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Assessment of oil pollution by Tar Ball along Red Sea Coast of Hodeidah, Yemen

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Abstract

Traffic rout of the Red Sea due to cross of many oil tankers may cause environmental damage and marine resources pollution through oil spill. A study was conducted to determine the concentrations of tar ball detected at selected locations in Red Sea Coast of Yemen to indicate the state of oil pollution. Six stations along the Red Sea coast of Yemen were selected according to their suitability and accessibility. The visual descriptions and physical characterization of each sample were clarified. The level of tar balls ranged from 0.055 to 0.631 g/m2. The significant value was recorded in the Ras Isa-II station which reflected continued discharge from tankers (ballast water and tank washing) and the spill at the Safir oil loading terminal. The nature of the tar balls at all beaches was varying from fresh to semi-hard which reflect renewable inputs of oil. The detectable tar ball along costal of Red Sea- Hodeidah, Yemen given clear indication the slightly effected by oil pollution that probably display risk to the marine organisms, human health and national economy.

***Keywords*:** Oil pollution; Evaluation; Tar Ball; Tankers; Red Sea; Yemen.

1. Introduction

Tar balls are stranded oil residues and has been used as an indicator of the impact oil pollution (Clark, 2002). Tar balls as fragments or lumps of oil weathered to a semi-solid or solid consistency, sticky to the touch and are difficult to remove from contaminated surface (Kamaruzzaman and Zain, 2016). During oil spills, the components of crude oil particularly the heavier refined products floating on the ocean surface. Physical characteristics of the oil will change, the lower molecular weight hydrocarbons will normally evaporate and the heavier compounds will spread into a thin slick. Winds and waves tear the slick into smaller patches that are scattered over a much wider area. Eventually, it will undergo several physical, biological and chemical processes which will reach the shoreline as tar balls (Chandre, et al. 2008). The tar balls can be found in several sizes from a few millimeters to tens of centimeters and are generally spherical in shape (Goodman 2003). Pollution of the marine environment due to crude oil has received widespread attention globally for example aliphatic and aromatic components. This attention are due to the serious effects to marine environment and natural resources. Indeed, some of oil compounds are toxic and persistent to the biodegradation. The sources of oil pollution in marine environment could be spills from tankers accidents, offshore operations, water balance from land-based such as domestic, industrial, agricultural operations which eventually end up being washed to the rivers or run-off and to the sea (NRC 2002). The rapid development of Yemen as an oil producing country, and its geographic position on of the world busiest shipping route means a high risk of oil pollution in various forms. There are 25,000-30,000 ship transits annually in the Red Sea and more than 100 million tons of oil is transported through the Red Sea annually (Gladstone et al.1999). There are not oilfields located along the coast of Yemen Red Sea, but there are many of petroleum service installations, such as Safir terminal supertanker that used for oil storage. Crude oil is supplied by pipeline from the Mariab oilfield to Safir tanker, and then transferred from it to other vessels which caused oil spill or leakage during the loading process. Recent oil spill accident in the coast of Yemen occurred in October 2002 by Lumburge oil tanker, spilling more than 17,000 tons discharges to Gulf of Aden (NPA 2003). Yemen as many countries of the world could be effected by oil pollution due to its position in the busiest shipping route.

The oil pollution in the Red Sea is not surprising (Dicks 1987). There are few studies that have been done to estimate the concentrations of tar balls in the Red Sea Coast of Yemen. Al-Shwafi (2000) has studied the levels of tar balls along the Red Sea coast of Yemen during 1998-1999. The levels of tar balls per square meters ranged from 0.03 to 5.95 g/m² and the concentration of total aliphatic compounds in tar balls ranged from 0.100 to 1.56 μg/g. The study concluded that the sources of tar balls were due to the oil spills at the oil terminal and tanker ballast water. The study done by SAP (2001) found the rang of oil concentration in sediment of the Red Sea 0.565 – 1.767μg/g and Gulf of Aden 3 – 9000 μg/g. Corbin et al. (1993) provided a classification for tar ball levels on beaches: 0 –1.0 g/m negligible; 1.0 –10.0 g/m low, background; 10.0 –100.0 g/m moderate; >100.0 g/m high, unusable for recreational purposes. The present study is aimed to identify the concentrations and distributions of tar balls in the selected locations in the coastline of the Red Sea of Hodeidah, Yemen. Furthermore, the visual descriptions and physical characterization were made for each sample collected and the coastline. Morphological characterizations integrated: color, extraneous material, texture, pliability, core hardness, diameter, and individual tar ball weight measurements. The results will be used as a background or baseline data for policy and decision makers in controlling and monitoring the sources of oil pollution in this area of the world.

1. Materials and Method

1.1 Study Area

Sampling stations were between khawidah and Alsallif (latitude 42° 67.0 E 16° 15.3 N and longitude 43° 23.0 E 13° 55.0 N, figure 1). These stations cover most costal line of Hodeidah city which located in the Red Sea of Yemen. Such sampling station was divided into zones, each 2 meters wide between the surf zones to the most recent high water line. The lengths were however vary between 250 to 500 m depended on the suitability and accessibility. The collection covered all tar balls in the square segment (2 m X 250 or 500 m) and collection of tar ball was repeated twice on each station. The sampling stations were chosen based on them being a) a sandy beach so that it would be easier to collect the tar ball which combines with sand more than mud, b) slow moving waters and less human activities and used vehicles which may conceal the tar balls and c) slightly sloping beach so the tar balls can be deposited as recommended by MOOPAM (1999) (figure 2).

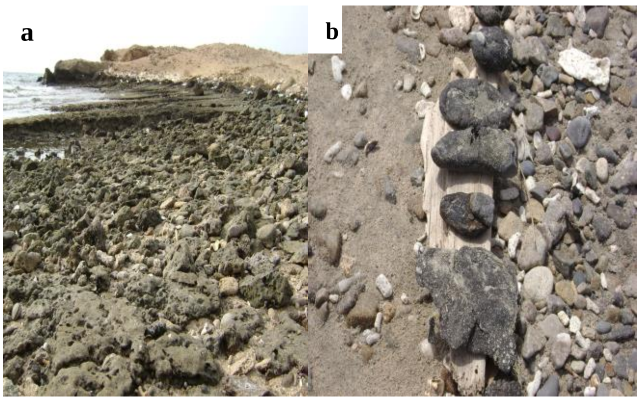

Figure 2. **a)** Ras Isa-II shoreline, **b)** Tar Ball samples in different sizes

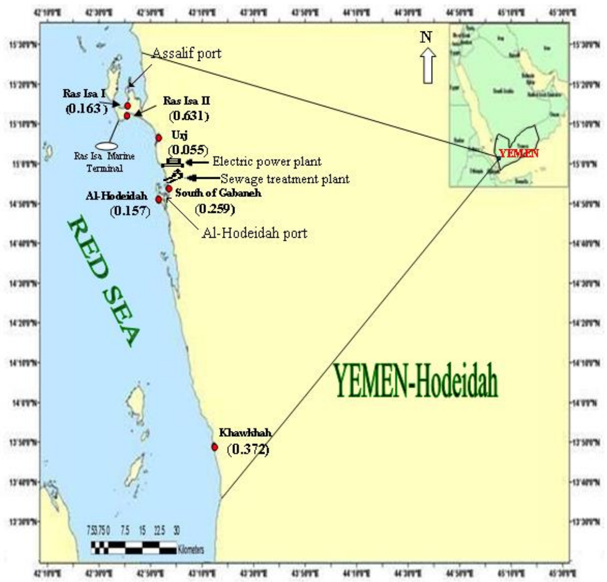

Figure 1. Location of sampling stations along the coastal line of Red Sea Yemen- Hodeidah

1.1 samples collection

The tar ball samples (figure 2) were collected carefully by spoon and cleaned from any debris like sand or coral by using a brush. They wrapped in aluminum foil and then kept in plastic bags (Ziploc) and stored in dark place for transport to the laboratory. The tar balls samples were stored under -5 ºC until analyzed.

2.3 Samples analysis

The tar balls of each location were precisely weighted by a sensitive balance after cleaned from grass, alga, sand, and shell fragment. The visual descriptions and physical characterization were identified for each samples. Morphological characterizations are integrated: color, extraneous material, texture, pliability, core hardness and diameter.

3. Results and discussion

3.1. Quantitative assessment of tar balls

Table 1 illustrates the physical characterization of tar balls at different sampling stations along the coast of Red Sea-Hodeidah, Yemen. Figure 3 shows the concentrations of tar ball in six sampling stations. The tar ball concentrations ranged from 0.055 to 0.631 g/m^2, with mean concentration of 0.27 ±0.21 g/m^2. The highest concentration was found in Ras Isa II 0.631 g/m^2 which was expected due to the continues oil spill that is occurred during load and transport of the crude oil from Safir oil loading terminal. This source of oil spill is reported by Al- Shiwafi (2000) and NPA (2003). The concentrations of tar ball in Khawkhah and Gabaneh stations were 0.372 and 0.259 g/m^2 respectively. In the south of Gabaneh, there is the electric power plant and primitive wastewater plant. Both of plants may discharge treated and untreated waste to coastal area which contribution in the increasing of tar ball level in this station. Khawkhah coast is affected by, fishing ships and boats that disposal the used crankcase oil to the sea or costal area, and tankers that cross the Red Sea. Tar ball concentrations for Ras Isa I, Urj and Al-Hodeidah stations were 0.163, 0.055, 0.157 g/m^2 respectively. The concentrations in these stations were low compared to other stations. These were due to the structure of shoreline on those stations that appeared straight which reflect low accumulation of oil slick and the variable of the environmental factors of wind speed and currents which may have transferred the tar balls to open sea or/and other sites along the coastline and then deposit them. These reasons of low concentration were similar with the reasons given by Emile Asuquo (1991) in Nigeria's tar balls survey. Finally, all sites of tar balls along the coast of Red Sea-Hodeidah, Yemen can be affected through oil spillage, direct discharge of wash tanker, ballasting activities caused by passing ships, and ports and boats activities.

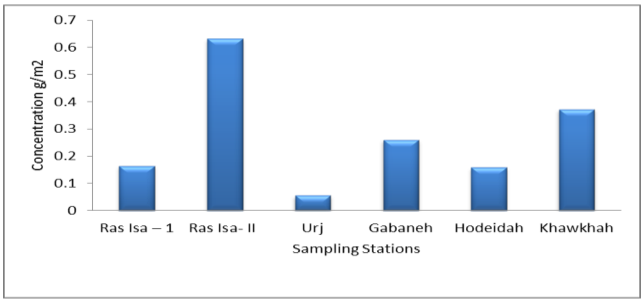

Figure 3. The concentrations g/m² of tar balls on six stations of costal Red Sea- Hodeidah, Yemen.

Table 1. The physical characterization of tar balls and locations on several stations of costal Red Sea- Hodeidah, Yemen.

No	Stations	Position	Description of Tar Balls and samples station: Tar balls	Description of Tar Balls and samples station: sampling station	Net weight of tar ball (g) (Rang)	Area of Stations (m²)
1	Ras Isa – 1	N 15° 12.360 E 42° 39.973	Tar balls sticky on rock mixed with sand and shell fragment. Fresh-soft tar ball. Pliable tar balls.	Wide tough sand beach- covered with coarse shell fragments and coral reef rock. gentle slope.	162.81 (9.99- 24.76)	1000
2	RasIsa- II	N 15° 14.144 E 42° 40.469	Tar balls in form of small flat thin mixed with sand and covered by alga. Soft fresh-tar ball. Pliable tar balls.	Broad coarse sandy, shells beach. Gentle slope.	441.78 (36.7 - 72.2)	700
3	Urj	N 15° 06.309 E 42° 52.361	Tar balls in shape of small, medium mixed with sand and covered by brown alga, Old and fresh tar ball. Some non-pliable tar balls. Some others pliable.	Fin sand- little of mud. It is estuary-slightly slope.	38.75 (1.12 - 28.89)	700
4	Gabaneh	N 14° 53.651 E 42° 56.944	Tar balls stocky on rock – fresh- old tars- Some non-pliable tar balls. some others pliable	Fin sand beach covered by sponge and grant rock. slightly slope	181.37 (40.00 - 76.41)	700
5	Hodeidah	N 14° 51.391 E 42° 53.068	Tar balls were mixed with sand and bi-valves-. Fresh and soft tar balls. Pliable tar balls.	Long Fin grey sandy beach- little slope-slightly slope	125.56 (8.57- 36.99)	800
6	Khawkhah	N 13° 49.856 E 42° 13.919	Tar balls in form of big flat and mixed with sand and coral reef fragment Fresh soft and semi-hard old tar balls. Pliable tar balls.	Long wide sandy beach-medium coral reef fragments with brown alga. Gentle slope.	371.55 (3 - 70.14)	1000

The area which contains the least quantities of tar balls can be considered polluted than other regions of the world. Table 2 shows a comparison of the concentration of tar balls found in this study with data from other regions of the world. The comparison indicates that the abundances determined in the present study were sometimes exceedingly low and approximately lower by 1340 to 37 orders of magnitude than the tar balls estimated by other studies in Dominica coast (Corbin et al. 1993), United Arab Emirates coast (Abu- Hilal, 1993), Oman coast (Coles & Al-Riyami 1996), and Saudi Arabia (Jeddah) (Oostdam, 1984). The high levels of tar balls in different locations of the world could be said to be the result of continuous deposition of oil (crude and products) derived from different pollutant sources: atmospheric input, run-off to coastal environment from refineries and oil wastes, drilling operation, pipelines and shipping 'notably spill from vessels' (Al- Shiwafi 2000; Coles & Al-Riyami 1996; Coles & Gunay 1989; Gabche et al. 1998; Asif et al., 2022). The tar balls here are nearly similar to the levels present in the coast of south-east Nigeria (Antia,1993), and Red Sea coast of Yemen (Al- Shiwafi, 2000). In general, the tar ball levels in along Red Sea Coast of Hodeidah, Yemen is low in compared with the findings from previous studies. The low levels of tar ball in most beach of oil producing countries are probably due to improved regulation of oil dumping and replacement of older tankers with ships equipped with separate ballast systems or mechanisms for reducing release of oil with water deballasting (Coles and Gunay, 1989). The other reasons may be due to the differences of physical environments like; speed and direction of wind, prevailing currents, water temperature, geological structure of the beach, quantities of oil introduced to this environment, and distance from shipping lines (Al-Shiwafi 2000). High temperature will lead to the increase activity of weathering processes (spreading, evaporation, emulsification, dispersion and biodegradation, photo-oxidation) (Literathy 1993).

Table 2. Comparison of tar ball concentrations collected from different locations worldwide.

Site	mean concentration	Rang	Reference
Dominica coast	10.1 g/m	0.6 –37.0 g/m*	Corbin et al. 1993
Nigeria coast	000 g/m²	8 – 40 g/m²**	Antia,1993
Cameroon shoreline	1.76 g/m²	0.11 – 4.8 g/m²	Gabche, 1998
Sudan coast	129.6 g/m	45.0 – 169.2 g/m	Oostdam, 1984
Arabian Sea	0.25 mg/m²	0 – 4.6 mg/m²	Sen Gupta, 1993
United Arab Emirates coast	361.7 g/m	0 – 48600 g/m	Abu- Hilal, 1993
Egyptian Red Sea Coast	0.493 mg/ m²	0.0 – 2.49 mg/ m²	Hanna, 1983
Red Sea Coast of Yemen	000 g/ m²	0.03 – 5.95 g/ m²	Al- Shiwafi, 2000
south-east Nigeria Coast	0.4 g/ m²	0.04 – 1.39 g/ m²	Asuquo, 1991
Oman Coast	115.1 g/ m	0 – 5230 g/m	Coles & Al-Riyami, 1996
Saudi Arabia (Jeddah)	29.8 g/m	………non………..	Oostdam, 1984
Red Sea Yemen-Hodeidah	**0.27 g/ m²**	**0.055 – 0.631 g/ m²**	**Present Study, 2008**

* The results in gram per length (g/m) ** The results in gram per area (g/m²)

4. Conclusion

The concentrations of tar ball were measured along costal line of Red Sea - Hodeidah, Yemen. The nature of the tar balls at all beaches was varying from fresh to semi-hard which reflect renewable inputs of oil. The high concentration of tar balls that detected at Ras Isa-II station was due to oil spill during load and transport of the crude oil from Safir oil loading terminal and other oil tankers. The area which contains the least quantities of tar balls can be considered polluted and posed significant environmental and health risks to marine organisms, human and socio-economic sector. Therefore, the monitoring of oil pollution by annual survey on the level of tar balls along the coastline of Yemen is more encourage for protection and sustainability of the Red Sea resources.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conficts of interest.

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