could be because of lack of awareness on the consequences from such work.

This section of the study sought to establish the implantation of formation and training of firefighting teams in both BPDS and IPDS.

Table 4.9: Formation and Training of Firefighting Teams

Variable	**BPDS**				**IPDS**			
	Implemented		**Not Implemented**		**Implemented**		**Not Implemented**	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Formation of firefighting teams	12	38.7	19	61.3	2	12.5	14	87.5
Training of firefighting teams	15	48.4	16	51.6	4	25	12	75

The study established that 48.4% of branded petroleum dispensing stations and 25% of independent petroleum dispensing stations had trained staff on fire safety. This was attributed to the fact that most of these workplaces rely on county fire brigade on response to fire incidents. It was also established that 38.7% of BPDS and 12.5% of

IPDS had formed firefighting teams while 61.3% of the BPDS and 87.5% of the IPDS had not implemented this requirement.

This was contrary to a study carried out by Kulkarni et al. (2016) on Knowledge and practices regarding fire safety amongst health care workers in tertiary care teaching hospital in Marathwada region of Maharashtra, India. Indicating that 53.96% received a training of fire safety.

4.4.1 Mounting of Portable Fire Extinguishers

Measurements were carried out to further establish the implementation of mounting of portable fire extinguishers on the height of not less than 60cm from the floor at the petroleum dispensing stations.

The height established was measured from the base of the extinguisher and the level of the floor, to establish compliance to the stipulated requirements.

Table 4.10: Height of Mounted Portable Fire Extinguishers

Height in cm	Number of extinguishers	Percentage
Not mounted 0cm	80	32%
60cm	45	18%
61 – 100cm	70	28%
Above 100cm	55	22%

According to the Fire risk reduction rules LN59 (2007) 29(3) it is required that every occupier should ensure that any portable fire extinguisher is mounted at an easily accessible height of not less than 60 cm from the floor. It was established that 80 number of the fire extinguishers were not mounted as indicated on table 4.10. However, 55 were mounted at a height which was not easily accessible being above one metre from the floor. 45 number extinguishers had been mounted at an appropriate height as required by the law as illustrated on plate 4.1. Though the requirement does not specify the maximum height, extinguishers should be easily

accessible for quick response in the event of an incident. according to a study carried out by Muindi (2014) on assessment of workplace fire safety preparedness in KMTC in Eastern Kenya region, it was established that Embu Campus had almost all fire extinguishers been stored in a room.

Plate 4.1: Recommended 60cm Height of Portable Extinguishers

This section of the study set to establish the statistical association between the duration the PDS had been in operation and implementation of the FRRR. Chi square test was used to establish the association, with a p-value of ≤0.05 indication strong association, as indicated on table 4.11.

Table 4.11: Association between Duration PDS has been in Operation and Extent of Implementation of the FRRR.

FRRR	Duration PDS has been in operation	Status of implementation Implemented	Chi – square
Safe storage and handling of highly flammable substances	0 – 1 year	2 (4.2%)	
	1 – 5 years	22(46.8%)	
	5 years and above	16(34.2%)	$\chi2=2.62,df=4,\ p=.042$
Availability of adequate firefighting equipment and detection systems	0 – 1 year	4(8.5%)	
	1 – 5 years	11(23.4%	
	5 years and above	12(25.5%)	$\chi2=2.35,df=6,\ p=.025$
Carrying out of fire safety Audits	0 – 1 year	1(2.1%)	
	1 – 5 years	4(8.5%)	
	5 years and above	6(12.8%)	$\chi2=0.327,\ df=1,\ p=0.002$
Training and formation of firefighting teams	0 – 1 year	2(4.3%)	
	1 – 5 years	3(6.4%)	
	5 years and above	13(27.7%)	$\chi2=1.602,\ df=2,\ p=.003$
Installation of spark proof electrical equipment and fittings	0- 1 year	2(4.3%)	
	1 – 5 years	3(6.4%)	$\chi2=1.957,\ df=4,\ p=.024$
	5 years and above	6(12.8%)	

The results indicate a strong statistical significance between the number of years a station had been in operation and implementation of the FRRR. Most of the PDS which have been on operation for more than a year had implemented a good number of FRRR than the ones which have been on operation for less than a year. Availability of adequate firefighting equipment and detection systems indicated a strong relationship between the number of years a station had been in operation and implementation where $\chi2=2.35$, $p=0.025$. This implies that the duration which a PDS has been in operation highly determines its implementation on various aspects of FRRR, knowledge and importance attached to the implementation of the regulations is given key priority.

Safe storage and handling of highly flammable substances was also statistically significant, this being the FRRR which was implemented in most of the PDS, at a 95% confidence level p value was 0.042.

4.5 Fire Safety Status

The third objective of the study sought to identify the fire safety status in petroleum dispensing stations. The Fire risk Reduction rules are meant to ensure the fire safety status of the workplaces are not compromised at any given time, hence the unsafe occurrences and acts at the PDS experienced after implementing the laid down requirements would indicate the approximate safety status of a given workplace.

4.5.1 Nearmiss and Unsafe Acts

The supervisors of the PDS were interviewed to establish the number of near misses, incidents and unsafe acts which have been recorded at the PDS. As indicated in table 4.12.

Table 4.12: Near miss and Unsafe Acts at the PDS

Type of near miss and unsafe acts reported and observed	Frequency
Number of fuel spills reported during offloading and fueling of petroleum products	37
Smoking at close proximity to fueling site	12
Use of mobile phones during fueling	150
Fueling of vehicles while vehicle engine is running.	370
Driving off before disconnecting fueling hose	6

It was noted that despite varied efforts on implementation of the fire risk reduction rules, the PDS continue to record several dangerous occurrences and unsafe acts which place the fire safety status of the workplace in a worrying trend. These factors

could easily escalate to full fire incidents if efforts to curb them are not put in place immediately.

From the study it indicated that 37 fuel spills were recorded in the various stations, some occurred at offloading sites due to disconnect of hoses before completion of the exercise and two number cases were because of driving off vehicles during the fueling process. 150 cases use of mobile phones at the fueling site was reported and observed in the PDS, though there aren't demarcated sites where the gadgets should be used away from the site of high fume concentration. However, the most violated requirement was Fueling of vehicles while the engines are running which can lead to fire occurrence, 370 cases were reported and observed.

Installation of breakaway devices for fuel dispenser hoses as a safety device in case of careless drive away by motorists during fueling either intentionally or accidentally was not implemented in any of the stations visited, this if implemented would reduce the number of spillage and curb fire incidents.

4.5.2 Measurement of Explosive Vapors

Petroleum dispensing stations handle highly flammable substances which give off flammable vapors that form explosive atmospheres with air. Special precaution to curb this by ensuring continuous monitoring of presence of such conditions should be carried out. Mitigation measures be established to control sources of ignition hence prevent fires and explosion. Measurements of flammable vapors are carried out to establish the concentration of the explosive vapors in the air and the required zoning of the hazardous areas as per the Dangerous Substances and Explosive Atmospheres Regulations, UK. (2002). The use of an explosimeter to obtain explosive limits within the petroleum dispensing stations would assist in achieving the above target. Explosive limit is the concentration range where a flammable substance can result into an explosion in the presence of an ignition source. Above the upper explosive limit (UEL) is when the mixture of vapor and air is too rich to burn while the below the lower explosive limit (LEL) is too lean to burn. Any concentration of the vapor between the LEL and UEL can explode or ignite with introduction of an ignition source. Gasoline has LEL of 1.2 % and UEL of 7.1 % by

volume (Carl 2011). With the introduction of a single spark or adequate ignition temperature, an explosion can occur when the measurements recorded using the explosimeter are 1.2% and above.

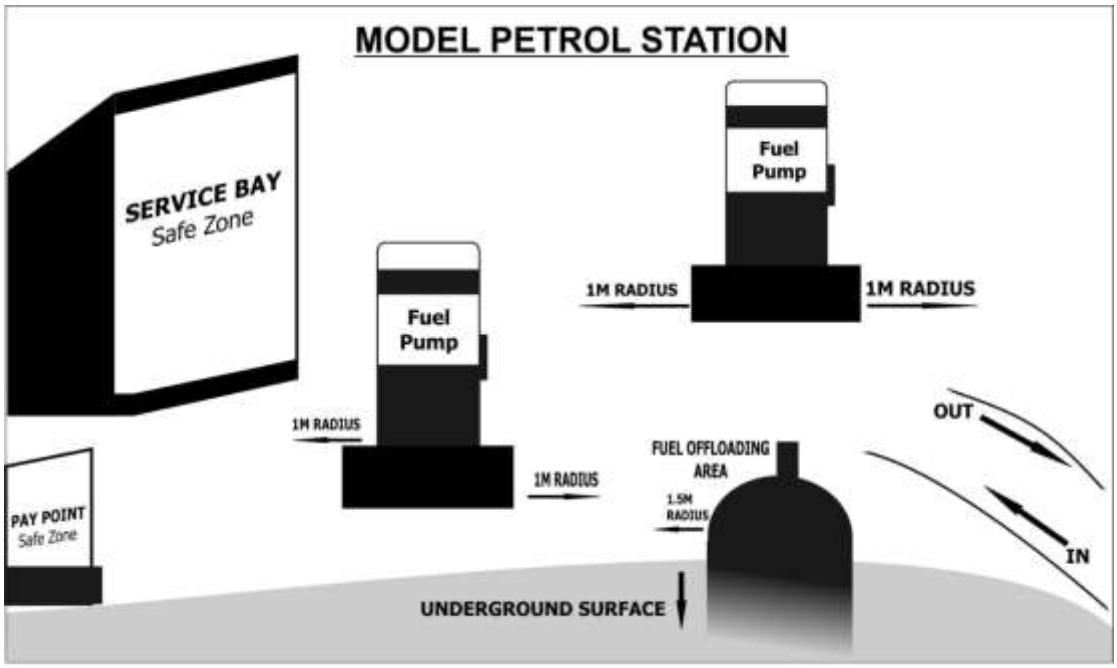

Figure 4.12: Model Petrol Station

The model petrol station was used to illustrate the state of presence of explosive vapors present during normal operations within the petroleum dispensing stations, indicating safe points where electronic payments could be made and act as a guide to precautions to be taken during certain high-risk works being undertaken at the stations.

An Explosimeter was used to measure the presence of Explosive vapor at the fueling pump site points in the 47 PDS'S. An average percentage of the results obtained from the forty-seven (47) PDS'S was calculated as indicated in figure 4.1.

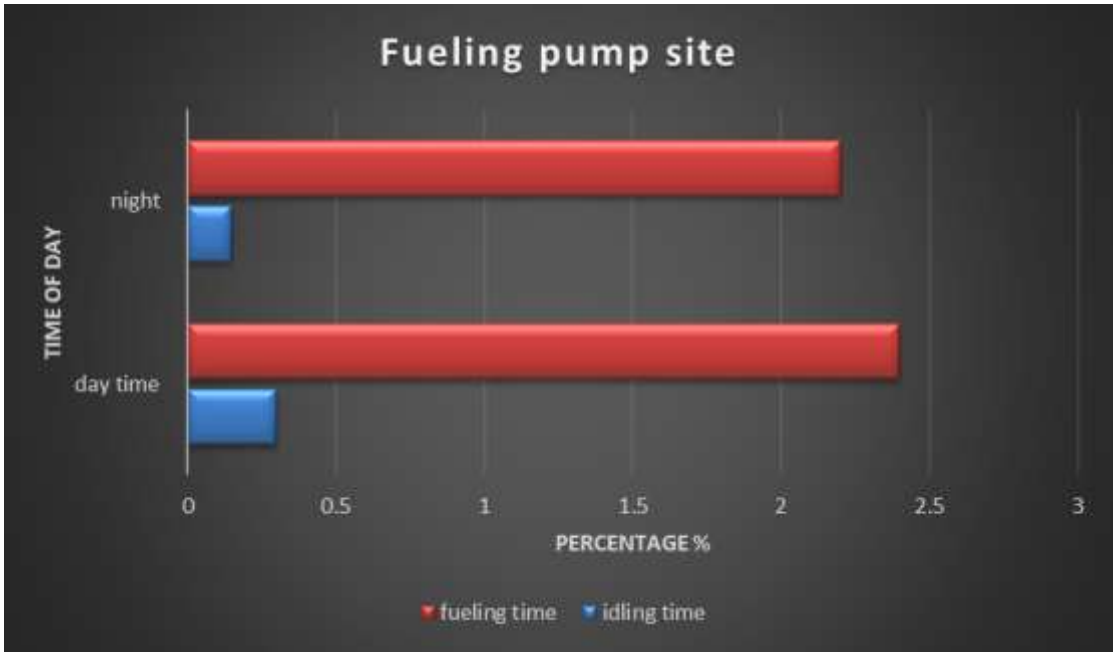

Figure 4.13: Explosive Limit Measurements at the Fueling Pump Site.

The measurements obtained from the fueling pump site indicated presence of explosive vapors during fueling time at readings of 2.4% during daytime between 1000hrs and 1600hrs. and 2.2% during the nighttime between 0800hrs and 1000hrs. The measurements were taken at a radius of 2meters from fueling nozzle. This implies that at these points in the PDS introduction of source of ignition a fire could certainly occur. Readings recorded when the pump site was idle or not fueling established it was below the lower explosive limit, which indicated being too lean to burn.

In figure 4.14, presence of explosive vapors was measured at the fuel storage site. The measurements were carried out during offloading time and non-offloading time. The results of the forty-seven PDS'S was obtained, and an average calculated as indicated in figure 4.14.

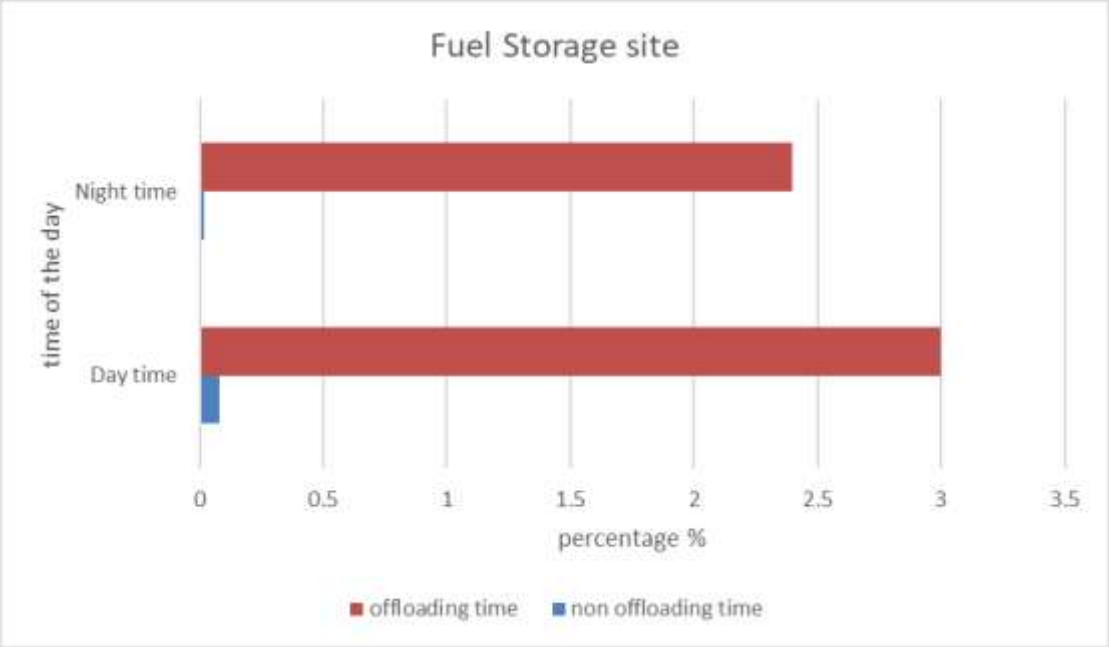

Figure 4.14: Explosive Limit Measurements at the Fuel Storage Site

The fuel storage site had varied or readings during the offloading of gasoline. 56 readings were obtained by taking measurement during offloading and non-offloading times at the 47 PDS. An average of the readings was conducted, it was established that the average concentration of the explosive vapor was 3.0% during daytime and 2.4% at night, this indicated the danger of explosion at introduction of an ignition source during both periods. The idle time indicating flammable vapor concentration being too lean to support combustion, the measurements obtained were below 0.05%, which a times could not even be detected by the explosimeter gadget.

The service bay at the PDS are sites where vehicle routine checks are conducted, tyre repairs are carried out, among other works except fueling which is done at the fueling site. Measurements were carried out to establish the presence of explosive vapors in the site. Thirty PDS'S had provision for service bays which were operational. The obtained results are as indicated in figure 4.15.

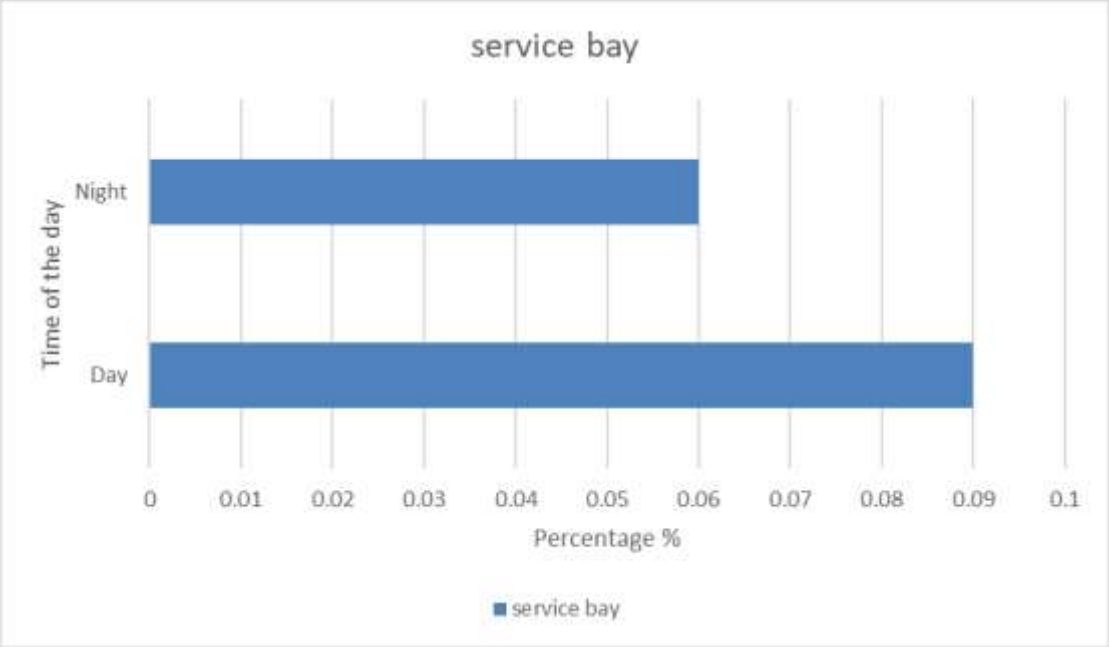

Figure 4.15: Presence of Explosive Vapors Measurements at the Service Bay.

The service bay could be considered the safe place in the petroleum dispensing stations as the readings during both night and day are below the lower explosive limits. This could be attributed to the fact that the works carried out in these sites does not entail direct handling of gasoline. Though due to wind direction changes, the bays could receive the flammable vapor concentration from either the pump dispensing site or the fuel storage area. This was established to be the safest area within the petroleum dispensing station where electronic and mobile payments would be made without posing a fire risk to the workplace.

The presence of explosive vapor in the PDS was conducted using an explosimeter equipment, which is a Gas Alert MAX XTII model. as indicated in Plate 4.2.

Plate 4.2: Explosimeter Equipment.

The researcher also sought to find out the number of fire incidences which had occurred at the petroleum dispensing stations and the approximate financial impact. This is indicated on table 4.13.

Table 4.13: Number of Fire Incidents Recorded in PDS.

Number of fire incidents	Economic and social impact
5	12 Employees lost their jobs. 2 Number fuel pumps damaged. 3Employees got injured. 1 Station closed temporarily for one year.

It was established that 5 number fire incidents of different magnitudes had occurred as reported from the PDS, of which 4 occurred at the IPDS and 1 at BPDS. The fire

incidents which were managed at station level were 2, however the 3 were contained by the county fire brigade. The cost implication of the incidents was Ksh. 850,000 for the damaged fuel pumps, the medical cost spent was approximately ksh. 700,000. One PDS closed business because of the fire incident. The rest of the losses could not be quantified since the supervisors interviewed had scanty information. The major cause of the incidents at the affected PDS was human error and negligence on adherence of safety regulation.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The overall objective of this study was to assess the application and influence of the fire risk reduction rules in petroleum dispensing station.

The first specific objective sought to establish the level of awareness of the fire risk reduction rules in the PDS. It can be concluded that majority of the respondents were aware of safe storage and handling of flammable substances in the workplace at 81%. However, none of the responds was fully aware of all the stipulated fire risk reduction rules.

The second specific objective was to determine the extent of implementation of the Fire Reduction Rules in the petroleum dispensing stations. It was concluded that Safe storage of the flammable substances was largely implemented at 90.3% and 68.8% at the BPDS and IPDS respectively. Fire safety audits were rarely carried out in most of the PDS'S. Training of workers in fire safety and formation of fire teams was not implemented fully as required, though these requirements are key to effective emergency response and incident containment. It was further concluded that BPDS performed better in implementation of the FRRR than the IPDS.

The third specific objective sought to assess the status of fire safety in the Petroleum dispensing stations. It was concluded that the status of fire safety in petroleum dispensing station was largely compromised, this posed high fire risk to life and property. it was established that despite the efforts to partly implement the fire risk reduction rules, the motorists who visit these workplaces as the customers tend to jeopardize the fire safety status of the PDS.

Zoning of hazardous areas in the petroleum dispensing stations was not carried out. There were inadequate enforcement efforts in the PDS on adherence of the FRRR.

5.2 Recommendations

The study recommends:

(i). Development and enforcing of standard operating procedures of all works involving handling of petroleum products in the PDS.

(ii). The government to enact regulations on ensuring vehicles are equipped with onboard refueling vapor recovery systems which function by directing vaporized gasoline into a canister on the vehicle.

(iii). The DOSH and County fire brigade officers issued with the responsibility to monitor the implementation of FRRR should ensure compliance and create awareness on the FRRR.

(iv). Zoning should be done within the petroleum stations according to concentration of fumes using the explosive limit levels, this will allow activities which are deemed to be sources of ignition to be carried out in specific zones without posing a risk to the workplace and surrounding.

(v). Installation of breakaway devices for fuel dispenser hoses should be made mandatory in each PDS, this will prevent spillage of petroleum product in the event of vehicular drive off in the process of fueling, this isn't included in the existing FRRR.

(vi). Petrol dispensing stations being hazardous workplaces should be constructed at certain proximities from residential and other workplaces which could provide a source of ignition, the specific distances should be specified on the FRRR.

(vii). The Petroleum dispensing station supervisors should ensure that enforcement of FRRR is done, and standard operating procedure is in place.

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APPENDICES

Appendix I: Questionnaire

This questionnaire is issued with the purpose of collecting individual responses on the Research topic "**Assessment of application and Influence of fire risk reduction rules on the fire safety status at petroleum dispensing stations in Kisumu County, Kenya**" and as a requirement for the award of Master of Science in Occupational Safety and Health. All the views collected will be treated with confidentiality.

Instructions to the Participants

1.Name (Optional)

……

2. Please tick/fill in the Blank spaces as appropriate.

Section A:

Demographic information

1. What is your Gender?

a) Male ☐
b) Female ☐

2. What is your age: …….

3. What is your educational level?

a) Primary ☐
b) secondary ☐
☐

c) Certificate
d) Diploma ☐
e) Others …….

4. What is your working experience in years in this petroleum dispensing station?

a) 1 day – 5years ☐
b) 5 -10 years ☐
c) 10-15 years ☐
d) 15 yrs. and above ☐

5. Name of petroleum filling station ……

Section B: awareness of FRRR

6. Which of the fire risk reduction rules are you aware of existence in your station? (Tick where applicable)

Fire risk reduction rule	**aware**	**Not aware**
1.Safe storage of petroleum products a. Fixed storage tanks in safe position		
b. Availability of breathers on storage tanks		
c. Storage tanks should be constructed of fire-resistant material		
2.Availability of firefighting equipment and detection systems a. Fire detectors		

b. Fire alarm system		
c. Dry powder type extinguisher		
d. Water type extinguisher		
e. Carbon dioxide type extinguisher		
3.Training in fire safety and formation of fire teams		
4. Display of and availability of relevant signage a. NO smoking sign		
b. Restricted use of mobile phones		
c. Fire assembly point		
5.Fire safety audits carried out		
6.Installation of spark proof electrical equipment		

Any other (specify).....

Appendix II: Observation and Interview Checklist on FRRR Implementation and Fire Safety Status

How long has the petroleum dispensing station been operational? (tick where appropriate)

No of years	
0 – 1year	
1 – 5yrs	
5years and above	

Have you had a fire incident at the station since commencement of operation YES……. NO …….

If YES, was the incident managed internally or by external assistance …….

How much is the approximate loss ……?

Type of near miss and unsafe acts	Number observed and reported
Number of fuel spills occurred	
Smoking incidents near fueling or offloading point	
Running engines while fueling	
Driving of before disconnecting fueling hose	
Use of mobile phone at restricted areas	

1. Check for general cleanliness

2. fire extinguishers availability

3. Check that entrance is kept free from obstruction

4. Check that exit is kept free from obstruction

5. Check the presence of NO Smoking signage

6. status of electrical equipment if spark proof

7. availability of fire safety audits and safety policy

8. installation of breakaway devices for fuel dispenser hoses.

9. availability of fire safety training information

Fuel Offloading Site

2. Check if earth bonding is available

3. Check the type of storage Tank

4. Check availability of firefighting equipment

5. Fuel hose break away safety devices

Appendix III: Research Authorization Letter.

THIS IS TO CERTIFY THAT:
MS. CAROLYNE JEPCHIRCHIR KEBUT
of JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,
0-40100 KISUMU,has been permitted to conduct research in Kisumu County

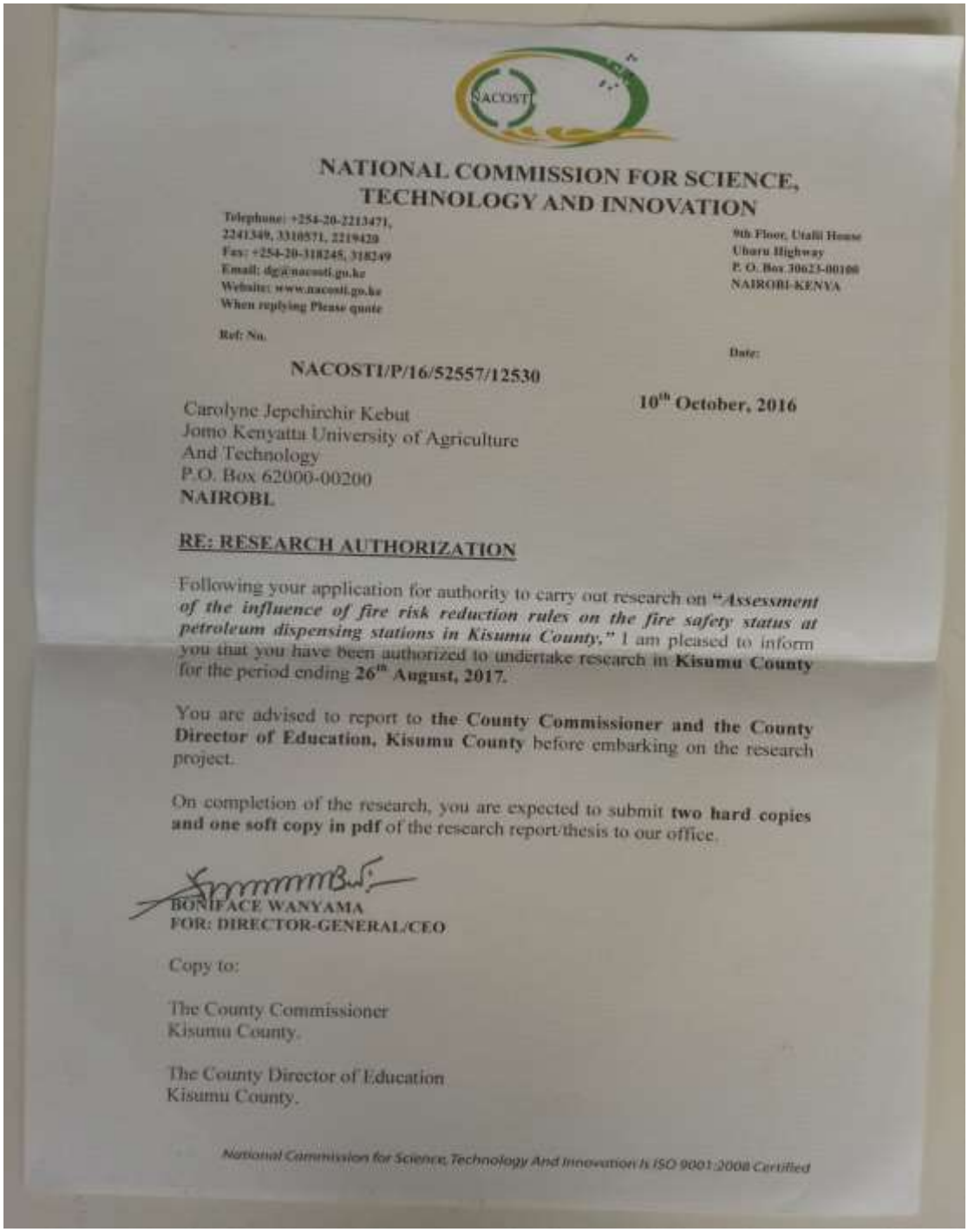
on the topic: ASSESSMENT OF THE INFLUENCE OF FIRE RISK REDUCTION RULES ON THE FIRE SAFETY STATUS AT PETROLEUM DISPENSING STATIONS IN KISUMU COUNTY

for the period ending:
26th August,2017

Applicant's Signature

Permit No : NACOSTI/P/16/52557/12530
Date Of Issue : 7th October,2016
Fee Recieved :ksh 1000

Director General
National Commission for Science, Technology & Innovation



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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NAIROBI-KENYA

Ref: No. NACOSTI/P/16/52557/12530

Date: 10th October, 2016

Carolyne Jepchirchir Kebut
Jomo Kenyatta University of Agriculture
And Technology
P.O. Box 62000-00200
NAIROBI

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Assessment of the influence of fire risk reduction rules on the fire safety status at petroleum dispensing stations in Kisumu County,"*** I am pleased to inform you that you have been authorized to undertake research in **Kisumu County** for the period ending **26th August, 2017.**

You are advised to report to **the County Commissioner and the County Director of Education, Kisumu County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kisumu County.

The County Director of Education
Kisumu County.

National Commission for Science, Technology And Innovation is ISO 9001:2008 Certified