International Journal of Applied Sciences: Current and Future Research Trends
(IJASCFRT)
ISSN (Print) , ISSN (Online)

https://ijascfrtjournal.isrra.org/index.php/Applied_Sciences_Journal

History, Adverse Effect and Clean Up Strategies of Oil Spillage

Abdulhalim Musa Abubakar[a*], Musa Alhassan[b]

[a]*Department of Chemical Engineering, Faculty of Engineering, Modibbo Adama University (MAU), P.M.B 2076, Yola, Adamawa State, Nigeria*

[b]*Department of Chemical Engineering, Faculty of Engineering, University of Maiduguri (UNIMAID), P.M.B 1069, Maiduguri, Borno State, Nigeria*

[a]*Email: abdulhalim@mautech.edu.ng*

[b]*Email: musaalhassan@ymail.com*

Abstract

Over 178 billion liters of oil had been lost to the environment over the past 120 years, majorly as a result of improper handling, sabotage and accidents. Estimated cost of this lost is 81 billion US dollars. From the highest, locations most impacted by the spills are Kuwait, United States, Persian Gulf, Mexico and Nigeria. The effect is felt as a whole by living organisms (birds, livestock, plants, soil micro-organisms, fish, intertidal fauna, dwarf seahorse, humans etc) and their habitats. This paper investigates, clean up techniques like boom, skimmers, berms, dispersants, in-situ burning, sorbents, bioremediation and high-pressure hosing, noting that none of these is effective and search has to continue towards finding a more effective clean up approach. It can be concluded that the best way to tackle the menace of oil spillage is prevention.

Keywords: Oil spill; Clean up; Oil recovery; Oil Tankers; List of oil spills.

1. Introduction

Oil is one of the main drivers for the growth of modern economies because of its multifaceted use in transport, energy and manufacturing [1]. Levine (2002) estimated that 3.65 billion gallons of oil per day is consumed worldwide. Contaminated soils often occur as a result of leaking underground storage tanks, vandalization of pipeline, leakage of surface storage tanks, indiscriminate disposal of oil on the grounds on/off loading of the oil in various refineries/processing plants and depots [2,3]. Natural oil spills can occur through petroleum seep, which occurs due to activity inside the earth causing the escape of liquid or gaseous hydrocarbons to the earth's surface [4].

---

* Corresponding author.

When a spill event occurs, one of the most important predictors of impact is its location. Spills closer to shore and human populations have greater economic impacts and are more expensive to clean [5]. Effects on sea shores tend to be caused by organisms becoming coated or smothered by oil, as depicted in Fig. 6. This inhibits or prevents movement, excludes oxygen and clogs respiratory surfaces, excludes light required by seaweeds, phytoplankton and corals, and penetrates the feathers of seabirds, affecting their buoyancy and water repelling and thermal insulating properties [6].

The oil spill clean-up and recovery techniques (as in Fig. 8-10) are challenging and usually involve complex mechanical, chemical, and biological methods. Usually, mechanical removal of free oil is utilized as an effective strategy for clean-up in aquatic and terrestrial environments; however, they are expensive and need specialized personnel and equipment [7]. Three different types of equipment—booms, skimmers, and sorbents—are commonly used to recover oil from the surface [8]. Towards ensuring an environmentally friendly approach of major oil spills, Scientists have developed a new type of nanosponge that can absorb more than a hundred times its own weight in oil and which can be reused over and over again [9].

2. Oil Spillage across the Globe

As oil transportation worldwide continues to increase, many communities are at risk of oil spill disasters and must anticipate and prepare for them [5]. Zhang and his colleagues (2015) finds that 90% of oil is transported via sea where Galierikova and his colleagues (2020) asserts that Asia-Pacific, Europe and North America consumes this product the most; and this oil comes from Middle East and the former Soviet Union where its concentration is highest.

Figure 1: Oil Leaking from a Barge off the North Coast of Puerto Rico [10]

The world have recorded major spills of damaging effects continuing from 1900s till this present time. Those spills are either onshore or offshore (Figure 1) and are measured in volumetric units. It is established by [11], that 1 tons of crude oil is equivalent to 7.33 barrels (= 307.86 US Gallons or 1165 litres). A list of spills from 1000 tonnes (approximately 7000 barrels) of crude oil and above that occurred across the globe is recorded in Table 1:

Table 1: Maximum Oil Spill Volume across the Globe from 1900-2021

Rank	Date	Location	Spill Name	Size of Spill		
				US Gallons	Litres	Barrels
1	1991	Kuwait	**Kuwaiti Oil Fires**	41999999993	1.58936E+11	999999999.8
2	1991	Kuwait	**Kuwaiti Oil Lakes**	2098989480	7942970000	49975940
3	1910	United States	**Lakeview Gusher**	378000000	1430422920	9000000
4	1991	Persian Gulf	**Gulf War Oil Spill**	252445200	955300000	6010600
5	2010	United States	**Deepwater Horizon**	193028220	730455000	4595910
6	2004	United States	**Taylor Energy**	150851400	570850000	3591700
7	1979	Mexico	**Ixtoc I Oil Well**	139768440	528910000	3327820
8	1976-1996	Nigeria	**Niger Delta**	99517743.01	376593810.9	2369470.07
9	1979	Trinidad & Tobago	**Atlantic Empress**	88355820	334355000	2103710
10	1979	Uzbekistan	**Fergana Valley**	87740100	332025000	2089050
11	1991	Angola	**ABT Summer**	80043600	302900000	1905800
12	1983	Persian Gulf	**Nowruz Field Platform**	80043600	302900000	1905800
13	1983	South Africa	**Castillo De Bellver**	77580720	293580000	1847160
14	1994	Russia	**Komi Oil Pipeline**	77507757.18	293303895	1845422.79
15	1978	France	**Amoco Cadiz**	68652780	259795000	1634590
16	1991	Italy	**Haven**	44331840	167760000	1055520
17	1980	Libya	**Production Well D-103**	43100400	163100000	1026200
18	2018	China	**Sanchi Oil Tanker Collision With CF Crystal**	42484680	160770000	1011540
19	1988	Canada	**Odyssey**	40637520	153780000	967560
20	1967	United Kingdom	**Torrey Canyon**	36635340	138635000	872270

21	1972	Oman	**Sea Star**	35403900	133975000	842950
22	2018	China	**Sanchi**	34788180	131645000	828290
23	1971	Belgium	**Texaco Denmark**	32941020	124655000	784310
24	1980	Greece	**Irenes Serenade**	30786000	116500000	733000
25	1976	Spain	**Urquiola**	30786000	116500000	733000
26	1940	United States	**Greenpoint, Brooklyn**	29999999.56	113525626.9	714285.7037
27	2010	Nigeria	**Exxonmobil**	29400630	111257500	700015
28	1977	Hawaii	**Hawaiian Patroit**	29246700	110675000	696350
29	1979	Turkey	**Independenta**	29246700	110675000	696350
30	2010	China	**Xingang Port Oil Spill**	27707400	104850000	659700
31	1975	Portugal	**Jakob Maersk**	27091680	102520000	645040
32	1993	United Kingdom	**Braer**	26168100	99025000	623050
33	1992	Spain	**Aegean Sea**	22781640	86210000	542420
34	1992	Mozambique	**Katina P**	22165920	83880000	527760
35	1996	United Kingdom	**Sea Empress**	22165920	83880000	527760
36	1985	Iran	**Nova**	21550200	81550000	513100
37	1989	Morocco	**Khark 5**	21550200	81550000	513100
38	1979	Ireland	**Betelgeuse**	19703040	74560000	469120
39	2002	Spain	**Prestige**	19395180	73395000	461790
40	1975	Puerto Rico	**Epic Colocotronis Spill**	18779460	71065000	447130
41	1970	Sweden	**Othello**	18471600	69900000	439800
42	1974	Chile	**Vlcc Metula**	15700860	59415000	373830
43	1968	South Africa	**World Glory**	14161560	53590000	337180
44	2012	Venezuela	**Guarapiche River**	12622260	47765000	300530
45	1976	Colombia	**Saint Peter**	11715920.16	44335240	278950.48

46	2020	United States	**2020 Colonial Pipeline Gasoline Spill**	11698680	44270000	278540
47	1989	United States	**Exxon Valdez**	11390820	43105000	271210
48	1975	United States	**Corinthos**	11082960	41940000	263880
49	1977	Taiwan	**Borag**	10467240	39610000	249220
50	1971	United States	**Texaco Oklahoma**	9697590	36697500	230895
51	1077	South Africa	**Venpet-Venoil Collision**	9389730	35532500	223565
52	2009	Australia	**Montara Oil Spill**	9235800	34950000	219900
53	1973	Chile	**Napier**	9235800	34950000	219900
54	2006	Lebanon	**Jiyeh Power Station Oil Spill**	9235800	34950000	219900
55	2003	Pakistan	**Tasman Spirit**	9235800	34950000	219900
56	1954-1994	United States	**Guadalupe Oil Field**	8927940	33785000	212570
57	1976	United States	**Argo Merchant**	8620080	32620000	205240
58	1977	Norway	**Ekofisko Oil Field**	8496936	32154000	202308
59	1971	South Africa	**Wafra**	8312220	31455000	197910
60	1958	United States	**African Queen**	6465060	24465000	153930
61	1975	Brazil	**Tarik Ibn Ziyad**	6157200	23300000	146600
62	1967	United States	**R.C. Stoner**	6157200	23300000	146600
63	2020	Russia	**Norilsk Diesel Fuel Spill**	5387550	20387500	128275
64	1991	Australia	**Kirki**	5319820.8	20131200	126662.4
65	1981	Soviet Union	**Globe Asimi**	5233620	19805000	124610
66	1990	United States	**Mega Borg Oil Spill**	5079997.86	19223665	120952.33
67	1973	Sweden	**Jawachta**	4925760	18640000	117280
68	1994	United Arab Emirates	**Seki**	4894974	18523500	116547
69	1962	United States	**Mississippi River Oil Spill (1962-1963)**	4617900	17475000	109950
70	1969	United States	**Santa Barbara**	4310040	16310000	102620

71	1980	France	**Tanio Oil Spill**	4156110	15727500	98955
72	1978	Chile	**Cabo Tamar**	3848250	14562500	91625
73	1968	Puerto Rico	**Ocean Eagle**	3848250	14562500	91625
74	2002	Yemen	**Limburg (Bombing)**	3755892	14213000	89426
75	2005	United States	**Bass Enterprises Oil Spill (Hurricane Katrina)**	3694320	13980000	87960
76	2007	South Korea	**Hebei Spirit**	3386460	12815000	80630
77	2007	South Korea	**Korea Oil Spill**	3324888	12582000	79164
78	1970	Canada	**SS Arrow**	3180193.8	12034450	75718.9
79	1978	Brazil	**Brazilian Marina**	3090606.54	11695435	73585.87
80	1989	South Africa	**Pacificos**	3078600	11650000	73300
81	1972	South Africa	**Oswego-Guardian/Texanita Collision**	3078600	11650000	73300
82	1988	United States	**Ashland Oil Spill**	3078600	11650000	73300
83	2001	Nigeria	**Shell Ogbodo**	2924670	11067500	69635
84	1984	United States	**Alvenus**	2819997.6	10671400	67142.8
85	1937	United States	**SS Frank H. Buck/ SS President Coolidge Collision**	2730718.2	10333550	65017.1
86	2008	United States	**2008 New Orleans Oil Spill**	2709168	10252000	64504
87	1979	United States	**Burmah Agate**	2598338.4	9832600	61865.2
88	1907	United Kingdom	**Thomas W. Lawson**	2436000.743	9218283.85	58000.0177
89	1987	Chile	**Cabo Pilar**	2308950	8737500	54975
90	2006	United States	**Citgo Refinery**	2001090	7572500	47645
91	1997	Japan	**Nakhodka**	1921046.4	7269600	45739.2
92	1980	Czechoslovakia	**Druzhbia Pipeline**	1847160	6990000	43980
93	2011	Nigeria	**Niger Delta**	1679992.02	6357405	39999.81

94	1998	Nigeria	**Mobil Nigeria Oil Spill**	1679992.02	6357405	39999.81
95	1973	Puerto Rico	**S.S. Zoe Colocotronis Spill**	1591636.2	6023050	37896.1
96	1968	Bahamas	**General Colocotronis**	1553769.42	5879755	36994.51
97	2013	Canada	**Lac-Megantic Derailment**	1486963.8	5626950	35403.9
98	1984	United States	**Puerto Rican**	1470031.5	5562875	35000.75
99	2014	Israel	**2014 Israeli Oil Spill**	1323798	5009500	31519
100	2020	Mauritius	**2020 Pointe D'esny Mv Wakashio Oil Spill**	1323798	5009500	31519
101	1999	France	**Erika**	1260000.172	4768077.05	30000.0041
102	1968	South Africa	**Esso Essen**	1259763.12	4767180	29994.36
103	2007	Norway	**Statfjord Oil Spill**	1231440	4660000	29320
104	2011	Canada	**Little Buffalo Oil Spill**	1169868	4427000	27854
105	2005	United States	**Shell (Hurricane Katrina)**	1077510	4077500	25655
106	2005	United States	**Murphy Oil USA Refinery Spill (Hurricane Katrina)**	1049802.6	3972650	24995.3
107	2010	United States	**Kalamazoo River Oil Spill**	1000545	3786250	23822.5
108	1989	United States	**World Prodigy**	999313.56	3781590	23793.18
109	2005	United States	**Chevron (Hurricane Katrina)**	985152	3728000	23456
110	2013	United States	**North Dakota Pipeline Spill**	865086.6	3273650	20597.3
111	1971	United States	**Arizona Standard/Oregon Standard Collision**	831222	3145500	19791
112	2020	Venezuela	**El Palito Refinery**	831222	3145500	19791
113	1994	Puerto Rico	**Morris J. Berman**	800436	3029000	19058
114	2017	Greece	**Agia Zoni Ii**	769650	2912500	18325
115	2010	Singapore	**Mt Bunga Kelana 3**	769650	2912500	18325

116	1996	United States	**North Cape**	769650	2912500	18325
117	1994	South Africa	**Apollo Sea**	738864	2796000	17592
118	1990	United States	**Apex Barges Oil Spill**	677292	2563000	16126
119	1978	United States	**Trans-Alaska Pipeline Sabotage by Explosives**	665593.32	2518730	15847.46
120	1968	Panama	**Witwater**	588012.6	2225150	14000.3
121	2007	Mexico	**Kab 101**	575390.34	2177385	13699.77
122	1990	United States	**Arthur Kill Pipeline**	566462.4	2143600	13487.2
123	1991	Saint Kitts & Nevis	**MB Vesta Bella**	558458.04	2113310	13296.62
124	2004	United States	**MV Selendang Ayu**	480261.6	1817400	11434.8
125	1978	Puerto Rico	**Peck Slip Spill**	477183	1805750	11361.5
126	2006	Phillippines	**Guimaras Oil Spill**	474104.4	1794100	11288.2
127	2010	United States	**Port Arthur Oil Spill**	461790	1747500	10995
128	2005	United States	**Bass Enterprises (Hurricane Katrina)**	461790	1747500	10995
129	1953	United States	**SS Jacob Luckenbach**	456864.24	1728860	10877.72
130	2000	South Africa	**Treasure**	431004	1631000	10262
131	1985	United States	**Grand Eagle**	431004	1631000	10262
132	2017	United States	**Keystone Pipeline 2017 Spill**	406990.92	1540130	9690.26
133	1903	Australia	**SS Petriana**	400218	1514500	9529
134	2015	United States	**Illinois Train Derailment**	400218	1514500	9529
135	2013	United States	**North Dakota Train Collision**	400218	1514500	9529
136	1950(?)-1996	United States	**Avila Beach Pipeline**	400218	1514500	9529
137	2017	United States	**Delta House Floating Production Platform Spill**	394060.8	1491200	9382.4
138	2020	United States	**Keystone Pipeline 2019 Spill**	381746.4	1444600	9089.2

139	2010	United States	**Trans-Alaska Pipeline**	369432	1398000	8796
140	2001	Taiwan	**Amorgos Oil Spill**	354039	1339750	8429.5
141	2012	United States	**Arthur Kill Storage Tank Diesel Spill (Hurricane Sandy)**	347881.8	1316450	8282.9
142	2000	Brazil	**Petrobras Pipeline**	338646	1281500	8063
143	2016	United States	**2016 Colonial Pipeline Leak**	336183.12	1272180	8004.36
144	1973	Venezuela	**Trinimar Marine Well 327**	335875.26	1271015	7997.03
145	2019	Brazil	**Northeast Brazil Oil Spill**	307860	1165000	7330
146	2008	Nigeria	**Shell Bodo Pipeline Oil Spill**	307860	1165000	7330
147	1953	South Africa	**Sliedrecht**	307860	1165000	7330
148	2007	Ukraine	**Kerch Strait Oil Spill**	307860	1165000	7330
149	1976	United States	**Nepco 140**	307860	1165000	7330
TOTAL				**46,985,668,525**	**177,802,585,043**	**1,118,706,393**

Data in Table 1 contained spills recorded for over 120 years, excluding spill incidents whose volumes are less than 307,000 gallons. A total of more than 149 incidents occurred worldwide. The table also summarized spill events for Nigeria [year ranging from 1976-1996], as culled from Inoni and his colleagues (2006); and the United States [1950(?)-1996 & 1976-1996]. Other sources used are Patel and his colleagues (2017), Melina (2010), ITOPF (2019) and Wikipedia (2013).

Above is a list of 52 countries where oil spill had triggered world outcry for the past 12 decades. Some of these countries had experience spill events almost on yearly basis. Countries like the United States (US) and Nigeria, ranked 2nd and 5th in the world currently, cumulatively lost approximately 21 million and 3.3 million barrels respectively of petroleum products to the ecosystem.

It is estimated that around 47 billion US gallons of crude oil had been spilled across the globe. Since 1991 to this present day, no country recorded oil-related offensive on the terrestrial environment than Kuwait, spilling over 1 billion barrels of crude oil/product; a value representing approximately 93.85% of total spill (Figure 2) in world history. Forty eight countries takes just 3.3% of the world total spill. It can be deduced from Figure 2, that only 0.71% of the spill was recorded in the Persian Gulf, an area surrounding UAE, Bahrain, Kuwait, Saudi Arabia, Iran, Qatar and Iraq.

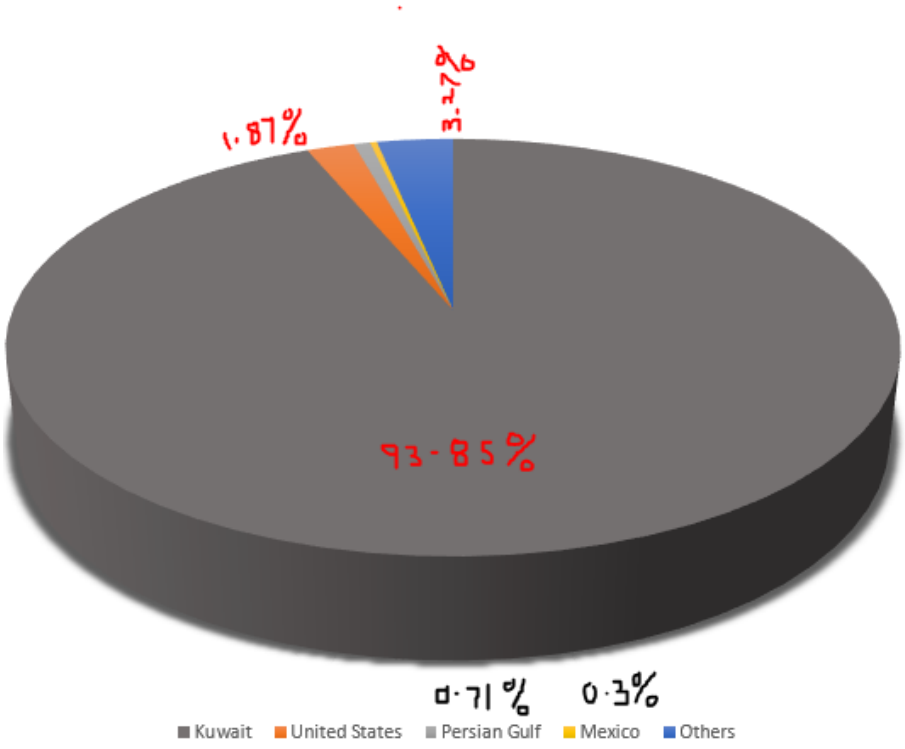

Figure 2: Percentage of Spill from 1900-2021 for 25 Countries

A spill is not peculiar to countries producing crude oils/product, but any country making use of the substance, as smaller countries like Chile, Mauritius, Saint Kitt and Nevis and others are not left out (see Figure 3).

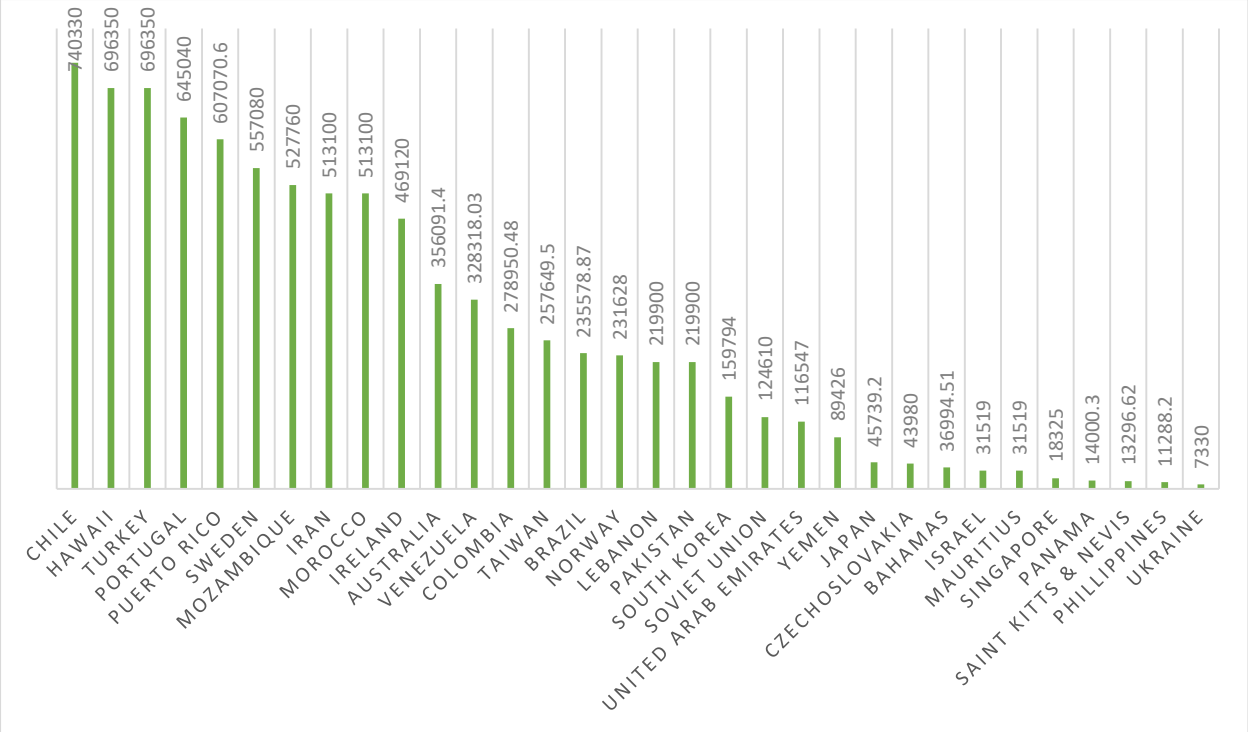

Figure 3: 32 Countries Showing Barrels of Crude Oil Spill Up to 2021

3. Causes and Hazards

Spills are unpredictable events. They constantly occur and are summarily caused by;

a) Sabotage: Crude oil theft, terrorists attack, countries at war, vandals and illegal dumpers detrimentally cause severe damage to nation's economy also leading to huge loss of lives.
b) Natural gas flaring
c) Corroded oil pipelines
d) Mistakes caused by reckless handling
e) Natural disaster: Catastrophic weather conditions like hurricanes undoubtedly could result in oil boats summersaulting and emptying its content into water bodies.
f) Leakages from faulty oil tanks: Obvious is the fact that oil spills from tankers or ships due to accidents, seriously affects human/animal health, crew's life (leading to economic losses to individual cargo/tanker owners) and revenue loss to a nation. Vancouver is an example of a coastal metropolitan area facing the possibility of substantially increased oil tanker traffic and the associated risk of oil spills [5].

Figure 4: Leakage Caused by Barge and Towboat Collision in Lower Mississippi River [12]

g) Oil well drilling
h) Equipment breakdown: Maintenance activities of oil companies in recent years had adversely affected the environment, with large volume being spilled on farmlands and rivers, depriving the host communities of their means of livelihood.
i) Accidents: As seen in Figure 4, U.S. Coast guard reported that Barge E2MS 303 collided with a towboat on February 22, 2014 and began leaking 750 barrels of Bakken crude oil into the lower Mississippi River [12].
j) Explosions of terminals/wells/stations

Hazards of crude oil exposure through spillage in broad sense, affects living organisms (humans, plants, animals and micro-organisms) and their habitats:

3.1. Impacts on Environment

Ideally, when oil spills, natural actions like weathering, evaporation, oxidation, biodegradation and emulsification reduces its severity and accelerates the recovery of the affected area. It is very rare for oil to sink. It needs to adhere to heavier particles such as sand, algae, or silt to sink. An exception is a kind of oil used for burning in electric utility plants. This oil can actually sink in water since it is heavier than water [10]. Regarding oil spillage impact on the soil, a study was done by Abdulrahman and his colleagues (2020) on soils found in Northern Nigeria where oil exploration began in 2018 (by allowing crude oil to infiltrate into the soil for six weeks) and results show negative consequences for road and building construction as the material physical property of the soil is altered. Soil properties like acidity, colour, nutrients and weight are strongly impacted by oil spill as investigated by Dorris (2010).

Figure 5: A Devastated Farmland in Ogoniland (Nigeria) Source: [13]

Deliberate or accidental spill on the environment (especially land-Figure 5) affects food production in several ways. They are; altered taste of produce, soil fertility reduction, burning and yellowing of crop leaves, contamination of water sources of livestock, outbreak of diseases and death of livestock, decay of tuber plants, increased soil temperature and toxicity, destruction of soil micro-organism etc. In water bodies, aquatic animals are severely injured and killed. Therefore, contaminated soil must be treated and washed before safely disposing it of in a landfill site.

3.2. Impacts on Humans

As stated by Shultz and his colleagues (2014), 45000 Gulf cleanup manpower during the Deepwater Horizon Oil Spill of 2010 developed oil-spill-associated illnesses (some of which are heat stress, sprains, respiratory complaints, dispersant and oil-contact skin problems) due to non-compliance to use of personal protective equipment (PPE). Potential sources of oil pollution in Denmark as identified by [14] are: (i) operational discharge from ships, (ii) accidental spill from ships, (iii) operational discharge from offshore production, (iv) accidental spills from offshore production, and (v) land based discharges.

In Nigeria, oil was first discovered in Ogoniland of Rivers State in 1958; a hunting, fishing and agrarian society in the Southern part of the country, often called the Niger-Delta… comprising of nine states, which are Rivers, Ondo, Imo, Edo, Delta, Cross-River, Bayelsa, Akwa-Ibom and Abia (just 7.5% of Nigeria's total land mass). Possible causes of oil spills in Nigeria according to [14] and [15] are loading/discharging of oil, bunkering, pipeline vandalization (about 800 reported cases in year 2000 alone), fire & explosion and routine ship operations. Intermittent oil spillage have rendered vast stretches of indigenous farmlands useless [15]. Health-wise, effect of these are impaired lung function, tracheities, skin reactions, chemical bronchitis and other hazards like choking from smoke, trauma and water contamination as evidenced in the research carried out by Nwachukwu and his colleagues (2014) on water quality of Abacheke community of Imo State of Nigeria. Also discovered is that ocular anterior segment disorders are prevalent in communities affected by oil spillage and could be due to exposure to petroleum-related chemical irritants [16].

3.3. Impacts on Micro-organisms and Other Animals

Oil floats on fresh water (rivers & lakes) and salt water (oceans), rarely sinking when heavy in freshwater [12]. With a lighter density than water, oil released into the marine environment usually makes its way to the sea surface, forming oil sheens, slicks (Fig. 1), or emulsions of gas, water, and oil commonly referred to as 'mousse' [17]. Oil can affect marine organisms by coming into contact with either the external or internal body surface [6].

Microalgal community (predominated by pinnate diatoms, and including cyanobacteria, chlorophyta, chrysophyta and few species of centric diatoms) found in the sandy beach of the estuary to a recent oil spill had been investigated by Essien and his colleagues (2005) concluding that a significant percentage is lost as a result of the spill.

Fish species that live or spend time close to the water surface, the shore, or the sea floor in shallow water are the most vulnerable to oil spills. Plankton are killed by relatively low concentrations of oil, but are present in such numbers that lost individuals are replaced quickly with little detectable disturbances. Benthic species can be killed when large amounts of oil accumulate on the bottom sediments. Animals are also at risk from ingesting oil, which can reduce the animal's ability to eat or digest its food by damaging cells in the intestinal tract [8].

Figure 6: A Bird Coated with Oil

The two major pathways of oil exposure for birds are fouling of the feathers (Fig. 6) and ingestion [18]. Upon contact, bird's feather loses its function of buoyancy, insulation and flight. When a seabird's feather contacts (atleast 10 ml of oil) slicks on shorelines or water, the birds rapidly lose its body heat and may lead to death [6]. This concentration varies with organism involved and may reach up to a maximum of 20,000ppm. On land, heat lost is not severe and birds may survive but could contaminate their eggs or young in which only a few drop is enough to kill them. Egg laying may stop or reduce with small ingestion of oil as well as hatchability of the eggs [10]. Coastal dolphins, after chronic exposure will face a long-term health challenges.

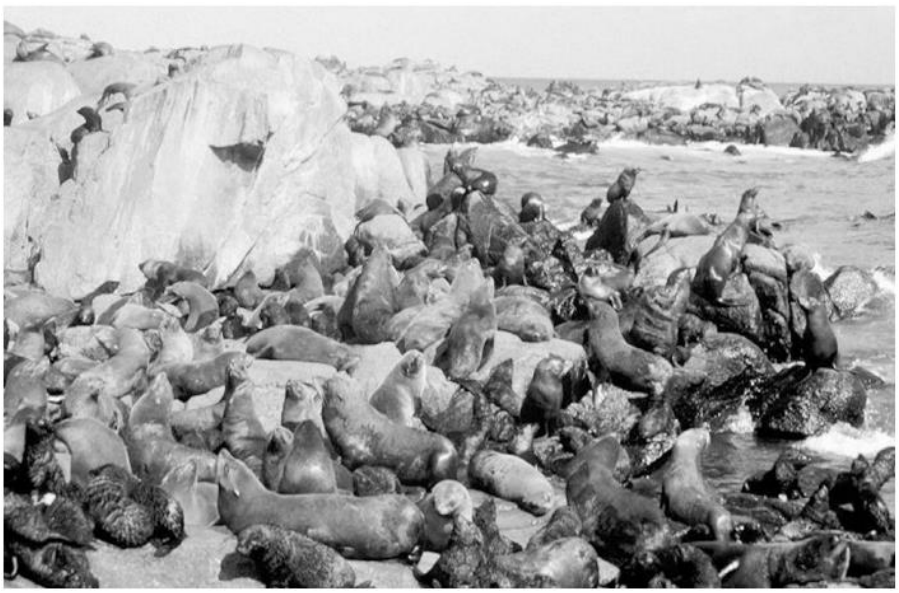

Figure 7: A Scene in Uruguay where 10000 Baby Seals Perished by a Rocky Shoreline

As depicted in Fig. 7 [18], after a large oil spill in South America, about 10,000 baby seals perished when the beaches of their island were contaminated by oil. Older seals, sea lions, and walruses can take a large amount of oiling without causing death.

4. Compensation and Cleanup Strategies

Loses due to petroleum spills are immense set back to nations. It is therefore important to device a workable environmentally friendly curtailing strategy to prevent or reduce the adverse effect caused by oil spilled on land or waters. Developing a safe clean up strategies in addition to creating laws sanctioning deliberate reckless attitude of oil workers that resulted in the spill will go a long way in (at least) mitigating the problem.

4.1. Enacting Laws

Agu and his colleagues (2015) suggested that the oil companies responsible for oil exploration like Shell, BP and others be compelled to pay adequate compensation to the people when such devastation occurs. Example where such was done was in the United States where victims of the Exxon Valdez oil spill (Table 1) were compensated after the swift passage of the Oil Pollution Act of 1990 (OPA 1990) as well as the Deepwater Horizon oil spill incident as reported by Ramseur (2015). Nigeria's first step towards addressing crude oil spill issues was becoming a member of the International Maritime Organization (IMO) as well as establishing the Ministry of Environment. It is again necessary to order clean up by authorities to companies responsible for such spills. Even though, clean up is costly and time consuming, clean-up expenses are minor compared to the negative impact on an organization's brand and image.

4.2. Clean up Procedures

There are many methods of crude oil clean up for land and sea oil spills. Factors affecting the selection of these

methods are shoreline geology and rate of water flow, oil type, and sensitivity of organisms affected to the clean up strategy. These are explained below:

4.2.1. Containment and Recovery

Containment of an oil spill refers to the process of confining the oil, either to prevent it from spreading to a particular area, to divert it to another area where it can be recovered or treated, or to concentrate the oil so it can be recovered or burned [19]. A boom is a floating mechanical barrier designed to stop or divert the movement of oil on water. Booms are generally the first equipment mobilized at a spill and are often used as long as the oil persists on the water surface [8,18].

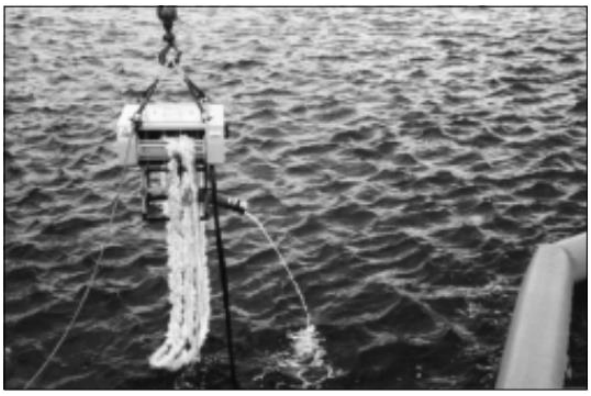

Figure 8: Oleophilic Skimmer [8]

Recovery is the next step after containment in an oil spill cleanup operation. Skimmers (Fig. 8) are mechanical devices (examples are oleophilic, weir and suction) designed to remove floating oil from a water surface [8]. They vary greatly in size, application, and capacity, as well as in recovery efficiency. Skimmers are classified according to the area where they are used, for example, inshore, offshore, in shallow water, or in rivers, and by the viscosity of the oil they are intended to recover [18]. Skimmers separate oil from the water by: centripetal force, lifting oil on a conveyor belt off the water surface or wringing out the oil that clings to oleophilic (oil-attracting) rope mops. This technique is the most widely used as it is least destructive and only 10-15% efficient under even the best circumstances [10].

Scrapers, bulldozers and front-end loaders are also mechanical recovery equipment (used in limited capacity), having potentials of causing severe and long-lasting damage to sensitive environments. Possible areas of applications are agricultural land, roadsides and urban areas. Construction of berms/trenches/dikes are temporary or permanent method of containment involving the setting of barriers (using retaining walls, soil, sand bags or construction material) in the path of oil to prevent oil from spreading horizontally. This enhances oil recovery from the dogged trenches or burned by in situ burning.

4.2.2. Dispersant

Chemical dispersants which function best in hot water can be applied to the oil to break down the oil into small

droplets. It was reported by Othumpangat and his colleagues (2014) that the Exxon Valdez spill was contained utilizing the method of burning and chemical dispersants. As explained by Levine (2002), dispersant are chemicals that act like detergents to break oil up into tiny droplets to dilute the oil's effect and to provide bite-sized bits for oil eating bacteria. Table 2, reiterated that the use of chemical dispersant comes with demerits; one of which is weathering of oil, often due to increase in viscosity.

Table 2: Positive and Negative Impacts of Chemical Dispersants Use [18]

Advantages	**Disadvantages**
• Removes surface oil and dilutes oil into the water column • Facilitates natural oil biodegradation • Reduces exposure to workers recovering oil at the surface • Minimizes impacts on shoreline habitats • Minimizes impacts on populations with long life-spans (birds, mammals, turtles)	• Temporarily increases the bioavailability of toxic oil fractions • Temporarily increases localized risks particularly to entrained aquatic species (eggs, plankton, less mobile animals) • Cannot be used under certain weather conditions • Cannot be used on all oil types and are less efficient on weathered oils

4.2.3. Burning

In situ burning is a method of burning freshly spilled oil, usually while it's floating on the water [12]. Burning is usually 95-98% efficient, but does cause black smoke [20].

Figure 9: Oil spill Clean Up Source: [21]

When conducting in-situ burning on land, berms or trenches serve a similar containment function as fire-resistant booms [22].

4.2.4. Sorbent

Oil can be removed through absorption or adsorption process using sponges made from diaper-like substances (or materials made from straw, grasses, coconut husks or wood chips) as they are capable of soaking up liquids. Sorbents can be natural or synthetic materials. Natural sorbents are divided into organic materials; such as peat moss, perlite, glass, wool, sand, volcanic ash or wood products and inorganic materials; such as vermiculite or clay. Synthetic sorbents include man-made materials that are similar to plastics, such as polyurethane, polyethylene, and nylon fibers [8]. Sorbents are available in a loose form, which includes granules, powder, chunks, and cubes, often contained in bags, nets, or socks [10].

4.2.5. Bioremediation

Spill situations can be remedied using plants or animals in form of micro-organisms. They are of two types; bioremediation and phytoremediation. Bioremediation is a method of increasing the rate of biodegradation by adding materials to the environment, such as fertilizers or microorganisms. Natural processes, such as oil-eating bacteria and wave action, also help to disperse and degrade oil, and may be more effective than human efforts[23,24]. Biodegradation is a process by which microorganisms such as bacteria, fungi, and yeasts break down complex compounds into simpler products to obtain energy and nutrients [8]. Phytoremediation is a green process that involves the use of plant in removing or degrading contaminants in the environment. Plants are able to remove pollutants through processes such as biodegradation, phytovolatilization, accumulation, and metabolic transformation [7].

4.2.6. Shore-line Clean up

Many methods are available for removing oil from shorelines or land forms. Some are tilling and aeration, sediment reworking, sorbents, and chemical cleaning agents.

Figure 10: High Pressure Washing a Rock Beach in Alaska [10]

High-pressure hosing (Fig. 10) can be applied to rinse oil back into water to be skimmed up. This usually does more harm than good by driving the oil deeper into the beach and by killing every living thing on the beach [10].

5. Conclusion

Findings shows that the largest oil spill in world history occurred in Kuwait in 1991 representing 93.85% of the entire spills. The world had recorded over 1 billion barrels of spill in the past century. Even 1% of the total spill (see Table 1; approximately 11 million barrels) if spilled accidentally is capable of causing tremendous damage to organisms and environment. It can be concluded that oil spill prevention remains the only way to manage the transportation and exploration of this hazardous material, as no foolproof cleanup methods have been discovered. It is recommended to prevent oil spillage by making sure oil workers work with standardized project management techniques during exploration and other activities. Modification of the existing clean up techniques to make it less hazardous to the ecosystem will be a probable solution to clean up challenges faced currently.

References

[1] A. Galierikova and M. Materna, "World Seaborne Trade with Oil: One of Main Cause for Oil Spills?," Transportation Research Procedia, vol. 44, p. 297–304, 2020.

[2] S. Abdulrahman, S. I. Malami, T. A. Adedokun, A. Haruna, Y. B. Attahiru and S. I. Haruna, "Effect of crude oil spillage on engineering properties of tropical residual," in 2nd International Conference on Civil & Environmental Engineering, Malaysia, 2020.

[3] U. Umaiyan and S. Karthigeyan, "Geotechnical Characterization of Contaminated Sand by Oil Spillage," in First Annual Conference on Innovations and Developments in Civil Engineering, ACIDIC-2014 NITK,

Surathkal, 2014.

[4] S. Othumpangat and V. Castranova, "Oil Spills," Encyclopedia of Toxicology, vol. 3, p. 677–681, December 2014.

[5] S. E. Chang, J. Stone and M. Piscitelli, "Consequences of oil spills: a review and framework for informing planning," Ecology and Society, vol. 19, no. 2, pp. 1-26, 2014.

[6] R. J. Snowden, "Monitoring the impacts of the Gulf war oil spillages: the implications of inadequate baseline data," Baseline Data, vol. 8, no. 1, pp. 2-8, 2012.

[7] A. C. Ndako, E. O. Oladoja and A. Kamoru, "Application of phytoremediation in the management of oil spillage: A review," Global Journal of Earth and Environmental Science, vol. 3, no. 3, pp. 16-22, August 2018.

[8] EPA, Understanding Oil Spills And Oil Spill Response, USA: Environmental Protection Agency, USA, 1999.

[9] L. Donaldson, Nanotechnology, 6 ed., vol. 15, 2012.

[10] E. Levine, "Effects of Oil on the Marine Environment, Contingency Planning and Spill Response," 2002. [Online]. Available: http://response.restoration.noaa.gov.

[11] BP, "Approximate Conversion Factors," BP plc, 2021. [Online]. Available: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-approximate-conversion-factors.pdf. [Accessed 18 July 2021].

[12] NOAA, "Office of Response and Restoration," 5 February 2019. [Online]. Available: response.restoration.noaa. [Accessed 14 July 2021].

[13] M. A. Ebim, "An Ecolinguistic Study of Media Depictions of Oil Spillage in Ogoniland," Language & Ecology, pp. 1-20, 2016.

[14] J. L. Daura, "Developing an effective mechanism of oil pollution management in the Niger Delta," World Maritime University Dissertations, pp. 1-80, 2000.

[15] O. P. Agu, A. O. Ani, C. A. Peter-Onoh, J. A. Echetama, C. O. Madueke, F. O. Ugwoke and A. L. Onoh, "Effect of Oil Spillage On Agricultural Production in Rivers State, Nigeria," FUTO Journal Series, vol. 1, no. 2, pp. 55-61, 2015.

[16] E. A. Awoyesuku, N. E. Chinawa and S. C. Ejimadu, "Distribution of Ocular Disorders in Communities Affected by Crude Oil-spillage in Rivers State," Ophthalmology Research: An International Journal, vol. 11, no. 3, pp. 1-5, 2019.

[17] S. J. Harrison, "Lessons from the Taylor Energy Oil Spill: History, Seasonality, and Nutrient Limitation," 2017.

[18] J. Michel and M. Fingas, "Oil Spills: Causes, Consequences, Prevention, and Countermeasures," in Fossil Fuels, vol. 16, Concordia University College of Alberta, 2015, pp. 159-200.

[19] M. F. Fingas, "The Basics of Oil Spill Cleanup," Taylor and Francis, 2012.

[20] F. Cumo, F. Gugliermetti and G. Guidi, "Best available techniques for oil spill containment and clean-up in the Mediterranean Sea," Water Resources Management IV, vol. 103, pp. 527-535, 2007.

[21] H. Kelley, "Introduction: Oil Spill Effects and Solutions," 2018. [Online]. Available: http://questgarden.com/137/13/2/111211134752/index.htm. [Accessed 19 July 2021].

[22] API Energy, "In-situ Burning," 2021. [Online]. Available: oilspillprevention.org/oil-spill-cleanup/oil-spill-cleanup-toolkit/in-situ-burning. [Accessed 17 July 2021].

[23] T. C. Hazen, E. Dubinsky, T. Z. DeSantis, Y. Piceno, N. Singh, J. K. Jansson, A. Probst, S. E. Borglin, J. L. Fortney, W. T. Stringfellow, M. Bill, M. E. Conrad, L. M. Tom, K. L. Chavarria, T. R. Alusi, R. Lamendella, D. C. Joyner, C. Spier, J. Baelum, M. Auer, M. L. Zemla, R. Chakraborty, E. L. Sonnenthal, P. D'haeseleer, H.-Y. Holman, S. Osman, Z. Lu, J. D. Nostrand, Y. Deng, J. Zhou and O. U. Mason, "Deep-Sea Oil Plume Enriches Indigenous Oil-Degrading Bacteria," REPORTS, vol. 330, pp. 204-207, 8 October 2010.

[24] J. S. Gutierrez, M. W. Dietz, J. A. Masero, R. E. Gill, A. Dekinga, P. F. Battley, J. M. Sanchez-Guzman and T. Piersma, "Functional Ecology of Saltglands in Shorebirds: Flexible Responses to Variable Environmental Conditions," Functional Ecology, vol. 26, pp. 236-244, 2012.

[25] H. X. Zhang, Q. Ji and Y. Fan, "What drives the formation of global oil trade patterns?," Energy Economics, vol. 49, pp. 639-648, 2015.

[26] J. M. Shultz, L. Walsh, D. R. Garfin, F. E. Wilson and Y. Neria, "The 2010 Deepwater Horizon Oil Spill: The Trauma Signature of an Ecological Disaster," The Journal of Behavioral Health Services & Research, pp. 1-20, 2014.

[27] A. N. Nwachukwu and J. C. Osuagwu , "Effects of Oil Spillage on Groundwater Quality In Nigeria," American Journal of Engineering Research (AJER), vol. 3, no. 6, pp. 271-274, 2014.

[28] J. P. Essien and S. P. Antai, "Negative effects of oil spillage on beach microalgae in Nigeria," World Journal of Microbiology & Biotechnology, vol. 21, p. 567–573, June 2005.

[29] O. M. Dorris, "Impact of Crude Oil Spillage on Soil and Food Production in Rivers State, Nigeria," Journal of Money, Investment and Banking, no. 19, pp. 28-34, 2010.

[30] J. L. Ramseur, Deepwater Horizon Oil Spill: Recent Activities and Ongoing Developments, Congressional Research Service, 2015.

[31] R. Melina, "Top 10 worst oil spills," 29 April 2010. [Online]. Available: https://www.nbcnews.com/id/wbna36852827.

[32] Wikipedia, "List of Oil Spills," 2013. [Online]. Available: https://en.m.wikipedia.org/wiki/List_of_oil_spills. [Accessed 18 July 2021].

[33] K. D. Patel and W. J. Rea, Reversibility of Chronic Disease and Hypersensitivity-The Environmental Aspects of Chemical Sensitivity, vol. 4, CRC Press, 2017.

[34] ITOPF, "Oil Tanker Spill Statistics 2020," January 2019. [Online]. Available: www.itopf.org. [Accessed 18 July 2021].

[35] O. Inoni, D. Omotor and F. Nkem, "The Effect of OIl Spillage on Crop Yield and Farm Income," Journal of Central European Agriculture, vol. 7, no. 1, pp. 41-48, 2006.