Factors Contributing to Oil Pipeline Leakages in Tanzania Ports

[1]Rajabu Chaka, [2]Benjamin Mbeba Meli and [3]Lucas Pastory Mwisila
[1]Rajab Chaka, P.O. Box 21328, Dar es Salaam, Tanzania, East Africa,
Email: rchaka30@gmail.com
[2]Benjamin Mbeba Meli, Dares Salaam Maritime Institute, Department of Science and Management, P.o Box 6727, Dares Salaam, Tanzania, East Africa, email: benjaminmbeba@gmail.com / Benjamin.meli@dmi.ac.tz
[3]Lucas Pastory Mwisila, Dares Salaam Maritime Institute, Department of Science and Management, P.o Box 6727, Dares Salaam, Tanzania, East Africa, email: lmwisila@yahoo.com/ lucas.mwisila@dmi.ac.tz

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Abstract
This paper employed the data from the study conducted at Dares Salaam port aimed to examine the factors contributing to oil pipeline leakages in Tanzania ports. Specifically, the study focused on identifying factors contributing to oil pipeline leakages, exploring installation techniques for the pipelines and evaluating the efficacy of current leakage protection measures for the pipelines in place at Dar es Salaam port. The study adopted exploratory research design and both quantitative and qualitative approaches to collect primary data from 92 actual respondents with aid of questionnaires and interview guide selected through simple random and purposive sampling techniques. Quantitative data was analyzed using SPSS V26 in descriptive and inferential statistical analysis while qualitative data was analyzed through content analysis. Findings of the study revealed concerns about: factors contributing to oil pipelines leakages, installation techniques and leakage protection measures in pipeline infrastructures. It suggests gaps in maintenance documentation, installation techniques, and the effectiveness of marine paint against formation of corrosion, monitoring systems, and personnel training. The study emphasizes the need for infrastructure upgrades, regulatory oversight, and stakeholder collaboration to address factors causing oil pipeline leakages in Tanzania Ports, including types of pipelines used, installation techniques, and corrosion prevention measures. Recommendations include improving maintenance practices, enhancing installation standards, investing in leakages protection measures, conducting regular inspection, and promoting collaboration among stakeholders to improve safety standards and prevent future leakages.

Key words: *Pipeline networks, pipeline corrosion, Oil Merchant Companies, environmental pollution and oil receiving jetties.*

1.0 Introduction

Pipeline networks are the most efficient, economic and safest means of transporting Petroleum Products. Pipeline as mode of transportation must meet strict requirements for reliability, efficiency and safety. However, pipeline system faces main challenge of leakages which may be caused by many factors. Boaz *et al*. (2014) stated that leakage detection in transportation pipelines is most important for safe operation. Delay in leakages detection leads to

environmental pollution and loss of property and living organisms. Leaking of petroleum products causes negative impacts on the eco system such as global warming and water pollution. With the time increase on the use of oil-gas pipelines, pipeline corrosion, as well as the destruction of other natural and human factors, it is possible for the leakages of oil-gas pipeline to occur. Accidental oil and gas pipeline leaks can harm the environment, result in casualties, and result in property damages. Therefore, one of the most crucial study areas is how to effectively detect leaks in oil-gas pipelines. This will make it possible to estimate volume and control spills more effectively (Kan *et al.*, 2018). Significant of oil pipeline failures have garnered worldwide attention. Despite the fact that pipelines are statistically quite safe and reliable, accidents involving pipelines have led to deaths, environmental harm, and a decline in public trust in the pipeline sector (Revie *et al.*, 2015).

Dar es Salaam port has two oil receiving jetties, Kurasini Oil Jetty (KOJ) located in Dar es Salaam Port at Kurasini area with its Manifold, this Oil Jetty receives all type of oil and serve direct oil depot located in Kigamboni and Kurasini, Single Buoy Mooring Oil Jetty located offshore with its manifold in Kigamboni, this Oil Jetty receives only Diesel and serve direct oil depot located in Kigamboni and for the oil depots located in Kurasini are served via TIPER Depot.

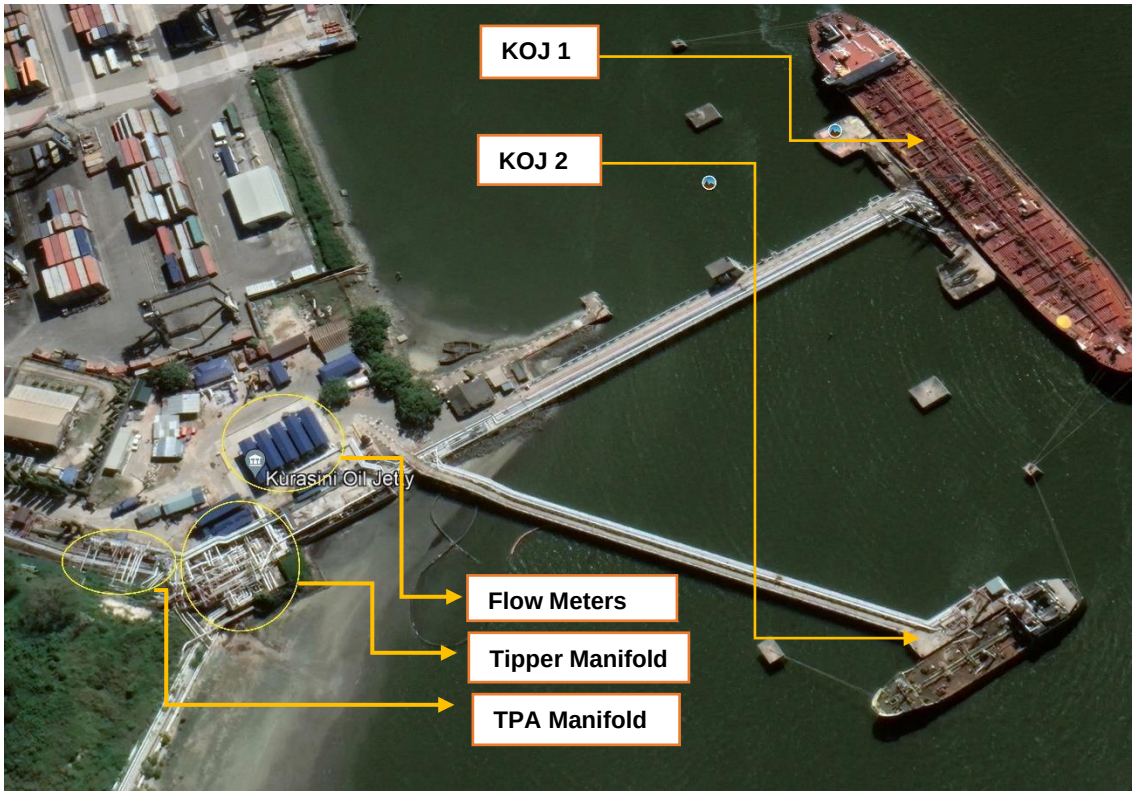


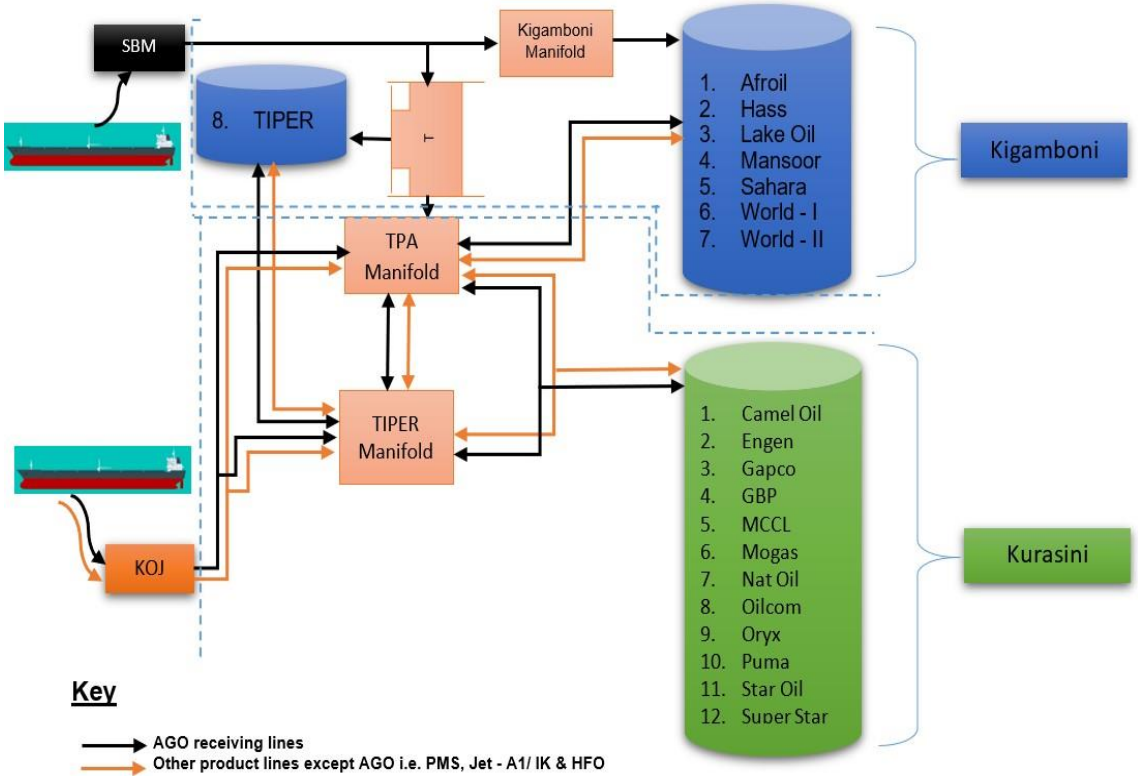
***Figure 1. 1*: Kurasini Oil Jetty**

Dar es Salaam port serve seventeen (17) oil depots owned by Oil Merchant Companies located in both Kurasini area and Kitopeni area in Kigamboni. Dar es Salaam port is responsible for the port infrastructure include the Jetty, pipeline manifolds, flow meter and pipelinesections which are located inside the TPA premises, for pipelines located outside TPA premises Oil Merchant Companies are responsible. Every depot has oil receiving pipeline infrastructure,

however some of the depots do share a section of receiving pipelines infrastructure. The length of each pipeline ranges from 600m to 3500m from main manifold (Kurasini manifold) to oil depots. See table 1

Table 1: List of Petroleum Storage Depots at Dar es Salaam;

S/N	PETROLEUM STORAGE DEPOTS	PIPELINES	PRODUCTS
1.	AFROIL INVESTMENT LTD	2	PMS & AGO
2.	CAMEL OIL (T) LTD	3	PMS, AGO & HFO
3.	GAPCO TANZANIA LIMITED	3	PMS, AGO & JET
4.	GBP TANZANIA LIMITED	4	PMS, AGO, JET & HFO
5.	HASS TERMINAL (T) LTD	2	PMS & AGO
6.	LAKE OIL LIMITED	5	PMS, AGO, JET & BASEOIL
7.	MANSOOR INDUSTRIES LIMITED	3	PMS & AGO
8.	MOGAS TANZANIA LIMITED	3	PMS, AGO & BASEOIL
9.	OILCOM (T) LTD	4	PMS, AGO, JET, IK & HFO
10.	ORYX OIL COMPANY LIMITED	4	PMS, AGO, IK & HFO
11.	PUMA ENERGY TANZANIA LTD – DAR ES SALAAM TERMINAL	4	PMS, AGO, JET & HFO
12.	SAHARA ENERGY TANZANIA LTD	3	PMS & AGO
13.	STAR OIL TANZANIA LIMITED	2	PMS & AGO
14.	SUPER STAR FORWARDERS LIMITED	3	AGO, JET & HFO
15.	TANZANIA INTERNATIONAL PETROLEUM RESERVES COMPANY LIMITED	6	PMS, AGO, JET & HFO
16.	WORLD OIL (T) LTD – TERMINAL I	3	PMS & AGO
17.	WORLD OIL (T) LTD – TERMINAL II	3	PMS & AGO



Schematic Flow Diagram of Dar es Salaam Petroleum ProductsReceiving Infrastructures.

There has been advanced pipeline technology made recent years, however incidents of the oil leakage at Dar es Salaam Port have been often reported in previously years to regulatory agencies in Tanzania, these incidents at Dar es Salaam Port leads to the environmental pollution which cause negative environmental impacts to the marine environments to date, and destroy flora surrounding the area including mangroves. Recently, in the previous government year 2022/2023 ten oil leakage incidents, 2021/2022 eight oil leakage incidents and 2020/2021 eleven oil leakages incidents has been reported to the National Environment Management Council (NEMC) which occurred at Dar es Salaam Port area. Tanzania Ports Authority and Tanzania Shipping Agencies Corporation. Additionally, it should be emphasized that collaborative investigation teams formed by government agencies are increasingly, inspecting pipeline to ascertain if a leak was caused purposefully or not, in 2022 an inspection team formed to inspect oil spillage by NEMC reported 300m^3 of oil were missing during reconciliation of oil discharge to one depot. For these reasons, it was necessary to carry out this study since it will examine factors contributing to oil pipeline leakage at Dar es Salaam Port and alert the pipeline owners to find the best techniques to prevent leakages incidents before occurred

2.0 Literature Review

Over time in operation, these pipelines due to ageing, corrosion and wear, design faults, operation outside design limit or deliberate damage in act of vandalism etc. are caused to leak. Due to the vast mileage of pipelines throughout the nation, it is important that

dependable leak detection systems are used to promptly identify when a leak has occurred so that appropriate response actions are initiated quickly. The swiftness of these actions can help reduce the consequences of accidents or incidents to the public, environment, and facilities. Leak detection systems capable of locating the position of the leak are obviously of an environmental kind. But the economical aspect of it is also important. In fact, pipeline leaks are also frequent problems to the producers and transporters of these hydrocarbons and failure to detect it can result in loss of life and facilities, direct cost of loss product and lie downtime, environmental clean-up cost and possible fines and legal suits from habitants.

2.1 Pipe Materials for Hydrocarbon (Oil) Transportation

Materials selection for pipes are depending on the pipeline design, external and internal forces, laying and jointing techniques, impermeability, strength and maintenance frequency. The following are types of pipes used; Plastic pipe, are typically utilised for water transfer in a long-distance. Plastic pipes are lightweight, resistant to wear, and chemical influences. Cast Iron Pipes, are coated and lined to improve resistance from corrosion since are mostly produced by gray cast iron. Steel Pipes, are produced for water pipelines can be in large diameters and extended over large distances. Pipelines are seen to be the safest and most cost-effective way to move petroleum products such as offshore to onshore. However, pipelines are susceptible to leaks brought on by a variety of circumstances, including third-party tampering and corrosion (Diao *et al.*, 2020).

2.2 Pipeline Designing and Construction

Pipelines are designed to facilitate transportation of fluids in an optimal and cost-effective manner, considering operating costs and environmental impacts. Factors affecting pipeline routing, including terrain, access issues, and constructability of the facility, such as ease of moving construction equipment in and out of the proposed route, land data, environmental impact studies and their conclusions (*N.S. Nandagopal,* 2013).

Also, soil samples are taken often during the design and site preparation phases to assess mechanical and thermal stability, corrosivity, and electrical conductance. At critical locations, such as river crossings, soils and subsurface materials are also assessed for their capacity to withstand the weight of the pipeline support structures. Determined are soil characteristics such seepage, slope stability, tensile strength, and soil structure. The American Society of Civil Engineers (ASCE) has produced industry guidelines that provide the required site characterization investigations (ASCE, 2013).

2.3 Pipeline Inspection

Pipeline integrity management, which keeps the pipeline in excellent condition, includes pipeline inspection. The pipeline safety regulations are the guidelines that govern inspection. The pipeline is often routinely inspected. The operator is required by the pipeline safety requirements to ensure that a pipeline is kept in a functional state, in effective operating order, and in good repair. Both internal and external inspections are part of the pipeline inspection process. Inspection of pipeline is taken in both phases during construction and operation. During construction inspection is taken to ensure the laid pipeline is fit for the uses before

commissioning to the operator some of inspection tests/methods used are Hydrostatic testing, Holiday test etc. (Yong Bai *et al.*, 2014).

2.3.1 Welding Inspection

Weld defects always affect the reliability of the overall structure, potentially resulting into the serious structural damage. Electromagnetic and eddy testing is often used in weld inspection due to its advantages such as speed, non-contact and no need for coupling agent. (Gao, P. *et al*., 2015). Electromagnetic and eddy current are NDT in weld inspection. If long-lasting performance is to be anticipated, pipeline welding in upstream, middle, or downstream oil and gas operations must be of a high caliber. Other factors that make robust welding desirable include extremes in temperature, pressure, and chemical reactions. However, considering the difficulties involved in welding pipelines, such as potential weld faults, challenging weld setup for various pipe sizes, and inappropriate welding around complex geometrical areas, the necessity for inspection becomes critical.
Visual examination, all technicians primarily use visual inspection to establish judgements about the pipeline weld quality. It is the least expensive and sophisticated inspection technique available, and it is efficient in spotting any significant weld problems as they arise. Visual inspection can be done before, during, or after welding to catch flaws before they affect the process's next step. It is simple to find the more obvious faults such cracks, weld spatter, deformation, incomplete fusion, and bigger pores. A simple method for checking for leaks in pipeline welds is to pressurize the pipeline and use a medium like soap water that can be used to see air exiting as bubbles. The drawback of this inspection technique is that it cannot detect all microscopic and underlying faults in the weld surface. It can, however, be utilised to avoid serious faults, which lessens the requirement for in-depth nondestructive testing (NDT) analysis. Dye penetrant testing, this method of enhanced visual inspection is frequently referred to as dye penetrant testing. Any cracks or pinholes that are difficult to see during visual examination can be presented as a contrast in colour as the visible dye penetrant is added to the weld surface. Even though it is rapid, portable, and appropriate for all geometries, it can only detect surface faults on smooth surfaces, which might be problematic, especially for vital infrastructure like pipelines.

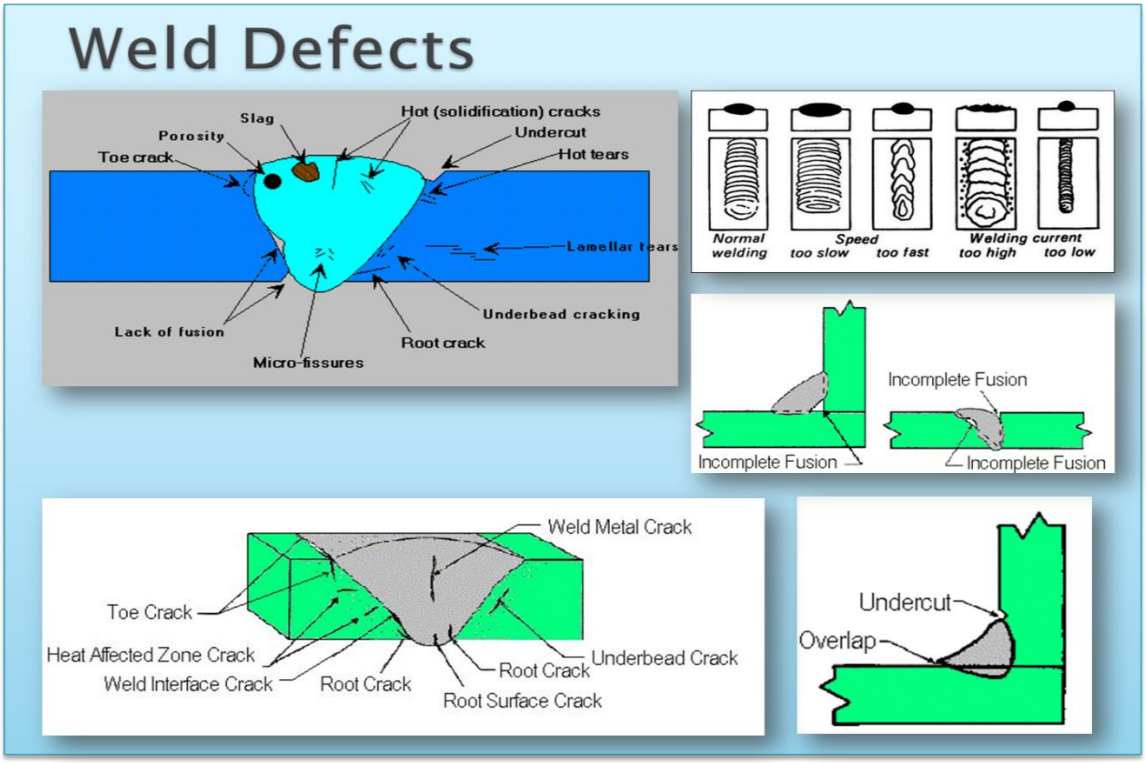


***Figure 2. 2*: Welds Defects**

2.3.2 Hydrostatic Test

Hydrostatic testing is the most preferred method for the fluid pipeline leakage. The test is performed at a PT pressure equal to 1.5 times the design pressure P times the temperature correction factor. The temperature correction factor compensates for the fact that the test can be performed at lower temperatures, when the material has greater strength under design conditions.

2.3.3 Holiday Test

Holiday testing is a non-destructive test technique used on coatings that are protective to find pinholes and other unwanted discontinuities that compromise the quality of linings. A circuit of electricity is checked to verify if it has enough coating to withstand an electrical charge and current flows to complete the circuit. If electrical flow is found, there may be a pinhole or a holiday (discontinuity) present. Continuity testing is another name for holiday testing (Ritesh Patel, 2021).

Holiday test divided into two methods, Method A uses regular tap water and an applied voltage of less than 100 V d-c to identify defects such pinholes and voids in thin-film coating that range in size from 0.025 to 0.254 mm (1 to 10 mils). If an agent for wetting is added to the water, it works on films up to 0.508 mm (20 mils) thick. The procedure will not find thin patches in the coating, it ought to be emphasised. Due to the low voltage used, this test might be regarded as nondestructive. Because of the greater induced voltages, Method B may be employed as well to find thin areas in pipeline coatings. Method B is intended to find holidays such pinholes and voids in pipeline coatings. This approach uses applied voltages between 900 and 20000V d-c

and can be utilised on pipeline coatings of any thickness.2 Because of how often the coating is destroyed at thin locations by the high voltages used, this technique is regarded as destructive. (ASTM, 2022).

2.4 Pipeline Operation Phase

2.4.1 Right of Way Inspections

A stretch of property with varied widths that may accommodate one or more pipelines is known as a pipeline right-of-way (ROW). Occasionally needs to cross both private and public lands in order to provide desperately needed petroleum via our network. Employees can access the site for construction, operations, inspection, maintenance, testing, or in an emergency thanks to the presence of a ROW. In order to safeguard both public safety and the integrity of the pipeline, it also denotes a location where specific activities are forbidden (Enbridge, 2022).
The continual work of removing pipeline rights-of-way supports the pipeline's safe and effective operation. The protection of the pipeline's integrity, quick emergency response, and raising the public's understanding of the pipeline's existence are all made possible by right-of-way clearing. The safety of the neighborhood is improved by removing trees from the right-of-way that pose a risk to the integrity of the pipeline. Heat and humidity are attractive to a tree's root system, which is why irregular, excessive root development patterns are frequently seen close to pipes. Trees that are inside or close to the pipeline must be cut down because their roots could encircle the pipe and harm its covering, which would lead to corrosion (Equitrans Midstream, 2023).

2.4.2 Pipeline Markers and Aboveground Facilities

Where pipelines and any related facilities are exposed, the proper pipeline marker should be put in place. There should be pipeline markings that are readable and visible at both ends of any hazardous liquid pipes that are hanging from bridges or other structures that span an area. Pipeline owners post markers along the pipeline's right of way to aid landowners, excavators, and emergency response teams by showing the general position but not the exact level of an underground pipeline. Pipeline markings are placed at road crossings, fence lines, and street intersections even though they are absent in certain places. The markers list the substance being transported along the pipeline, the name of the pipeline operator, and an emergency contact phone number. (Nebraska, 2016).

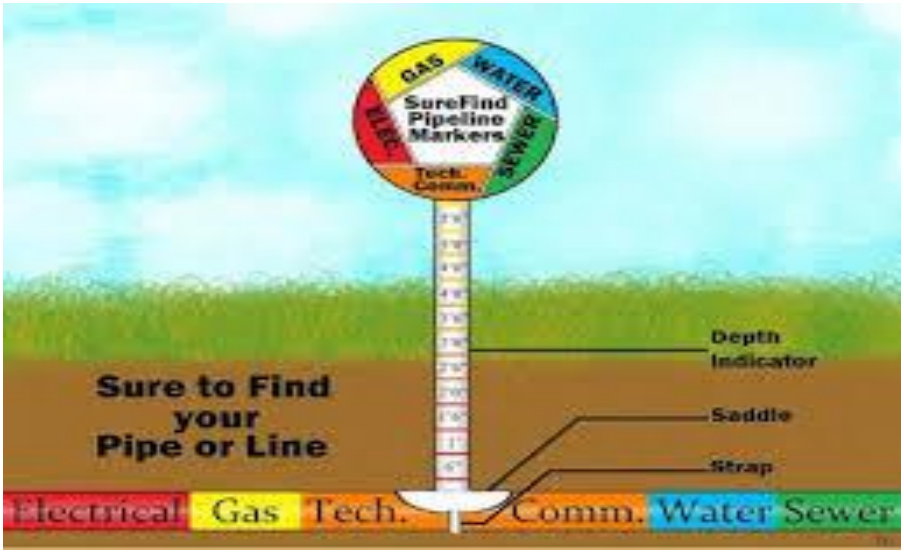


***Figure 2. 3*: Pipeline Marker**

2.4.3 Pigging Activities

The condition and integrity of pipelines are monitored using a range of inspection methods and technology. Assessing metal loss due to corrosion is typically the pipeline inspection's most crucial purpose. However, inspection also reveals dents and other deterioration that could eventually result in failure and leaks. Pipeline internal inspections require pigs that can do a number of jobs. Pigs are made so that sealing components interfere positively with the pipe wall. Pigs are propelled through a line after being inserted by exerting pressure in the direction of the desired movement. The pig moves in the direction of the pressure drop as a result of a pressure differential that is formed across it. In functioning lines, the line product applies this pressure, however in uncommission lines, the propulsive medium can be selected to meet the needs of the task at hand, such as water for flooding or dry air or nitrogen gas for dewatering. Notably, adequate flow is necessary to guarantee pig movement at the proper speed. The pig will move in the direction of the applied force (pressure) once that force exceeds the frictional force working against it. The "break-out" or "stiction" pressure is the point at which the pig starts to move. This is characterized by a pressure rise followed by a pressure drop to a plateau for the pig launching procedure and tends to be higher than the pressure needed to keep movement. Pigs may run in a line in a single direction or backwards or forwards, depending on the design of the sealing element. Unidirectional pigs contain polyurethane sealing components in the form of a cone or cup and can only be operated in one direction. These kind pigs are typically utilized in existing pig gable lines. Bidirectional pigs' flat sealing components offer an equal seal in either direction, increasing versatility in previously unpigged lines. Pigs can have additional sealing components added to them, improving their sealing capabilities while increasing the pressure differential needed to drive the pig. Support discs or, for pigs with considerable diameters, centralizing wheels can be used to support the pig to guarantee that it stays in the middle of the line. Pigs come in many different shapes and sizes, with mandrel, single bolt, solid cast, foam, articulated, and spherical being the most popular (Gupta *et al*., 2016).

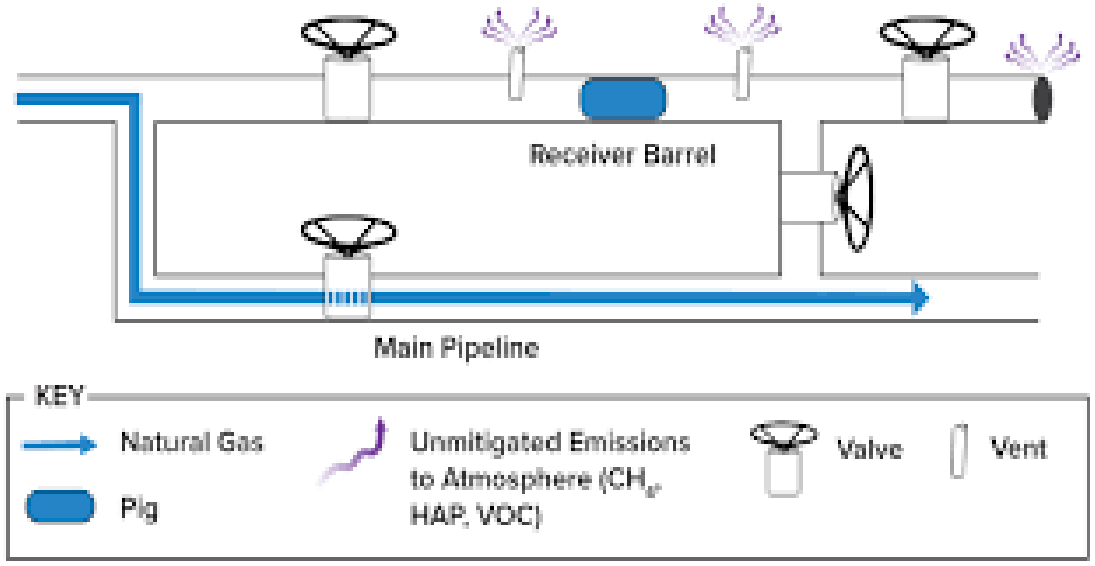


***Figure 2. 4*: Pipeline Pigging System**

2.5 Pipeline Protections Measures

2.5.1 Cathodic Corrosion Protection

Cathodic Protection is a corrosion preventive method for protecting underground and underwater metal structures, such as oil and gas pipelines and bonded foundations
structure. Cathodic protection is now widely applied in protecting oil rigs, shipyards, piers, ships, submarines, condenser tubes of heat exchangers, bridges and aprons, and ground transportation systems. The design of a cathodic protection system is quite complex but it is based on simple electrochemical principles. Electrical current flowing between regions with varying electric potentials can cause underground corrosion of steel pipelines. Corrosion will occur in the anode, which has a higher potential, but not in the cathode, which has a lower potential. The soil can function as an electrolyte in the case of a subterranean pipeline, enabling the flow of electrons between the ground and a metallic item like the pipe (the anode in this electrochemical engine). There are areas with varied electrical potentials all along a pipeline's path, and the size of these variances depends on the local soil type and a variety of other factors. In a cathodic protection system, anodes are installed along the pipeline route, electrically bonded to the pipe, and made of materials that are more suitable for delivering electrical current than the steel of the pipeline. This causes an electrical current to flow from the anodes to the ground. These anodes decay as electrons flow from them, giving rise to the term "sacrificial anodes" because they are being sacrificed and allowed to corrode instead of the pipe. As long as some anode material is present, the pipeline serves as the system's cathode and prevents corrosion. (Mobin *et al.*, 2023).

2.5.2 Protective Paint

Protective coating is a putty or liquefied product that contains pigments and turns into a protective opaque film on the surface when applied. Painting with protective coatings remains one of the simplest and most basic pipe protection techniques. Coated pipes will prevent the

outer surface from coming into direct contact with the corrosive environment. But protective coatings are easily damaged, especially during construction and in harsh operating environments (Ameh *et al.*, 2017).

3.0 Methodology

The study employed a quantitative and qualitative research approach. This based on the nature of the problem, objectives, data collection methods as well as analysis and interpretation in order to establish the associations between variables and to determine the relationship between the two variables. Quantitative approach focuses much on measurement of numerical data consequently to the presented filled information by the respondents. The approach will enable the researcher to collect large data from sample subset, it will also allow researcher to ignore the doubtful information data according to the response from respondents when filling the data (Saunders *et al.*, 2015).

The qualitative study approach using descriptive research methods was employed in this study as Kothari (2019) recommends, the qualitative study should be employed when the objective of a study is to understand complex issues, investigate a contemporary phenomenon, and in studies which seek to answer what, why, who and where questions as intended in the current study. Qualitative approach in this study allows for a deeper understanding of the interpersonal emotions, feelings on the projects, enhancing the

The sample had twenty Operation Manager form OMC, thirty-three Engineers/Operation Officer from OMC, fifty-two Engineers/Environmental/HSE Officer from Regulatory Agencies and twenty-eight Operation Officers from Government Agency since those are ones who involved in pipeline operations. Those Oil Merchants Companies are the ones who owns pipelines at Dar es Salaam port, see table below.

Table 2: **Sample Size, Categories and Respondents**

SN.	Categories	Population	Sample Size	Responded	Method
1	Operation Managers from OMC	24	20	13	Interview
2	Engineers/Operation Officer from OMC	48	33	22	Questionnaire
3	Engineer/Environmental Officer/HSE Officer from Regulatory Agency	110	52	42	39 Questionnaire, 3 HSE Interview
4	Operation Officers from Government Agency	40	28	15	Questionnaire
	Total	**222**	**133**	**92**	

3.2 Data Collection Methods

The choice of the best data or evidence to address your inquiries is the most crucial issue in relation to data collection. You must consider the questions to be addressed and the information sources accessible while planning data collecting. Additionally, you must start planning how the data will be arranged, scrutinized, and understood before being delivered to different audiences. This research used the following as data collection methods; observations, questionnaire, in-depth interviews and documentary review.

3. 2.1 Observations

This approach suggests that information was gathered by the investigator's own observation, rather than through speaking with the respondents. The information gathered is relevant to the present and is not complicated by the respondents' past actions, future intentions, or views. There is no doubt that this procedure is expensive, and it also yields very little information. As a result, this approach is inappropriate for studies involving large samples. In this study observations with other methods to obtain data for the research, the researcher visited pipeline locations and observed the existing situation of the pipeline at the site. This method enabled researcher to obtain virgin information of the existing structures.

3.2.2 Questionnaire

A questionnaire is a list of questions that are submitted in an organized way to a population sample from which information is sought. The questionnaire is perhaps the data collection tool that is utilized and abused the most. Both preparation and administration are simple. In this method both open and closed end questionnaire was used to gather information from Engineers/Operation Officer from OMC, Engineer/Environmental Officer from Regulatory Agency and Operation Officers from Government Agency.

3.2.3 In-Depth Interviews

Interviews give the researcher the chance to get information from certain participants, draw their attention to particular topics of interest, and learn their opinions on the subject. A researcher can learn about the experiences, viewpoints, and emotions of persons being interviewed through interviews. This approach of gathering data is typically done in an organized or unstructured style, where output greatly depends on the interviewer's skill, where both methods will be used. In this method staff who are responsible for the daily operation of the pipeline were interviewed which are Operation Managers from OMC and HSE officers. This allowed researcher to obtain information on the daily activities undertaken relating to pipeline, how it secured and maintenance information.

3.2 .4 Documentary Review

In document review methods the researcher reviewed different documents from the regulatory agency and pipeline owner. Also, research studies taken by other researchers were reviewed to obtain necessary information relating to the study. Leakages incidents reports were reviewed to gather information regarding incident that occurred.

3.5. Data Treatment and Storing Method

Observation and interview session were noted on the paper for the storage. Each interview was named accordingly to a specific imaginary pipeline name whereby after the interview the document was reviewed to establish notes for the study.

3.6 Data Analysis Plan

Data analysis is the systematic use of data or the application of statistical tools to describe, organize, summarize, and compare the acquired data and to break them down into digestible portions. The qualitative data was analyzed through content analysis. The qualitative data analysis primarily entails classifying things, persons, events and the properties which characterize them. The qualitative data obtained from open-ended questions, observations and in-depth interview was first be translated, transcribed and categorized into various themes and sub-themes. Eventually, the data was interpreted, presented and discussed according to their content in order to reveal the views of the informants. The quantitative data was examined using descriptive statistics to understand the aspect of the data such as mean and standard deviation, also Inferential Statistics methods were used to explore relationships between variables including correlation analysis. SPSS V26 software were used to analyse quantitative data.

After analyzing qualitative and quantitative data process of integration the results were implemented to provide comprehensive understanding. The integration of the results involved review for the findings, identifying similarities or differences in the findings, comparison and contrast of the findings and interpretation of the integrated findings in light of the research question or objective.

4.0 Findings of the Study

4.1 Factors contributing the pipeline leakages at Dar es Salaam port

The first objective of this study was to determine the types of pipes used for pipelines at Dar es Salaam Port. Respondents were provided with several statements and required to rate the best of them. Findings are presented in Table 4.3.

Table 4. 1: **Types of Pipes**

	N= 76	**Mean**	**Std. Deviation**	**Interpretation**
TP1	The types of pipes used in the construction of pipelines at Dar es Salaam port are clearly defined.	3.42	1.268	Agree
TP2	The corrosion resistance of the pipes used in pipeline construction is a critical consideration for preventing leaks.	3.62	1.177	Agree
TP3	The durability and lifespan of the pipes used in pipeline construction are adequate for the demanding conditions at Dar es Salaam port.	3.72	1.015	Agree

TP4	The pipes used in pipeline construction are compatible with the properties of the oil being transported	3.61	1.021	Agree
TP5	The maintenance requirements for each pipe used in pipeline construction are well-documented and effectively communicated.	2.24	.978	Disagree
TP6	Overall, the pipes used for the pipelines at Dar es Salaam port contribute to a reliable and leak-resistant infrastructure.	2.53	1.183	Disagree

Source: Field Data, (2024)

The study aimed to assess perceptions regarding the factors contributing the pipeline leakages at Dar es Salaam port, presenting findings in Table 4.3. Each statement (TP1 to TP6) was rated on a scale indicating levels of agreement or disagreement.

Based on the findings presented in Table 4.3, it is evident that the majority of respondents agreed on the types of pipes used for the pipelines at Dar es Salaam port. Respondents with average mean 3.42 generally agreed that the types of pipes used in pipeline construction were clearly defined. Hence, it's contributed to better understanding and management of pipeline, ensuring appropriate selection and usage. There was agreement among respondents with average mean value 3.62 regarding the corrosion resistance was critical for leak prevention. Corrosion can weaken pipelines over time, leading to leaks or failures, so ensuring materials have adequate corrosion resistance is crucial for pipeline integrity. Respondents with average mean 3.72 agreed that, the durability and lifespan of pipe met the demanding conditions at the port. This suggests confidence that the pipe selected can withstand the environmental and operational challenges present at the port.

Respondents with average mean 3.61 agreed that pipes are compatible with the properties of the transported oil. Compatibility is essential to prevent chemical reactions or degradation that could compromise the integrity of the pipeline or the quality of the transported oil. Findings also show that a mean value of 2.24 of total respondents disagreed that maintenance requirements were well-documented and effectively communicated. This suggests a perceived gap in the availability or clarity of maintenance instructions, which could impact the long-term performance and safety of the pipelines. Finding further show that respondents of mean value 2.53 disagreed that the types of pipes contribute to a reliable and leak-resistant infrastructure. This implies concerns about the overall reliability and leak resistance of the pipelines, possibly due to perceived deficiencies in maintenance practices.

While respondents generally agreed on certain positive aspects such as clarity of pipes definitions, corrosion resistance, durability, and compatibility, there are notable concerns regarding maintenance documentation and overall infrastructure reliability. Addressing these concerns could improve the safety and effectiveness of oil transportation operations at Dar es Salaam port and reduce oil pipeline leakages in Tanzania Ports.

The researcher interviewed Operation Engineers and Health and Safety Officers on the types of pipes used for pipelines at Dar es Salaam port. Within the interview respondents were asked to provide insights into the types of pipes used for the pipelines currently at Dar es Salaam port, and how these pipes types may contribute to or mitigate the risk of oil pipeline leakages.

Within an Interview Operation Managers Responded that,

As an Operation Manager working at Dar es Salaam port, I confirm that most of the pipelines in use are predominantly carbon steel pipes. Carbon steel pipes is a popular choice due to its strength and durability, making it suitable for transporting oil over long distances. However, carbon steel is susceptible to corrosion over time, especially when exposed to moisture and certain chemicals present in the oil. This corrosion weakens the pipeline walls, increasing the risk of leakages if not properly maintained and monitored (Interview, Operation Manager A, 2024).

Types of pipes used in some pipelines is stainless steel, particularly for sections that require resistance to corrosion. Stainless steel contains chromium, which forms a protective oxide layer on the surface, reducing the risk of corrosion. While stainless steel offers better corrosion resistance than carbon steel, it is also more expensive. Therefore, its use is often limited to critical sections where corrosion resistance is paramount (Interview, Operation Manager D, 2024).

Older pipelines at the port are made of carbon steel, which was a common material in the past. While carbon steel is durable than steel. (Interview, Operation Manager C, 2024).

Within an Interview Health and Safety Officers Responded that,

The types of pipes are important in determining the potential risks associated with oil pipeline leakages. For instance, carbon steel pipelines, although strong, can pose environmental risks if not properly maintained due to the risk of corrosion-induced leaks. Regular inspections and maintenance are essential to detect and address corrosion early to prevent environmental contamination and potential hazards to workers (Interview Health and Safety Officers B,2024).

Stainless steel pipelines offer a better safety profile due to their corrosion-resistant properties. However, it's still essential to monitor these pipelines for any signs of wear or damage to ensure their integrity. Proper training for personnel involved in pipeline maintenance and emergency response protocols further mitigate risks associated with potential leakages (Interview Health and Safety Officers A,2024).

HDPE pipelines, being resistant to corrosion and abrasion, are generally considered safer and more environmentally friendly than metal pipelines. However, they still require careful handling to prevent physical damage that could compromise their integrity. Health and safety training programs should emphasize the importance of proper handling and installation practices to minimize the risk of accidents and leaks for those who uses HDPE pipe (Interview Health and Safety Officers C,2024).

The findings reveal a diverse range of types of pipes used at the Dar es Salaam port, each with its unique advantages and vulnerabilities. Carbon steel, despite its strength and cost-effectiveness, presents a significant risk due to its susceptibility to corrosion over time. This corrosion weakens the pipeline walls, escalating the likelihood of leakages if not diligently maintained and monitored. While stainless steel offers enhanced corrosion resistance, it comes at a higher cost, limiting its application to critical sections. The popularity of high-density polyethylene (HDPE) pipelines, which are characterized by their flexibility and resistance to corrosion, is not used. However, they are not without limitations, as they are susceptible to physical damage from external factors.

The findings of this study underscored the importance of a comprehensive approach to pipeline management at Dar es Salaam port. While the selection of the types of pipes such as stainless-steel pipes and carbon steel pipes demonstrates a proactive effort to enhance safety and environmental protection, it is crucial to implement rigorous maintenance and monitoring protocols across all pipeline types. This includes regular inspections, proactive corrosion

detection, and robust emergency response plans to mitigate potential leakages. Moreover, the implementation of training programmes for personnel engaged in the maintenance and operation of pipelines can enhance awareness and adherence to best practices, thereby reducing the risk of accidents and environmental contamination. Overall, a balanced strategy that combines material selection, maintenance, and personnel training is essential for ensuring the long-term integrity and safety of the pipeline network at Dar es Salaam port.

4.4.2 Installation Techniques Used for the Pipelines at Dar es Salaam Port

The second objective of this study was to eexplore installation techniques for the pipelines used at Dar es Salaam port. Respondents were provided with several statements and required to rate the best of them. Findings are presented in Table 4.4.

Table 4. 2: **Installation Techniques**

	N= 76	**Mean**	**Std. Deviation**	**Interpretation**
IT1	The welding techniques employed during the installation of pipelines at Dar es Salaam port are of high quality.	2.20	.924	Disagree
IT2	The joints and connections of the pipelines at Dar es Salaam port are well-made and durable.	2.55	1.171	Disagree
IT3	The ROW, depth and alignment of pipelines at Dar es Salaam port meet the required standards for safe and efficient operation.	2.30	1.071	Disagree
IT4	The impact of soil conditions on pipeline installation is adequately considered and addressed at Dar es Salaam port.	2.37	1.031	Disagree
IT5	The installation of pipelines at Dar es Salaam port strictly adheres to industry standards and regulations.	2.30	.849	Disagree

Source: Field Data, (2024)

The findings from Table 4.4 present respondents' ratings on various statements related to installation techniques for the pipelines used at Dar es Salaam port. were each statement is accompanied by its mean score, standard deviation, and an interpretation based on a predefined scale

Based on the findings presented in Table 4.4, it is evident that the majority of respondents Disagreed on installation methods for the pipelines used at Dar es Salaam port. Respondents with average mean 2.20 generally disagreed that the welding techniques used for pipeline installation were of high quality. This suggests concerns about the welding process, which is critical for the structural integrity of pipelines. There was disagreement among respondents with average mean value 2.55 regarding the joints and connections of the pipelines were well-made and durable. This raises concerns about the quality and reliability of the connections, which are essential for preventing leaks and ensuring the integrity of the pipeline system. Respondents with average mean 2.30 disagreed that, the depth and alignment of pipelines met

the required standards. Proper depth and alignment are crucial for avoiding damage and ensuring efficient operation, indicating potential issues with installation practices.

Findings also show that a mean value of 2.37 of total respondents disagreed that the impact of soil conditions on pipeline installation was adequately considered and addressed. This suggests that soil conditions may not have been adequately assessed or mitigated during the installation process, which could lead to future issues such as instability or corrosion. Finding further show that respondents of mean value 2.30 disagreed that pipeline installation strictly adhered to industry standards and regulations. This indicates potential gaps in compliance with established standards, posing risks to safety, reliability, and regulatory compliance.

The findings suggest significant concerns regarding various aspects of pipeline installation techniques at Dar es Salaam port, including welding quality, joint durability, alignment, soil condition considerations, and adherence to industry standards. Addressing these concerns is essential for ensuring the safety, reliability, and efficiency of the pipeline infrastructure and reduce Oil Pipeline Leakages in Tanzania Ports.

The researcher conducted an interview for getting responses for objective two on Installation techniques for the pipelines used at Dar es Salaam port. Within an interview session Operation Managers were asked to explain in terms of pipeline installation techniques, what practices and technologies are employed at Dar es Salaam port, and how do these methods impact the integrity and longevity of the pipelines.

Operation Managers responded that,

At Dar es Salaam port, one of the primary techniques we employ for pipeline installation is the traditional trenching method. In this approach, we excavate a open trench in the ground where the pipeline will be laid. This method allows us to visually inspect the ground conditions and address any potential issues such as unstable soil or obstructions. By ensuring proper backfilling and compaction, we aim to protect the pipeline from external stresses and maintain its integrity over time. However, this method may require more time and labor compared to other techniques also its difficult to inspect buried pipeline (Interview, Operation Manager F, 2024).

To minimize disruptions and environmental impact, we also utilize Horizontal Directional Drilling (HDD) for pipeline installation across roads. HDD allows us to install pipelines beneath existing structures, without the need for open trenches. This method reduces surface disturbance, which is essential in maintaining the port's operations and minimizing downtime. Proper drilling techniques and material selection are essential to ensure the longevity and integrity of the pipelines installed using HDD (Interview, Operation Manager G, 2024).

For projects that requires pipelines to cross the sea we use pulling and towing techniques to cross the water body, this is the only available technique in the country though it requires to have detailed sea bed survey because this method is only usable when sea bed is smooth other wis rough sea bed will damage the pipeline (Interview, Operation Manager I, 2024).

Regardless of the installation method chosen, we prioritize the selection of high-quality materials and protective coatings for our pipelines. At Dar es Salaam port, we use corrosion-resistant materials such as stainless steel or carbon steel and apply robust coatings to enhance their durability and resistance to external factors. Regular inspections and maintenance are carried out to identify and address any potential issues promptly, ensuring that the pipelines remain in optimal condition throughout their service life (Interview, Operation Manager, 2024).

Moreover, respondents were asked from their experience, what are the common challenges faced during the installation and maintenance of oil pipelines at the port, and how do these challenges relate to the potential for leakages.

On other side of the coin, operation manager responded that,
One of the common challenges we face during the installation and maintenance of oil pipelines at the Dar es Salaam port is the difficulty in ensuring consistent and proper sealing of the joints. Poorly sealed joints can be a significant risk factor for leakages, as they can allow oil to escape and lead to environmental contamination. Regular inspections and quality checks are crucial to address this issue and prevent potential leaks (Interview, Operation Manager H, 2024).
Challenges on corrosion and wear of pipeline materials over time, especially in a marine environment like a port. Corrosion weakens the integrity of the pipelines, making them more susceptible to leakages. Implementing corrosion protection measures and using durable materials can help mitigate this risk and extend the lifespan of the pipelines (Interview, Operation Manager K, 2024).
Maintaining proper pressure levels within the pipelines is essential to prevent leaks. Fluctuations in pressure can put excessive stress on the pipelines, leading to cracks or ruptures. Monitoring and controlling the pressure levels through effective operational practices and safety measures are vital to ensuring the integrity of the pipelines and minimizing the potential for leakages (Interview, Operation Manager J, 2024).
The findings from the interview with Operation Manager at Dar es Salaam port shed light on the diverse installation techniques employed to ensure the integrity and longevity of pipelines. Traditional trenching offers a visual advantage by allowing ground condition inspections during installation but demands more time and labor. Horizontal Directional Drilling (HDD) minimizes surface disruptions, crucial for uninterrupted port operations, while pulling and towing techniques may not be suitable if the sea bed features are not known. These methods underscore the commitment to selecting high-quality pipes and protective coatings like stainless steel pipes or carbon steel pipes, ensuring durability and resistance to external factors.

However, challenges persist, notably in ensuring proper joint sealing, combating corrosion in the marine environment, and maintaining consistent pressure levels to prevent leaks. These challenges highlight the importance of regular inspections, quality checks, and corrosion protection measures to safeguard pipeline integrity and mitigate environmental risks.
The installation techniques at Dar es Salaam port reflect a balance between traditional and advanced techniques tailored to specific project needs, emphasizing both efficiency and environmental responsibility. While innovative methods like HDD, pulling and towing, and micro-tunneling reduce disruptions and offer precision, traditional trenching remains relevant for its thoroughness in ground inspection. Despite the advancements, challenges related to joint sealing, corrosion, and pressure management necessitate rigorous maintenance and monitoring protocols. Addressing these challenges is crucial, as they directly impact the risk of leakages and environmental contamination, reinforcing the importance of proactive measures to ensure pipeline integrity throughout their service.

4.4.3 The Efficiency of Current Pipeline Leakages Protection Measures at Dar es Salaam Port

The third objective of this study was to evaluate the efficiency of the current pipeline leakage protection measures for the pipelines at Dar es Salaam port. Respondents were provided with several statements and required to rate the best of them. Findings are presented in Table 4.5.

***Table 4. 3*: Current leakage protection measures**

	N= 76	**Mean**	**Std. Deviation**	**Interpretation**
CLPM1	The marine painting used for pipeline protection are effective in preventing corrosion.	2.38	1.045	Disagree
CLPM2	The current monitoring systems in place at Dar es Salaam port are efficient in promptly detecting pipeline leaks.	2.52	1.142	Disagree
CLPM3	The emergency shutdown procedures implemented during a pipeline leak are swift and effective.	2.46	1.101	Disagree
CLPM4	The regular maintenance checks conducted on the pipelines contribute significantly to leak prevention.	2.57	.998	Disagree
CLPM5	Personnel at Dar es Salaam port are well-trained in safety protocols, and their adherence helps prevent pipeline leaks.	2.39	.967	Disagree

Source: Field Data, (2024)

The findings from Table 4.5 present respondents' ratings on various statements related to the efficiency of the current pipeline leakage protection measures at Dar es Salaam port. Each statement is accompanied by its mean score, standard deviation, and an interpretation based on a predefined scale.

Based on the findings presented in Table 4.4, it is evident that the majority of respondents Disagreed on efficacy of current leak protection measures for the pipelines at Dar es Salaam port. Respondents with average mean 2.38 generally disagreed that the marine painting used for pipeline protection are effective in preventing corrosion. This suggests doubts about the effectiveness of marine painting in mitigating corrosion-related risks. There was disagreement among respondents with average mean value 2.52 regarding the current monitoring systems were efficient in promptly detecting pipeline leaks. This indicates concerns about the effectiveness or adequacy of the monitoring systems in place. Respondents with average mean 2.46 disagreed that, the emergency shutdown procedures were swift and effective during a pipeline leak. This suggests perceived shortcomings in the emergency response protocols in place.

Findings also show that a mean value of 2.57 of total respondents disagreed that regular maintenance checks significantly contribute to leak prevention. This implies doubts about the effectiveness or thoroughness of the maintenance checks conducted. Finding further show that respondents of mean value 2.39 disagreed that personnel were well-trained in safety protocols and that their adherence helped prevent pipeline leaks. This suggests concerns about the adequacy or effectiveness of safety training and adherence among personnel.

Findings indicate significant doubts and concerns regarding the efficiency of current leakage protection measures for the pipelines at Dar es Salaam port. There are perceived shortcomings in corrosion protection, monitoring systems, emergency shutdown procedures, maintenance checks, and personnel training, highlighting areas that require improvement to enhance leakage prevention and overall pipeline safety in Tanzania Ports.

The researcher conducted an interview for getting responses for objective three on the efficiency of the current pipeline leakage protection measures at Dar es Salaam port. Within interview operation managers were asked on how they assess the efficiency of the current leakage protection measures in place for the pipelines at Dar es Salaam port and if there are any gaps or areas that they believe need improvement.

From the narrations of the Operation Managers responded that,

> *In assessing the effectiveness of our current leakage protection measures at the Dar es Salaam port, we primarily rely on regular inspections and maintenance checks. We look for any signs of wear and tear, corrosion, or damage on above ground pipeline that could potentially lead to leaks. Additionally, we monitor pressure levels and flow rates to detect any anomalies that may indicate a leakage (Interview, Operation Manager L, 2024).*
>
> *One area where we see room for improvement is in our monitoring technology. We need to have some sensors and alarms in place, there's a need for more advanced and real-time monitoring systems that can provide immediate alerts in case of any abnormalities or leaks. This would enable us to take swift action and minimize potential damage (Interview, Operation Manager M, 2024).*
>
> *A gap we've identified is the need for better training and awareness among our staff. Ensuring that everyone understands the importance of leakage prevention and knows how to respond in case of an emergency is crucial. We're working on implementing regular training programs to address this issue (Interview, Operation Manager N, 2024).*
>
> *There's a need for a comprehensive risk assessment to identify any potential vulnerabilities in our current leak protection measures. This would involve evaluating the age, condition, and material of the pipelines, as well as assessing environmental factors and operational risks. By conducting a thorough risk assessment, we can develop more targeted and effective strategies for leak prevention and mitigation (Interview, Operation Manager, 2024).*

Furthermore, Health and Safety Officers responded to interview question that,

Our primary methods of evaluating the efficiency of the present leak protection procedures for the pipes at the Dar es Salaam port are routine inspections and monitoring systems. These examinations assist us in locating any indications of wear and tear, possible weak spots, or potential leaky regions. In order to identify the underlying reasons of any previous mishaps and assess the efficiency of the current preventative measures, we also examine historical data on such instances. Even while our existing policies have had some success, there is always room for improvement. In order to guarantee prompt reaction and leak prevention, we think that more sophisticated leak detection systems and ongoing training for employees are required (Interview Health and Safety Officers B,2024).

We regularly carry out risk assessments and audits to evaluate the effectiveness of the leak prevention systems put in place for the pipelines at the port of Dar es Salaam. These evaluations assist us in locating any weaknesses in the current systems and assessing how effective the preventative measures put in place are. In order to compare our existing procedures to those of other ports, we frequently hold discussions with industry experts and examine their best practices. We have found several gaps despite our best efforts, especially in the areas of emergency response processes and maintenance scheduling. By making these improvements, we might lower the likelihood of environmental dangers and increase the overall efficacy of our leak protection strategies (Interview Health and Safety Officers A,2024).

More over Health and Safety Officers we asked in the context of health and safety, what protocols and procedures are followed to ensure the well-being of personnel involved in pipeline operations at the port

Health and Safety Officers responded that,

In terms of leakage protection measures for the pipelines at Dar es Salaam port, we have stringent protocols in place to ensure the safety and efficacy of our operations. We are planning to employ advanced leak detection systems that continuously monitor the pipelines for any signs of leaks or abnormalities. Additionally, regular maintenance and inspection routines are carried out to identify and address potential issues before they escalate. Our goal is to minimize the risk of leaks and ensure the integrity of the pipeline infrastructure, thereby safeguarding both the environment and the port's personnel (Interview Health and Safety Officers B, 2024).

Regarding the health and safety protocols for personnel involved in pipeline operations at the port, we prioritize comprehensive training and awareness programs. All personnel undergo extensive training on safety procedures, emergency response protocols, and the use of personal protective equipment (PPE). Regular safety briefings and drills are conducted to reinforce these practices and ensure everyone is prepared to respond effectively in case of an incident. Furthermore, we have a dedicated health and safety team that monitors

compliance with these protocols and provides ongoing support to ensure the well-being of our staff (Interview Health and Safety Officers C,2024).

Our approach to ensuring the well-being of personnel involved in pipeline operations at Dar es Salaam port is holistic and proactive. Beyond the technical and procedural aspects, we focus on fostering a culture of safety and responsibility among our workforce. This includes promoting open communication, encouraging reporting of potential hazards or safety concerns, and actively involving employees in the development and review of our health and safety policies. By engaging our team and empowering them to take ownership of safety, we aim to create a workplace where everyone is committed to maintaining a safe and healthy environment (Interview Health and Safety Officers A,2024).

The findings from the interviews with Operation Manager and Health and Safety Officers at the Dar es Salaam port highlight several key insights regarding the efficiency of the current leakage protection measures in place for the pipelines. Both groups emphasize the importance of regular inspections, monitoring systems, and maintenance checks to identify potential weaknesses or abnormalities that could lead to leaks. However, there is a shared recognition of the need for more advanced and real-time monitoring technologies to enhance early detection and response capabilities. Furthermore, there is a recognized deficiency in the training and awareness of personnel, which emphasizes the necessity of educating them on leak prevention strategies and emergency response protocols. Additionally, a comprehensive risk assessment is regarded as crucial for identifying vulnerabilities and developing targeted strategies for leak prevention and mitigation.

The implications of these findings suggest that while existing leakage protection measures at the Dar es Salaam port have some effectiveness, there is room for improvement to enhance the overall safety and integrity of the pipeline infrastructure. The implementation of advanced monitoring technologies, regular training programmes and comprehensive risk assessments can significantly bolster the port's leak prevention and mitigation efforts. Adopting a proactive approach that combines technical enhancements with robust training and awareness initiatives can reduce the risk of environmental hazards, minimize potential damage, and ensure the well-being of both personnel and the surrounding environment. These insights underscore the importance of continuous improvement and adaptation in maintaining and enhancing the efficiency of leakage protection measures at the Dar es Salaam port.

4.5 Inferential Statistical Analysis

The study applied inferential statistical analysis which enabled researchers to draw meaningful conclusions and make predictions about populations based on data collected from a sample. It involves a systematic process of hypothesis testing, confidence interval estimation, and regression analysis, analysis of variance, correlation analysis, normality and collinearity tests. Within inferential statistical analysis the study applied inferential on examining the factors contributing to oil pipeline leakages in Tanzania ports.

4.5.1 Model Summary

In Examining the Factors Contributing to Oil Pipeline Leakages in Tanzania Ports. Multiple linear Regression model was applied to assess the influence of dependent variable (Oil Pipeline Leakages) and independent variables (leakage protection measures, installation techniques and identifying factors). Regression analysis was employed after the study met the regression assumptions. The significance level of 0.05 with 95% confidence interval was used.

***Table 4. 4*: Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.940[a]	.883	.878	.354	.643

a. Predictors: (Constant), leakage protection measures, installation techniques, identifying factors
b. Dependent Variable: Oil Pipeline Leakages
Source: (Field Data, (2024)

The regression model (Table 4.6) presents how much of the variance in Oil Pipeline Leakages in Tanzania Ports is explained by the underlying Factors affecting it. The predictor variables i.e. leak protection measures, installation methods, identifying factors have accounted 0.878 of adjusted R square which indicates 87.8% of Oil Pipeline Leakages in Tanzania Ports was explained by the variation of the three predictor variables whereas the remaining 12.2% are explained by other variables not explained in this model. It also indicates that the value of R (0.940) implies that the independent variables (Factors Contributing to Oil Pipeline Leakages) have positive strong correlation in Tanzania Ports.

4.5.2 Analysis of Variance (ANOVA)

In assessing the statistical significance of the result, it is necessary to look in the table 4.7 labelled ANOVA. This measure means of population when they differ from each other. It tests the hypothesis that multiple R in the population equals 0. If the Sig. value is less than 0.05 (0.01, 0.0001), then the variable shows a significant unique influence/ effect to the prediction of the dependent variable. If greater than 0.05, then you conclude that variable is not making a significant unique contribution to the prediction of your dependent variable.

***Table 4. 5*: Analysis of Variance (ANOVA)**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	68.161	3	22.720	181.029	.000[b]
	Residual	9.036	72	.126		
	Total	77.197	75			

a. Dependent Variable: Oil Pipeline Leakages
b. Predictors: (Constant), leakage protection measures, installation techniques, identifying factors
Source: Field Data, (2024)

The ANOVA (Analysis of Variance) table 4.7 provides information about the overall significance of the regression model in explaining the variance in the dependent variable (Oil Pipeline Leakages), as well as the individual contributions of each predictor variable. The finding from the assessment of the statistical significance of the result indicated in Table 4.7 labelled ANOVA indicates that there is level of significance which exists between dependent and independent variables. This tests the hypothesis that multiple R in the population equals 0. The model reaches statistical significance (Sig = 0.000, this really means p< 0.05) and the F-value of 181.029 suggests that the regression model explains a significant amount of variance in the dependent variable. Thus, Overall, this ANOVA table provides strong evidence that the regression model is effective in explaining the variance in Oil Pipeline Leakages and the predictors are statistically significant at 95% confidence interval and 0.05 significance level.

4.5.3 Correlation Analysis Test

In this study Pearson's correlation coefficient was used to determine whether there is significant relationship between independent variables (leakage protection measures, installation techniques, identifying factors) and dependent variables (Oil Pipeline Leakages). The following section presents the results of correlation on which are linear and positive ranging from moderate, strong to very strong correlation coefficients.

***Table 4. 6*: Correlation Analysis Test**

	Mean	**Std Deviation**		**IF**	**IT**	**LPM**	**OPL**
IF	3.61	1.021		1			
IT	2.24	.978		.736**	1		
LPM	3.42	1.268		.923**	.736**	1	
OPL	3.72	1.015		.923**	.779**	.900**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
IF= Identifying factors, IT = Installation techniques, LPM = Leakage protection measures, OPL = Oil Pipeline Leakages
Source Field Data (2024)

The correlation analysis table (Table 4.8) shows Pearson's correlation coefficients between the independent variables (identifying factors, installation techniques, leakage protection measures) and the dependent variable (Oil Pipeline Leakages). As it is clearly indicated in Table 4.8 Material compositions show a very strong positive correlation with Oil Pipeline Leakages ($r = 0.923$, $p < 0.01$). Installation methods also exhibit a strong positive correlation with Oil Pipeline Leakages ($r = 0.779$, $p < 0.01$) and Leakage protection measures demonstrate a very strong positive correlation with Oil Pipeline Leakages ($r = 0.900$, $p < 0.01$). These correlation coefficients indicate that there are significant positive relationships between the independent variables (identifying factors, installation techniques, leakage protection measures) and the dependent variable (Oil Pipeline Leakages), suggesting that as the values of these independent variables increase, the Oil Pipeline Leakages tend to increase as well.

4.5.4 Multicollinearity Testing

When independent variables exhibit connection, it is said to be multicollinear (r=0.9 and higher). This multiple regression analysis assumption is significant since it illustrates the relationship between the independent variables. However, Tabachnick and Fidell (2001) noted that multicollinearity is undesirable in multiple regression models. They contend that it degrades the regression model's quality. Commonly, measures like the Variance Inflation Factor (VIF) and Tolerance—both of which are accessible in SPSS—are used to identify multicollinearity.

The study especially looked at the existence of collinearity problems when evaluating the dataset. For this, the Value of Inflated Factor (VIF) and Tolerance Value (TV) were used. In order to show that there are no issues with collinearity across variables, TV should ideally be above 0.1 and VIF for all variables should be below 10. The results from Table 4.9 revealed that there was no collinearity problem among the predators, as the Tolerance Values (TV) exceeded 0.1, and the Values of Inflated Factor (VIF) were below 10.

***Table 4. 7*: Collinearity statistics**

Variable	**Collinearity Statistics**	
	Tolerance Value	**VIF**
Identifying factors	.140	7.131
installation techniques	.437	2.289
leakage protection measures	.140	7.129

Source Field Data (2024).

4.5.5 Normal Distribution

In order to ensure that data was tested properly, the researcher conducted normality test of variables to establish whether data was normally distributed or not. The study applied Shapiro Wills, W test which is best for normal and small sample size. A Shapiro-Wilk test ($p > .05$) indicated that the data for all variables were generally regularly distributed. The Shapiro-Wilk test, a statistical measure of data distribution normality, yielded alpha values greater than 0.05, indicating acceptance of the null hypothesis about the normality of the population sample. This suggests that additional parametric analysis may proceed (Razali and Wah, 2011). The SPSS output findings are shown in Table 4.11.

***Table 4. 8*: Tests of Normality**

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
Variable	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Identifying factors	.374	76	.000	.764	76	.000
installation techniques	.385	76	.000	.753	76	.000
leakage protection measures	.360	76	.000	.796	76	.000
Oil Pipeline Leakages	.370	76	.000	.781	76	.000

a. Lilliefors Significance Correction

Source: Field Data (2024).

4.5.6 Multiple Regression Analysis

To draw conclusions on the study hypothesis, we conducted multiple linear regression analyses. This involved individually assessing the impact of predictor variables on the dependent variable by examining the measurements of each predictor variable in relation to the dependent variable. Through this analysis, it is able to evaluate the influence of each predictor variable separately, thereby reaching conclusions regarding the various hypotheses outlined in the study.

***Table 4. 9*: Linear Regression Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.619	.162		3.829	.000
	Identifying factors	.549	.107	.552	5.129	.000
	installation techniques	.193	.063	.186	3.054	.003
	leakage protection measures	.203	.086	.253	2.352	.021

a. Dependent Variable: Oil Pipeline Leakages
Source: Field Data (2024).

The table 4.11 presents the results of a multiple linear regression analysis, specifically the linear regression coefficients for each predictor variable in relation to the dependent variable (Oil Pipeline Leakages). Study findings indicate that all predictor variables (identifying factors, installation techniques, leakage protection measures) have statistically significant coefficients ($p < 0.05$), indicating that they are significantly related to Oil Pipeline Leakages. Types of pipes have the highest standardized coefficient, suggesting that they have the strongest impact on Oil Pipeline Leakages among the predictor variables. Installation techniques and leakage protection measures also have significant but relatively smaller standardized coefficients compared to material compositions. These coefficients represent the estimated change in the dependent variable (Oil Pipeline Leakages) for a one-unit change in each predictor variable, holding all other predictors constant. Finding indicate that the constant coefficient (.619) represents the estimated value of the dependent variable when all predictor variables are zero. The coefficient for types of pipes (.549) indicates that for every one-unit increase in types of pipes, the Oil Pipeline Leakages are estimated to increase by .549 units, holding other predictors constant. Similarly, the coefficients for installation techniques (.193) and leakage protection measures (.203) represent the estimated change in Oil Pipeline Leakages for one-unit increases in those respective predictor variables. So, these results provide insight into the individual contributions of each predictor variable to Oil Pipeline Leakages.

5.0 Conclusion

In conclusion, the findings of this study underscore the critical importance of addressing the underlying factors contributing to oil pipeline leakages in Tanzania Ports. By prioritizing infrastructure upgrades, strengthening regulatory oversight, and fostering collaboration among stakeholders, significant progress can be made towards mitigating the risks associated with pipeline operations and ensuring the safety and sustainability of oil transportation activities. It is hoped that the insights gained from this study will inform evidence-based decision-making and contribute to the development of targeted interventions aimed at safeguarding the integrity of pipeline infrastructure and minimizing the environmental and socio-economic impacts of oil spills in Tanzania Ports.

Based on the research findings, it can be concluded that types of pipes, corrosion resistance, durability and lifespan, maintenance requirements, installation techniques, and leakage protection measures significantly influence oil pipeline leakages in Tanzania ports. While there are positive aspects, such as the suitability of materials and certain protective measures, there are also notable concerns regarding maintenance practices and adherence to industry standards. Addressing these concerns is crucial for enhancing the safety, reliability, and efficiency of oil transportation operations in Tanzania ports.

The study also conducted at Dar es Salaam port highlighted a variety of pipeline with their respective strengths and weaknesses. Carbon steel, although durable and cost-effective, is prone to corrosion, necessitating meticulous maintenance to prevent leakages. Stainless steel offer better corrosion resistance, but the former is costlier, and the latter requires careful handling to avoid damage. The OMC is phasing out older pipelines in favor of more new robust pipes, indicating a commitment to upgrading infrastructure for improved safety and efficiency. In terms of installation techniques, OMC use pulling and towing technique in laying water body crossing pipeline and blend of traditional trenching and advanced techniques like Horizontal Directional Drilling (HDD) and micro-tunneling for the onshore pipeline.

While traditional techniques allow for thorough inspections during construction, innovative approaches and ensure precise alignments. Despite the emphasis on durable materials and protective coatings, challenges remain in joint sealing, corrosion prevention, and pressure management, underscoring the need for stringent maintenance and monitoring protocols. Feedback from Operation Managers, Operation Engineers and Health and Safety Officers revealed confidence in current leak protection measures, including regular inspections and maintenance. However, there's a consensus on the need for advanced real-time monitoring systems, improved personnel training, and comprehensive risk assessments to address existing gaps in technology, awareness, and targeted leak prevention strategies. Generally, while Dar es Salaam port has made strides in pipeline infrastructure and safety measures, there's a clear imperative for further advancements in technology, training, and risk assessment to ensure long-term integrity and minimize environmental risks.

6.0 Recommendations

Based on the findings of the study aimed to examine the factors contributing to oil pipeline leakages in Tanzania ports and in light of the conclusions drawn from the research findings, the following recommendations are proposed to improve the safety and reliability of oil pipeline infrastructure in Tanzania ports:

To Enhance Maintenance Practices

Implement comprehensive maintenance protocols and documentation procedures to ensure the longevity and reliability of pipeline infrastructure. Regular inspections and preventive maintenance activities should be conducted to identify and address potential vulnerabilities before they escalate into major issues.

To Improve Installation Standards

Strengthen adherence to industry standards and regulations during pipeline installation processes to minimize risks and ensure compliance with safety protocols. Training programs for installation crews should emphasize the importance of quality workmanship and adherence to established procedures

To Enhance Leakage Protection Measures

Invest in advanced techniques such as cathodic protection, monitoring systems, emergency shutdown procedures, and personnel training to enhance leak prevention and response capabilities. Continuous monitoring and regular testing of protective measures should be conducted to ensure their effectiveness and reliability in real-world conditions.

To Conduct Regular Inspection

Establish a system for regular inspections of pipeline infrastructure to identify and address potential vulnerabilities and compliance issues. Independent inspector by qualified experts can provide valuable insights into the effectiveness of existing safety measures and identify areas for improvement.

To Promote Collaboration

Promote collaboration between industry stakeholders, regulatory bodies, and government agencies to develop and implement robust safety standards and protocols. Information sharing and cooperation among stakeholders are essential for identifying emerging risks and implementing timely interventions to mitigate them.

7.0 References

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