Exploring the Sources of Marine Debris and their Effects on Magogoni Ferry Operations Efficiency

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Abstract:- Marine debris poses significant challenges to the operational efficiency of the Magogoni Ferry in Dar es Salaam, Tanzania. This study investigates the sources of marine debris in the ferry's operational environment and evaluates their effects on operational efficiency. Field surveys, interviews, observations, and document reviews were conducted to identify debris sources and quantify their impacts on ferry operations. Findings indicate diverse debris origins, including urban waste, coastal littering, and shipping activities, contributing to operational disruptions through increased maintenance needs and service delays. The study underscores the importance of debris management strategies for sustaining ferry operations. It was found that a large quantity of marine debris reaching the Magogoni Ferry was brought by rivers during the rainy seasons, namely River Tegeta, River Mzinga, and River Msimbazi. Marine debris which impairs ferry operations at Magogoni Ferry includes fishing lines, fishing nets, wood, ropes, textiles, and plastic bags. The effects were seal damage, pump jet blockage, impeller entanglement, mechanical obstruction of the pump jet, and engine stoppage. These breakdowns cause navigational hazards, environmental pollution due to oil leakages, and increased costs of maintenance. It was found that between 2019 and 2023, the cost of maintenance due to breakdowns, whose sources were established to be marine debris, amounted to an average of Tsh120 million per year. to ensure the ferry channel is safe for navigation it was recommended to make it free from debris through implementing educational campaigns to raise awareness, regular cleaning, prohibiting fishing by angling near the ferry area, and the use of technology both to block the entrance of land-based waste to the sea and to improve ferry systems by making them able to withstand debris challenges, for example, the introduction of cutting blades to cut nets, ropes, and fishing lines, protecting the propulsion components.

Keywords:- *Marine Debris, Magogoni Ferry, Operational Efficiency, Debris Sources.*

I. INTRODUCTION

Ferries play a pivotal role in connecting coastal communities and facilitating trade and commerce (Tanko, 2017). However, the sustainability and efficiency of ferry operations are increasingly threatened by the pervasive issue of marine debris. Operating in an environment increasingly affected by marine debris, ferries face challenges from various sources of litter and debris. These items, ranging from plastics to derelict fishing gear, not only degrade water quality and pose navigational threats but also impact the efficiency and reliability of ferry operations. Understanding the origins and effects of marine debris is essential for developing appropriate mitigation strategies.

According to the United Nations Environment Program (UNEP, 2019), marine debris is a worldwide issue that impacts all oceans. It creates environmental, economic, health, and aesthetic challenges stemming from inadequate solid waste management, insufficient infrastructure, careless human actions, and a lack of public awareness regarding the potential effects of these behaviors. The UNEP Global Initiative on Marine Debris has established a robust framework for implementing regional efforts to tackle marine debris globally, including initiatives from the 12 Regional Seas programs (Jeftic, L., Sheavly, S., Adler, E., Meith, 2009).

Marine debris has been identified as a significant navigational hazard for vessels in the North Atlantic. The increasing number of rescues of vessels with fouled propellers is alarming. For instance, in 2008, there were 286 rescues of vessels with fouled propellers in UK waters, costing between $930,148 and $2,453,126, plus the financial implications of coastguard rescue operations. Additionally, the safety of crew members in these situations is at risk, making it a top priority (Mouat, Lopez and Bateson, 2010).

It has been estimated that from 2015 to the present, the total costs associated with marine debris affecting the marine industry in the APEC region have reached $10.8 billion. A significant portion of this impact is felt in the transport and shipping sector, which accounts for $2.95 billion (27.2%). Other affected sectors include fisheries and aquaculture, contributing $1.47 billion (13.6%), and marine tourism, which accounts for $6.41 billion (59.2%) (McIlgorm *et al.*, 2022). The substantial financial burden on transport and shipping highlights the urgent need for effective solutions to address marine debris, as it also involves the safety of people at sea.

According to Chitaka, Onianwa and Nel (2022) in their work, *The African Marine Litter Outlook*, marine debris in ocean waters, especially fishing gear, ropes, and plastic bags, poses significant risks for vessel navigation and crew safety. Evidence from other regions indicates that propellers can become entangled in discarded ropes and fishing lines, leading to vessel instability. Additionally, plastic bags can block water intakes, potentially damaging pumps, while

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collisions with debris can harm propellers, creating hazards that could result in injuries or even fatalities for personnel (Hollyfiel, 2017).

The impacts of marine debris have been noted in the Port of Durban, South Africa, especially after heavy rainfall in 2019. The incident resulted in considerable cost implications. The estimated clean-up expenses for marine debris in the Port of Durban due to storm events ranged between $3,400 and $68,400, accumulating to a total of $284,800 during that time. Marine litter can be substantial and may have enduring effects on the safety of marine vessels and the nation's economy (Chitaka, Onianwa and Nel, 2022). Due to the impact of marine debris on vessel safety at ports, crossings, and channels, deliberate efforts to solve this problem are important.

In Tanzania's Mwanza region at the Kigongo-Busisi ferry crossing, owned by the government agency TEMESA, marine debris in the form of fishing lines (angling) and nets were established as sources of ferry breakdowns. These breakdowns included damaged bevel gears (crown wheel and pinion) and damaged stern tube liners and seals, costing over Tsh 80 million in the financial year 2018/2019. This debris also caused ferry delays, extended downtimes, navigational hazards, and environmental pollution due to gearbox oil leaks into the lake (Kigongo Ferry Technical Report, 2019).

Generally, the effects of marine debris have been observed to include blockage of intake water pipes of ship systems (e.g., cooling systems), propeller fouling, increased vibrations, impeller suction blockage for jet pumps, stern tube seal damage, hull damage, speed reduction, increased fuel consumption, impaired trip schedules, and cost implications arising from damage, maintenance, and downtime. Oil leaks into the sea and navigational hazards are also of concern (Sheavly, 2005; Thompson *et al.*, 2011; Hollyfiel, 2017).

Marine debris poses a significant threat to the efficient and sustainable operations of ship propulsion systems, and the Magogoni Ferry crossing in Dar es Salaam, Tanzania, is no exception. The escalating levels of debris in the waters surrounding Magogoni Ferry have been observed to adversely impact ferry operations, including impeller propulsion seal damage, jet pump intake blockage, increased vibrations, hull damage, oil leaks, speed reduction, and mechanical obstruction of the propulsion system. These issues also contribute to environmental pollution due to oil leaks and pose navigational hazards. The cost of maintenance caused by marine debris at Magogoni Ferry amounts to Tsh 120 million per year, due to spare parts and maintenance work, not to mention the revenue lost during downtime (Magogoni Ferry Technical report,2023).

Furthermore, the heightened occurrence of breakdowns not only compromises the reliability of Magogoni Ferry but also raises concerns about passenger safety. As marine pollution exacerbates the strain on ferry engines and components, it is imperative to address the underlying causes and implement effective solutions to ensure the long-term sustainability and resilience of ferry operations(Kim, Lee and Kim, 2023).

Despite the observable challenges posed by marine debris, a comprehensive investigation into the specific impacts on Magogoni Ferry and the formulation of targeted mitigation strategies is notably lacking. Therefore, the overarching problem addressed by this research is the need to understand and address the relationship between the sources of marine debris and their detrimental effects on the mechanical and operational aspects of Magogoni Ferry. The aim of this study is to explore the sources of marine debris and their effects on Magogoni Ferry operations, providing actionable insights for sustainable ferry operations in the face of this environmental challenge.

II. LITERATURE REVIEW

A. Marine Debris

Marine debris refers to any type of manufactured or processed material that has been discarded, abandoned, or otherwise introduced into the marine environment. These are human-made objects that make their way into the ocean either intentionally or accidentally, often transported via rivers, drainage systems, sewage networks, or carried by the wind (Thompson *et al.*, 2011). Although this definition covers a broad array of materials, the majority of marine debris typically consists of a limited number of specific items. When these items reach waterways, they pose significant challenges to the operation of marine vessels.

The introduction of debris into the marine environment constitutes marine pollution. According to the International Maritime Organization, marine pollution is defined by the United Nations Environment Programme (UNEP,2019) as the introduction by humans, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in harm to living resources, hazards to human health, hindrance to marine activities (including fishing), impairment of the quality of seawater, and reduction of amenities. From this definition, the research lays its foundation on the hindrance to marine activities, specifically the impairment of ferry operations at Magogoni Ferry as a case study.

B. Sources of Marine Debris

Determining the origins of marine debris can be challenging, as trash and litter often travel long distances before eventually reaching shorelines or sinking to the ocean floor, bays, or riverbeds. Marine debris researchers typically categorize the sources of debris into two main types: land-based and ocean-based, depending on where the waste originates(Sheavly, 2005)

Marine and freshwater debris, such as plastics, ceramics, cloth, glass, metal, paper, rubber, and wood, is widespread across Africa. The large quantities of debris littering coastlines or being carried by rivers highlight its prevalence and leakage from various sources in the region. These sources can be traced back to both land-based and sea-based activities. Land-based sources include poor municipal

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solid waste management, direct littering, wastewater and sludge release, agricultural practices, industrial production, and activities in harbors or ports. Sea-based sources are primarily linked to the fishing and aquaculture industries, as well as waste dumping from ships and offshore platforms (Chitaka, Onianwa and Nel, 2022).

Understanding the specific sources of debris at Magogoni Ferry and their effects on ferry operations informs targeted interventions, ensuring that mitigation efforts are tailored to the local context.

C. Effect on Ferry Operations

Marine pollution has far-reaching operational impacts beyond the mechanical damage of parts, with increased fuel consumption being a key concern. Pollution-induced blockages in ship impellers and propulsion systems heighten resistance to the flow of water into jets, resulting in higher fuel usage to maintain propulsion (Magogoni Ferry Technical Report, 2023). Additionally, the frequency of mechanical failures tends to increase, leading to disruptions in ferry schedules and raising safety concerns for passengers.

The operational consequences of marine pollution on ferry services have been discussed by various economists and transportation specialists(Bergmann, Gutow and Klages, 2015). They highlight increased operational expenses, potential revenue loss due to delays and breakdowns, time inefficiencies, and the broader economic strain on coastal communities as critical issues associated with such disruptions.

D. Mitigation Strategies

Formulating effective mitigation strategies is imperative for sustainable ferry operations. The study aims to propose strategies that not only address the immediate impacts on Magogoni Ferry but also have broader applicability to other ferry systems. Collaborative efforts between ferry operators, environmental authorities, and the community are essential for the success of these strategies. According to Sheavly, (2007) successfully solving the problem requires a good understanding of marine pollutants and how people behave. It was added that it’s crucial for people to have the right information to make smart choices about using and disposing of waste. Educational programs, clear regulations, and enforcement by both government and private groups are the foundation for a successful plan to prevent marine pollution. The plastic industry also needs to educate its workers and customers and find ways to use technology to reduce the problem.

Research specific to coastal regions and ferry routes(Agamuthu, Mehran and Norkhairiyah, 2019) shows the need for a localized understanding of pollutants. Coastal waters, being susceptible to industrial discharges and urban waste runoff, can exhibit numerous pollutants that significantly affect ferry operations.

Building on these challenges, researchers such as Tisma, Boromisa and Cermak, (2019) and Watkins *et al.*, (2015) explore various mitigation strategies. These include preventive measures, technological innovations, and policy frameworks aimed at reducing pollution and enhancing the resilience of ferry services. Understanding these strategies is crucial for informing the development of effective interventions in the specific context of Magogoni Ferry.

Marine pollution is a complex issue with numerous contributing factors, and the role of coastal residents in the deposition of debris, such as plastics, clothes, ropes, and other waste materials, is a significant concern. Understanding the dynamics of how coastal communities contribute to marine pollution is essential for developing effective mitigation strategies (M.E. Iñiguez, J.A. Conesa, 2016).

Marine debris is a critical environmental issue affecting ferry systems worldwide. Although numerous studies (Widmer and Hennemann, 2010; Baulch and Perry, 2014) have documented the global impact of marine pollution on maritime operations, the specific sources and effects of debris on ferry operations, particularly for the Magogoni Ferry in Dar es Salaam, remain underexplored. The existing literature highlights common pollutants such as ropes, chemical contaminants, fishing nets, and plastic litter, all of which pose significant threats to operational safety and environmental health. However, there is a notable gap in understanding how these pollutants specifically affect the operational efficiency of the Magogoni Ferry, given its unique environmental and operational challenges.

Global studies have broadly addressed the issue of marine debris, but they often fail to delve into localized challenges. For instance, research by Hong, Lee and Lim, (2017) examined the navigation threats posed by marine debris to naval ships in Korean seas, but the operational environment and propulsion technology of the Magogoni Ferry differ substantially, highlighting the need for a targeted investigation. Similarly, although (Hardesty and Wilcox, 2017) developed a risk framework for maritime pollution preparedness, it primarily focused on plastic pollution and did not encompass other types of marine debris prevalent in areas like the Magogoni Ferry route.

By exploring the sources of marine debris and their operational consequences at Magogoni Ferry, this study aims to bridge the existing gap and provide specific, actionable insights for enhancing the operational efficiency of the Magogoni Ferry, while also contributing to the broader discourse on marine pollution management and safe navigation.

III. METHODOLOGY

A. Research Design

This study employed a mixed-method, case study approach integrating Failure Modes, Effects, and Criticality Analysis (FMECA) alongside qualitative and quantitative data collection methods to assess the impact of marine debris on the operational efficiency of the Magogoni Ferry.

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B. Study Area

Magogoni Ferry, operating in Dar es Salaam, Tanzania, serves as the study site. The ferry plays a critical role in connecting local communities, but its operations are increasingly disrupted by marine debris. This location is chosen due to the recurrent debris-related challenges affecting the ferry's mechanical and operational systems resulting to inconvenience to passengers due to delays, navigational hazards and cost implications of the maintenance.

C. Data Collection

➢ *Primary Data*

- *Questionnaires and Interviews*

Structured questionnaires were distributed to ferry operators, ferry divers, fishermen, passengers and residents near ferry to give their perceived sources of marine debris and operational impact on ferry operation at Magogoni. Semi-structured interviews were conducted with NEMC officers, EMESA Managerial, engineers and maintenance personnel to gather detailed information on mechanical failures caused by debris and sources of Marine debris reaching at Magogoni Ferry.

- *Direct Observation*

On-site observations are conducted to identify the types of debris encountered by the ferry and their effects on mechanical components, such as the propulsion system, the observations are supplemented by detailed analysis of ferry operational downtime and maintenance activities.

➢ *Secondary Data*

- *Maintenance and Operational Records*

Maintenance logs and operational records provide quantitative data on ferry breakdowns, repairs, and maintenance costs. Historical data were analyzed to assess trends in debris-related failures and their financial impact.

D. Failure Modes, Effects and Criticality Analysis (FMECA)

➢ *Application of FMECA*

FMECA was employed to identify potential failure modes in the ferry's mechanical systems that result from marine debris. The following steps were taken,

➢ *Identification of Failure Modes.*

Through observation, interviews, and maintenance records, failure modes related to marine debris (e.g., propulsion system blockage, impeller entanglement, mechanical obstruction) were identified.

- *Effects Analysis*

The operational consequences of each failure mode were established, including impacts on propulsion, maneuverability, and downtime.

- *Criticality Assessment*

A criticality analysis was performed to rank each failure mode by its severity, frequency, and detectability. Failure modes are prioritized based on their impact on operational efficiency and safety.

- *FMECA Tools*

A FMECA worksheet is used to document the failure modes, their causes, effects, and criticality rankings. This analysis allows for the identification of high-risk components that require immediate attention and informs the development of mitigation strategies. In this study FMECA have been used to show the effects of marine debris on the ferry systems as each failure mode has marine debris as established source.

To scale severity the following table were used.

Table 1: Severity Scale of Marine Debris

Severity Level	Impact on Operation	Safety Concerns	Environmental Impact	Repair/Cost Implication	Severity Category
1 (Low)	Little to no impact on operation.	No safety concerns.	No environmental damage.	Minor repair, negligible time or cost impact.	Low Severity
2 (Low)	Minor disruption, but system can continue functioning.	Minor safety issues that can be managed easily.	Minimal environmental impact, no lasting damage.	Quick repair, low cost, can be handled by one person.	Low Severity
3 (Low)	Slight reduction in performance or efficiency.	Very minor safety concerns, easily resolved.	Negligible environmental consequences.	Minor repairs with slight cost/time increase, often handled by one person or a small team.	Low Severity
4 (Moderate)	Noticeable impact, reduced system performance.	Moderate safety concerns that require attention.	Some environmental impact but manageable.	Moderate repair costs, requires more than one person, takes time but doesn't halt operations.	Moderate Severity

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5 (Moderate)	Partial operation failure, but system is still functional.	Safety concerns could arise if unresolved.	Minor pollution or environmental effects.	Repair takes more than 2 hours, moderate costs, needs multiple personnel.	Moderate Severity
6 (Moderate)	Significant reduction in efficiency, delays in operation.	Safety concerns need immediate attention but manageable.	Moderate environmental impact, can be controlled.	Repair requires major effort or significant cost, but system not at risk of total failure.	Moderate Severity
7 (High)	Significant operational disruption, partial failure.	Serious safety risks that need urgent attention.	Risk of major environmental impact.	Extensive repairs needed, high costs, requires a larger team and major downtime.	High Severity
8 (High)	System operation severely disrupted, likely partial failure.	High risk to personnel safety or operational hazards.	Significant environmental damage if unresolved.	Major repairs, high time/cost, likely requires outside help and takes system out of service temporarily.	High Severity
9 (High)	Near-total system failure, severe operational breakdown.	Major safety risks to personnel and passengers.	Serious environmental damage possible.	Extensive, time-consuming repair, major downtime, requires multiple experts to resolve.	High Severity
10 (Catastrophic)	Total system failure, complete operational shutdown.	Loss of life or severe safety risk to personnel.	Catastrophic environmental damage (e.g., pollution).	Repair is extremely costly, requires immediate intervention	Catastrophic

Table 2: Ranking Criteria for Scale Detection

Detection Rating	Detectability	Description
1 - 2	Extremely High Detectability	Failure is very easy to detect, usually with automated systems that provide instant alerts.
3 - 4	High Detectability	Failure is detectable but might require some manual intervention or has a slight delay in detection.
5 - 6	Moderate Detectability	Detection is reliable but often occurs during periodic checks or with systems that are not continuously monitored.
7 - 8	Low Detectability	Failure is hard to detect before it causes significant issues; relies on manual inspections or occasional monitoring.
9 - 10	Very Low/Impossible to Detect	Failure is almost impossible to detect before it results in failure. No effective early detection methods are in place.

Example, detection of seal damage due to fishing line is 10 while engine stoppage is 2.

E. Frequency of Occurrence

Frequency of occurrence were determined from a Technical reports together with established source of breakdown caused by marine debris.

F. Data Analysis

In the examination of gathered data from participants, this research employed excel and Use Failure Mode, Effect and Criticality analysis .These tools processed and analysed the collected information, ensuring the derivation of quick insights for the study. The application of excel, specifically utilizing descriptive statistics like frequency tables, serves to minimize errors, enhance data integrity, and diminish data redundancy, as outlined by (Sileyew, 2019).

IV. RESULTS

A. Debris Sources

Coastal littering emerged as a primary source of marine debris along the Magogoni Ferry route, contributing plastic bottles, bags, and packaging materials to coastal waters. Shipping activities also contributed to debris accumulation, with derelict fishing gear and ship-generated waste posing navigation hazards and operational challenges.it was established that ocean based debris from marine activities makes 40% of the total forms of debris found at magogoni ferry.

It was revealed that during the rainy season, land-based waste is carried by rivers near the Magogoni Ferry and finds its way into the ferry area during high tides. The rivers contributing to marine debris at the Magogoni Ferry include the Tegeta River, Msimbazi River, and Mzinga River. Land-based waste accounts for about 60% of the total marine debris found at the Magogoni Ferry.

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Although plastic bottles were relatively abundant in the ferry area, they were shown to have no significant impact on ferry operations.

The study found that some local fishermen are fishing with fishing lines (angling) near the ferry lamps, where there are rocks. The fishing lines often snap and remain on the water's surface before being sucked into the jet pumps, causing damage to the seal impeller.

It was also observed that some plastic bags used to carry ice to the fish markets were floating in the ferry channel, suggesting poor waste management practices at the nearby fish market.

Insignificant debris, such as leaves from ocean plants and mangroves from the coast, was also present but do not pose a threat to operations because they are sucked and discharged by the pump jets without affecting any part. They also does not block the cooling water flow in cooling systems as they pass through.

The table below shows popularity index of debris at Magogoni ferry as it was revealed by the study,

Table of availability of debris, sorted from highest to lowest popularity,This popularity is the probability that one will find a certain type of pollutant at magogoni ferry.

Table 3: Shows Availability of Particular Debris at Magogoni Ferry

Rank	**Debris Type**	**Availability**
1	Plastic Bottles	100%
2	Fishing Nets	79%
3	Fishing lines	73%
4	Ropes	70%
5	Logs and wood chunks	56%
6	Plastic bags	41%
7	textiles	33%
8	Sean plants leaves and mangroove	26%
9	Woven baskets	2%

Fig 1: Shows Availability of Particular Debris at Magogoni Ferry
Source: Field Study (2024)

Table 4: Shows Availability of Particular Debris at Magogoni Ferry

Source(originating) of pollutants		**Number of respondents**	**percentage**
Marine activities	Shipping	4	33.7%
	fishing	20	
	Ferries	7	
Urban waste		55	59.8%
Other	Mangrove swamps Sea leaves	6	6.5%
	TOTAL		**100%**

B. *Effects on Ferry Operations Efficiency*

Increased debris presence was associated with heightened operational challenges for the Magogoni Ferry. Instances of propeller fouling and hull damage were observed to increase with rising debris levels, necessitating frequent maintenance interventions and operational adjustments to maintain service reliability. Service delays due to safety concerns and passenger inconvenience were reported during periods of peak debris influx.


Fig 2: Left is the Impeller with Damaged Seal, Right is Propeller Caught Fishing Lines

Table 5: Shows Occurrence of Failure Showing Caused Debris

SN	FAILURE	ESTABLISHED CAUSE	YEAR	OCCURANCE	AVERAGE
1	ENGINE STOPPAGE	FISHINGN NET	2019	10	
			2020	8	
			2021	6	
			2022	9	
			2023	7	8
2	MECHANICAL OBSTRUCTION	LOGS AND WOOD	2019	5	
			2020	8	
			2021	6	
			2022	5	
			2023	6	6
3	IMPELLER ENTAGLEMENT	ROPES	2019	5	
			2020	7	
			2021	4	
			2022	5	
			2023	4	5
5	SEAL DAMAGE	FISHING LINES	2019	6	
			2020	9	
			2021	4	
			2022	7	
			2023	4	6

Source: Magogoni Ferry Technical Reports

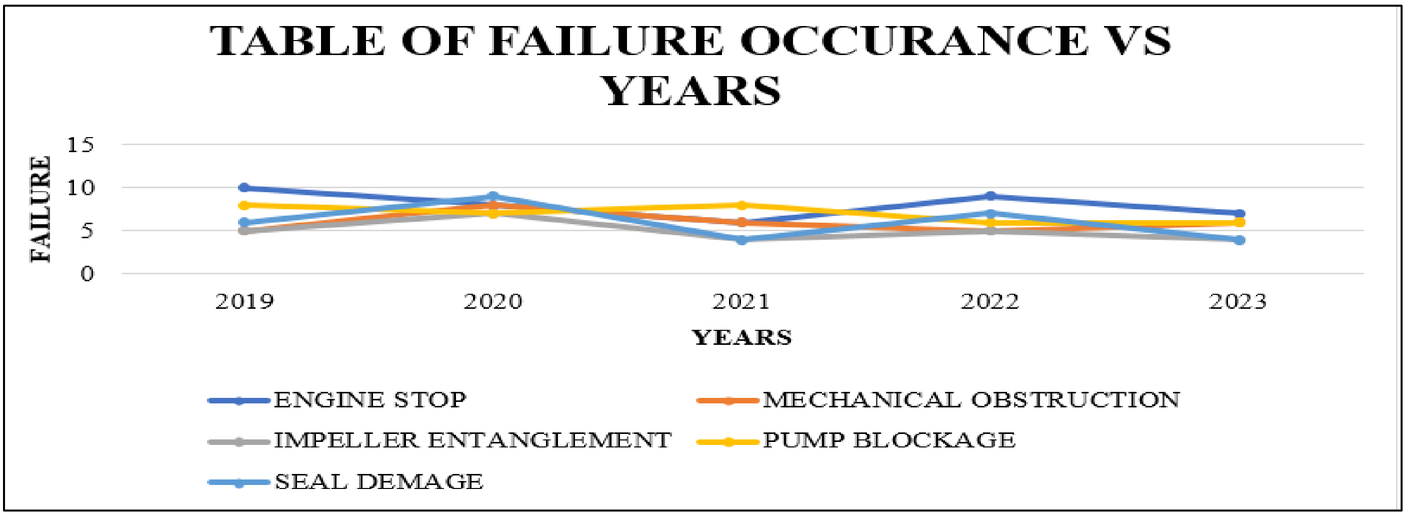

Fig 3: Shows Graph of Failure Occurance Against Years
Source: Field Study (2024)

Table 6: FMECA Table for Magogoni Ferry Analysis Shows Severity, Occurrence and Detection of a Failures Caused by Marine Debris at Magogoni Ferry

Sn	Failure	Severity	Occurance	Detection
1	ENGINE STOPPAGE	9	8	2
2	MECHANICAL OBSTRUCTION	7	6	5
3	IMPELLER ENTANGLEMENT	8	5	4
4	PUMP BLOCKAGE	6	7	7
5	SEAL DAMAGE	9	6	10

Table 7: Indicating Failure mode, effect, Severity, Causes, Occurrence, Detection, RPN and Mitigation Strategy

Failure Mode	**Effect**	**Severity (S)**	**Cause**	**Occurrence (O)**	**Detection (D)**	**RPN**	**Mitigation Strategy**
Engine Stoppage	Downtime, Safety Hazard	9	Fishing Nets	8	3	216	Regular net removal, improved detection
Mechanical Obstruction	Delays	7	Logs and Wood	6	5	210	Physical barriers, frequent clearing
Impeller Entanglement	Maintenance, Downtime	8	Ropes	5	4	160	Regular inspections, preventive measures
Pump Blockage	Reduced Speed, Increased Fuel	6	Plastic Bags	7	4	168	Public awareness, regular cleaning
Seal Damage	Component Failure, Downtime	9	Fishing Lines	6	5	270	Protective guards, regular inspections

By using FMECA the following was found Highest RPNs indicate critical areas requiring immediate attention. These are seal damage due to fishing lines has the highest RPN (270), suggesting it is a major concern, followed by fishing nets RPN (216) and logs RPN (210)

Mitigation Strategies are developed based on the priority of failure modes. For high RPN failure modes, strategies such as regular inspections, physical barriers, and public awareness campaigns are recommended.

Continuous Monitoring and periodic FMECA reviews ensure that new failure modes are identified and mitigation strategies are updated accordingly.

V. DISCUSSION

The study found that sources of marine debris affecting Magogoni Ferry operations are both land-based and ocean-based debris. The results indicate coastal littering is the predominant contributor of marine debris along the ferry route, with plastic bottles, bags, and packaging materials identified as the most common item. However the study shows debris with most detrimental effect to the ferry operations are sea based debris in form of abandoned or lost fishing gears. This aligns with the study done by (Hong, Lee and Lim, 2017) in North Korea it was noted that Marine pollutants can cause navigational hazards to ships at sea due to entangled propellers.

Interestingly, the study found that while land-based waste accounts for about 60% of the debris found at the Magogoni Ferry, it was established that plastic bottles, despite their abundance, do not impact ferry operations. This finding contrasts with research by (Arabi, Neehaul and Sparks, 2022) which emphasized that some plastic items can cause severe operational disruptions for vessels by blocking intake valves . In the case of the Magogoni Ferry, the specific characteristics of ferry such as the type of vessels and their propulsion designs, may mitigate the operational risks associated with these debris types.

The seasonal variability observed in the composition of marine debris, particularly during the rainy season when land-based waste is washed into the ferry area via rivers such as the Tegeta, Msimbazi, and Mzinga, is another critical aspect of this study. The study's observation that heavy rains can exacerbate debris accumulation aligns with research by (Chitaka, Onianwa and Nel, 2022) which found that increased rainfall significantly elevates the levels of runoff litter entering coastal waters. Such patterns indicate the necessity for integrated river basin management strategies to address pollution sources upstream, particularly in the context of urbanization and increased rainfall due to climate change.

Moreover, the study revealed poor waste management practices at nearby fish markets, evidenced by the presence of plastic bags in the ferry channel used for transporting ice to and from the fish markets. This issue mirrors findings from (Athuman *et al.*, 2023) who reported that there is inadequate waste disposal practices and hygiene in fish market with suggest poor waste management system . Addressing these local practices through community education and better waste management systems could be pivotal in reducing the quantity of debris entering the marine environment.

In particular, fishing lines were found to be the most critical pollutant, as evidenced by their highest Risk Priority Number (RPN) of 270 in the Failure Mode, Effects, and Criticality Analysis (FMECA) detailed in Table 6. This high RPN indicates a critical area requiring immediate attention. The presence of fishing lines in the waterway causes

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significant operational issues, including damage to seals, which in turn leads to component failure. This failure results in prolonged downtime and substantial cost implications, as it necessitates the replacement of seals, oil changes, and the hiring of cranes. FMECA indicated that other debris which have effects on ferry operation are logs, wood chunks, ropes, fishing net, plastic bags and textiles. The extended downtime required to address these issues directly impacts customer satisfaction, as ferry operations are delayed or halted. This highlights the critical need for targeted interventions to manage and mitigate the impact of fishing lines and other high-risk pollutants to ensure efficient and safety of ferries hence customer satisfaction.

VI. CONCLUSION

This study contributes to the growing body of literature on marine debris by providing specific insights into the unique sources and implications of debris along the Magogoni Ferry route. The findings emphasize the need for collaborative efforts in waste management, regulatory enforcement, and community engagement to mitigate the impacts of both land-based and ocean-based debris on ferry operations. Additionally, the research underscores the importance of seasonal monitoring and proactive measures to address debris accumulation, ultimately informing better practices for sustainable maritime operations

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