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Baseline study to determine the implementation area of an oily waste management system for artisanal fishing vessels

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Abstract This work seeks to perform a baseline study to determine the implementation area for a management system of oily waste generated by artisanal fishing boats within the Peruvian context. This explanatory study, conducted based on quantitative and cross-sectional considerations, includes a regulatory review; content analysis of polynuclear aromatic hydrocarbons (PAH) and total petroleum hydrocarbons (TPH) both in seawater and sediments; and metal assessment in sediments and waste oil, with the corresponding result correlations. In this study, the results reveal that while regulations are adequate, their implementation is not evident. In addition, no evidence of contamination by PAH and TPH was found. However, traces of metal contamination were found in sediments, and, after being correlated with the metal values from waste oil, a Spearman's Rho correlation coefficient of 0.619480 was reported. Hence, we can conclude that the regulations to prevent marine pollution from oily waste contained in the International Convention for the Prevention of Pollution from Ships MARPOL agreement have been accepted and approved for implementation. In fact, they can even be applied to different activities that fall out of the scope of the agreement. Finally, the baseline study reveals oily waste generation indicators, as well as a correlation between waste oil metals and marine sediment metals that merits the implementation of an oily waste management system within the study area.

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Introduction

Ecosystems become contaminated whenever foreign elements or substances affect their natural characteristics. This contamination can be either natural or anthropogenic (Delgadillo-López et al. 2011). In many coastal ecosystems, anthropogenic contamination is related to oil hydrocarbon spills, including two-stroke and stationary engine oils (Beyrem et al. 2010) spilled from ship washing and maintenance activities (Vikas and Dwarakish 2015), both involving maritime transportation ships and other smaller vessels (Souza et al. 2014). These used lubricants usually have a high level of extremely toxic non-biodegradable polycyclic aromatics that may remain for a long time in marine sediments (Powell et al. 2005). In addition, they contain ashes, carbon waste, asphalt materials, metals, and water, among others, generated during the engine's lubrication process (Abdel-Jabbar et al. 2010).

In fact, oil by-products, including lubricants, are the most harmful marine pollutants, as they cause changes within the ecosystem and modify the behavior of any marine organisms affected. They also modify the natural properties and features of water. For example, they decrease oxygen contents and surface tension, which, in turn, affects human health (Alharbi et al. 2018; Chandra et al. 2013; Estrella and Guevara 2011; Prieto Díaz and Martínez de Villa Pérez 1999; Vikas and Dwarakish 2015).

Oily waste spills from fishing boats can be either accidental or intentional. While intentional spills can be attributed to poor environmental awareness or to limited resources for a proper management system, they may also be encouraged by a lack of adequate waste management and disposal legislation.

In the maritime field, different countries have adopted the regulations issued by the International Maritime Organization (IMO) to protect the seas and as provisioned in the International Convention for the Prevention of Pollution from Ships—MARPOL 73/78, which establishes standards to prevent pollution caused by hydrocarbon fuels and their derivatives applicable to ships exceeding 400 gross tons (GT) engaging on international voyages (Griffin 1994). These regulations provide for the installation of waste reception systems in ports or offshore terminals; however, there are still obstacles that prevent the efficient on-shore delivery of this waste (International Maritime Organization 2018; Lin et al. 2007), which means that IMO Member Countries must issue more rigorous laws. In addition, vessel owners must become accountable for the environment, port authorities should be stern in enforcing oil waste regulations, and fishers and fisheries must implement an oily waste management system that includes recording the amount of waste oil discharged from each fishing vessel to monitor whether any waste oil has been released into the ocean (Lin et al. 2007). Therefore, all authorities must play a role in preventing pollution, and not only the government.

In Peru, the government agency that manages the MARPOL Convention is the Maritime Authority (AM). In addition to regulating oily waste management for the vessels provisioned in the MARPOL agreement, the AM also regulates oily waste management for other vessels outside of the MARPOL scope, such as ships between 400 and 10,000 GT and vessels under 400 GT with engines over 300 HP (223.5 kW) (Dirección General de Capitanías del Perú 2005). However, no regulation has been found for artisanal fishing vessels under 400 GT with engines under 300 HP. In Taiwan, it was estimated that 3215 small boats under 100 GT, all with engines under 300 HP, can generate up to 321,700 L of oily waste per year. Since these vessels have small engines, they generally do not produce a large amount of oil waste per vessel, and, since it lacks recycling economic value, oil waste is commonly discharged into the bilge water, where most boats discharge waste directly into the ocean (Lin et al. 2007).

Regarding culture, fishermen form a number of social relationships where fishing is not the only activity, since we must also consider any social interactions that take place at different ports, which means that these groups are heterogeneous in nature due to the difference in spatial and sociocultural terms between ports and fishing terminals (Aguirre Munizaga and Moya 2014). This aspect is relevant because any study focusing on artisanal fishers may include differentiating elements from each fishing terminal.

Due to the absence of any regulation that may prevent marine pollution by lubricating oils from vessels under 400 GT and under 300 HP and considering the cultural aspects of the fishermen involved, this study seeks to conduct a baseline study to determine the implementation area of a management system for oily waste generated by artisanal fishing boats within the Peruvian context.

Materials and methods

Due to its characteristics, this study can be classified as exploratory in nature with quantitative and cross-sectional considerations. First, we reviewed the Peruvian regulations within the framework of preventing marine pollution from oily waste generated by fishing vessels. The purpose of this review was to assess the participation or concern denoted by the Peruvian Government in terms of maritime protection.

To conduct the study, the geographical area was taken into account; a wharf without any oily waste management system was first identified. Then, we estimated the amount of oily waste that was being generated by artisanal fishing vessels. For these purposes, we determined the number of boats and their corresponding horsepower. Next, we identified, according to the manufacturer's manual, the amount of lubricating oil used by their engines and, in turn, the average oily waste that could be generated. Subsequently, using geographic charts, we located the mooring area designated by the

Maritime Authority within the bay and proceeded to take both water and sediment samples.

The presence of total petroleum hydrocarbons (TPH) in seawater and sediments was assessed as this measurement provides acceptable information on the existence of pollution (Méndez et al. 2011). Likewise, the samples were analyzed to determine the presence of polynuclear aromatic hydrocarbons (PAH), because they are pollutants that may come from fossil fuel spills (Vera-Ávila et al. 2002) and their derivatives, such as lubricants. Additionally, we assessed marine sediment samples to determine the presence of metals since sediments act as filters for many pollutants that remain within the ecosystem under many different chemical forms (Acuña-Gonzales et al. 2004; Marín-Guirao et al. 2005; Salazar et al. 2004).

Finally, we characterized the waste oil from the engines of the vessels operating out of the selected wharf to determine whether there was a relationship between this waste oil and the results from the sea water and marine sediment assessments.

For these purposes, sampling was conducted within the mooring area established by the Maritime Authority. The seawater samples were taken at approximately 20 cm from the surface in 1 L amber glass bottles. These sample bottles were rinsed on-site and filled in triplicate. Then, the bottles were sealed, labeled, and stored at 4 °C until they were transferred to the laboratory. The sediment samples were taken directly in plastic containers at a depth of 6 m. Then, they were sealed in plastic bags and stored in refrigeration until they were transferred to the laboratory. To collect an engine oil sample, we had to mix oil waste from several random fishing boat engines. Two 100 mL plastic bottles were filled with this oil mixture and transferred to the laboratory for characterization.

The test methods used in the analysis laboratory for both the marine sediment and the seawater matrices were PAH determination: the test method issued by the United States Environmental Protection Agency (EPA) for Semi-volatile Organic Compounds by Gas Chromatography and Mass Spectrometry. TPH Determination (C10-C40): the Nonhalogenated Organics by Gas Chromatography test method issued by EPA. Metal Determination: the Microwave-Assisted Acid Sediment Digestion and Mass Spectrometry test method issued by EPA. Finally, to analyze oil waste, we used the ASTM D 5185–18 (2018) test method.

All test results were assessed, discarding any tests that did not reveal contamination by hydrocarbons or derivatives. Then, using only those results that evidenced contamination, a correlation was established with waste oil characterization data.

Results

Regulatory review

The Peruvian Government had already issued some regulations aimed at preventing pollution before subscribing to the MARPOL 73/78 agreement in 1979. For example, article 22 of Law No. 17752 of the General Law on Water, issued in 1969, expressly prohibits discharging any liquid waste that may contaminate water. Then, in 1990, Legislative Order No. 613 approves an environmental code that prohibits discharging contaminants. Subsequently, Resolution No. 342–91-DC/MGP, issued in 1991, establishes that all vessels with a gross tonnage not exceeding 400 tons are thereby required to store any oily waste in tanks. Later, in 1996, Resolución No. 0058–96/DCG states that all ports, terminals, and docks must provide facilities and services for collecting oily waste. Likewise, Resolución Directoral 0766–2003/DCG, issued in 2003, enacted a classification of waste reception facilities, the guidelines for developing waste management plans, and the waste reception and final disposal procedures under an environmental management plan, including fishing terminals. Finally, in 2005, Resolución Directoral 442–2005/DCG issued technical standards aimed at preventing pollution by oil waste and mixtures for ships over 400 GT but under 10,000 GT, and for ships under 400 GT operating at over 300 HP (223.5 kW) that do not transport hydrocarbons.

Location of study area

The area to be assessed is located in the province of Lima on the southwestern Pacific coast of Peru, namely, in the Bay of Ancón at 77°11′W and 11°46′S. The Bay of Ancón area is both protected and less exposed. This area was selected because artisanal fishing is one of its main economic activities (Arévalo et al. 2015), as well as due to its lack of a management system, its proximity, its fishery organization, and the willingness expressed by its fishers to support the implementation of a new management system (Fig. 1).

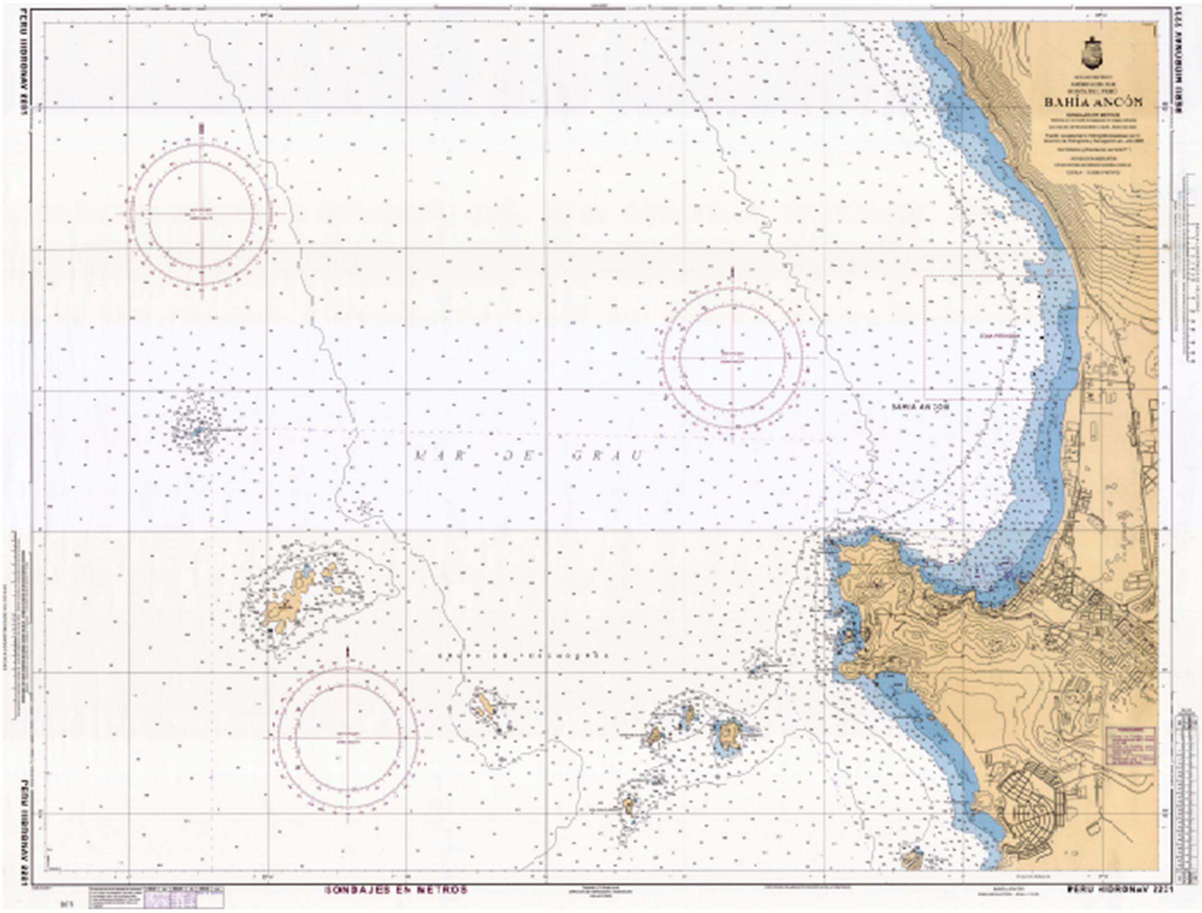

Fig. 1 Bay of Ancón; Hydrographic survey carried out by the Directorate of Hydrography and Navigation in July 2005; Perú Hidronav 2231. Marina de Guerra del Perú

Study area characteristics

The Bay of Ancón has a dock in the middle of the seaside city of the same name. It is managed by the District of Ancón. Different kinds of activities take place here, such as tourist activities, which include rides on outboard motor vessels, restaurants, victualling services, and unloading of artisanal fishing. There is a private club which only permits the entry to the beach to its members 200 m to the north, and there is a yacht dock 1 km to the south. The public access area of the Bay has about 1.5 km of beach, which is visited by most of the summer vacationers of the northern zone of Lima, leading to great overcrowding during the summer season.

The study area concentrates on artisanal fishing vessels, which is the subject of this study, outboard motors vessels used for tourist rides for the general public, and recreational yachts. Additionally, the bay is located 20 km away from the mouth of the Chillón River. During the high influx season, it discharges the solid waste that is disposed of in the river, and part of the solid waste is drifted to the Bay due to the Humboldt Ocean Current direction. We could identify that the yacht dock has an oily waste collection process; however, the artisanal fishing vessels and the tourist service vessels do not have a proper oily waste management system, nor have we got any evidence of how they dispose of this waste (Fig. 2).

Generation of oily waste

We collected data on the registered artisanal fishing boats operating out of the fishing wharf located within the area of study. In all, 177 small boats under 400 GT with engines not exceeding 300 HP were identified. Out of these 177 vessels, 152 use outboard motors of up to

Fig. 2 Aerial view of the Bay of Ancón by courtesy of Engineer Gustavo Vega

75 HP. Since these are two-stroke engines, their lubricants burn together with the fuel, generating 0.28 to 0.61 L of oily waste in every oil change. Therefore, if we assume an average of 10 oil changes per year, and since each oil change requires at least one new oil filter, these 152 boats generate at least 560.60 L of oily waste and use at least 1520 oil filters per year. In addition, we also identified 25 boats whose capacities do not exceed 400 GT using stationary engines of up to 200 HP. These engines require an average of eight oil changes per year, ranging from 9.6 to 25 L and using two new oil filters each, for an estimate of 3758.40 L of oil waste and 400 filters per year. In total, we estimate that 4319.00 L of oily waste from lubricants are generated, and 1920 used filters are discarded each year. Still, these estimates only include boats registered within the area of study, thus, excluding any fishing vessels operating out of other terminals that may periodically unload the product of the fishing operations in this area (Table 1).

After estimating oily waste and lubricant quantities and the number of filters used, we identified the area designated by the Maritime Authority as the anchorage area for the fishing boats under study. As per the coordinates for these anchorage area provided in Table 2, we selected the area at 11°46′14″ LS and 77°10′43″ LW to take our water and sediment samples, since this location is clearly impacted by boat activities when the boats are anchored.

Sample analysis

The samples taken were processed by a certified laboratory. For the sediment samples, a PAH analysis was performed as per the ES_EPA8270_PAH_MG_KG protocol, observing that the results did not evidence contamination by polynuclear aromatic hydrocarbons or their derivatives. Likewise, the TPH (C10-C40) analysis conducted as per the ES_EPA8015_TPH_MG_KG protocol also did not reveal contamination by TPH or their derivatives. However, when assessing sediment metals according to the ES_EPA3051_6020 protocol, some values were found that had to be reviewed and compared against the metals from the lubricant oil waste analysis. For the seawater samples, PAH and TPH tests were performed following the EW_EPA8270_PAH_MG_L and EW_EPA8015-TPH protocols, respectively. Both tests did not yield enough evidence to determine contamination by PAH or TPH. Finally, lubricant oil waste was assessed based on the ASTM D 5185–18 (2018) protocol, and the corresponding results were used to correlate these metals with the metal content values obtained in the sediment metal analysis (Table 3).

Table 1 Oily waste generated and motor filters discarded by artisanal fishing boats registered in the assessment area

Type of engine	Horsepower (HP)	Number of boats	Number of oil changes per year	Oil waste generated in each oil change per boat (in liters)	Oily waste generated per year (in liters)	Filters used in each oil change	Number of filters discarded per year (units)
Outboard	9	3	10	0.26	7.80	1.00	30.00
	10	4	10	0.26	10.40	1.00	40.00
	12	1	10	0.26	2.60	1.00	10.00
	14	1	10	0.27	2.70	1.00	10.00
	15	51	10	0.28	142.80	1.00	510.00
	16	21	10	0.28	58.80	1.00	210.00
	18	1	10	0.32	3.20	1.00	10.00
	20	1	10	0.32	3.20	1.00	10.00
	25	22	10	0.32	70.40	1.00	220.00
	35	1	10	0.33	3.30	1.00	10.00
	40	14	10	0.43	60.20	1.00	140.00
	60	31	10	0.61	189.10	1.00	310.00
	75	1	10	0.61	6.10	1.00	10.00
Stationary	80	3	8	9.60	230.40	2.00	48.00
	100	1	8	15.00	120.00	2.00	16.00
	120	3	8	16.00	384.00	2.00	48.00
	122	2	8	16.00	256.00	2.00	32.00
	125	1	8	16.00	128.00	2.00	16.00
	134	1	8	16.00	128.00	2.00	16.00
	145	1	8	20.00	160.00	2.00	16.00
	150	1	8	20.00	160.00	2.00	16.00
	160	1	8	20.00	160.00	2.00	16.00
	180	5	8	22.00	880.00	2.00	80.00
	195	2	8	22.00	352.00	2.00	32.00
	200	4	8	25.00	800.00	2.00	64.00
Total		177			4319.00		1920.00

Source: field work

Sample correlation

To obtain a probable contamination reference and establish the study and monitoring area for this baseline study, the metals assessed in the waste oil sample were identified against the metals found in the sediment sample. For these purposes, we performed a Spearman's Rho test based on 21 metals from the lubricant sample, obtaining a value of 0.619480. Hence, at a 95% confidence level, there is a correlation between the waste oil characterization and the sediment analysis results. In addition, a R^2 test yielded a value of 0.1284, thus, leading us to hypothesize that the metals contained in the waste oil account for 12.84% of the metals found in the sediments (Table 4).

Table 2 Vessel anchorage area coordinates according to the study

Reference	Latitude	Longitude
1	11°46′08″	77°10′37″
2	11°46′16″	11°46′32″
3	11°46′13″	11°46′56″
4	11°46′25″	11°46′44″

Source: Peru Hidronav 2231

Management system

The oily waste treatment of artisanal fishing vessels must comprehend from the generation of waste to its

Table 3 Results from sediment, seawater, and oil waste sample analyses

Sediment analysis				Seawater analysis		Oil waste analysis	
Metals		PAH and TPH-C10-C40		PAH and TPH-C10-C40		Metals	
Parameters	Results mg/kg	Parameters	Results mg/kg	Parameters	Results mg/l	Parameters	Results mg/kg
Arsenic	20,541	1-methylnaphthalene	<0.050	1-methylnaphthalene	<0.00010	Aluminum	1.6
Barium	17,834	2-methylnaphthalene	<0.050	2-methylnaphthalene	<0.00010	Barium	0,169
Lead	8458	Acenaphthene	<0.050	Acenaphthene	<0.00010	Boron	2.1
Cadmium	2553	Acenaphthylene	<0.050	Acenaphthylene	<0.00010	Calcium	3120
Chrome	14,302	Anthracene	<0.050	Anthracene	<0.00010	Cadmium	<0.10
Copper	17,158	Benz(a)anthracene	<0.050	Benz(a)anthracene	<0.00010	Chrome	<0.10
Aluminum	7129.560	Benzo(a)pyrene	<0.050	Benzo(a)pyrene	<0.00009	Copper	1.8
Antimony	0,512	Benzo(b+k)fluoranthene	<0.050	Benzo(b+k)fluoranthene	<0.00010	Iron	4.3
Beryllium	<0.173	Benzo(ghi)perylene	<0.050	Benzo(ghi)perylene	<0.00010	Lead	0.97
Bismuth	<0.103	Chrysene	<0.050	Chrysene	<0.00010	Magnesium	12.4
Boron	<17.195	Dibenz(a,h)anthracene	<0.050	Dibenz(a,h)anthracene	<0.00010	Manganese	<0.10
Calcium	9163.617	Phenanthrene	<0.050	Phenanthrene	<0.00010	Molybdenum	0.56
Zirconium	6045	Fluoranthene	<0.050	Fluoranthene	<0.00010	Nickel	<0.10
Cobalt	3651	Fluorene	<0.050	Fluorene	<0.00010	Phosphorus	1060
Scandium	1998	Indeno(1 2 3-cd)pyrene	<0.050	Indeno(1 2 3-cd)pyrene	<0.00010	Potassium	1.2
Tin	<0.940	Naphthalene	<0.050	Naphthalene	<0.00010	Silica	<0.10
Strontium	51,413	Pyrene	<0.050	Pyrene	<0.00010	Silver	0.43
Phosphorus	1535.680	TPH (C10-C40)	<15	TPH (C10-C40)	<0.15	Sodium	2.5
Iron	11,934.803					Tin	<0.10
Lanthanum	7069					Titanium	<0.10
Lithium	9400					Vanadium	<0.10
Magnesium	4787.510					Zinc	1260
Manganese	148,951						
Mercury	<0.262						
Molybdenum	4551						
Nickel	6065						
Silver	<0.268						
Potassium	1267.371						
Selenium	<3.605						
Sodium	6605.363						
Thallium	0,626						
Thorio	2395						
Titanium	508,503						
Uranium	2080						
Vanadium	31,591						
Tungsten	<0.231						
Yttrium	6046						
Zinc	37,386						

Source: Field Sample Analysis; Certified Laboratory

Table 4 List of metals used to establish a correlation between the metal values obtained from the sediment and the lubricant oil waste analyses

Metal	Sediments mg/kg	Waste oil mg/kg
Aluminum	7129.560	1.60
Barium	17,834	0.17
Boron	17,195	2.10
Cadmium	2553	0.10
Calcium	9163.617	3120.00
Copper	17,158	1.80
Chrome	14,302	0.10
Tin	0,940	0.10
Phosphorus	1535.680	1060.00
Iron	11,934.803	4.30
Magnesium	4787.510	12.40
Manganese	148,951	0.10
Molybdenum	4551	0.56
Nickel	6065	0.10
Silver	0,268	0.43
Lead	8458	0.97
Potassium	1267.371	1.20
Sodium	6605.363	2.50
Titanium	508,503	0.10
Vanadium	31,591	0.10
Zinc	37,386	1260.00

Source: Field Sample Analysis; Certified Laboratory

final disposition. It must also take into consideration its treatment and control processes. In Peru, two governmental institutions have the responsibility of the management system in accordance with Rule No. 38 of Chapter 6 of the MARPOL Convention (IMO 2002). The first institution is the National Port Authority, which is in charge of the control and treatment of waste derived from trading ships for its final disposition in the national port field (MTC-Peru 2013). The second institution is the Maritime Authority, which is in charge of establishing norms regarding technical, operative, and administrative matters; as well as planning, coordinating, operating, controlling, monitoring, and executing control and monitor actions in aquatic means regarding environmental protection and pollution prevention (MINDEF-Peru 2014); being, the national port field not included in their scope, the Maritime Authority is responsible of leading the management system design of the oil waste generated by artisanal fishing vessels.

With the purpose of maintaining a standardization in the national normative and in the absence of a normative, or a management system of oil waste applicable to artisanal fishing vessels with less than 400 GRT and 300 HP of power, an existing normative has to be taken as a base. The base norm concerning the management of oily waste is RD No. 087–2013-MTC for the Peruvian case, which could be adapted, adjusted, and implemented in the artisanal fishing vessel operations.

Discussion

There are several regulations in place that protect our marine environment from oily waste contamination from vessels over 400 GT or exceeding 300 HP. However, no regulations have been found for artisanal fishing boats operating at a lower capacity or horsepower. Likewise, the tests performed as part of this study revealed that even when the laws are taxative, none of the fishing terminals within the study area had an oily waste management system or even port waste reception facilities, thus, confirming the words from the President of the Peruvian Congress, who stated that many laws and regulations are neither executed nor enforced in the country (Palacios 2012). This was also confirmed by Lagos and Dammert (2012), who ranked Peru last among the 18 Latin American countries in terms of perception of law compliance. Therefore, any work associated with the implementation of an oily waste management system must be in accordance with the corresponding regulations but must be implemented focusing on raising awareness on marine preservation and enforcement.

In addition, Aguirre Munizaga and Moya (2014) suggest that fishing societies not only include fishers or fisheries but also all social authorities who play direct or indirect roles in these societies, such as shipbuilders, suppliers, public institutions, and the communities that support fishing activities. In this sense, the study area must exhibit these coexistence traits as ours.

In fact, we selected our study area for the implementation of a waste management system based on two referential variables: regulations and the social features exhibited by the community. Of course, our third reference was the amount of oily waste produced by fishing boats. Since 1 L of oil can contaminate 1000 L of water, the oily waste generated in this study area is enough to pollute the entire bay. Still, one of the constraints of this study is that marine currents were not considered when estimating total marine pollution rates. Also, some of the oil waste may have been discharged in land by the fishermen as there is no evidence of its final disposition, but as asserted by Lin et al. (2007), we must assume that this waste is discharged directly into the ocean since only a management system can provide evidence to the contrary.

Hydrocarbons and their derivatives are distributed throughout all ecosystems and are specially found in marine water bodies, mainly in areas with low stream activity and areas, which exhibit increased anthropogenic activity, such as bays. Since hydrocarbons are usually associated with particulate material in marine environments due to their hydrophobic nature, our assessment must first focus on finding these pollutants (Perra et al. 2009). Since these particulate materials contain hydrocarbons and heavy metals, they typically reach the seabed, where they are consumed and subsequently bioaccumulated by seafloor organisms. The first casualties are usually microscopic plankton organisms, which generate ecosystem losses (Candela-Sánchez 2006). Hence, to better assess metal waste contents, we must assess the metals found in aphids or other species residing in the area (Marín-Guirao et al. 2005). However, the tests conducted on seabed sediments taken from the assessment area provide a valuable reference for defining the area of influence for our study. In fact, these results were subsequently used to find a correlation between sediment metals and waste oil metals.

Regarding the TPH and PAH test results from water samples, none of these compounds surpassed detection limits; therefore, they were deemed as not found in these samples. This may be because of the hydrophobic nature of these components that causes them to precipitate toward the seabed or to other factors beyond the scope of this study.

Conclusions

Protecting our oceans from oily waste pollution is a worldwide concern. For example, the MARPOL agreement, which has already been adopted and implemented by several countries, can be applied to different activities, even those not explicitly provisioned therein. This study is aimed at assessing an implementation area of a waste management system based on:

(1) A full regulatory review within the area to assure compliance with the different processes established by each government, while focusing on raising awareness among the different authorities rather than on enforcing regulation during implementation
(2) Identifying a fishing area with no waste management system
(3) Estimating the amount of oily waste generated by fishing boats operating within the area
(4) Determining the anchorage area designated for small artisanal fishing boats
(5) Conducting analyses to determine the presence of PAH and TPH in the seawater and marine sediments, as well as the presence of metals in seabed sediments
(6) A characterization of lubricant oil waste and its correlation with seawater and marine sediments if sediment contamination from oily waste is indeed proven
(7) Adapting, adjusting, and implementing, the normative applied to the management of oily waste generated by trading vessels of the port field to the management of oily waste generated by artisanal fishing vessels

Our study did not find any evidence of PAH and TPH contamination, but it did find high metal values present in marine sediments. In fact, a correlation was established between these sediment metals and the metals contained in lubricant waste. Therefore, our baseline study supports the implementation of an oily waste management system based on the oily waste generation indicators and the correlation between the metals found in lubricant oil waste and marine sediments.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Code availability Not applicable.

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