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6M Fishbone Analysis of Implementation Challenges for MARPOL Convention Annex I

(A Case Study of MT. Rosa XVIII)

Sitti Ma'rifah Nisrina [1*], Andi Ningrat [2], Arifin H Abd Majid [3], Nur Amalianty [4], Muhammad Aris Kastian [5]

[1] Ship Operation Engineering Technology Department, Politeknik Maritim AMI Makassar, Indonesia
[2] Sea Transportation Department, Politeknik Maritim AMI Makassar, Indonesia
[3] Marketing, Innovation, and Technology Department, Politeknik Maritim AMI Makassar, Indonesia
[4] Maritime Logistics Business Department, Politeknik Maritim AMI Makassar, Indonesia
[5] Ship Machinery Engineering Technology Department, Politeknik Maritim AMI Makassar, Indonesia
Email : miiharui@gmail.com[1], autadaaning@gmail.com[2], arifin.pitpolimarim@gmail.com[3], amelianty26@gmail.com[4], mkastiani11@gmail.com[5]

**Corresponding Author: miiharui@gmail.com*

Abstract. Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL) regulates the prevention of oil pollution from vessels and constitutes a mandatory requirement for the operations of oil tankers such as the MT. Rosa XVIII (3,694 Gross Tonnage, PT. Mammiri Line). However, the implementation of these regulations often encounters various technical and operational obstacles in the field. This study aims to identify and analyze the factors causing compliance issues regarding MARPOL Annex I on board the MT. Rosa XVIII, utilizing a cause-and-effect analysis—specifically the "Fishbone Diagram" based on the 6M framework (Man, Machine, Method, Material, Measurement, and Milieu). A descriptive-qualitative research method was employed, involving observations, crew interviews, and a review of vessel specifications and operational records. The analysis reveals that the primary obstacles stem from limited crew competence (Man), maintenance issues with oil separation equipment (Machine, such as the Oily Water Separator), inadequacies in standard operating procedures (Method), errors in filling out the Oil Record Book (Material), inaccuracies in waste level measuring instruments (Measurement), and environmental and operational weather conditions (Milieu). This study offers strategic recommendations to enhance the effectiveness of safety management and marine pollution prevention within the shipping company.

Keywords: Fishbone 6M; MARPOL Annex I; MT. Rosa XVIII; Oil Pollution; Ship Safety Management.

1. INTRODUCTION

The global and national commercial shipping industries play a crucial role in the energy supply chain; however, this sector also poses a high risk of marine environmental pollution. Oil tankers—such as the MT. Rosa XVIII, operated by PT. Mammiri Line with a cargo capacity of 5,677.604 m^3—have significant potential to generate oil waste from cargo residues, tank cleaning operations, and the engine room, which is powered by a Hansin Diesel LH46LA main engine (3309 kW). To minimize this ecological impact, international regulations—specifically MARPOL 73/78 Annex I—are strictly enforced. This convention mandates that vessels adhere to operational standards for oil waste discharge, possess oil-water separation equipment certified by classification societies such as the Indonesian Classification Bureau, and maintain proper vessel documentation. Nevertheless, in actual shipboard practice, the implementation of MARPOL Annex I rules often encounters various operational, administrative, and technical

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obstacles. An analytical approach is required to systematically identify the root causes of these issues. One effective quality management tool for mapping root causes is the Fishbone (Ishikawa) Diagram, utilizing the 6M approach (Man, Machine, Method, Material, Measurement, Milieu). This study aims to conduct an in-depth analysis of the factors hindering the implementation of MARPOL Annex I, focusing specifically on the operational case study of the MT. Rosa XVIII.

2. RESEARCH METHODS

This study employs a qualitative descriptive approach through a case study focused on the operations of the vessel MT. Rosa XVIII (Indonesian flag, port of registry Jakarta, Call Sign YDMF3). A qualitative approach was selected to provide a comprehensive overview of actual conditions onboard regarding compliance with maritime environmental regulations. Data collection was conducted via: In-depth interviews with ship officers (Chief Engineer, First Officer) and engine room crew regarding technical challenges in handling oil waste; field observations to directly examine the functioning of pollution-prevention machinery (such as the Oily Water Separator/OWS and engine room piping systems); and a review of ship documentation, including the MT. Rosa XVIII Ship's Particulars, the International Oil Pollution Prevention (IOPP) Certificate, and the Oil Record Book (ORB). Data analysis involved data reduction, data presentation, and mapping using a 6M Fishbone diagram to identify the root cause of the problem.

3. RESULTS AND DISCUSSIONS

Based on field observations regarding MT. Rosa XVIII, the challenges in implementing MARPOL Annex I are categorized into six main elements of the Fishbone diagram, as follows:

Man (Human Resources)

The human factor ("Man") is the most dynamic yet crucial element in the maritime operational chain. Regardless of how advanced the machinery technology or how comprehensive the safety equipment installed on board may be, the effectiveness of marine pollution prevention ultimately relies heavily on the competence, discipline, and awareness of the crew operating the systems. Evaluations conducted on board (such as in the MT. Rosa XVIII case study) indicate that the human factor is often the root cause, manifesting in various operational obstacles:

Lack of Specific Training & Competency Gap

Regulatory Dynamics: International environmental regulations under MARPOL Annex I undergo continuous amendments, demanding increasingly stringent technical standards—particularly regarding oily waste management and the operation of Oil-Water Separators (OWS), which must meet a 15 ppm threshold and be equipped with an automatic stopping device.

Field Realities: In practice, crew members often face gaps in up-to-date technical knowledge. Their understanding is sometimes limited to conventional routines, lacking adequate refresher training on the operating mechanisms of modern sensors or the calibration procedures for waste monitoring equipment. Consequently, engineers or officers on watch are prone to misinterpreting procedures when encountering technical issues in the engine room.

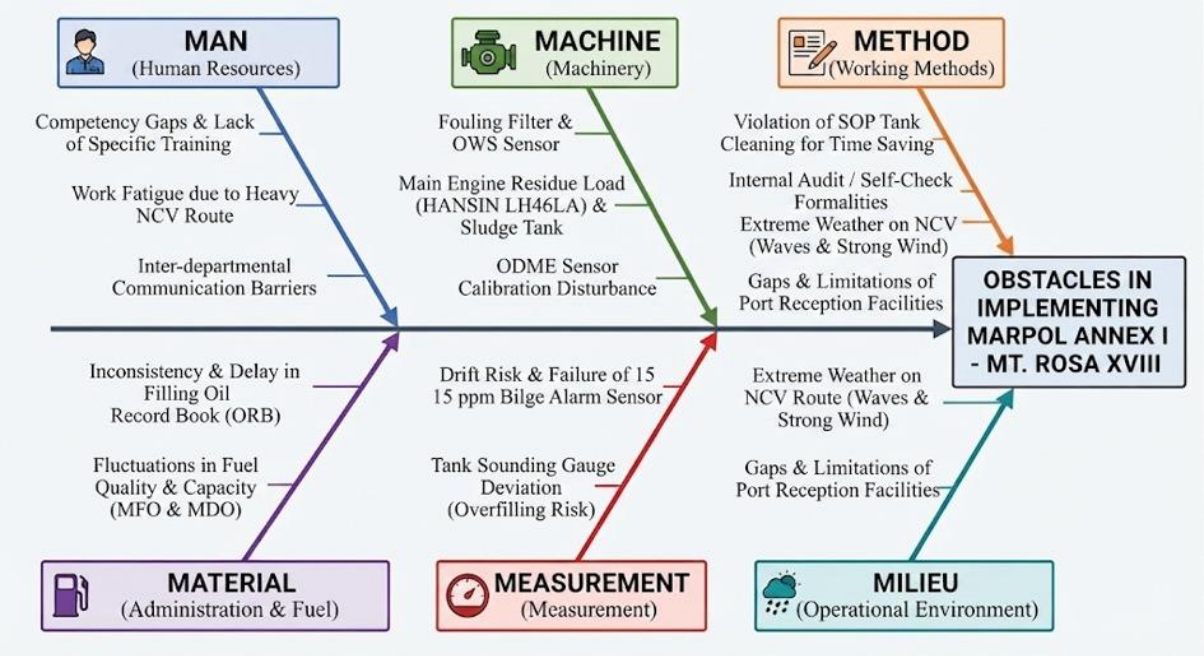


Figure 1. Diagram of 6M Fishbone Analysis of Implementation Challenges for MARPOL Convention Annex I: A Case Study of MT. Rosa XVIII.

Fatigue and High Workload

Route and Schedule Demands: The nature of Near Coastal Voyages (NCV)—often involving short routes and frequent port calls—imposes a very intense work rhythm on the crew. The rigorous cargo loading and unloading cycle significantly reduces the crew's rest time.

Impact on Oversight: This excessive physical and mental workload leads to chronic fatigue. Under these conditions, the crew's levels of alertness, attention to detail, and responsiveness decline drastically. Routine monitoring of critical parameters—such as checking OWS filters for sludge accumulation, monitoring holding tank capacities, and

ensuring timely administrative record-keeping—is often rushed or even neglected, thereby increasing the likelihood of human error.

Ineffective Inter-Departmental Communication

Operational Silos: Shipboard pollution prevention operations require solid synergy between the deck department and the engine department. The deck department bears full responsibility for ballast water handling and cargo management, while the engine department manages liquid waste generated by machinery.

Potential for Procedural Conflict: Obstacles arise when inter-departmental coordination is ineffective or information silos exist. For instance, a failure by the deck department to inform the engine department of the cargo tank cleaning schedule can result in insufficient capacity in the slop or sludge tanks. Poor coordination during daily safety briefings (toolbox meetings) is often a primary factor delaying preventive actions against potential water pollution.

Machine

Compliance with international environmental regulations—specifically MARPOL Annex I regarding the prevention of oil pollution—relies heavily on the operational reliability of shipboard machinery systems. On the MT. Rosa XVIII, several significant technical challenges frequently impact the effectiveness of liquid waste and oil residue management; these are detailed below:

Operational Constraints of the Oily Water Separator (OWS)

The Oily Water Separator is a vital component for processing engine room bilge water to ensure it meets safe discharge limits before being released into the sea.

1. Filter and Sensor Fouling: Filter elements and monitoring sensors are highly susceptible to fouling or scale buildup caused by oil sludge deposits.
2. Reduced Efficiency: This condition leads to a drastic drop in the unit's operational efficiency, significantly increasing the risk of failing to meet the discharge standard of less than 15 ppm.

Residue Load from Main and Auxiliary Engines

Powered by a Hansin Diesel LH46LA (220 RPM) engine, the MT. Rosa XVIII operates at high intensity, generating substantial amounts of combustion residues and waste lubricants.

1. Sludge Tank Capacity: This massive waste generation necessitates a containment system (sludge tank) with adequate capacity.
2. Mechanical Obstructions: Mechanical blockages in pipelines or sludge transfer pumps disrupt the waste management process and potentially create environmental issues on board.

Limitations of the Automated Monitoring System

The Oil Discharge Monitoring Equipment (ODME) automatically records and controls the discharge of waste into the water.

Calibration Issues: ODME sensors frequently experience calibration problems while the vessel is at sea, caused by engine vibrations or exposure to heavy residues.

Compliance Impact: Sensor inaccuracies can trigger safety alarms or force the crew to delay discharge procedures that are legally compliant under maritime law.

Method (Work Methods and Procedures)

Shipboard operations rely heavily on adherence to applicable Standard Operating Procedures (SOPs) to ensure navigational safety and prevent environmental pollution[9]. However, in practice, critical gaps are often overlooked in the interest of time efficiency, directly impacting legal and operational risks.

Violations of Cargo Tank Cleaning Procedures

Capacity and Risk: The cleaning process for cargo tanks with a total capacity of 5,677.604 m^3 demands high precision.

Bypassing SOPs for Time Efficiency: Pressure regarding schedules and port-stay efficiency targets often prompts crew members to skip crucial steps in the SOPs for tank washing and the discharge of wash water.

MARPOL Risks: If wash water is discharged without undergoing required separation procedures or meeting permissible concentration standards, the risk of violating the MARPOL (Marine Pollution) international convention increases significantly; this can lead to severe fines or even vessel detention.

Ineffectiveness of Periodic Internal Audits

Checklist Formalities: Self-inspection procedures—intended to serve as the final line of defense before the vessel undergoes annual audits or inspections by the Indonesian Classification Bureau (BKI)—are often treated merely as administrative formalities.

Field Findings: This superficial approach allows equipment malfunctions, incomplete safety documentation, or potential non-conformities to go undetected, thereby jeopardizing the vessel's seaworthiness status during official inspections.

Materials (Validity of Operational Record-Keeping and Fuel Quality Control)

The material aspect plays a crucial role in supporting vessel operational reliability and compliance with international maritime regulations[10]. In practice, this aspect focuses not only on the physical specifications of the fluids and fuels used but also on administrative traceability through accurate and transparent documentation.

Optimization and Compliance in Oil Record Book (ORB) Entries

Accuracy and discipline in maintaining the Oil Record Book—covering both ORB Part I (Machinery Space Operations) for the engine room and ORB Part II (Cargo/Ballast Operations) for cargo areas—serve as a primary defense against marine pollution[11]. In practice, administrative discrepancies often arise, such as:

1. Documentation Delays: Recording critical activities—such as bilge water discharge, sludge transfer from purifiers to sludge tanks, or tank washing procedures—is frequently delayed beyond reasonable operational timeframes, creating a risk of data inconsistency.
2. Operational Time Discrepancies: Time differences often exist between actual records in the automation/bell log and the times entered in the ORB. Such inconsistencies frequently result in major findings during Port State Control (PSC) inspections or ISM Code audits, potentially leading to vessel detention.

Fuel Quality and Capacity Management (MFO & MDO)

Comprehensive fuel management requires strict monitoring of the physicochemical characteristics of Marine Fuel Oil (MFO) and Marine Diesel Oil (MDO) stored onboard[12]. With MFO and MDO tank capacities of 227.94 m^3 and 55.34 m^3 respectively, variations in fuel quality received from bunker suppliers directly impact the engine's thermal and mechanical performance:

1. Impact on Engine Component Wear: Fluctuations in MFO quality—such as high levels of residues, sulfur, or catalytic fines—accelerate wear rates on high-precision components like fuel injection pumps, injector nozzles, and cylinder liner walls.
2. Sludge Deposit Accumulation: Incomplete combustion and poor fuel stability correlate directly with an increased volume of sludge accumulating within the purification system. This not only necessitates more frequent purging and separator cleaning but also drives up sludge disposal costs at ports of call.

Measurement (Measurement and Validation of Waste Parameters Onboard)

In modern maritime operations, measurement plays a pivotal role in ensuring compliance with international environmental regulations, particularly regarding the prevention of marine pollution caused by oil waste (MARPOL Annex I)[13]. The precision of measuring instruments not only guarantees operational efficiency but also averts the risk of severe legal sanctions for shipping companies.

1. **The Criticality of Oil Content Sensor Accuracy in Oily Water Separators (OWS)**

   The 15-ppm bilge alarm sensor within the OWS system serves as the first line of defense in validating the quality of effluent water before it is permitted to be discharged into the open sea.

   a. Risiko Risk of Detection Failure: If the sensor experiences drift or inaccuracy, the system may fail to detect oil content exceeding the legal threshold (15 ppm), potentially triggering severe marine ecosystem pollution.
   b. Impact of False Alarms: Conversely, excessive sensitivity caused by an uncalibrated sensor can trigger persistent false alarms, disrupt smooth engine operations and cause unnecessary interruptions to the dewatering process.
   c. Technical Mitigation: Periodic functional testing and laboratory calibration are mandatory to ensure sensor responsiveness remains aligned with international oil opacity standards.

2. **The Importance of Calibrating Measuring Instruments for Cargo and Sludge Tanks**

   Onboard liquid waste management relies heavily on the accuracy of volume data regarding contents stored in sludge tanks, bilge tanks, and other residue tanks.

   a. Reading Deviations: Sounding instruments—whether manual (using sounding tapes) or automatic (radar or ultrasonic sensor-based)—that have not been recalibrated are prone to producing volume reading errors.
   b. Risk of Overfilling: Errors in estimating actual tank capacity can lead to the danger of overflows or waste spills onto the ship's deck or into surrounding waters during transfer operations.
   c. Administrative Compliance (Oil Record Book): Discrepancies between actual tank data and official entries in the Oil Record Book (ORB) frequently result in major findings during Port State Control (PSC) inspections, leading to vessel detention.

Milieu (Ship Waste Management Operational Environment)

In shipping operations, the milieu—or external environment—plays a crucial role that lies beyond the direct control of the ship's crew[14]. External factors, such as natural dynamics and port authority policies, often create unique complexities, particularly regarding compliance with procedures for the discharge and management of liquid waste (such as oil sludge)[15]. Key obstacles that frequently present operational dilemmas include:

1. Extreme Weather Dynamics in NCV Operational Areas: Shipping routes designated as Near Coastal Voyage (NCV) possess distinct geographical and hydrographic characteristics. When vessels must transfer waste to onshore port reception facilities, adverse weather conditions—such as strong winds, high waves, and swift currents—often arise suddenly. These conditions make the process of connecting transfer hoses highly risky, potentially triggering oil spills into the sea and forcing the crew to postpone operations for the sake of navigational safety.
2. Infrastructure Gaps and Limited Port Facilities: Not all ports of call—particularly smaller ports or those in remote areas along NCV routes—possess adequate reception facilities. Some ports lack the infrastructure capable of handling large volumes of oil sludge or providing rapid handling standards. Consequently, master's Ioften face a complex operational dilemma: on one hand, they must comply with strict environmental regulations (such as the MARPOL Convention), while on the other, they are confronted with a lack of adequate onshore support facilities.

4. CONCLUSION

An in-depth analysis using the 6M Fishbone diagram regarding the operations of PT. Mammiri Line's vessel, MT. Rosa XVIII, reveals that the implementation of MARPOL Annex I faces complex, interconnected challenges spanning both internal and external aspects. Primary obstacles stem from human factors ("Man"), specifically gaps in technical competence, fatigue resulting from the demanding pace of Near Coastal Voyages (NCV), and poor inter-departmental communication. Regarding machinery ("Machine") and measurement ("Measurement"), issues such as OWS filter fouling, 15 ppm sensor calibration malfunctions, and fluctuations in fuel quality (MFO and MDO) exacerbate residue accumulation and the risk of technical failure. Aspects concerning methods ("Method") and administrative materials ("Material") also reveal shortcomings, including the bypassing of tank-cleaning SOPs to save time and inconsistent Oil Record Book (ORB) entries—practices that risk triggering legal sanctions or vessel detention. Furthermore, external environmental factors ("Milieu")—such as extreme weather along NCV routes and limited port reception facilities at ports of call—present distinct operational dilemmas for the master. Consequently, strong synergy—achieved through enhanced crew training, regular preventive machinery maintenance, administrative diligence, and adequate port facilities—is essential to ensure effective marine pollution prevention and the continuity of sustainable shipping operations.

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