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Article

Efforts to Reduce Cargo Residue After Tank Cleaning Last Cargo Palm Stearin to Next Cargo Palm Olein in MT Loading Tank. TIRTASARI

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A B S T R A C T

On chemical tanker ships, in addition to having strict safety regulations, the cargo is varied, sometimes with 2 or 3 different cargoes to be loaded. This requires the cargo tanks to be cleaned before loading the next cargo; however, there are often still cargo residues that can affect the quality of the cargo and cause failure during cargo tank inspections. This study aims to reduce the cargo residues that remain in the cargo tanks by observing several possible causes of the residues. This research uses descriptive qualitative research methods to address the problems occurring on the ship and employs data collection techniques including observation, interviews, and documentation, conducted while the researcher carried out sea practice on the MT Tirtasari ship for 12 months and 5 days, from October 5, 2023, to October 10, 2024.

1. Introduction

Indonesia's strategic geographical position on the equator, flanked by two oceans and two continents, provides great potential in supporting the world's maritime axis. In this sector, tankers play a vital role as a fleet specially constructed to transport flammable liquid cargoes, chemicals, and LNG. To meet logistics needs and comply with strict safety regulations, maintenance procedures such as tank cleaning have become crucial. This activity is defined as the process of cleaning residual cargo, hydrocarbon vapors, and hazardous gases to ensure that the tank is safe for inspection and ready to receive the next load.

The cleaning process requires technical collaboration between the deck crew and the engine crew, particularly in providing hot sea water through the boiler. If this procedure is not optimal, it results in cargo residues—classified as residual material from separation or purification processes requiring specific handling. According to environmental regulations, residue disposal must not be carried out directly into the sea but must be supervised by the Chief Officer using the Oil Discharge Monitoring (ODM) system in accordance with MARPOL Annex regulations. If residue remains, re-cleaning activities become absolutely necessary to ensure the cleanliness of the cargo area.

This research is driven by empirical problems observed on the MT Tirtasari ship (Voyage 14/24). Specifically, there was an incident of contamination of the RBD Palm Olein cargo due to residues remaining in tanks 1W to 5W. This contamination was verified through laboratory tests and resulted in the issuance of official documents such as a Letter of Protest and a Letter of Discrepancy. Based on these operational failures, this study aims to identify concrete efforts to minimize cargo residue until the tank is ready to load, as well as to analyze various operational obstacles that hinder the effectiveness of tank cleaning procedures in the field.

2. Literature Riview

2.1 Cargo Residue

Cargo residue refers to the leftover material remaining in holds, on decks, or within cargo tanks following unloading operations or tank cleaning. According to Chapter 12 of TSFS 2010:96, such residue—excluding minor dust—must be delivered to port reception facilities, regardless of its consistency (wet or dry). To manage this waste onboard, vessels typically utilize slop tanks. MARPOL Annex I, Chapter 4, Regulation 29.2.3 mandates that slop tank capacity must be at least 3% of the vessel's carrying capacity, although this requirement may be reduced to 2% if the ship is equipped with Segregated Ballast Tanks.

In the specific case of the MT Tirtasari, which lacks a dedicated slop tank, cargo tanks 5P/S have been designated for this purpose. This configuration requires a subsequent de-sloping process to transfer the collected residue to a barge. To ensure environmental compliance during discharge, MARPOL 73/78 Annex I requires tankers exceeding 150 GT to utilize an Oil Discharge Monitoring (ODM) system. On the MT Tirtasari, the Chief Officer operates this system to ensure that residue is discharged only when the vessel is en route (maintaining a minimum speed of 12 knots), located more than 50 nautical miles from the nearest land, and outside of special areas. Furthermore, the discharge is strictly regulated to ensure the effluent oil content does not exceed 15 ppm and the instantaneous rate remains below 30 liters per nautical mile.

2.2 Tank Cleaning

Tank cleaning is a critical operation designed to eliminate impurities and cargo residues adhering to tank walls or settling on the bottom that cannot be removed by cargo pumps (Widodo, B.W., Hartono, H., & Syam, A. 2016). The successful execution of this process relies on field operational personnel to ensure the smooth continuity of loading and unloading activities (Pasyah, A. C., & Afriliana, D. 2019). Ultimately, this procedure is vital for preparing the vessel to pass Cargo Tank Inspections, which verify the sterility and fitness of the tanks; failure to pass these inspections triggers investigations and exposes the shipowner or company to potential financial claims from the charterer.

2.3 Palm Stearin

Palm Stearin is a white, solid product derived from palm oil fractionation, utilized extensively in the production of margarine, soap, candles, and oleochemicals. Unlike liquid oils, Palm Stearin possesses physical characteristics that cause it to solidify—resembling butter—

when not heated, which creates significant challenges during tank cleaning operations. This high melting point means that any residue left in pipelines or tanks will harden rapidly, potentially contaminating subsequent cargoes if not completely removed. Consequently, maintaining the cargo in a liquid state via steam heating systems is critical; failure to strictly adhere to the temperature parameters outlined in the Material Safety Data Sheet (MSDS) can result in the cargo freezing, rendering it dischargeable and leading to substantial financial claims.

2.4 Palm Olein

Palm Olein is a yellow liquid product derived from palm oil fractionation, primarily utilized in cooking oils, commercial food preparation, and the oleochemical industry. Physically, it differs significantly from Palm Stearin; it possesses a lower melting point and lower viscosity, allowing it to remain in a more liquid state under standard conditions. Despite its natural liquidity, the cargo requires strict adherence to specific temperature parameters outlined in the Material Safety Data Sheet (MSDS) to ensure pumpability and prevent quality degradation. The Chief Officer must strictly monitor these reference temperatures throughout the voyage, as significant discrepancies between loading and discharge temperatures can result in financial claims against the shipping company..

2.5 Cargo Tank

According to Dwi Sandi (2010), a tank is defined as industrial equipment designed to contain organic or inorganic liquids, water, or gases. On the MT Tirtasari, the cargo tanks are constructed using stainless steel. While this material is primarily selected to prevent structural corrosion caused by acidic chemical cargoes and to ensure the cargo remains free from rust contamination, residue adherence remains a significant operational challenge. The mechanism of adherence in these tanks is driven by the physical interaction between the cargo and the metal surface; specifically, high-melting-point cargoes like Palm Stearin tend to solidify and mechanically bond to the tank walls and bottoms when the steel temperature drops. Consequently, despite the smooth surface of the stainless steel lining, the complete removal of these adhered residues requires a combination of thermal conditioning and mechanical washing to break the physical bond between the solidified cargo and the tank structur.

2.6 Chemical Tanker

A chemical tanker is a vessel specifically constructed or adapted to transport bulk liquid products listed in Chapter 17 of the International Bulk Chemical (IBC) Code, a definition that aligns with the Minister of Transportation Regulation on Merchant Marine Manning Chapter 1 Article 1 Paragraph 40. To handle the specific nature of these cargoes, the vessel's tanks are typically coated with stainless steel during construction. This specialized coating serves the critical purpose of protecting the tank structure from the corrosive effects often associated with chemical cargoes.

3. Research Methodology

This study employs a qualitative descriptive method aimed at exploring field realities to provide concrete solutions to the problem of cargo residue on ships. This design was selected because the phenomenon of cargo residue is a complex operational issue involving human behavior, technical procedures, and mechanical performance that cannot be fully explained through statistical quantification alone. By using a case study approach, the researcher investigates the specific "how" and "why" behind the procedural deviations and equipment failures observed during the tank cleaning process.

The research was conducted over a period of 12 months and 10 days, commencing from September 30, 2023, to October 10, 2024. The locus of the study was the MT Tirtasari, a vessel owned by PT Berlian Laju Tanker Tbk (BLT) where the specific incidents of residue contamination occurred.

To ensure comprehensive data acquisition, this study utilizes both primary and secondary data sources. Primary data was obtained directly from the incident site , while secondary data was derived from supporting documents such as the Oil Record Book Part II and Tank Cleaning Logs. The data collection techniques include:

The researcher conducted in-depth observations of residue-causing factors while serving as an active deck crew member. To minimize **observer bias** inherent in this role, the researcher strictly separated subjective personal experiences from objective data. Observations were cross-referenced against standardized checklists and the *Dr. Verwey's Tank Cleaning Guide* to ensure that recorded deviations were factual rather than interpretive.

Interviews were conducted with key operational personnel, specifically the Chief Officer and the Bosun. This format allowed for probing into the reasoning behind procedural non-compliance.

Technical documents, including the Tank Cleaning Plan and daily work logs, were collected to corroborate the interview statements.

To ensure the trustworthiness of the qualitative data, this study applies the principle of Triangulation of Sources. The validity of interview data was tested by comparing the statements of the crew (regarding flushing duration and chemical usage) with the physical evidence recorded in the Tank Cleaning Record and the actual conditions found in the tanks. Furthermore, a Member Checking process was utilized, where the researcher re-confirmed findings with the respondents to ensure that the interpreted data accurately reflected their operational realities, thereby enhancing the reliability of the descriptive analysis.

The collected data is analyzed using a Fishbone Diagram (Cause-and-Effect Diagram) approach. This method utilizes the 5M+1E framework (Machine, Method, Man, Material, Measurement, Environment).

This analytical tool is specifically chosen for its suitability in engineering management studies. Unlike linear analysis, the Fishbone Diagram allows for a systemic decomposition of the problem, acknowledging that the failure of tank cleaning is not caused by a single variable but by the interaction between human error (Man), procedural deviation (Method), equipment degradation (Machine), and chemical unavailability (Material). This structured approach enables the researcher to identify the root cause comprehensively and formulate targeted technical solutions.

4. Results and Discussion

4.1 Identification of Operational Deviations

Field observations combined with document verification (Tank Cleaning Plan vs. Record) revealed critical discrepancies between the planned engineering standards and the actual execution on the MT Tirtasari. While the *Dr. Verwey's Tank Cleaning Guide* serves as the mandatory reference, the investigation identified three primary deviations: duration of flushing, water temperature, and chemical selection.

Figure 1. Tank Cleaning Plan

Data from the observation indicates that the hot seawater rinsing process was terminated after only 45 minutes, significantly short of the mandated 90-minute duration. Furthermore, the water temperature recorded at the heater outlet fluctuated between 60-65°C, failing to reach the operational requirement of 70°C necessary for palm stearin removal. Additionally, logistical constraints forced a substitution of the required *Caustic Potash* with *Multipol*, a chemical additive not specified for this particular cargo transition. These deviations were not isolated incidents but were systemic, confirmed by interviews with the Bosun and Chief Officer as deliberate measures for time efficiency and inventory management.

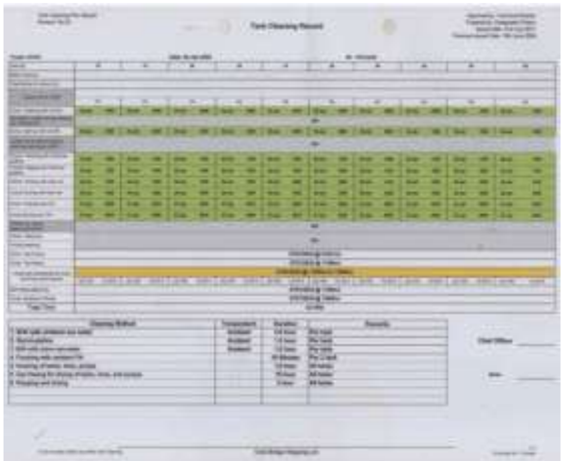

Figure 2. Tank Cleaning Record

Figure 3. Cargo Residue on Loading Tanks

4.2 Engineering Cause-Effect Analysis of Residue Formation

This section analyzes the technical mechanisms by which the identified operational deviations directly resulted in the failure of the tank cleaning process and the subsequent contamination of the cargo tanks (5S, 4P, and 3P).

1. **Thermal Deficiency and Viscosity Management**
   The reduction of rinsing time to 45 minutes and the failure to maintain water temperature at 70°C created a thermal deficiency within the cargo tanks. Palm Stearin is a high-melting-point fraction that relies on sustained heat transfer to reduce its viscosity and maintain flowability.

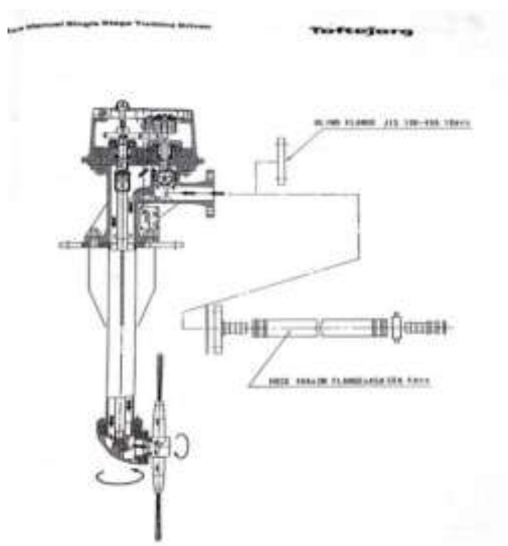

Figure 4. *Butterworth tank cleaning machine*

   Mechanism of Failure: The "Butterworth" cleaning mechanism relies on the combination of thermal energy (to melt the residue) and kinetic energy (impact of water). By rinsing at only 60-65°C for a shortened duration, the tank walls did not achieve the necessary thermal inertia to keep the stearin in a liquid phase. Consequently, the residue rapidly cooled and re-solidified on the stainless steel plating before it could be stripped by the stripping pump. The shortened duration meant the total heat energy transferred to the tank structure was insufficient to overcome the high melting point of the stearin layers.

2. **Chemical Incompatibility and Saponification Failure**
   The substitution of Caustic Potash with Multipol represents a critical chemical engineering failure.
   Mechanism of Failure: Caustic Potash (Potassium Hydroxide) is a strong alkaline agent specifically required for Palm Stearin because it induces saponification—a chemical reaction that converts fats (triglycerides) into soap and glycerol, which are water-soluble and easily flushed. Multipol, used as a substitute due to stock unavailability, failed to trigger this saponification process effectively at the dosage used. Without the chemical breakdown of the fatty acids, the stearin residue remained hydrophobic (water-repelling) and adhered to the tank bulkheads despite the mechanical spraying, directly leading to the residue spots found during inspection.

3. **Mechanical Impact and Coverage Efficiency**
   The effectiveness of the cleaning media was further compromised by mechanical inconsistencies. The study found that pre-operational inspections of the Butterworth machines were neglected.
   Mechanism of Failure: The Butterworth machine is designed to rotate on two axes to ensure 360-degree impact coverage. Observations indicated intermittent rotation failures. From an engineering perspective, when a machine stalls or fails to rotate, specific sectors of the tank (shadow sectors) receive zero impact energy. In these shadow zones, the residue is neither mechanically dislodged nor thermally treated, leaving

thick layers of solidified cargo that require manual "mopping" to remove.

4.3 Environmental and Human Factors

Beyond the technical parameters, environmental conditions exerted a destabilizing effect on the fluid dynamics within the tanks. Significant rolling caused by adverse weather disrupted the "stripping" efficiency. The sloshing effect caused the residue-laden wash water to re-coat the lower tank walls instead of being efficiently suctioned by the cargo pumpII regulations.

This technical failure was exacerbated by the human element (Man). The "6 on 6 off" watch system contributed to cumulative fatigue, which directly correlated with the decision to bypass the 90-minute rinsing standard. This confirms that the root cause of the residue was not merely equipment failure, but a socio-technical breakdown where fatigue led to the intentional violation of engineering protocols.

4.4 Discussion

The correlation between the procedural deviations and the resulting residue is physically and chemically consistent. The incident on Voyage 14/24 demonstrates that tank cleaning for high-viscosity cargoes like Palm Stearin cannot rely on partial compliance. The "High R^2" equivalent in this qualitative context is the strong triangulation between the low temperature/short duration (Cause) and the solidified residue (Effect). The failure was a cumulative result of insufficient thermal energy to melt the cargo, ineffective chemical reaction to dissolve fats, and mechanical gaps in spray coverage. To prevent recurrence, strict adherence to the Dr. Verwey thermodynamics parameters (Time and Temperature) and the restoration of proper chemical logistics supply chains are non-negotiable engineering requirements.

Table 1. Procedure Comparison

Yes	Procedure according to Dr. Verwey's tank cleaning guide	Procedures carried out on the MT Tirtasari ship
1	Rinse with hot sea water for 90 minutes	Rinsing is only done for 45 minutes
2	The use of chemical caustic potash as many as 2 jerry cans in each loading tank	Using chemical multipol as many as 3 jerry cans in each loading tank
3	Check every before and after tank cleaning the tank cleaning machine	Rarely checking and often cleaning tanks without checking machinery
4	The hot water temperature temperature should be 70 degrees Celsius to remove residue	Ship heaters are only capable of producing temperatures of around 60-65 degrees Celsius

5. Conclusion

This study successfully achieved its objective of identifying the root causes of cargo residue persistence during the transition from Palm Stearin to Palm Olein on the MT Tirtasari. The analysis confirms that the contamination was not an isolated incident but the direct result of systemic procedural deviations from the Dr. Verwey’s Tank Cleaning Guide. Specifically, the study concludes that the formation of residue was driven by a **thermal deficiency** caused by halving the rinsing duration to 45 minutes and failing to maintain the required 70°C water temperature. Furthermore, the investigation verified that **chemical incompatibility**—the substitution of Caustic Potash with Multipol due to logistical stockouts—failed to trigger the necessary saponification process required to dissolve high-melting-point stearin fats. These technical failures were compounded by human factors, specifically fatigue from the "6 on 6 off" watch system, which led to the neglect of mechanical inspections.

The broader engineering implication of this study is that tank cleaning for high-viscosity cargoes cannot rely solely on mechanical effort; it requires strict adherence to thermodynamic and chemical parameters. The findings demonstrate that substituting specific alkaline agents with generic cleaners is scientifically ineffective against solidified fats, regardless of the crew's physical effort. However, this study is limited by its design as a single-case qualitative study on an aging vessel, meaning the findings are heavily influenced by the specific ship's equipment condition and crew culture.

To extend the value of these findings, future research should move beyond descriptive analysis toward quantitative studies. Researchers are encouraged to investigate the statistical correlation between water impact pressure (bar) and residue thickness, or to explore the implementation of automated monitoring systems (IoT) that can control valve timing and temperature, thereby minimizing the human error and fatigue factors identified in this research.

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