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RESEARCH ARTICLE

Environmental and safe optimization of crude oil washing on crude oil tankers

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Abstract

Crude oil is one of the most harmful substances for the environment because of its components. Pollution can be divided in two categories: sea pollution and air pollution. For that reason, discharging of crude oil and its products into the sea should be minimized by means of crude oil washing operation optimization not to destroy the environment. During the transportation of crude oil, the most difficult problem encountered is discharging of crude oil. There are some threats, advantages, disadvantages and opportunities during vessel's crude oil washing operation to discharge its entire crude oil cargo. Under the light of this study, safety measures and auxiliary equipments was investigated to optimize the safe crude oil washing operation. Threats and consequences which are expected after or at the time of crude oil washing and as well as its advantages and disadvantages were analyzed. In this study, vessels at different conditions were compared to each other according to simulations and we aimed to enlighten the crude oil transportation which takes an important position in maritime sector. Under all these safety precautions, human and environmental safety requirements which need to be taken priority were investigated in detail at the time of optimization period.

Key words: Crude oil washing, optimization, tanker safety, pollution prevention.

Introduction

Many people were interested in crude oil historically and they faced the problems of its transportation since old days. They solved these problems in accordance with the terms and possibilities of those days. Due to increase of petroleum product usage and spreading all over the world, tankers became a solution for transportation of petroleum and its products from where they were produced to application areas.

At the early times of oil cargo transportation, cargo contaminations or cargo residues were directly pumped to sea. It was understood that the crude oil and its products were extremely harmful to environment (Fernanda *et al.* 2012).

In addition to all these developments in the late 1960's, "environment" became the most important concept and this affected the design and construction of tankers. SBT (Segregated Ballast Tanks) application started to spread all over the world. These tanks have been used until today in different parts of tankers. United States of America issued "Oil Pollution Act of 1990" (OPA '90) by U.S. Congress in 1990 because of the vessel named Exxon Valdez aground in Alaska which caused an environmental disaster. As one of the innovations of this act, tankers need to be built in compliance with a double hull model.

Also ODME (Oil Discharging Monitoring Equipment) system has been a mandatory equipment in order to control discharging oil into the sea.

Special sea areas were created to limit discharging of crude oil into the sea. These areas were selected according to the sensitiveness of designated areas for oil pollution. They are all indicated in MARPOL and serious charges are made at the time of violation of these rules (Ismail and Karim 2012).

Crude Oil Washing (COW) operation is the most critical and the most important point of crude oil discharge operation to prevent the environment pollution.

Materials and Methods

The literature review was performed and international & national sources about the subject were investigated. Various crude oil washing types were identified.

At the first stage, crude oil washing operation was described by explaining the structural features which are necessary for safe operation. Then, different operation scenarios were performed by changing variables at simulator program to obtain the optimization.

Transas Liquid Cargo Handling Simulator which was programmed in accordance with IMO 2.06-Cargo and Ballast Handling Simulator, IMO 1.01-Oil Tanker Familiarization, STCW-95, MARPOL 73/78 and other international requirements containing cargo discharge pumps, line system, eductor system and stripping system was used to determine the optimization criteria. The prototype vessel is a modern designed tanker of 240 m in length, 60000 dwt, 32 m in breath.

Sludge Problem

Almost all crude oil contains relatively heavy components containing sticky and asphaltic materials (see Figure 1 for petroleum products). These components go down in the cargo tank during the voyage and a significant amount of sludge occurs on the horizontal and vertical tank structures. This formation is called sludge (Havold 2010).

Hydrogen Sulphite Problem

If there is sour crude oil or sour product in the cargo tank, the cargo may produce hydrogen sulphite which is very harmful for environment.

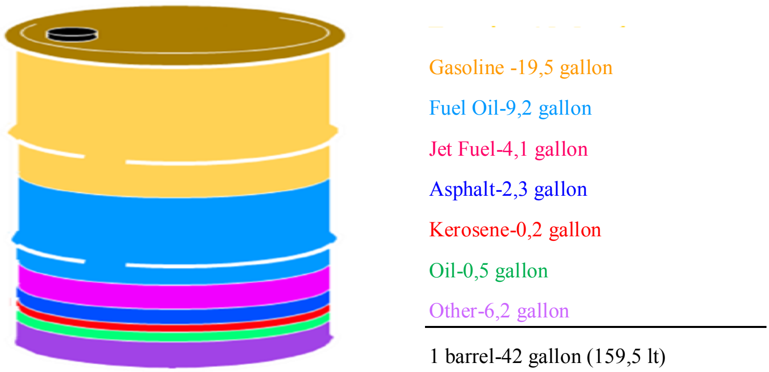

Figure 1. Crude oil products

Static Electricity

Many petroleum types have the ability to accumulate static electricity charges and discharge it in the form of spark. These charges can ignite hydrocarbon gas and air mixture if there is enough energy (Bhatia and Dinwoodie 2004).

Operation Processing Order

The first step is straining the water inside crude oil by means of spooling method to perform the washing operation with pure crude oil. After sailing from the port of loading to the port of discharge, free water will go down to the bottom of the cargo tank due to the density difference during transit period (Arslan and Er 2008) (Figure 5 for flow diagram of COW).

If a single grade cargo is carried discharging should be arranged in accordance with ensuring the ship's trim and inclination as previously planned (for types of COW operation Figure 2).

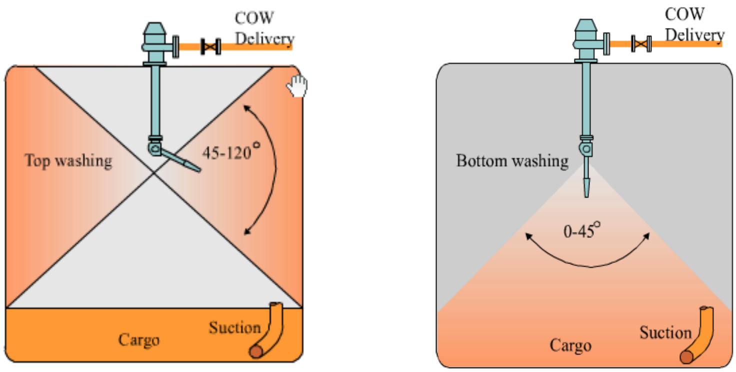

Figure 2. Top and bottom washing

Inherent viscosity of crude oil usually causes a sediment layer on the cargo tank walls causing the accumulation on the tank bottom and tank walls. This situation increases freight loss (please see Figure 3 for fault tree of non-pumpable cargo).

Requirements for Operation Optimization

1. Tank washing operations should be adhered to a schedule planned with the utmost care (please see Figure 4 for fault tree of tank explosion).
2. The communication between cargo control room, engine room and deck should be effective and in a rapid way. Third person should not be used for communications as much as possible (SOLAS 2009).
3. All valves should be arranged without turning off the cargo pump to be able to pump the cargo from one slop tank to the other one in order to gain time.
4. A seaman should be ready to turn on the branch valves for COW gun on deck in order to gain time while the pump man is arranging the valves in the pump room.
5. Cargo pump speed should be increased until it reaches the sufficient pressure (COW Systems 2000).
6. When the washing machine cycle is completed, the branch valve should be closed and dipping value is obtained.
7. At the meantime, vacuum pump should be operated for each cargo tank receiver in order to discharge the remaining cargo (Verwey 1992).

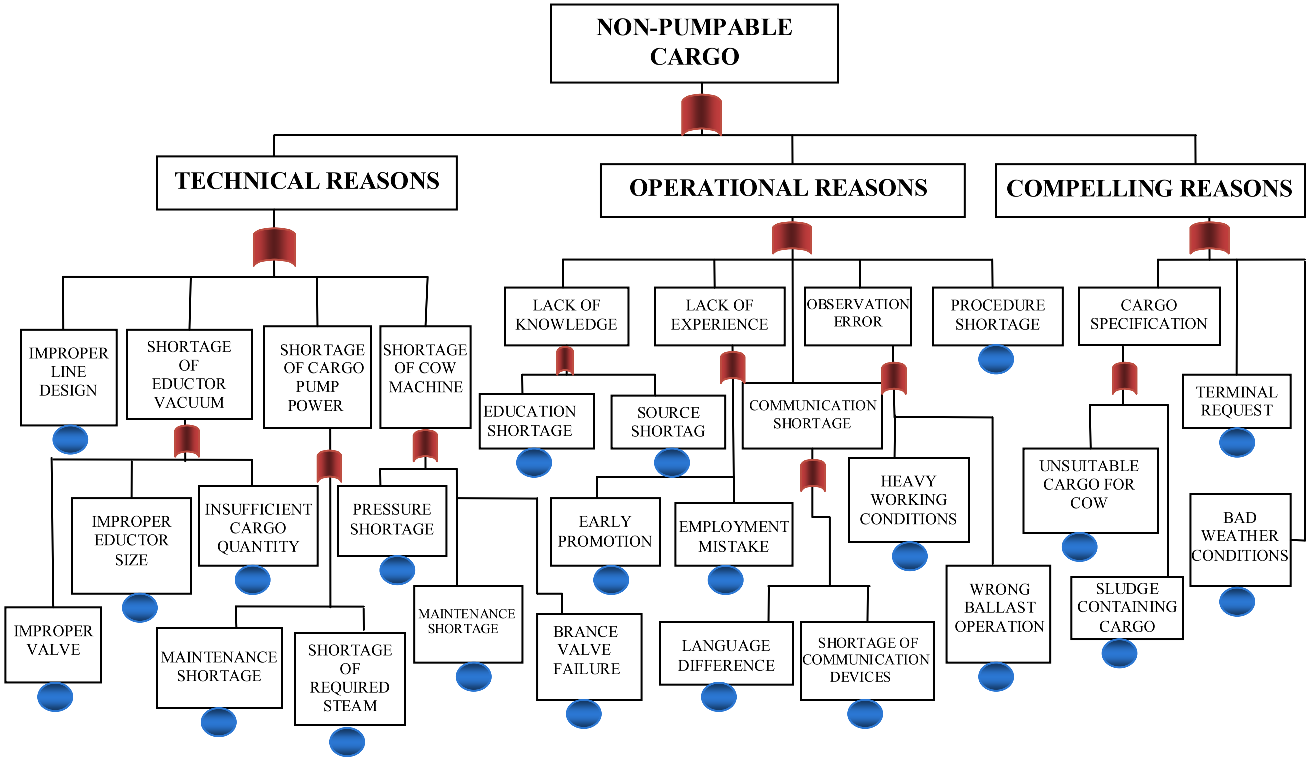

Figure 3. Fault tree of non-pumpable cargo

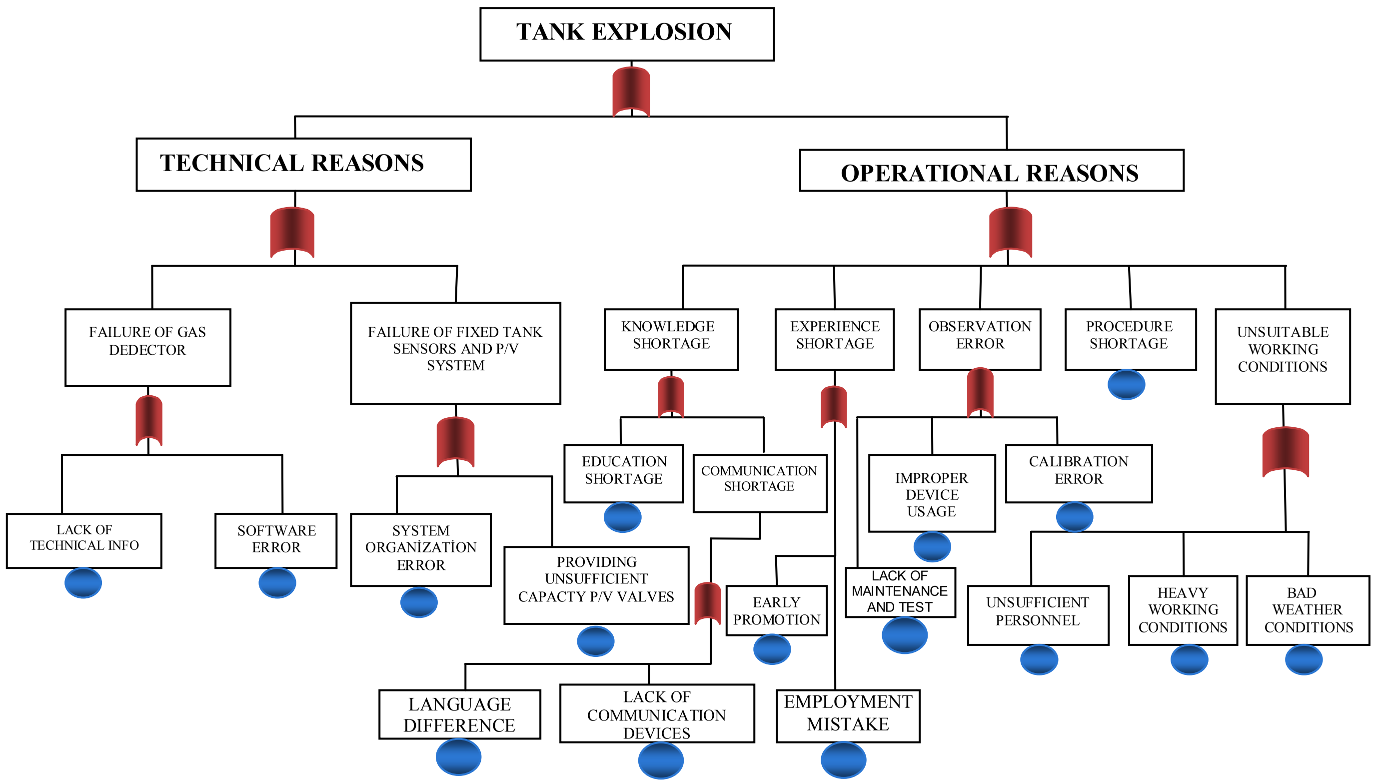

Figure 4. Fault tree of tank explosion (Celik 2009 and Sun *et al.* 2005)

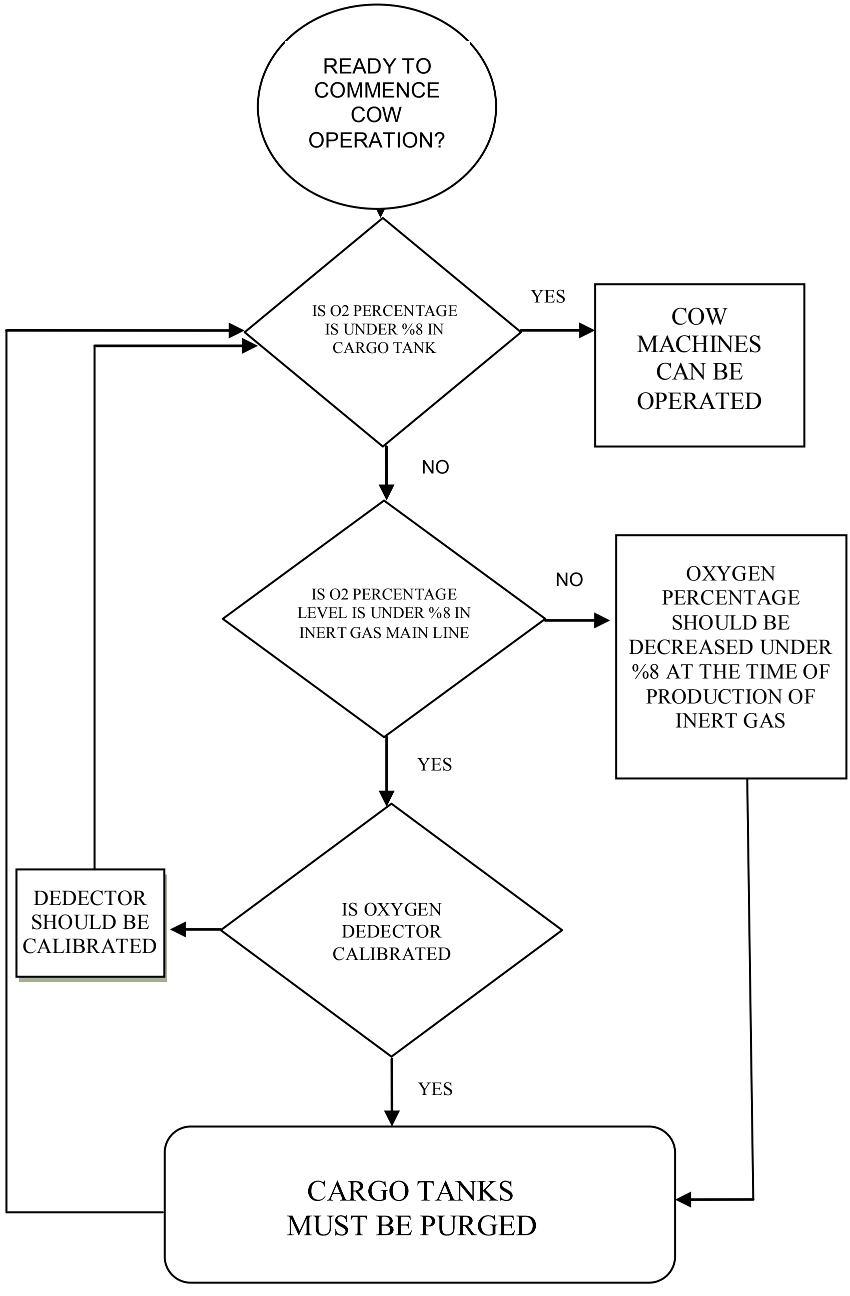

Figure 5. Flow diagram of crude oil washing operation (Hanninen and Rytkonen 2006)

Results and Discussion

In order to optimize crude oil tank washing, required data should be collected and translated to numeric data. This section describes the conclusions and results at different operations.

Washing with 4 Machines

11.2 manifold pressure decreases to 9.2 bars while opening a COW valve. In these circumstances, 4 COW machines causes 2.0 bars decrease the manifold pressure. As a result of this situation each COW gun causes a decrease of 0.5 bar at the manifold pressure (Table 1).

Table 1. Parameters during washing with 4 machines

Manifold pressure (bar)	11.2
Manifold pressure while COW machines are working (bar)	9.2
Crude oil pump quantity (pieces)	1
COW line pressure (bar)	10.2
COW machines pressure (bar)	8.5
Cargo quantity passing through COW machines (m^3/hour)	109

Manifold pressure loses will reduce our vessel's cargo discharge rate at multi-phase washings. Therefore, to meet the hourly amount of average cargo requested by terminal, other cargo pumps' speed should be provided. All related bypass valves in the manifold area should be turned on in order to synchronize the pressure as a safety precaution against sudden pressure peaks (ISGOTT 2006).

COW Machine Performances at Different Pressures

Four minutes differ between the worst and best washing operations. Thus, when we think of a Full Wash (120-0) for each cargo tank, this will provide 16 minutes gain per pair of cargo tank. If we think 8 pair of cargo tank on board, this situation will provide 128 minutes gain (Table 2). Such amount of time saving means significant economic and labour savings for large vessels.

Table 2. Parameters at different pressures

	Scenario No:1	Scenario No:2	Scenario No:3	Scenario No:4	Scenario No:5
COW machine quantity (pieces)	4	4	4	4	4
COW machine revolution (RPM)	960	1110	1250	1350	1500
Initial COW main line pressure (bar)	8.1	10.7	13.6	15.8	19.7
COW line pressure while COW machines are working (bar)	6.8	8.2	11.4	13.2	15.9
COW machines working pressure (bar)	6.1	7.8	9.5	10.8	12.7
COW machines cargo rate (m³/h)	77.6	99.2	120.7	137.3	161.9
COW machines set angle	120°-90°	120°-90°	120°-90°	120°-90°	120°-90°
COW duration (minutes)	18	17	16	18	20

Comparison of Single-Stage Washing with Multi-Stage Washing

Profit for the washing between 40°-0° was calculated by means of a simulation. Washing between 120°-0° takes 64 minutes despite washing between 40º-0º takes 24 minutes (Table 3). This situation provides 40 minutes time saving. In total, 160 (4x40) minutes saving will be possible if all cargo tank groups are full washed (based on 4 different groups).

Table 3. Parameters during washing between 40º and 0º

COW machine quantity (pieces)	4
COW machine revolution (RPM)	1240
Initial COW main line pressure (bar)	13.5
COW line pressure while COW machines are working (bar)	11.3
COW machines working pressure (bar)	9.4
COW machines cargo rate (m³/hour)	119
COW machines set angle	40° - 0°
COW duration (minutes)	24

Comparison of COW Operation Performed with One Cargo Pump and Double Cargo Pump

Cargo discharge quantity from a cargo tank was 1253 cbm per hour while using one cargo pump. If two cargo pumps were used cargo discharge quantity would increase up to 1551 cbm per hour at the same cargo tank. A total of 298 cbm earning were obtained per hour (Table 4).

Table 4. Parameters during washing with one and double cargo pumps

	Scenario No:1	Scenario No:2
COW machine quantity (pieces)	4	4
COW machine revolution (RPM)	1240	No 1: 1240 No 2: 1350
Initial COW main line pressure (bar)	12.6	12.6
COW line pressure while COW machines are working (bar)	10.2	10.2
COW machines working pressure (bar)	8.5	8.5
COW machines cargo rate (m^3/hour)	109.0	109.0
COW machines set angle	120° - 0°	120° - 0°
Manifold pressure (bar)	9.2	9.2 (2 Manifolds)
Discharge rate	1253	1551

Performance Comparison between COW Operation at the Same and Different Cargo Tanks

8.5 bar pressure was obtained by means of operating four COW machines at the same tank. This pressure was not an efficient washing pressure due to long washing period and lack of effectiveness. Two of four COW machines were turned off in the same cargo tank and two COW machines at a different cargo tank were turned on. As a result of this operation main line pressure decreased to 10 bars and COW machine pressure increased to 9.5 bars (Table 5).

Table 5. Parameters during washing at the same and different cargo tanks

	Scenario No:1	Scenario No:2
COW machine quantity (pieces)	4	2+2
COW machine revolution (RPM)	No 1: 1240 No 2: 1350	No 1: 1240 No 2: 1350
Initial COW main line pressure (bar)	10.2	10.0
COW line pressure while COW machines are working (bar)	8.5	9.5
COW machines cargo rate (m^3/hour)	109.0	120.7
COW machines set angle	120° - 0°	120° - 0°

It was seen that 9.5 bar washing pressure was the most efficient and effective washing pressure as a result of all simulations. In this way, all cargo tanks can be washed by this cross technique (Hayrinen *et al.* 2001).

Changes When Operating 6 COW Machines Instead of 4 COW Machines

8.2 bar pressure adversely affects the discharging rate which is away from the ideal pressure (Yağız 1988). At the same time, the cargo coming from six COW washing machine was generally over the eductor capacity (Table 6). Therefore, it is determined that the ideal washing pressure was 9.5 bar while operating four COW machines.

Table 6. Parameters with 4 and 6 COW machines

	Scenario No:1	**Scenario No:2**
COW machine quantity (pieces)	4	4+2
COW machine revolution (RPM)	1240	1240
COW line pressure while COW machines are working (bar)	9.8	8.9
COW machines pressure (bar)	9.5	8.2

Conclusions

First of all, qualified seamen are required to ensure safe optimization of COW operation. The quality and standard of the education should be same for all institutions. An inspection corporation should establish a mechanism to maintain the same standards. However, the qualified and experienced educators should be selected to work at these institutions.

Internal and external controls should be carried out within the prepared plan and all deficiencies should be noted in related documents regarding safety management systems. Troubleshooting paths should be followed and corrective actions should be taken to clear the deficiencies (Altun 2013).

Control systems should be created to prove the maintenance with tangible evidence by management companies. Port states and class organizations should check these evidences within determined periods.

COW plan which is prepared by chief officer has to be explained to all crew and it has to be sure that everyone understands the orders for safe operation optimization (Arslan 2009).

Cargo level in slop tanks should be adjusted to maintain 9.5 bar COW gun pressure. Lack of cargo quantity will cause insufficient pressure.

If a COW operation is not performed according to the minimizing requirements indicated below, management costs will increase, labour losses will occur, troubles for environment and human health will arise.

Oil spill pollution and tank explosion are the main risks during the COW operations. Both of these events are extremely dangerous for environment and health of people. A small amount of crude oil can pollute a large amount of sea water in a short time and millions of living creatures cannot get rid of negative effects of this oil pollution for many years (MARPOL 2011).

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Ham petrol tankerlerinde ham petrolle tank yıkamasının çevresel ve emniyetli optimizasyonu

Özet

Ham petrol içeriği nedeniyle çevre için en zararlı maddelerden biridir. Kirlilik iki şekilde olabilmektedir: deniz kirliliği ve hava kirliliği. Bu yüzden, çevrenin tahribini önlemek maksadıyla ham petrol ve ürünlerinin denize boşaltımını minimize etmek için ham petrolle yıkama operasyonunun optimize edilmesi gerekmektedir. Günümüzde birçok endüstri alanında kullanılan, birçok sanayi ürününün ham maddesi olan ve eşdeğerinin bulunmasının çok zor olduğu ham petrolün sevkiyatı esnasında karşılaşılan zorlukların başında ham petrolü taşıyan tankerlerin tahliye problemi gelmektedir. Ham petrol tankerlerinin yükü tamamen tahliye edebilmesi için gerekli olan ham petrol yıkaması birçok tehlike, avantaj, dezavantaj ve fırsatları da beraberinde getirmektedir. Tüm bu bilgilerin ışığında yapılan bu çalışma ile ham petrol yıkamasının emniyetli optimizasyonu için gerekli olan öncelikle emniyet tedbirleri ile gerekli olan yardımcı teçhizatlar ayrıntılı olarak incelenmiştir. Ham petrolle yıkama esnasında ve sonrasında oluşabilecek tehlike ve fırsatlar ile ham petrol yıkamasının bize sağlayacağı avantaj ve dezavantajlar analiz edilmiştir. Yapılan bu çalışmada gerçekleştirilen simülatör uygulamaları ile farklı kondisyonların birbiriyle karşılaştırması yapılmış olup denizcilik sektöründe çok önemli bir yere sahip olan ham petrol taşımacılığına bir ışık tutması amaçlanmıştır. Optimizasyon sürecinde tüm emniyet gereklilikleri çerçevesinde insan ve çevre emniyeti ön planda tutulması için gereklilikler detaylı olarak incelenmiştir.

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