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Research Article

Dominant constraints to the effective use of oily-water separator (OWS) in the control of ship-based oil pollution in West African waters

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Abstract
The International Regulations for the Prevention of Marine Pollution from ships (MARPOL 73/78) provided for the deployment of oily-water separator (OWS) technology for ship-based oily-water pollution in the marine ecosystem. Previous studies on the efficiency and effectiveness of the use of OWS technology showed failure rates of about 40 % and ineffective use, while also identifying a multiplicity of correlated factors constraining the effectiveness of the use of the technology onboard. To overcome the constraints posed by the identified factors to the effective use of OWS technology requires a systems approach, which demands the determination of the dominant and significant factors most constraining the effective use of the technology and prioritization of the elimination of the significant factors. The study used a survey design approach, employing primary data and principal component factor analysis, to determine the existence of about five principal factors significantly constraining the effective use of the technology by ship operators in West African waters. The policy implications were discussed, and recommendations for effective use of the technology were proffered.

1. Introduction

Annex 1 of the International Regulations for the Control of Marine Pollution from ships (MARPOL 73/78), drafted to prevent ship-based oil pollution in the marine environment, among other things placed limits on the bilge water oil content which a vessel is legitimately allowed to discharge into the marine environment in the course of her operation (Liu & Maes, 2011; Szepes, 2013; IMO, 2011; Berger et al., 2014). To ensure the implementation success of the aforementioned regulatory requirement, MARPOL 73/78 Annex 1 further provides that vessels be fitted with oil discharge monitoring and control systems or oily water separator (OWS) technology with capacity to filter oily water mixtures until the oil content in water from bilge systems is less than 15 parts per million of the water mixture (IMO, 2011, Bucharest Convention, 1992). Basically, OWS technology is employed onboard ship to monitor the oil content of liquid wastes from various sections of the ship, such as engine rooms, cargo holds, bilges, sludge tanks, slop tanks, oil tanks, oil-contaminated spaces, and other sources of oily water wastes onboard (IMO, 2011; UNEP, 2011). The mandatory use of OWS technology onboard ships stems from the prohibition of any

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direct discharge of oily water mixture into the sea under paragraphs 2, 3, and 6 of MARPOL 73/78 Annex 1, Regulation 4, which goes further to provide conditions for the handling and treatment of oily water mixture onboard and how it can be discharged at sea. The regulations provide that, for all ships of 400 gross tonnage and above, the discharge of oily water mixture is only allowed in these circumstances:

(i) As the vessel is en route;

(ii) The oily water mixture must be filtered through the use of oily water separator (OWS) technology that meets the basic requirements spelt out in Regulation 14 of Annex 1;

(iii) The oil content is not above 15 parts per million, and

(iv) For tankers, the oily water mixture is not mixed with oil cargo residues, among others provisions (Mohit, 2019; Hendrick & Van, 2017).

The aforementioned regulations have become the basis for the enforcement of the use of OWS technology for ship-based oil pollution control by maritime jurisdictions. Ship inspectors in various Port States Control (PSC) regimes note the importance of OWS technology in the prevention of marine pollution by oil; thus, most PSC regimes consider it a major equipment of interest in the course of ship inspection in ports (Carpenter, 2005; Arvanitis & Loukis, 2009). Available statistics from the Abuja MoU on PSC jurisdictions in the West and Central African regions suggest that ship operators show reluctance in using procedures with the technology, leading to defective use of OWS technology by ship operators and subsequently, failure of the use of the technology in achieving the control and prevention of ship-based oily-water in some cases, with many detentions in ports (Abuja MOU, 2015). Thus, there appears to be a serious challenge concerning the effectiveness of use of the technology, particularly in the maritime domain of Nigeria (Bans-Daban et al., 2017; Elenwo & Akankali, 2015).

The effective and efficient use of OWS technology is a necessity if the technology must be deployed to achieve the goal of preventing operational discharge of oil from ship-based sources into the marine ecosystem. For example, a survey of the Nigeria maritime industry, targeted at ship owners and operators to determine the effectiveness of the use of the oily-water separator (OWS) technology in ship-based oily water pollution control, by Cyril (2020) found that OWS technology was rated to have about 60 % of effectiveness in the use for control of ship-based oily-water pollution in Nigeria. This suggests some level of ineffectiveness in the use of the technology in the prevention of ship-based oily-water pollution. The study did not, however, investigate further the reasons for the about 40 % ineffectiveness rating of the use of OWS technology by some ship operators and owners sampled in the survey (Cyril, 2020). Apart from the work of Cyril (2020), the works of Hal, (2017), Arpit (2019), Szepes (2013), and Mohit (2019) identified several factors that limit the efficiency and effectiveness of use of OWS technology and are in agreement that the use of OWS technology does not offer a 100 % assurance for the prevention of ship-based oily-water pollution. For example, reports by the Abuja MoU on PSC (2015), similar to Szepes (2013), found that the oil content (contaminant) in the waste water and ballast water discharges of most ships detained for breach of the oily-water discharge regulation was above the 15 parts per million stipulated in the IMO's oily-water discharge regulations, suggesting a defective use and/or failure of the technology to effectively be employed by ship operators to achieve the total limitation of ship-based oily-water discharge in the marine environment.

The varied views of ship operators and owners, aforementioned, suggests that, while the technology is effective in ship-based oily water pollution control for a section of users, it cannot effectively serve the needs of some portions of the sampled populations of ship operators and users; particularly, those who have, at some point, been detained by PSC inspectors, for the failure of and/or inappropriateness of equipment and the use of OWS technology (Cyril, 2020).

The findings of Cyril (2020), Hal (2017), Szepes (2013), and Arpit (2019) lay credence to the existence of constraints to the effective use of oily-water separator for ship-based oily water pollution control. For example, studies by Mohit (2019) note that OWS technology is segmented into three (3) main units, such that the malfunction of any segment or unit could lead to poor outcomes and the ineffective use of OWS technology. According to Mohit (2019), OWS technology was segmented as per the below:

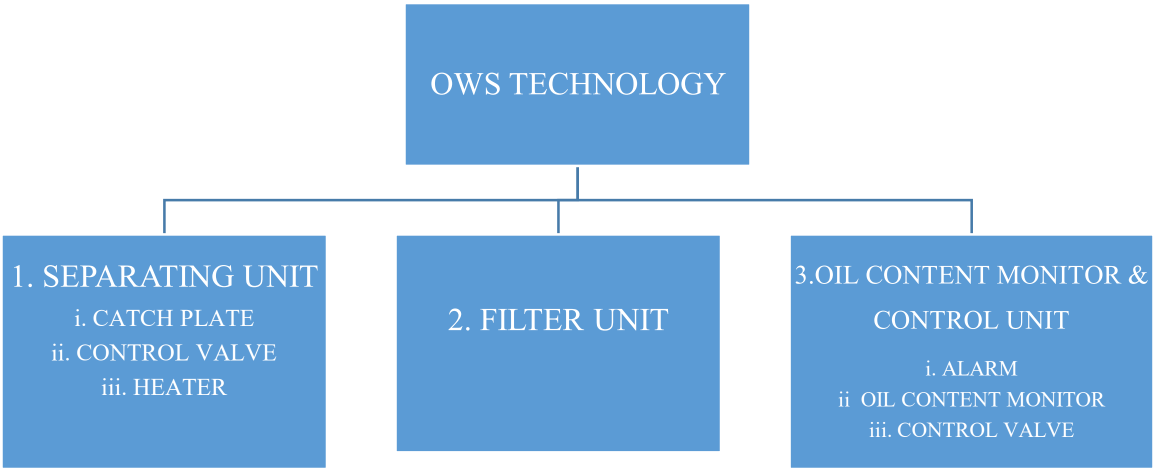

Figure 1 Segments of OWS technology. Source: Adapted from Mohit (2019).

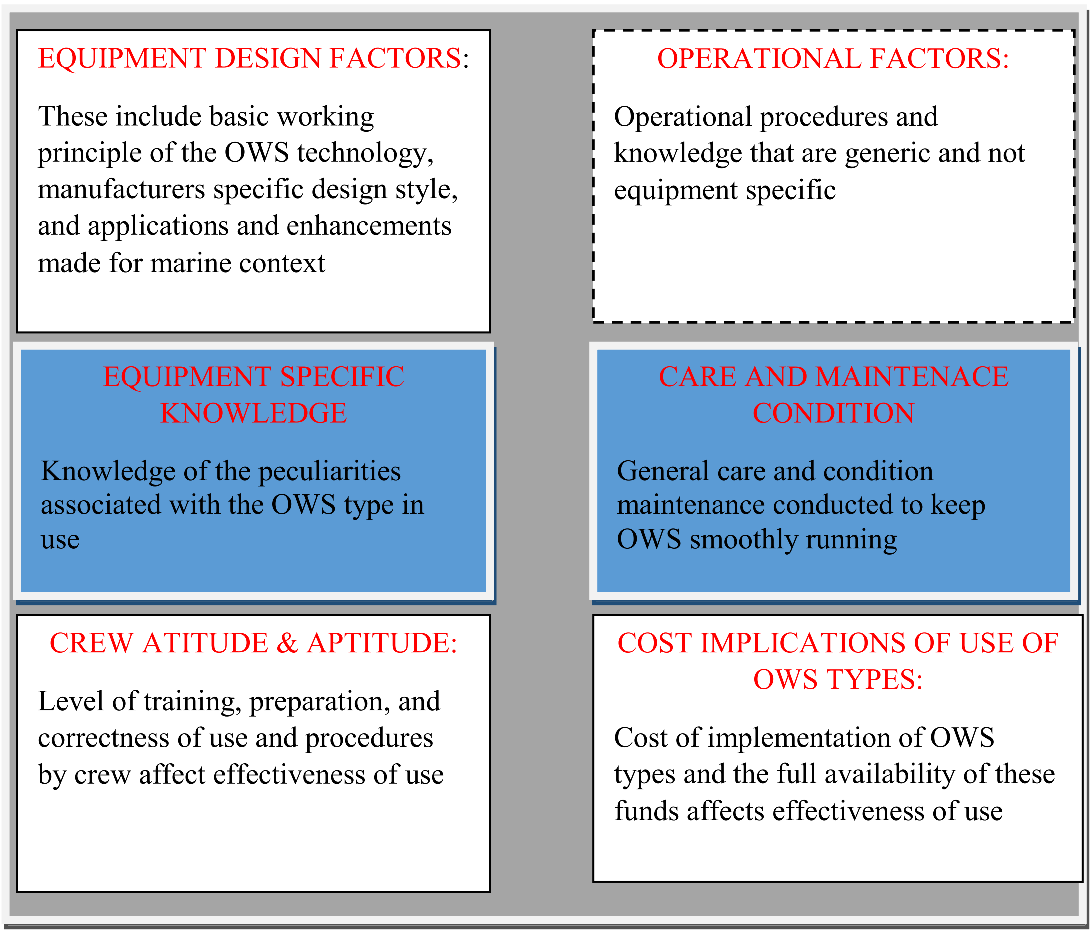

Figure 2 Source: Prepared by authors with insight from Arpit (2019) and Mohit (2019).

By implication, the working conditions of the segments and units of OWS can affect the outcomes and effectiveness of use of the technology in oily water pollution control. Apart from the operating conditions of OWS technology, Mohit (2019), Hendrick and Van (2017), and Arpit (2018) agree that factors such as equipment design factor, operational factors, care and maintenance condition, equipment specific knowledge, crew attitude and aptitude, cost implications of usage, and conditions of bilge management also affect the outcomes and effectiveness of use of OWS. Stuart (2019) and Meiling et al. (2019), in addition to the above factors, note that the type and make of OWS technology also affects the effectiveness of its use, as some OWS technology types (various manufacturers) have easier operational guidelines and more user friendly man-machine interfaces than other available technology types. Arpit (2018) and Hal (2017) gave a summary of the factors that affect the effectiveness of use of OWS technology, as shown below:

The implication is the existence of correlated multiple and complex factors influencing the effectiveness of the use of OWS in the prevention of ship-based oily-water pollution in Nigeria. Overcoming the risk of constraints posed by the factors to the effective use of OWS technology demands a systems approach. Such a systems approach requires that the magnitude of the influence of each factor in limiting the effectiveness of use of the technology be determined and ranked, in order of increasing or decreasing magnitude or influence, so that the factors that possess the greatest ranks are prioritized for elimination first, before factors with lesser degrees of influence (Dasilveria, 2002; Cheng & Grimm, 2006; Helen & Sako, 2016). The challenge to this approach, however, is that of identifying which factors constitute the determinant factors affecting the effectiveness of the use of oily-water separators in the prevention of ship-based oily water pollution in Nigeria and West African waters. This is important because, once identified, the efficient and effective use of the technology is guaranteed by addressing, firstly, the major component and significant limiting factors. This, in turn, will address the constant problem of pollution and degradation of the marine environment occasioned by the ship-based operational discharge of oil into the marine environment. Poised to bridge the identified knowledge gap, the study will determine the significant factors that constrain the effectiveness of use of OWS technology in the prevention and control of ship-based oily-water pollution, and rank the identified significant factors in order of increasing influence.

2. Materials and methods

2.1 Research design and sources of data

The study employed a survey research design in which primary data was sourced from a sample of ship operators and ship owners in Nigeria using survey instruments of a questionnaire and an interview. The questionnaire was designed to elicit responses from the sampled respondents on what constitute their major challenges and constraints to the effective use of OWS technology in the control of ship-based oily water pollution in Nigeria. The interview was used to augment the responses to the questionnaire. The six constraints identified in previous sections, which were equipment design factors, operational factors, equipment specific knowledge, care and maintenance condition, operator/crew attitude and aptitude, and cost implications of use of OWS types, were the factors considered from which respondents were to make preferences from among the factors constraining their effectiveness in using OWS technology, as well as to provide empirical ratings of the degree of constraints posed by each identified factor, based on a scale of 0 to 1. Respondents were equally allowed to identify and include any other factors, not listed among the above six, which limit their effectiveness of the use of the technology. Since the study is more of a traffic study, the sample size and sampled population of ship operators and ship owners were drawn from those contacted in the field in Onne seaport, Port-Harcourt, in Rivers State, Nigeria, in the course of the survey. For traffic survey, the ship traffic found in the port during the various periods of time the survey was carried out form the sample size and population targeted in the survey. The Nigeria Ports Authority (NPA, 2019) statistical report indicates that the average ship call (traffic) to the berths in the port is about 16 vessels per day. However, to limit error associated with data collection, and to access higher volumes of data from as many ship operators as the time limitations could permit, the survey was conducted in 3 days, within a two week interval, targeting a population of at least 48 ship operators in those 3 days. Thus, the 48 ship operators represented the sample size used in the study.

A total of about 40 ship operators and owners, out of the 45 survey instruments distributed, returned their questionnaires, out of which only about 36, representing 75 % of the sample size, were accurately filled and were used for the study. The ship operators sampled included both operators of local and foreign ships of various flag states operating in the Nigerian waters and seaport environment. This implies that about 75 % of IMO OWS standard vessels were operating in the ports per during the period covered in the survey.

2.2 Data analysis technique

Principal Component factor Analysis (PCA) was employed in determining the major component constraints to the effectiveness of use of OWS technology in the prevention of ship-based oily water pollution. PCA constitute is a statistical tool, used as a data reduction method to determine which sets of factors have more significant effect or influence in a decision-making process. The significant factors are, thus, preferred as the best basis for decision purposes to the non-significant factors, since they affect most decisions about a given dependent variable or central factor. The non-significant factors may be ignored as having no major influence on the central decision variable. Thus, PCA as an exploratory data analysis method is used for dimensionality reduction by projecting each data point onto only the first few principal components to obtain lower-dimensional data, while preserving as much data variation as possible. Since the aim of the study is to determine the major component factors that constrain the effectiveness of use of OWS technology from among the six factors identified in the literature, the PCA method forms a good tool which is used to achieve the purpose of the study. Using SPSS version 20.1, the study employed the PCA analytical method in analyzing the data obtained from the field survey, with the results and findings discussed in section 3, below.

3. Results and discussion

Table 1 shows the results of the major component factor analysis conducted to determine the major component factors that limit the use and effectiveness of OWS technology onboard vessels for oily-water monitoring and pollution control. The results of the study, as shown in the table, indicate that equipment design factor, which has to do with limitations imposed on the effectiveness of use of OWS technology occasioned by equipment design issues, has a mean value of 0.3611, with standard deviation of 0.48714. Operability factor, which is associated with challenges in operating OWS technology which subsequently limits its use and effectiveness, has a mean value of 0.3056, with standard deviation of 0.46718. Level of specific knowledge of the equipment as a limiting factor has a mean score of 0.1944, with standard deviation of 0.40139. Operators (Crew) attitude to the use of the equipment and equipment care and maintenance challenges have mean scores of 0.0278 and 0.556, respectively, with respective standard deviations of 0.16667 and 0.23231, while the cost of use and/or operating the equipment as a limiting factor has a mean score of 0.556, with standard deviation of 023231.

The results of the major component factor analysis further reveal that equipment design factor, operability factor, level of specific knowledge about the use of the equipment, operator attitude in the use of the equipment, and care and maintenance condition of OWS equipment have respective Eigen values of 1.504, 1.304, 1.100, 1.059, and 1.033. Since each of the identified factors have Eigen values greater than one (Eigen value > 1), we assert that they constitute the major component factors limiting the use and effectiveness of OWS technology in the control and prevention of ship-based oily-water pollution. Note that cost of use and operation of the OWS equipment has an Eigen value of -4.977E-016, which is less than 1 (-4.977E-016 < 1); therefore, it is not a significant factor limiting the use and effectiveness of OWS technology for ship-based oily-water pollution control.

Table 1 Determining the major component constraints affecting ship operators' effectiveness of use of OWS technology in the control of ship-based oil pollution.

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Design factor	0.3611	0.48714	36
Operability factor	0.3056	0.46718	36
Equipment specific knowledge	0.1944	0.40139	36
Operator attitude	0.0278	0.16667	36
Care and maintenance	0.0556	0.23231	36
High cost of operation	0.0556	0.23231	36

Communalities

	Initial	Extraction
Design factor	1.000	1.000
Operability factor	1.000	1.000
Equipment specific knowledge	1.000	1.000
Operator attitude	1.000	1.000
Care and maintenance	1.000	1.000
High cost of operation	1.000	1.000

Extraction method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.504	25.059	25.059	1.504	25.059	25.059
2	1.304	21.740	46.800	1.304	21.740	46.800
3	1.100	18.341	65.140	1.100	18.341	65.140
4	1.059	17.647	82.787	1.059	17.647	82.787
5	1.033	17.213	100.000	1.033	17.213	100.000
6	-4.977E-016	-8.295E-015	100.000			

Component Matrix[a]

	Component				
	1	2	3	4	5
Design factor	-.924	-.337	-.177	.000	-.034
Operability factor	.791	-.572	-.214	.000	-.039
Equipment specific knowledge	.142	.912	-.381	.000	-.056
Operator attitude	.027	.072	.257	.000	.963
Care and maintenance	.041	.116	.637	.728	-.222
High cost of operation	.041	.116	.637	-.728	-.222

Extraction method: Principal Component Analysis. [a] Source: Authors' calculations.

a. 5 components extracted.

These findings are in agreement with the findings of Hal (2017), who found that some OWS technologies built to the previous Marine Environmental Committee (MEPC) 60 (30) standards were not efficient or effective in reducing concentrations of emulsified and otherwise organic oily materials to the 15 parts per million (ppm) level provided for in MARPOL73/78, as amended. However, Hal (2017), having found the ineffectiveness of some OWS technology types, particularly gravity-based separators, did not go further to investigate the causal factors of the ineffectiveness of use and prioritize them for possible systemic elimination. The findings also agree with the findings of Hendricks and Van (2017), which identified mainly design factors and operational factors as being responsible for the inefficiency and ineffectiveness of use of some OWS technology types. However, the current findings differ from the findings of Hendrick and Van (2017); additional to design factors and operational factors, they also determined that level of specific knowledge on the use of OWS types by operators, operability issues, and equipment care and maintenance status/culture significantly limit the effectiveness of use and efficiency of OWS technology.

The major component limiting factors for the effective use of OWS technology is ranked in order of decreasing Eigen value (influence) by means of a bar chart, as shown in **Figure 3** below.

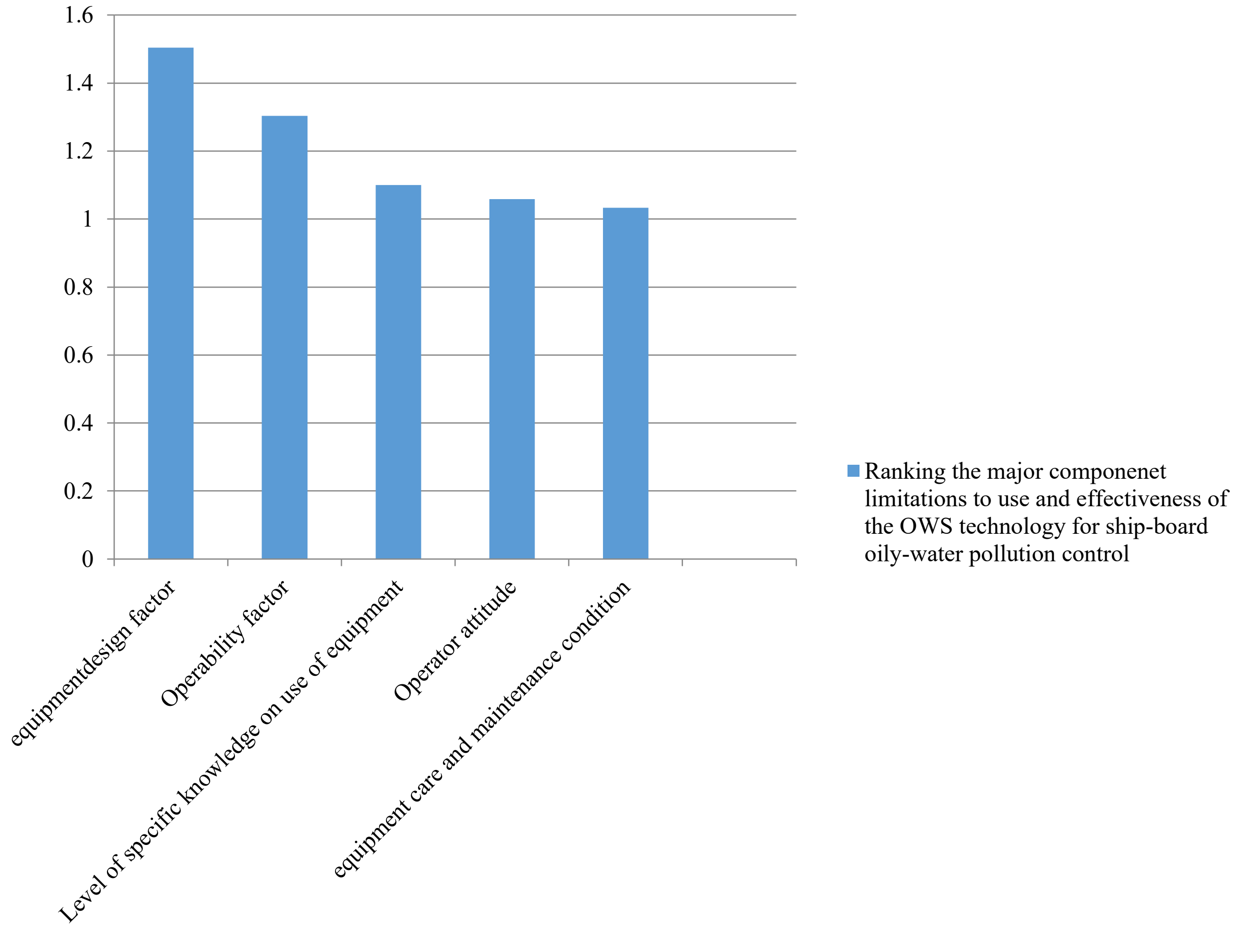

Figure 3 Ranking the major component limitations to use and effectiveness of OWS technology for ship-board oily-water pollution control. Source: Prepared by the author.

4. Conclusions

The results of the major component factor analysis reveal that equipment design factor, operability factor, level of specific knowledge about the use of the equipment, operator attitude in the use of the equipment, and care and maintenance condition of OWS equipment have respective Eigen values of 1.504, 1.304, 1.100, 1.059, and 1.033. Since each of the identified factors have Eigen values greater than one (Eigen value > 1), we assert that they constitute the major component factors limiting the use and effectiveness of OWS technology in the control and prevention of ship-based oily-water pollution. Note that cost of use and operation of OWS equipment has an Eigen value of -4.977E-016, which is less than 1 (-4.977E-016<1); therefore, it is not a major factor limiting the use and effectiveness of OWS technology for ship-based oily-water pollution control.

The studies of Arpit (2019) and Mohit (2019) also identified the above factors, in addition to some others aforementioned in previous chapters, as limiting effectiveness of use and efficiency of OWS technology with recourse to determining the levels of the limiting influence of each factor. The current study was able to determine this using the PCA, which is different from the methods used by Arpit (2019) and Mohit (2019) that identified equipment design factor, operability, level of specific knowledge about OWS technology type, operator attitude while using OWS, and equipment care and maintenance culture as the significant factors limiting effectiveness of use and efficiency of OWS technology in ship-based oil pollution control. The implication of the findings is that ship-owners and operators in West African waters should concentrate more on addressing first the most significant factors limiting the effectiveness of use of OWS technology in ship-based oil pollution control.

5. Recommendations

It is recommended that the identified five major component factors which limit the effectiveness of the use of OWS technology should form the focal point of the drive towards improving the performance of OWS technology, such that improving the conditions of the factors in the use of OWS technology will limit their constraints to the effectiveness of use of the technology; this will improve the use and effectiveness of OWS technology in the prevention and control of ship-based oil pollution in the marine environment.

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