

EVALUATION OF MBS QUALITY ASSURANCE STANDARDS AND SYSTEMS USED AT FUEL DEPOT AND FILLING STATIONS OF MALAWI

SHADRECK CHIPIKO

Thyolo, Malawi

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DISSERTATION APPROVED BY:

SUPERVISOR:

MR.F. JOSIAH Signature:

ASSESSOR:

Signature: _____

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ABSTRACT

The cases of selling poor quality liquid fuel has been daily alarm which perturbing the customers and nation to cause poor engine performance (engine wear) and other associated consequences. Therefore, the aim of this study titled "evaluation of MBS Quality Assurance Standards and Systems used at Fuel depots and Filling Stations" is to develop a framework that can drive and efforts for continual improvement of the depots and service station quality approach in operations and particularly for improvement of diesel and petrol fuel quality assurance system in reference to applicable requirements of the MS-113, 114, 121 and MS-172 of Malawi Standards was realised by means of checklist and questionnaire, from which I identified non-conformities. There is average overall non-compliance of 38.89% (7 from 33 applicable requirements. Thus using the '5 whys' approach (root cause analysis) and Pareto diagrams I found that 54% of identified non-conformities result from poor documentation and poor implementation of procedures, 14% from Poor regulatory and quality control team/watch amongst others. I acknowledge that it might not be possible to meet all requirements of Malawi standards immediately since there is different quality management systems (private and Government), and life span of storage tanks, and therefore, is will be essential to allow different acceptable operations that can effectively impact in quality assurance according to standards. I then used the FMEA approach to analyse these non-conformities and ranked them according to their effective cost maintenance in fuel quality. The results from arrangement highlighted four most critical findings with highest performed and cost management of quality assurance. These are: the non-existence of quality assurance and operational manual, personnel lack of training (formal experts); poor fuel storage tank cleaning periods, poor documentation and implementation of quality assurance procedures. I then develop an action plan, a monitoring plan and a follow-up plan to ensure effective complied with required standards and operational systems for improvement of fuel quality in supply chain systems.

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ACRONYMS/ABBREVIATIONS

MBS…… Malawi Bureau of Standard

Vol……Volume

SAPIA…… South Africa Petroleum Industry for Aviation

API……..American Petroleum Institute

ISO…….. International Organization for Standardisation

ASTM……American society for Testing and Materials

NOCMA…… National Oil Company of Malawi

MERA……Malawi Energy Regulatory Authority

MS……..Malawi standard

SANS…….. Southern Africa National Standards

PIL……petroleum importers limited

FMEA…….....Failure Mode and Effect Analysis

CoA…….....Certificate of Analysis

RC…… Release certificate

RTC……..Recertification Test certificate

QA …… Quality Assurance

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Chapter 1: INTRODUCTION

1.0. Background

Quality assurance (QA) is management method that is defined as "A systematic monitoring and evaluation of the various aspects of a project, service or facility to maximize the probability that minimum standards of quality are being attained (Quhn, 2005). It is all those planned and systematic actions needed to provide adequate confidence that a products, service or result will satisfy given requirements for quality and be fit for use. It is a key approach that, in Malawi every fuel depot and filling stations' quality assurance management should be in line with all Malawi quality standards and specifications as well as worldwide. The strictest compliance with all the specifications is essential and must be verified at each stage of handling the products, from storage to distribution (retail). The potential consequences of a failure to attain the correct guidelines, systems and specification of construct, operate, and managing liquid fuel and have following problems like contamination of the liquid fuel, pollution to the environment, engine wear or malfunction and overall sell substandard fuels (jennifer Lloyd, 2006)

A key institution for directing and enforcing necessary regulations and operations in Malawi is the Malawi energy regulatory Authority (MERA). It is a specialized energy regulatory government agency of Malawi which plays a crucial role in enforcing fuel stakeholders (distributors, retailers, transporters, storage) to be complied with national quality standard for storage, Distribution and handling of petroleum products in Malawi (Gregory E. T. Gamula1, 2012)

The Malawi Bureau of Standard (MBS) is the national standard board which plays a crucial in quality assurance management by development petroleum products standards and crediting system practices with the reference from International Organization for Standardization(ISO), American petroleum institute(API), American society for Testing and Materials(ASTM), SANS etc., MBS elaborated MS113, MS114, MS 121 and MS172 (Fung, n.d.).

In reference from MBS' document 2001 manual titled "MBS standard works programme'' on products and services in Malawi, there are standards that inform

petroleum products' stakeholders about existence of accepted petroleum products practices and reinforces the need for compliance with them and also highlights the importance of appropriate knowledge throughout the fuel supply chain. Amongst these industry good practices, operation and management standards are; MS 113, MS 114, MS 121, and MS 172 standards (quality assurance requirements for the storage, distribution (transportation) and handling of oil fuel to depots) (An, Earley, & Green-Weiskel, 2011). Some industry players recognised the need to make better the internal quality assurance through of key mandatory provisions considered essential for maintaining the quality of liquid fuels from receipt point(port), in storage tanks (NOCMA & PIL storage tank depots and stations), to distribution. This is manifested through creating the working group to do quality control operation and management at their depots.

This thesis is concerned with the study and evaluation of quality assurance standards and systems used in fuel depots and filling stations of Malawi in reference to MS 113, MS 114, MS121, and MS 172 as well as develop a framework for better and continual improvement.

1.1. Problem Statement

Ensuring quality standards and systems of liquid fuel demands stakeholders or players in the petroleum products sector must understand the standards and operational guidelines required in storage, handling and transportation; the importance, possible ways of fuel contamination, and effects at each and every stage of supply chain management.

According to MERA (2018) report claims that over 200 service filling stations across the country have been constructed without following standard guidelines and are operating with poor fuel quality management and systems. For example in reports in 2016 motorists who fuelled their cars at three puma service stations in Lilongwe area 28, Gemini and area 18, were complaining that they were buying contaminated fuel from those stations and the results after MERA investigation and sample taken shows that these stations have been operating for some couple of years without storage tank inspections hence tanks corroded and resulted fuel contaminated with particulates and water from underground rain water.

According also to (mhone, 2020) MERE closed a Total service station in Lilongwe city centre along the independence drive for allege of supply of contaminated diesel following the complaints from motorists.

Therefore, hypothetically, Malawi petroleum products industry follows basic traditional practices and management system at expense of modern international and MBS requirements- for operations as well as for the assurance of petroleum products' quality at delivery and that's, the quality assurance system compliances hence these practices have been resulted into fuel contamination, engines wearing, environmental pollution.

1.2. Main and Specific Objectives

The main objective of this thesis is to develop measures for improvement of fuel quality assurance standards and systems in fuel transportation, storage and handling

1.2.1 Specific objectives;

i. Evaluate standards in reference to MS113 MS114, MS 121, and MS172
ii. Analyse existing gap, their causes, effects and finding faults.
iii. Develop framework (supportive structure) for improving the system standards

1.3 Research Questions

i. What is gap between the standards requirements and the actual situation?
ii. What are the causes of the gaps, their effects
iii. What measures could be used to ensure proper fuel quality assurance?

1.4 Significance of study

There is need for a well-defined framework of procedures and facilities alongside a proper documentation of improved description to carryon and enhance liquid fuel (e.g. petrol, diesel and or even Jet-A 1 fuel) quality assurance in our depots and filling stations. This thesis offers better provisions as per requirement of the MS 113, MS 114 MS 121 and MS 172. These thesis could be useful in other aspects such as scientifically, managerial plan

i. Scientifically aspect; this research can serve as benchmark for all those who are keen to build on quality management in general and on the development and implementation of a quality assurance system in particular

ii. Managerial plan aspect; this work provides an in-depth view of the state of the quality assurance system of the enterprise. The improved proposals provided are as per requirement of the MS 113 MS 114, MS 121 and MS 172 and shall go a long way to enhance Petrol, Diesel and or even Jet-A1 operations in enterprise. Furthermore, the enterprise shall be able to claim compliance with the standard, which is a very strategic advantage in the petroleum industry.

1.5. STUDY AREA

Malawi has three major public strategic reserve depots in all regions of total capacity of 60,000,000 million litres managed by NOCMA and some minor depots and private depots managed by PIL members' e.g. Total energy limited, PUMA, Petroda, just to mention some. NOCMA controls 90% of liquid fuel importation and storage of liquid fuel (Diesel, Petrol and or Jet-A1), and PIL control mostly the fuel retailing.

NOCMA has a mission to promote upstream oil and gas activities and ensure a competitive, secure and sustainable supply of liquid fuel to all parts of the country, and one of their core values is Safety, Health and Environmental care which part is part of quality assurance management of their liquid fuel (NOCMA).

MERA and MBS are public institutions which work hand in hand with NOCMA and PIL members for quality assurance of liquid fuels in the country. MERA and MBS are responsible for ensuring that fuel quality meets the required standards in Malawi. They conduct quality control inspections and tests of petroleum products and their facilities (storage tanks and tankers) (w.D.Saiwa, 2017).

Blantyre is one of the districts where there is one of public strategic reserves depot and some PIL depots. According to (MERA, 2016) report, claims that Blantyre has more than 50 service filling stations which operates across the district. Map shows some filling stations in the Blantyre city.

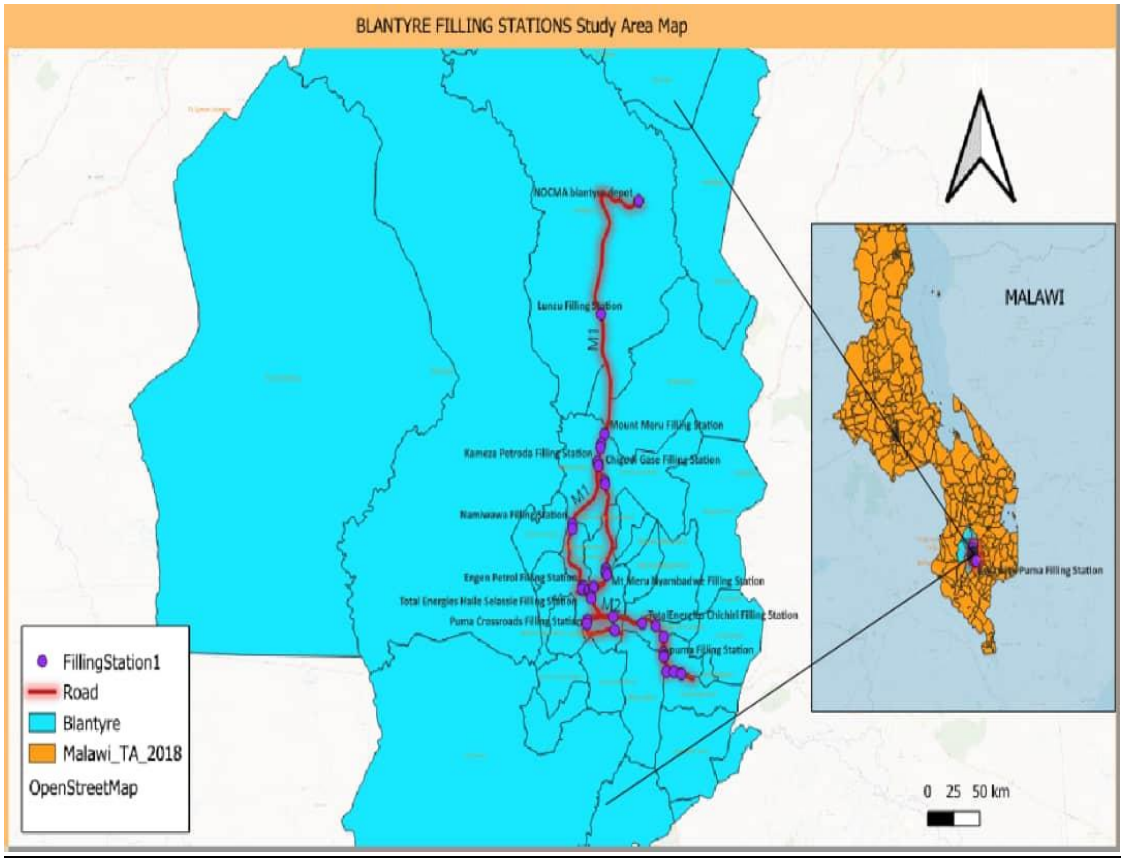


Figure 1: Study Area Map Showing Blantyre city with depot points and filling stations

Chapter 2: Literature Review

Quality assurance is a crucial element in the fuel industry as it ensures the safety, reliability, and efficiency of fuel products (Caldeira, 2017). In the specific case of Malawi, the Malawi Bureau of Standards (MBS) plays a significant role in establishing standards, testing and enforcing fuel quality through inspection. But fuel standards alone are insufficient.

Numerous studies highlight the significance of quality assurance in the fuel industry, emphasizing that poor fuel quality can have severe consequences on environmental pollutions, poor engine performance, emissions, and contamination (Yilmaz, 2017). Hansen et al. (2019) conducted research demonstrating that low-quality fuels contribute to increased engine wear, decreased fuel efficiency, and ultimately result in higher maintenance costs and negative environmental impacts. Therefore, implementing quality assurance measures becomes crucial to ensure that fuels meet the necessary specifications, thereby enhancing performance, reducing emissions, and improving consumer satisfaction.

MBS sets monitoring practices for quality assurance of liquid fuel and ensure that every stakeholder is following in sector (Fung F. , 2011). Some of the practices of standard and system are fuel sampling and testing, storage tank inspection, leakage testing, and certification of fuel structures i.e. Storages and Tankers.

2.1. Review of the MS 113, MS 114, MS 121 and MS 172 of Malawi standards

Malawi standards (MS 113, 114, 172-2 and 840) were developed by MBS, to provide guidance to fuel companies including NOCMA to assist in maintenance of fuel quality from its point of storage to retail pump station (customers). Thus, they contain mandatory provisions and good practices recommendations for the design/functional requirements of facilities, and operational procedures for entities in the fuel supply chain: from NOCMA (storage), road transport to storage terminal handling.

Table 1: review Malawi standards

Malawi standards	Recommendations
MS-113 & MS-114	• Tank painting

	• Tank testing
MS-121 & MS-172	• Corrosion protection • Frequency of tank cleaning • Fuel sampling and testing • Tank design and installation • Minimum distance from water ways

Source; www.mera@meramw.com : descriptions of Malawi standards specification.

2.2. Liquid fuels (petrol, diesel or Jet-A1) quality

2.1.2 Types of oil fuels

Malawi through NOCMA import (store, distribute and retail) six types of oil fuels namely: petrol, diesel, paraffin (kerosene), Jet kerosene (Jet-A), aviation gas (Av-gas) and LPG. But research will focus on the MBS' standards and systems of storage, distribution (transportation), and handling of petrol, diesel and jet-A at different depots which promote quality assurance of petroleum products in Malawi (chikuni, 2023).

2.2.1. Main properties that define these fuel quality

Petroleum products are complex hydrocarbon mixture and have various chemical and physical properties that determine fuel quality. Malawi market retailing fuel companies sell both blended and non-blended fuels, so therefore, there is need to consider some of these parameters that MBS focuses (MBS, Malawi Bereu of Standards, 2017);

i. Flashpoint

This is the lowest temperature at which a fuel under atmospheric pressure, the vapours emitted by a hydrocarbon ignites in the presence of a source of ignition (flame, spark, heart source). This gives the general indication of the flammability or combustibility of the fuel (Teresa L. Alleman, 2011). This is significant property not for only the operability of fuel, but also for storage and handling. (dennis P.Nolan, 2011).

Pensky-Martens method is better method for determining flashpoint of diesel, petrol, paraffin and jet A-1 (Israel, 2019). And the method is done in accordance ASTM- 93/ ISO 2791 (helgaG. Aleme, 2012).

The flash point of Diesel, Petrol, and Jet-A is greater than or equal to 38^0C

ii. Density

This refers to the ratio of oil fuels' mass to volume. It is usually expressed in grams per millilitre (g/ml). This property depends on factors such as temperature, composition and additives.

The density of diesel, petrol, and Jet-A fuel is ≥0.78

iii. Water content

Moisture in petroleum products causes several issues: corrosion and wear in pipelines and storage tanks, an increase in debris load resulting in diminished lubrication, blocked filters, or even harmful bacterial growth. As a result, increased water content can lead to infrastructure damage, higher maintenance costs, or even unwanted downtimes. Due to these costly factors, water content is a critical factor regulated in many trade specifications, and also defines the price of these products. An accurate and reliable determination is therefore necessary, since even small deviations can have a large impact on the selling price (Emoshoriamhe Erua, 2015).

The water content in the fuel samples can be determined by using the method called **coulometric Karl Fischer titration.** Most of the time this method is used because is most accurate, and can even trace low level of free, emulsifies and dissolve can be detected (which cannot be detected with other such as crackle test (worley, 2019). The method is done according to the three procedures outlined in ASTM Method D6304. A comparison is given between the procedures to determine which is most suitable for different sample type.

This method has following accepted range of water content in fuel; Gasoline and diesel fuels are expected to be very low usually below the range of 0.003% - 0.5% by volume.

iv. Octane rating/number

This is a measure of the anti-knock properties of oil fuels. It indicates the fuel's ability to resist knocking or pinging during combustion inside an engine.

The octane number of most of petrol or diesel is greater than or equal to 87 while Jet-A1 is around 15 at the pump.

v. Distillation characteristics

This is describes the boiling ranges at which distillate fuels (e.g. diesel, and gasoline) will form vapours during combustion in the engines, or even evaporation (pouya Hosseinifar, 2021).

In order to determine this boiling range of the petroleum product, the standard test method called ASTM D86 is used. This is done by performing a batch distillation at atmospheric pressure resulting in a distillation curve. This standardised test is related to volatility and fuel performance for gasoline and diesel fuels (Ma Mercedes del Coro Fernández-Feal, 2017).

This property covers all other properties that define fuels

2.3. Liquid fuel management at depot / filling station

Quality control and assurance, that reflects both either good accepted national or international practice, is part of global quality management and quality management tools offer support for the management of risks to fuel engine safety and storage facilities (Sickels, 2012). It is, therefore of fundamental importance that every responsible organisation or companies involved in fuel supply, storage, transport, Testing fuel has such system in place for managing quality, in order to maintain the fuel specification and quality while under their control. (Predesh, 2013) States that these that:

a. Facilities and equipment are maintained in good condition for the safe delivery on specification, clean and uncontaminated from receipt to delivery.
b. An auditable and documented record exists, conforming correct handling and testing of oil fuel throughout the supply chain from receipt to delivery.
c. Traceability is maintained to ensure that products are on specification and fit for the purpose on delivery.

The operations for effective quality management are described and documented properly. And some of these operation are;

i. Quality control testing for determine quality parameters according to national standards.
ii. Documentation of practical procedures for specific operation.
iii. Label storage tanks and tanker to avoid contamination of fuel through mixing.
iv. Storage tank cleaning and maintenance through regular inspection to prevent corrosion, and leaks which can contaminate the fuel.
v. Documentation of records of fuel quality tests, maintenance activities and inspection for regulatory compliance.

2.4. Quality assurance standard of fuel transportation mode

Currently, Malawi transports fuel products through two transport modes systems since is landlocked country, they only depend on road and railways through tankers (Government, 2018).

According to MS 172-2 of MBS standard is a mandate to certify these tankers in order to meet their specifications of their standard in order to ensure quality and safer fuel products in Malawi. Some of the practice that are done on the tankers to ensure good quality of petrol, diesel and or Jet-A1 are: cleaning, testing the leakage, and certifying the material and structures fuel of the tanker.

2.4.1. Certifying the materials and structures of a tanker

According to Sunsky Vehicles reports, which is currently one of the tanker vehicle exporting to Malawi, tell that the best tank trailer are made up of **aluminium alloy** rather than carbon steels (Vehicles, 2021). This is so because the aluminium is highly resistance to corrosion when scraping with fuel or water, and others are **cylindrical carbon steel** or **stainless steel**. All these tankers, have to be with materials which are non-corrosive (MBS, Malawi Bureau of Standards, 2023). The table below shows some specifications according ISO and ASTM standards of non-aluminium tankers i.e. Carbon steel tankers.

Table 2: Specification of carbon steels tankers

Items	Specifications
Dimension (L x W x H)	118000 x 2500x 3750 mmm
Material	Carbon steel
Capacity	42000L
Manhole	Aluminium alloy Ø500mm +breather valve
Discharge valve	Aluminium alloy discharge valve with cover
Foot valves	Pneumatic control DN80 aluminium alloy foot valve
Prime & Topcoat painting	S.A.2.5 standard sandblasting; Zinc-rich & Poly urethane painting

Source: https://www.sunskytrailer.com

2.5. Quality assurance of fuel storage tanks

According to (MBS, 2014) declarations, Malawi has two types of diesel and petrol storage tanks which are; above the ground and underground storage tank. In order for quality assurance, tanks have to be designed and constructed in accordance of MS 113, MS 840 and MS 114 of MBS specific standards.

There are some activities to be done in order to ensure that fuel products that are being store should not lose their quality due corrosion and water contamination, and these activities are;

i. **Painting and protection:** ensure that all tanks are painted in accordance with MS 113

ii. **Storage tank cleaning:** in all tanks should cleaned in accordance with MS 172-1. As general guides shall be cleaned at intervals. The table below shows frequencies;

iii. **Leakage test:** this is done to prevent pollution to environment and fuel contamination. This is done to both connection pipes and tanks.

Table 3; shows frequency of cleaning storage tank

Product	Frequency
All aviation fuels	Cleaning intervals should not exceed five years
Other white products (petrol, illuminating paraffin, gas oil etc.)	As necessary- a maximum of 10 years
Black products (Diesel and fuel oil etc.)	As necessary- a maximum of 10 years
All products	When changing grade, if product quality may be affected and in the circumstances listed in this sub section.

Source; www.meramalawi.mw

The tables below are for leak detection for aboveground and underground storage tanks and as well as piping systems of the tanks which have been developed according API-653 of American standards for international accepted period and practice.

Table 4: leak Detection testing and monitoring of aboveground storage tanks

Leak detection testing and monitoring of above ground storage tanks			
Types of containment	**Commissioning test**	**In-service monitoring continuous / periodic**	**Leak suspected**
Contained open vertical tank	Visual inspection		Tank floor inspection

	during liquid fuel test	Tank floor inspection every 10years	
Contained open horizontal tank	Visual inspection		whole- visual inspection
Double walled	Visual inspection	Secondary wall containment monitoring	Secondary containment

Table 5: leak detection testing and monitoring of underground storage tanks

Leak detection testing and monitoring of underground storage tanks				
Single walled	N/A	In-service monitoring		Leak suspected
		Continuous	Periodic	
		Inventory reconciliation	Precision test at every 2years	Precision leak detection test
		Inventory reconciliation and monitoring wells	Precision leak Detection test every 5 years	
		Statistical inventory reconciliation		
Double walled	Precision leak detection test or secondary containment test	Secondary containment monitoring	10 years	Precision leak detection test or secondary containment test

Table 6: leak detection testing and monitoring of piping systems

Leak detection testing and monitoring of storage tanks piping systems			
Type of containment	**Commissioning test**	**In-service monitoring**	
		Continuous	**Periodic**
Single walled (buried / above)	N/A	Inventory reconciliation	Per 2 year (annually for mechanical connections)
		Inventory reconciliation & monitoring wells	5 years (annually for mechanical connections)
		Single check valve	
Flexible hose lines over water	Pipe leak detection test	Visual inspection. Secondary containment monitoring	Every 12 months (per year)
Double walled			None required

2.6. Types of fuel contamination and where it can occur

Malawi depots receive fuel through two routes which are road and railway (rail tanker or road tanker). The risk to the integrity of the fuel, in relation to its inherent properties and from contaminants, can occur at any point in the supply chain from the point of receiving at the point up to the final delivery point to customer, and create the potential to adversely affect fuel systems, including fuel tanks, vehicles fuel systems and engines (E.Lois, 2003)

The primary types of contamination are water, particulate and micro-biological material. Fuel contamination by water is either usually as a result of condensation of water molecules contained in the air in the fuel storages, or water infusion, in case of a reservoir that is not completely sealed. Contamination by particulate (solids) is as result of rusting in the wall of reservoir, pipeline, and transport facilities, atmospheric dust and textile fibre from clean tissues. Contamination by micro-organisms is as a result of their development overtime in storage facilities. They come from

contaminated water that comes in contact with the fuel and contaminated atmospheric dusts (Vangsness, 2012).

In addition, contamination can occur from other fuel grades and chemical that may be in multi-product transport (non-dedicated) systems. The fuel may also be rendered off-specification by either under closing/ overdosing of additives, using an incorrect additive or from product testing issues not limited to, but including poor sampling, incorrect test procedures and un-calibrated laboratory equipment (yoram zvirin, 2001).

2.7. Key Petrol, Diesel and or Jet-A fuel quality assurance elements

The two key quality assurance concepts for petroleum products: batches and traceability. A batch of fuel is a distinct quantity of either diesel or petrol / Jet-A1 that can be characterised by one set of test results. Each batch, therefore, is recognised by means of identifier which is defined according to applicable standards.

Petrol or Diesel quality assurance is based on certification at on loading at port (or even at our boarders' entry points) and procedures to verify that the quality does not change significantly and remains within the specification limits during handling and distribution (pipeline, 2022). Key documents are:

i. Certificate of analysis
ii. Recertification test certificate
iii. Release certificate

Table 7: type of certificate document and its description composition

Document	Description composition
Certificate of analysis (CoA)	-storage tank number -batch number or unique identifier -quantity of fuel in the batch -specification name and issue -properties tested including specification limit, test method and result of test

	-date of certification
Recertification test certificate	- All activities in CoA - Volume of each originating batch that comprises the new batch - Properties tested including specification limit, test method and result of test including comparison checks
Release certificate	-date and time of release - certified batch density -test report number(CoA) - quantity of fuel - visual appearance

In addition, other field test are undertaken during storage and handling process, and results recorded, to provide quality assurance as part of the operating procedures of the facility concerned, including:

i. Corrosive inspection
ii. Appearance check
iii. Microbiological testing

The test data (as recorded by above documents/ certificates) is used throughout the fuel handling system to establish conformance of the product to specifications.

Traceability, indicates the ability to track any batch of fuel in the distribution system back from port which requires certification documentation (CoA, RT certificates and RC).

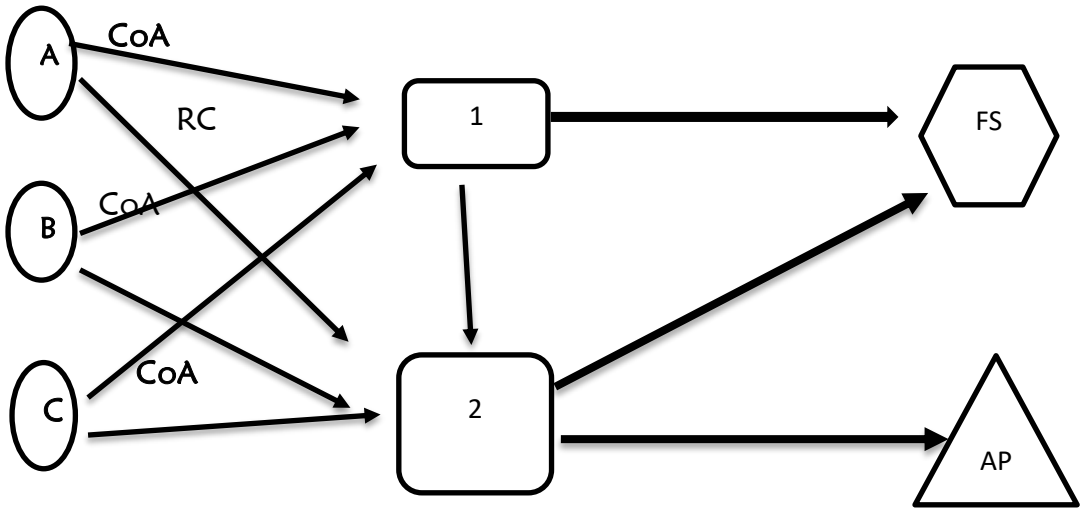


Figure 2: shows points where certificate is attained

In the scenario above is that, either depots 1 or 2 receive from fuel from point A, B and C; and or depot 2 receives fuel from depots 1; where CoA is issued (ports/ Boarders with MBS experts). From depots (NOCMA) 1 to depots 2 (PIL depots) has RT certificates; and from depot 1 and 2 need to have RC in its possession, which verify that they meet all specific requirements of particular batch.

Chapter 3: Methodology

The research done at NOCMA and some companies (PIL companies) involved in the storage, distribution and handling of oil fuels in Malawi, to be specific around Blantyre district which have over some years now, adopted to a certain degree, a total management approach. However, as concerns in most liquid fuel operations, emphasis is only made on basic traditional practices at the expense of modern MBS and international requirements- for operations as well as for the assurance of fuel products quality at delivery.

The following methodology was adopted in this study:

Table 8: methodology

Specific objectives	Activities	Methods	Tools	Justification
Evaluate depot and filling station compliances with reference from MS 113, 114, 172-1 and MS 840	Identification of the existing gaps between NOCMA & other companies' fuel quality assurance system and the MS 113, 114, 172-1 & MS 840	• Check similarity with requirements	i. Excel ii. MS 113, 114, 172-1 & MS 121 iii. Checklist	This study shall bring out the gaps between
Analysis of existing gaps	Identification, classification, analysis of the causes of existing gaps and their effects, and calculation of	• Effect analysis • Root cause analysis	i. Excel ii. Pareto diagram	This analysis provides the RPN that is then used as a ranking index for the prioritization of corrective efforts

	their risk priority numbers(RPN)			
Proposition of supportive structure for standards improvement	Elaboration of action, monitoring and follow-up plan for the implementation of corrective measures and continuous improvement	• PDCA model • Gantt • 5 WH	Microsoft project	This provides depositions for the implementation of compensating provisions and continuous improvement of the quality assurance system

During this study, a comprehensive data collection strategy was adopted. Below are the details on data types, sources and collection techniques.

3.1 Data types, sources and collection techniques

3.1.1. Secondary data

3.1.1.1. Sources

We obtained secondary data from operating procedures; QSE manual; internet researched files; MERA inspections report, MBS fuel quality assurance standard analysis report, technical document and websites.

3.1.1.2. Technique

The data were obtained by consulting the aforementioned sources.

3.1.2. Primary data

I obtained primary data from personnel (interviews), site visits (visual inspection), impregnation periods at different working post (realization of daily operations).

3.1.2.2. Technique

Interviews and discussions with the employees in their various work stations provided us with data on the realization of operational activities. This was done by means of questionnaires with closed end questions reflecting each requirement of the standard. Workers directly concerned with the requirements were presented with these questions in a comprehensive manner, and then their responses were collected and treated.

Site visits and field works were made in a bit to obtain information on the effective implementation of procedures as well as verify compliance the requirements of the MS 113, 114, 172-1 and MS 840 standard such as those related with storage tank design, filtration systems, piping and paintings etc.

3.2. Conceptual framework

The research framework was designed to be carried out in two phases as shown in Figure 3 below with a view to achieve the above stated objectives.

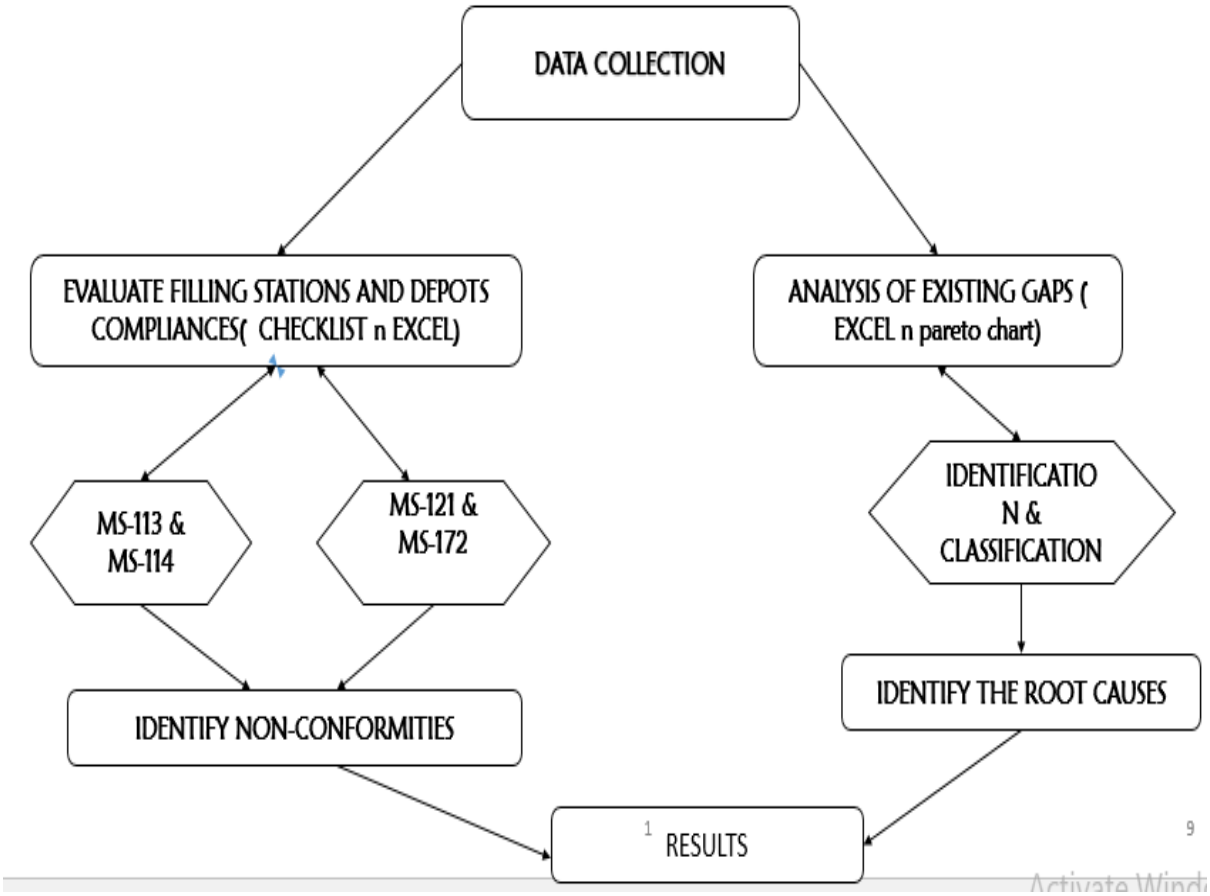


Figure 3: Research conceptual framework

3.3. Similarity/ conformance assessment

3.3.1. Identification of the existing gaps between NOCMA and PIL depots & Service stations fuel quality assurance system; and the MS 113, MS 114. MS 121 and MS 172 of Malawi standards.

To identify gaps between NOCMA liquid fuel quality assurance system and the MS 113, MS 114, MS 121, and MS 172 requirements.

MBS sets out many accepted standards requirements for quality assurance of liquid fuel in upstream depots. However, my major target is on requirements for liquid fuel transportation, storage and handling.

My assumption is that each depot and filling station are in full compliance i.e. all mandatory requirements must be met in order to claim compliance with the standards.

Therefore, Assessment questionnaire was developed and used for survey which provides questions that relate to the applicable mandatory requirements of MS 113, MS114, MS 121 and MS 172 related with operations of liquid fuel transportation, storage and handling, since the standards cover the entire supply chain of Malawi. Requirements were transformed in to closed end questions requiring a 'Yes' to indicate conformance or a 'No' to indicate non-conformance. Where requirements is not applicable an 'N/A' option was provided.

All findings were then reported in to excel fill and used for the FMEA analysis

Structural description of checklist

Table 9: The gap assessment checklist contains the following information:

Heading	Content description
Question number	Number for each question
Clause references	Provides references to the MS 113, MS 114, MS 121 & MS 172

Mandatory/ Non-mandatory indication for requirements	Gives indication on the mandatory/ non-mandatory status of the requirement
Assessment questions	Transformed requirement
Assessor's findings	Allows assessor to note findings

3.3 Analysis of existing gaps

3.3.1. Failure mode and effect analysis (FMEA)

This is a tool used to analyse different failure modes and their effects on a system. It is a step by step approach for identifying all possible failures in the process, product or services. It aims at providing actions that can be taken to eliminate or reduce failures, starting with the highest-priority ones.

"Failure modes means the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and be potential or actual. Effects analysis refers to studying the consequences of these failures. The failures are then prioritized according to how serious their consequences are, how frequently they can occur and how easily they can be detected (Mohr, 2002).

The purpose of the FMEA is to document knowledge and actions to eliminate or reduce failures, starting with the highest priority ones, for continuous improvement.

The objective was to analyse the different non-conformities to the requirements of the MS113 MS114 MS 121 and MS 172 and potential effects on the liquid fuel transportation, storage and handling activities as well as their prioritization in the order in which they should be addressed.

Chapter 4: Results and discussions

This chapter presents the results I have obtained from applying the methodology described in the previous chapter. I first present a quantitative overview of my findings and go further to present the final results of my FMEA analysis. Having the results and recommendations from the analysis, I propose the framework for improvement using the PDCA approach through an action plan, a monitoring and follow-up plan.

4.1. Compliance assessment and analysis of existing gaps

4.1.1. Identification and classification of non-conformities

The overall rate of non-conformity identified was 38.89% (7 from 33 applicable requirements). This prove that the general concept of quality assurance is not well developed and consequently not well organised. In 2018 MERE conducted compliances inspection research which was mostly focused on the filling stations site location and design in the country. And this report revealed that over 200 fuel storages site are non-compliant pertaining to Malawi standards and guidelines. But in this research, I used checklist and Questionnaire that was developed upon requirements of MS- 113, MS-114, MS-121, and MS-187 which mostly focuses specifically on liquid fuel quality assurance systems and operational guidelines. These standards contain some updates of some technical requirements of site location and also brought in more requirements on operating procedures and fuel quality management. This explains why most of the non-conformities are focused on operating procedures. 80% of the recorded non-conformities concerned with cleaning of the storage and procedures, 60% QA organisation (use of pump attendants), 40% QA traceability and receipt from releasing points among others (see figure below)

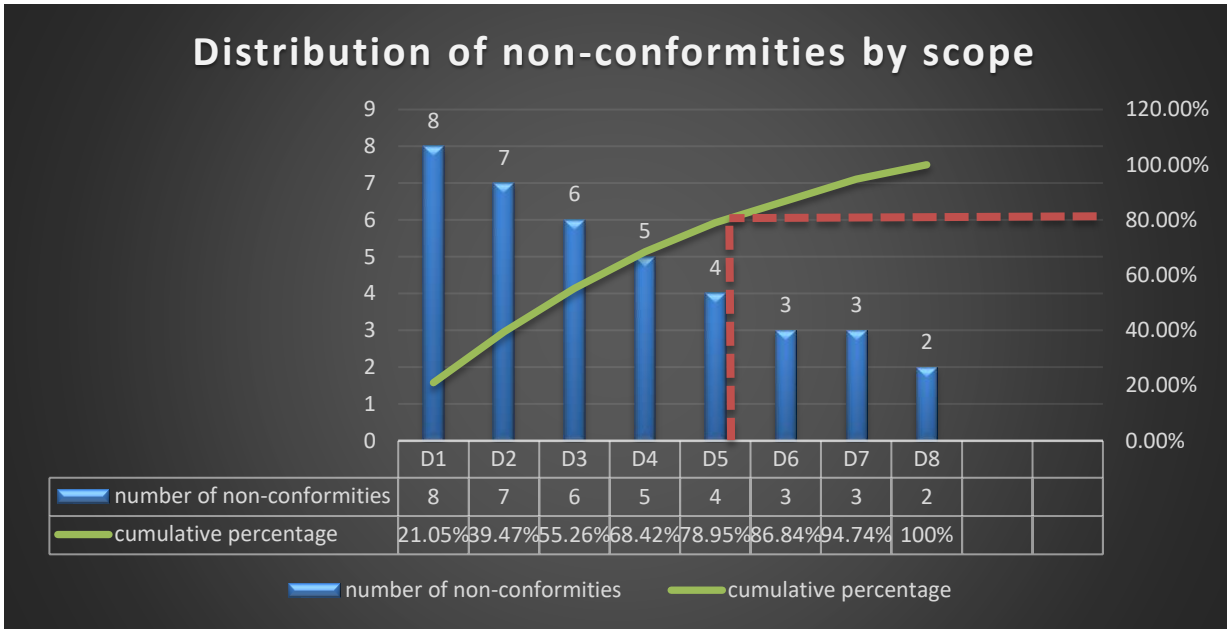


	CHART LEGEND
D1	WATER TANK, SEDIMENTS AND SAMPLING MANAGEMENT
D2	TRANSPORTATION TANKER REQUIREMENT
D3	FREQUENCY OF TANK CLEANING
D4	SAMPLING & TESTING OF FUEL
D5	QUALITY ASSURANCE TEAM
D6	TANK CORROSION INSPECTION
D7	TANK LEAK INSPECTION/DETECTION
D8	CERTIFICATION & RELEASE PROCEDURES

Figure 4: Distribution of non-conformities by scope

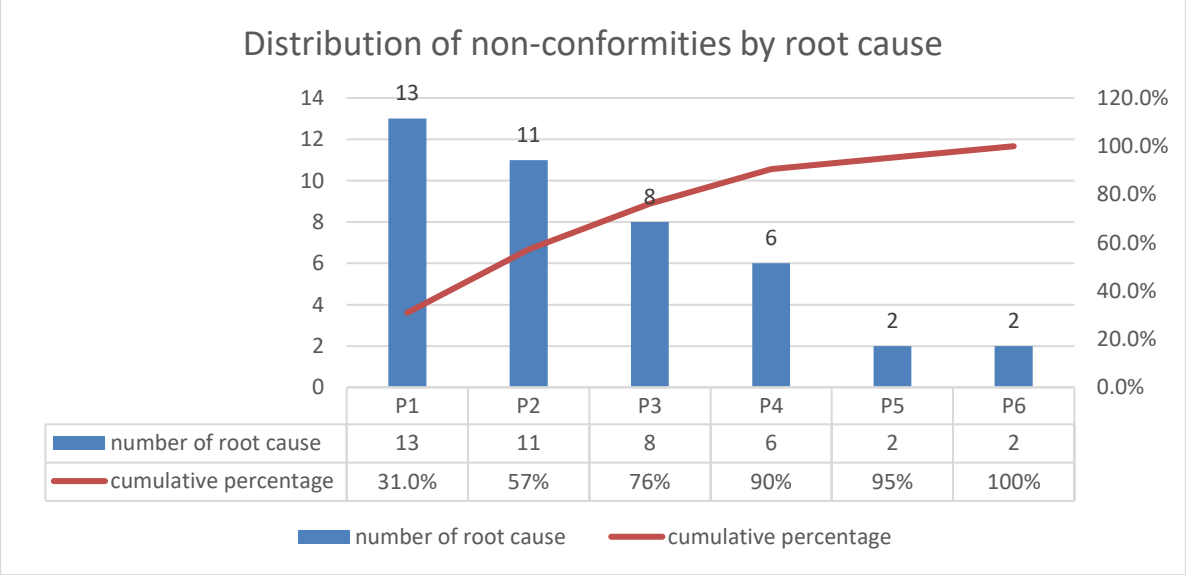
From the above figure 4, upon using FMEA analysis and Pareto principle, it was indicated that; D1, D2, D3, D4, and D5 are most commonly operational systems which cost more in the maintenance of fuel quality assurance standards and systems at the depots and filling stations.

4.1. Root cause analysis

Upon identification, I concluded an analysis on non-conformities according to the 5 whys approach for root cause analysis. These root causes were then reported on the FMEA table (see table below). I then used Pareto diagram based on Pareto principle which states that 80% of non-conformities come from 20% of the causes. This permitted me to rank frequencies of the found root causes of the observed non-conformities in decrease order of importance. The results show results show that 54% of the overall non-conformities from a poor documentation and implementation of

procedures, 14% from poor regulatory team, 10% from poor stock management, 10% from poor documentation review policy, 10% from outdated facilities design standards and 2% from material requirements follow up.

Whilst for most of these causes the FMEA table provides corrective actions, it is necessary to take special measures as concerns quality assurance regulatory team or watch at the depot. I found that the procedure on quality assurance regulatory team or watch mostly focuses on aspects related with fuel security, storage facility safety and pricing. Amongst all document sources cited in the procedure, none concerns product quality. Thus, it is necessary to include regulatory watch data sources relating to product quality requirements.



	LEGEND CHART
P1	POOR DOCUMENTATION OF PROCEDURES
P2	POOR IMPLEMENTATION PROCEDURES
P3	LACK OF FORMAL TRAINED PERSONNEL
P4	POOR QUALITY ASSURANCE TEAM
P5	OUTDATED FACILITIES DESIGN STANDARDS
P6	POOR MONITORING AND MATERIAL FOLLOW-UP

Figure 5: shows distribution of non-conformances by root cause

4.1.1. FMEA analysis

The analysis of the criticalities of the identified non-conformities was made by adopting the FMEA method and Pareto principle as analysis approach of associated risks (see table below). I acknowledged that it might not be possible to meet all the

requirements of the MS 113, MS 114, MS121 and MS 172 immediately since the design and construction of some supply chain facilities of depots and filling stations are usually built to past years and it will be essential to allow different combinations of facilities and procedures that effectively have acceptable risk levels as compromise with the requirements in standards. I then used the FMEA and Pareto principle approach to analyse these non-conformities and ranked them in order of their associated risks. I established rating scales of severity, occurrence, and detectability of the effects of non-conformities. A range of criticality was made to perform a classification of the deficiencies found and define compensating provisions to be implemented in consideration of their risk priority number (RNP). The results highlighted most critical findings with highest RPN. These are: the non-existence of a quality assurance and operations manual and personnel lack of training, non-respect of fuel storage tank cleaning periods, no quality assurance team. The non-conformities with the highest risk are to be treated as priority as their effects are most likely and costly to the liquid fuel quality maintenance.

Table 10: FMEA

Clause description	Assessment question	Findings evidence note	causes	Effects	Compensating provisions
Quality assurance organisation/ team	Are new personnel (permanent, and temporary including contractors & sub-contractors) thoroughly trained in all operation and procedures that they will be called upon to	There is no quality assurance and operations manual describing the system. Laboratory personnel and other agents lack training, though procedures exist for it. Some are working with liquid fuel but have never received	Poor implementation of documented procedures/ to management negligence	Critical activities such as routine quality operations may be overlooked. Poor handling of equipment, ignorance of industry best practice	Create a quality assurance and operation manual Training session for personnel handling liquid fuel and its installations.

	perform in the cause of their duties?	formal training on operations			
Storage design features and handling procedures- tank cleaning- evidence and risk assessment	Where tank cleaning records and inspection records are not meaningful/ well maintained are tank cleaning intervals in accordance to standards	Most tanks are yet to be cleaned, and requirements are such that it be cleaned after 6 -10 years	Poor implementation of procedures/ operational negligence	Build-up of sediment at tank bottom	Program the cleaning of tank in accordance
Sampling and testing of fuel/ transportation	Is there any additional quality assurance procedures been introduced?	the tankers that carries petrol also carries diesel	Poor regulatory watch from MERA	Risky of safety, contamination	Use one tanker vessel for one product
Filtration & fuel cleanliness differential pressure gauges	Are all differential pressure gauges tested every 6 months & and any inaccurate or defective gauge replaced	No report on effective testing/ inspection of filter elements	Poor implementation of procedures / operational negligence	Improper differential pressure leadings Contaminants can pass through easily	Maintenance check should be performed and recorded
Quality assurance organisation	When existing personnel are called upon on undertake new	Procedures exist for personnel training but training is not done formally	Poor implementation of procedures	Poor performance in the execution of duties	Organise a training session for personnel

	tasks are they trained before undertaking the new task without supervision?				handling of fuel and its installation
Laboratories training	Do staff have the education, qualifications, training, experience and or demonstrated skills required to carry out testing, calibrations	Laboratory personnel lack training, though procedures exist for it. Some are working with fuel but never received formal training on operations	Poor implementation of documented procedures. Management negligence	Poor performance in the execution of duties. poor test results	The operational directors should formerly address the need for training of laboratory personnel.

4.3. Framework for improvement

Having identified, analysed and classified non-conformities, it was necessary to come up with a program for implementation of the developed corrective actions and operations as it is one of the key objectives of this research. I have developed and prepared an action plan, a monitoring plan and follow-up plan with.

4.3.1. ACTION PLAN

I regrouped the developed solutions into elements of action plan. The participants of each activity have to receive directives from company coordinator or depot manager and provide to the best of their ability, with all relevant information and effort for successful completion of the activity. The development has been done by following PDCA model. It appears that most that critical activities are: the creation of the quality assurance and operation manual, personnel training and revision of

procedures. Any negligence to these activities will result to miserly in advocate and ensuring fuel quality during storage, distribution and at delivery point.

Table 11: action plan

activity	Description	coordinator	Participants
Creation of a quality assurance and operation manual	. creation of a working group . identification of all liquid fuel processes and associated responsibility . study of all applicable regulatory requirements . drafting .printing and despatching	. depot manager . filling station manager	MBS and MERE officials . depot / station management
Training of personnel	Train personnel on 1. Fuel properties 2. Fuel quality control operations 3. Fuel handling operations 4. Utilization of operational manual	. training institutions	All depot/service station personnel
Tank cleaning	Clean tank task	MBS and Management	Storage attendants
Material requirement planning	Create a requirement plan for suitable lab- sample materials	Warehouse operator/ procurement officer	Management (depot/station)

4.3.2. MONITORING PLAN

Implementing an action plan requirements efficient monitoring, it was therefore necessary that I define performance indicators that shall be used to track progress and efficiency of the execution of the action plan (see table below). I have defined the monitoring operations and their respective performance indicators on the table.

Table 12: monitoring plan

Activity	Steps	coordinator	operations	Performance indicators
Creation of a quality assurance and operation manual	. creation of a working group . identification of all fuel processes & associated responsibility .study all relevant applicable regulatory requirements . drafting, verification, printing and dispatching	. depot/filling station manager	1. verify that working group has all relevant duty and directives for the elaboration of the manual 2.revise, correction& printing verified manual	1. working group in place according their experience 2. completeness of available data
Training of personnel	Identification of trainee . contact training institution .training	Training services	Check the completeness and verify their effective training	1.number of successful trainees

Tank cleaning	.Contact subcontractor .Job safety analysis .clean tank .Sediment analysis	MBS or any recognised service company	1. verify subcontractor if they got all required equipment for the work	1. level of cleaning, quantity of sediments 2. completeness of cleaning sediments
Material requirements planning	i. analyse need pen in for laboratory ii. Develop yearly plan.	Procurement office / warehouse operators	1. verify the appearance of the plan, how well can it resolve the problem	Average daily, monthly and annual pen requirement

4.3.3. FOLLOW-UP PLAN

The overall performance indicator would be the number of non-conformities addressed with corrective actions, going from the most critical to the least critical. However, without follow-up, it would be difficult to tell whether the execution of the action plan was successful or not. Give the objective of full compliance, upon complete execution of the plan action and continuous improvement of the quality assurance system in the depot and filling station, I therefore, develop in the follow-up plan, management reviews and internal auditing (see table below).

Management review is a requirement of the ISO 9001: 2015 standard. It says that upon completion of a management review, an organisation shall be able to determine

opportunities for improvement, need for changes in the quality management system and requirement in resources.

Monitoring and follow-up activities aim at verifying and promptness in an activity. All non-conformities found, by checking performance indicators, from the findings of the monitoring and follow-up plans must be addressed accordingly and in due time, to avoid further deterioration of the quality assurance system and ensure improvement.

Table 13: Follow up plan

Activity	Performance indicator	Supporting documents	Data sources	coordinator	participants	frequency
Management review	Number of compensate non-conformities; number of recommendations	1. action plan; all recording of the execution of the action plan	Action plan	management	Management, QA operation team	6 months
Internal auditing	Number of non-conformities	Checklist and procedures	Personnel, Technical documents, Procedure manual	management	Reporting & statistics services QA team	Annually of each operations

CHAPTER 5. CONCLUSION & RECOMMENDATIONS

5.1 conclusion

Liquid fuel quality assurance systems are becoming more concern due to their impact on environment, engine performance. Some systems that can compromising the fuel quality are negligence in tank inspection, poor implementation procedures for sampling and testing, and lack of well trained personnel to conduct different operation at the depot or service station. It is therefore important to employ credited systems and operations to reduce fuel contamination, as so to mitigate some engine performance impacts and environmental pollution. In order to achieve this, firstly, identify and classify possible conformances of systems and of fuel at every point in liquid fuel supply chain management. This has helped to identify non-conformance, gap between Malawi Standards and reality on ground, and their root causes. This helps liquid fuel stakeholders as well as nation at large to trace and discover all available recommended standards and systems and also possible source of fuel contaminations.

This study has evaluated the quality assurance standards and systems used in fuel from target points which include NOCMA depots and PIL depot and service stations. It has also provide developed framework that can improve quality assurance systems.

The study found out that due to poor documentation of quality assurance procedures and poor monitoring programs were some of things that cost in maintenance of quality assurance standards and systems at service stations and depots.

5.2. Study limitations

The checklist and questionnaire which were adopted used as methodologies may not cover the whole required parts of quality management systems, and they only cover common systems. In order for the whole systems and adopt other methods, enough data will be required and must be available. Some of point that could be covered was economic risk of each non-conformances of recommended systems according to standards.

Other challenges were poor documentation of required data and also some officials were not expressing their more detail information that could require for the study.

The time factor was another challenge for this study. There was limited time to collect enough data for the large sample size that could cover hence a manageable sample size was used.

5.3. Study recommendations

This study only referred to as non-conformances, causes and gaps of quality assurance systems and standards used in fuel of Blantyre city service stations and depots. This is so because Blantyre is business centre, therefore a lot of non-recommended operations could be common and also is done this area because of short distance. But it seems like non-conforming operation are happening all over the nation e.g. Lilongwe, Mzuzu, Kasungu and many others. Therefore, since is national wide effects and also several non-conformances that contribute to poor quality management, but were not considered in this study, the study recommends and encourages other scholars to do a further research on the same and identify other non-conformances and trigger their root causes. Additionally, it is important that each and every depot and service station should use electrical digital fuel contaminates detector and also develop daily, monthly and annually quality assurance procedures according Malawi Standards. These will help to improve quality management systems of fuel that can to manage fuel contamination and environmental pollution due leakage hence reducing environment impacts and engine wearing.

REFERENCES

An, F., Earley, R., & Green-Weiskel, &. L. (2011). GLOBAL OVERVIEW ON FUEL EFFICIENCY AND MOTOR VEHICLE EMISSION STANDARDS: POLICY OPTIONS AND PERSPECTIVES FOR INTERNATIONAL COOPERATION. *The Innovation Center for Energy and Transportation (iCET)*.

Barabas, I., & & Todoru, :.-A. (2011). Biodiesel Quality, Standards and Properties.in G.Montero(Ed). *Biodiesel- Quality, Emissions and By-Products*.

Caldeira, E. (2017). oil and gas inspections: 5 tips for quality Assurance . *FTQ360*, 42-68.

chikuni, A. (2023). digest of Malawi Energy statistics. *Govt of Republic of Malawi*.

Das, m. (2020, january 20). perfomance and Emission characteristics of Biodiesel-Diesel Blend. *Encyclopedia of renewable and sustainable materials*, pp. 202-211.

dennis P.Nolan, i. (2011). fire and explosion protection engineering principles (2nd-ed). *physical properties of hydrocarbons*.

E.Lois, E. &. (2003). fuel contamination. *Encyclopedia of physical science and Technology: reference module in chemistry, molecular sciences and chemical engineering*, 275-314.

ED, m. R. (2001, october 8). encyclopedia of physical science and technology.

Emoshoriamhe Erua. (2015). Impact of Water Content in Hydrocarbons using Consequence Modelling. *HAZARDS* .

Fung, F. (2011, november 11). Best Practices for Fuel Quality Inspection Programmes. *Clean transportation*, pp. 4-8.

Fung, f. (2011). *Best Practices for Fuel quality inspection programs.* washington DC: international council on clean transportation.

Goto, S. M. (2010). Importance of Quality Control and Market. *Benchmarking of Biodiesel Fuel Standardization in East Asia*, 76-95.

Government, M. (2018, september 14). The Malawi Government Gazette. *national liquid fuels and Gas Emergecy plan for Liquid fuel and Gas supply Disruption*, pp. 761-782.

Gregory E. T. Gamula1, L. H. (2012). *An Overview of the Energy Sector in Malawi.* Energy and Power Engineering, 2013, 5, 8-17.

Haque, D. M. (2023). petrol Density: an in Depth understanding for Fuel Efficiency. *Lambda Geeks*.

Hartman, J. (2015, february 22). Kinematic and Dynamic Viscosity of Diesel,Biodiesel, and JP-900 Compared to Other Non-Standard Fluids with a Demonstrationof Viscosity Changes at Varying Temperatures.

Helga.G, A. R. (2012). Determination of specific gravity and kinematic viscosityof diesel using distillation curves andmultivariate calibration . *Fuel Processes Technology*.

helgaG. Aleme, P. J. (2012). determination of flashpoint and cetaneindex in diesel using distillation curves and multivariate calibration. *fuel*, 129-134.

Huitema, E. M., Schwietert, D., & Mandel, a. J. (28 october 2019). gasoline and diesil fuel, 6th. *world wide fuel chapter*.

Israel, R. (2019, october 26). the new safety standard for flash point testing of petroleum samples.

Jason Hartman. (2015, february 22). Kinematic and Dynamic Viscosity of Diesel, Biodiesel, and JP-900 Compared to Other Non-Standard Fluids with a Demonstration of Viscosity Changes at Varying Temperatures. pp. 3-6.

jennifer Lloyd, E. s. (2006). Field standard operating procedures for the PM performance evaluation program. *Quality assurance Guidance Document*.

Jones, c. (2013). viscosity measurements for petroleum products. *Analytical Instrumentation - Viscosity Spotlight*, 14-15.

King, C., & Bowen, &. C. (19 April 2023). The Fuel Efficiency Standard – Cleaner,Cheaper to Run Cars for Australia. *Department of Infrastructure, Transport, Regional Development and Communications* (pp. 10-15). Canberra ACT 2601, Austria: Commonwealth of Australia 2023.

Łukasz Macioszek, R. R. (2015, september- october 30). EVALUATION OF WATER CONTENT IN DIESEL FUEL USING IMPEDANCE SPECTROSCOPY. *XXI IMEKO World Congress "Measurement in Research and Industry*.

Ma Mercedes del Coro Fernández-Feal, L. R.-F.-F. (2017). Distillation: Basic Test in Quality Control of Automotive Fuels.

MBS. (2014). *Malawi government gazette-malawi bureau of standards--notice of declaration*, 118-119.

MBS. (2017). Malawi Bereu of Standards.

MBS. (2023, march). Malawi Bureau of Standards. *MBS Standards work programme*, pp. 23-24.

MERA. (2016). service station operation guidelines. *Malawi Energy Regulatory Authority Annual Report*.

mhone, c. (2020). suspension of operations at Lilongwe city centre Total service station. *MERA*.

Mohr, R. (2002). guidance for performing failure mode and effects analysis with performance improvement projects. *Failure Modes and Effects Analysis*.

NOCMA. (n.d.). *Malawi Oil Company of Malawi Limited.* Retrieved from nocma.mw: www.nocma.mw

pipeline, c. C. (2022, August). Quality assurance.

pouya Hosseinifar, H. S. (2021). A predictive method for constructing the distillation curve of petroleum fluids using their physical bulk properties. *petroleum sciences and engineering*.

Predesh, U. (2013). storage and handling of petroleum products at depots and Terminal. *oil industry safety directorate government of india: Ministry of petroleum and Natural Gas*, 21-62.

Quhn, d. A. (2005). manual of quality assurance for BNG Fuel solution. *BNG Fuel solutions*, 1-2.

Sickels, D. R. (2012). clean tanks and fuel mean reliable and efficient equipment. *advanced fuel services*, 6-28.

Teresa L. Alleman, L. F. (2011). Quality Parameters and Chemical Analysis for Biodiesel Produced in the United States . *National Renewable Energy Laboratory*, 3-8.

Vangsness, M. D. (2012). *Best practices for fuel system contamination detection and remediation.* the university of Dayton research institute.

Vehicles, S. (2021). *why are aluminium alloy tanker trailer the midstream of fuel tank trucks.* xiamen sunsky vehicles Co..Ltd.

w.D.Saiwa. (2017). quality control of renewable energy products-way Forward. *MERA*.

worley, c. (2019, october 29). karl fischer titration to measure biodiesel water levels.

Yilmaz, N. (2017). sustainable alternative fuel in aviation. *Energy*, 1378-1386.

yoram zvirin, M. G. (2001). Fuel effects on Emissions. *handbook of air pollution from internal combustion engines: pollutant formation and control*, 555 - 560.

Barabas, I., & Todoru, I.-A. (2011). Biodiesel Quality, Standards and Properties. In G. Montero (Ed.), *Biodiesel- Quality, Emissions and By-Products*. InTech. https://doi.org/10.5772/25370

Fung, F. (n.d.). *Best Practices for Fuel Quality Inspection Programs. 2011*.

Importance of Quality Control and Market Acceptance.pdf. (n.d.).

Petrol-and-Diesel-in-South-Africa1.pdf. (n.d.).

Serfontein, E., & Govender, K. (2020). Embedded Resilience Properties Identified in Quality Assurance and Corporate Governance in the South African Aviation Industry.