FSO SAFER: A SHIPWRECK IN SLOW MOTION

Greenpeace International briefing

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The humanitarian, economic and environmental impacts of an oil disaster in the making in the Red Sea

GREENPEACE

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FSO SAFER BRIEFING: EXECUTIVE SUMMARY

An ageing oil tanker, converted to a floating storage facility, called the FSO Safer is moored off the Yemeni coast in the Red Sea and is at risk of exploding or leaking its cargo – an estimated 1.14 million barrels (more than 140,000 tonnes) of Marib light crude oil.

The event could be one of the biggest oil spill disasters in history and would cause widespread severe environmental damage and exacerbate the humanitarian crisis unfolding in the country.

How could a spill or explosion on the FSO Safer be caused?

- Slow and constant leakage of oil if the hull is further damaged by weathering or corrosion (Huynh et al., 2021).
- An explosion due to the build-up of flammable gases on board the vessel or if it is struck, either deliberately or accidentally, by a missile (Huynh et al., 2021).
- The ship sinks, releasing its cargo of crude oil.

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1.2 What is at risk?

Environment:

Marine ecosystems in the Red Sea, in particular the southern Red Sea coral reefs and fragile coastal wetlands such as mangroves and seagrasses. Compounds in oil are toxic to plants and marine animals including plankton, fish, invertebrates and mammals, and can cause disease, slowed growth, reproductive problems and death – oil can also physically smother marine organisms and habitats.

Public health:

Exacerbation of the humanitarian crisis in Yemen (and neighbouring countries) because of reduced access to food aid, fresh water and fuel. Air pollution to Yemen and neighbouring regions from a possible explosion. Crude oil contains toxic and carcinogenic chemicals that are harmful to human health.

Economy

Disruption of global shipping trade through the Suez Canal. Closure of fisheries. Disruption to the tourist industry.

1.3 Where would the impacts be experienced?

Local (Yemen)

- Disruption to the Yemen ports of Hudaydah and Salif, through which 68% of aid is brought into the country. Disruption of supplies of food aid for up to 8.4 million people (Huynh et al., 2021).
- Desalination plants on Yemen's coast at Hudaydah, Salif and Aden could be affected, interrupting the drinking water supply for approximately 10 million people (Huynh et al., 2021).
- Yemeni fisheries, which support 1.7 million people, would be completely closed by an oil spill.

Regional (Red Sea)

- The entire Red Sea region's drinking water supply could be contaminated by oil. Modelling projections suggest that desalination plants on the coasts of Yemen, Eritrea and Saudi Arabia could be affected by oil in just three weeks following a spill (Huynh et al., 2021).
- An oil spill could drift to the coastline of Yemen's neighbouring countries of Djibouti, Eritrea and Saudi Arabia.

International

- Disruption to shipping routes through the Suez Canal.
- Tourism to the Red Sea resorts.

1.4 Risk timeframes

Short-term

Disruption to desalination plants, closure of fisheries, air pollution, disruption of shipping traffic through the Suez Canal. Exacerbation of the humanitarian crisis in Yemen from lack of access to aid and medical supplies. Severe environmental damage, particularly to the coral reefs and coastal wetlands of Yemen, Saudi Arabia and Eritrea. Marine animals and plants that come into contact with spilled oil will be coated.

Long-term

Contamination of fish and beaches with toxic chemical compounds from crude oil. Severe environmental damage to fragile coral reefs and other coastal ecosystems.

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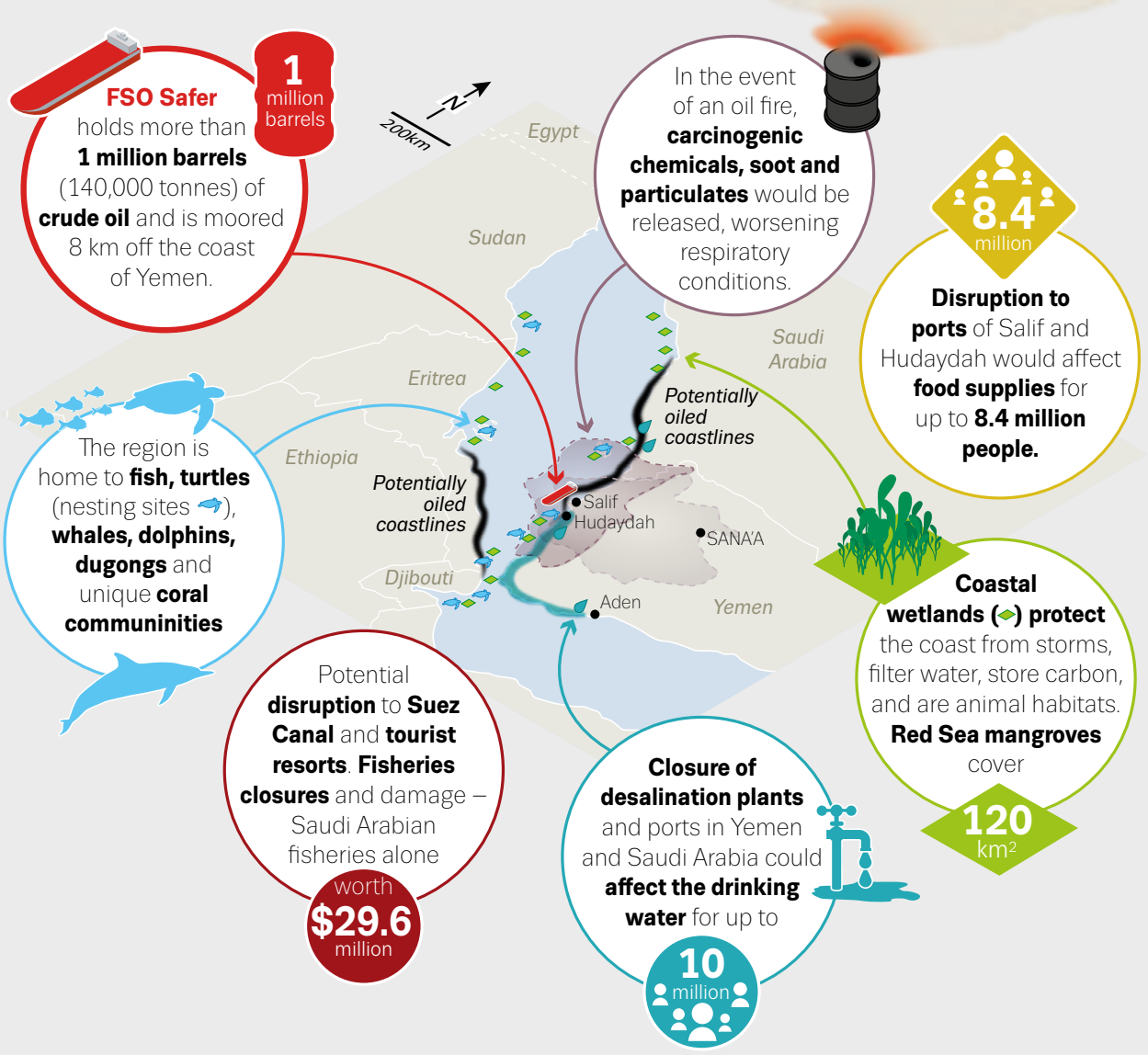
RED SEA ALERT

The health, environmental and economic risks of an oil spill from FSO Safer (a rusting tanker full of oil) are potentially severe and the impacts could extend throughout the Red Sea.

Depending on the conditions at the time of the spill, an oil slick or weathered oil could drift to Yemen's neighbouring countries of Djibouti, Eritrea, and Saudi Arabia. Exposure to oil is harmful to animals, plants and people, and could result in severe environmental damage.



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1.0 INTRODUCTION AND BACKGROUND

An ageing oil tanker, converted to a floating oil storage facility, the "FSO Safer", is moored off the Red Sea coast of Yemen and is at risk of leaking its cargo, which is an estimated 1.14 million barrels (more than 140,000 tonnes) of Marib light crude oil, or of exploding. Such an event could result in one of the biggest oil spill disasters in history and would cause widespread severe environmental damage and exacerbate what has already been called the world's worst humanitarian crisis (World Food Programme, 2021).

The floating storage and offloading unit (FSO) Safer has been moored 4.8 nautical miles (8 km) off the coast of Yemen for the past 30 years. The vessel was built for Exxon in 1976 as a single-hulled Ultra Large Crude Carrier (ULCC) 360 metres long and 70 metres wide. It was converted to an FSO in 1988 but since 2015 has not been inspected or received maintenance; it is no longer insured or "in class" and the ageing unit is deteriorating. The consensus among marine shipping experts is that the FSO Safer is beyond repair. An engine room leak in May 2020 was only partially patched up. The lack of maintenance is causing progressive structural deterioration that could lead to an oil spill from the tanker and/or an explosion as the inert gas system, designed to displace inflammable gases, is no longer working. The result of such an event could be catastrophic on humanitarian, environmental and economic levels (IMO, 2021).

Image: Greenpeace/Roger Grace


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2.0 SPATIAL RISKS

Image: © Rajiv Groochurn / Greenpeace

In the immediate aftermath of an oil spill (the first three weeks), Yemen, Saudi Arabia and Eritrea are projected to be negatively affected to various degrees by crude oil washing up on beaches, disrupting ports and desalination plants, and contaminating their territorial waters.

In winter, projections suggest a spill is most likely to spread northwards to the central Red Sea; in summer the spread is most likely to be to the south towards the Gulf of Aden and the southern Yemeni coast (based on modeling projections by Huynh et al., 2021).

The general behaviour of the type of light crude oil, which is on the Safer, is that it will partially evaporate and leave a residue of up to one-third of the amount spilled. Light crude contains moderate amounts of very toxic compounds and if spilled can result in long-term contamination of the environment (Section 3.3 in Lee et al., 2015). However, the crude oil on the Safer could have deteriorated – stored crude oil can oxidise and form a thick sludge (Koolivand et al., 2013) raising further questions about its potential impacts.

Air pollution

An oil spill will negatively affect air quality because toxic chemical compounds (including volatile organic compounds or VOCs) will evaporate from the oil – if the oil burns then additional pollutants will be released into the atmosphere.

The health risks to people who encounter air pollution from evaporating or burning oil are from exposure to toxic gases and small aerosols that can be inhaled and penetrate deep into the lung tissue.

In the event of an explosion, burning oil would be a serious air pollution risk because the fumes contain black carbon (also called soot, and which contains toxic polyaromatic hydrocarbons), particulate matter (which may be composed of toxic heavy metals and nitrogen/sulfur compounds), nitrogen oxides, sulfur oxides, carbon monoxide, carbon dioxide and VOCs. An additional and immediate risk is to personnel on board the tanker who may be caught in the fire (Mullin & Champ, 2003; Perring et al., 2011; Middlebrook et al., 2012; Bullock et al., 2019).

Studies of past oil spill fires can help to predict likely impacts of a fire on board FSO Safer. In the immediate aftermath of the 2010 BP Deepwater Horizon spill, workers attempting to mitigate the spread of crude oil in the Gulf of Mexico through controlled burning reported respiratory problems including wheezing, tightness in the chest,

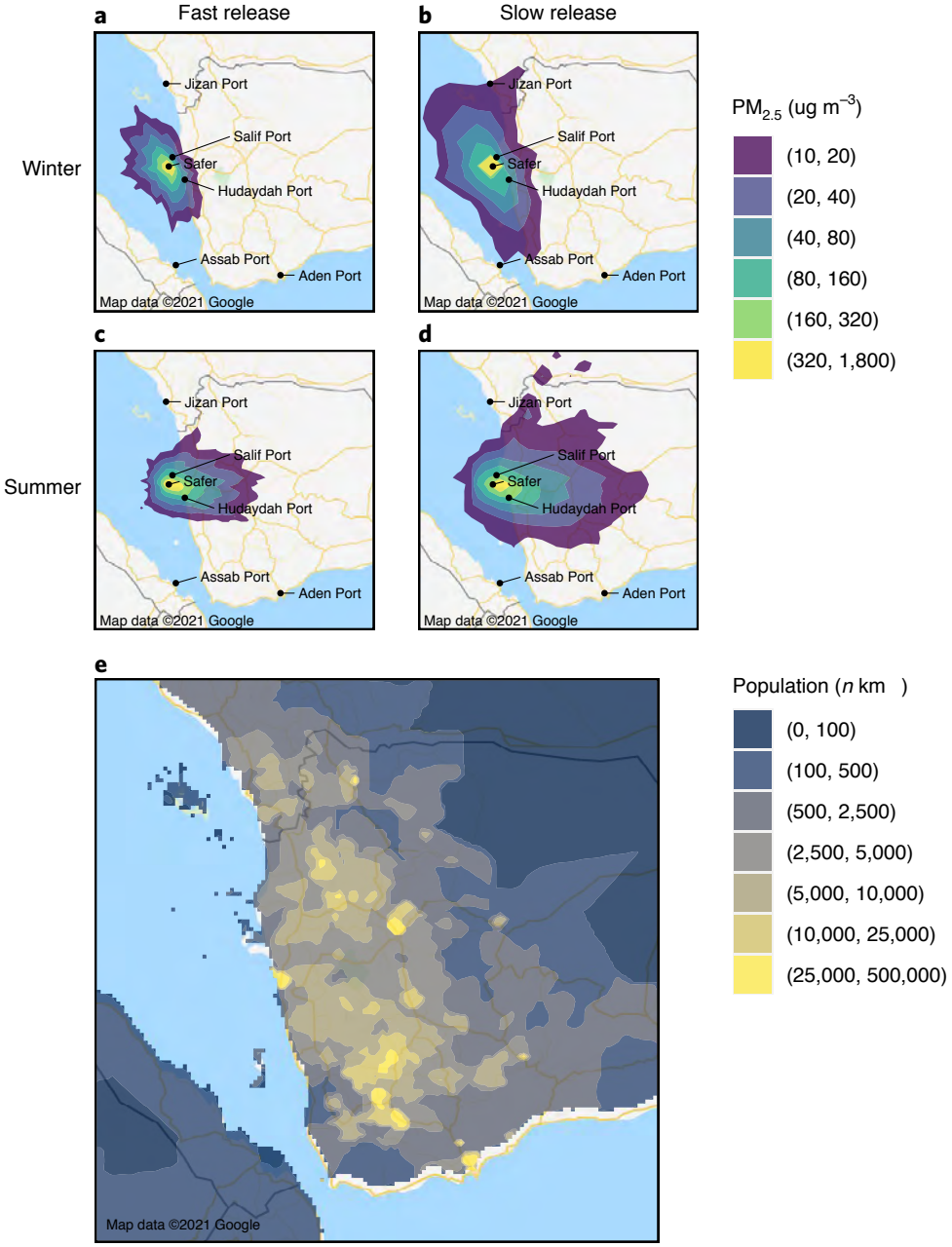
shortness of breath, itchy or runny nose and throat for up to three days after exposure to the fumes. Black soot is formed by the burning oil and can contain transition metals, salts and organics and compounds called polychlorinated dibenzofurans, the latter of which can disrupt the hormone system in animals and humans. Exposure to the chemicals and particulate matter in the smoke when crude oil burns can irritate the lungs and worsen the symptoms in people with asthma or other respiratory problems (Jaligama et al., 2015).

Within 24 hours of an explosion in which the oil on the FSO Safer catches fire, the extent of the smoke is projected to reach eastwards over Yemen in the summer or west over the Red Sea in the winter (Fig. 1). In both summer and winter, the smoke could potentially reach southwest Saudi Arabia. When crude oil burns it creates soot, coarse particulate matter called PM_{10} and fine particulate matter called $PM_{2.5}$, the latter of which are microscopic particles with a diameter of less than 10 and 2.5 microns, respectively. $PM_{2.5}$is a particular human health hazard because the particles are small enough to enter the airways and penetrate deep into the lungs and enter the blood system.

In the immediate vicinity of an explosion on the Safer, the concentration of $PM_{2.5}$ is projected by Huynh et al. (2021) to reach up to 1,600 micrograms per square metre (ug/m–3). To put this into context, the latest World Health Organization (WHO) ambient (outdoor) air pollution guidelines, which were updated in 2021, recommend the maximum exposure to fine particulates, or $PM_{2.5}$, is 15 µg/m3 over a 24-hour mean (WHO, 2021). It is very unlikely that members of the public would be exposed to these super high pollution levels in the immediate vicinity of an oil fire but the WHO guideline is at risk of being breached in almost all of the shaded areas on the map shown in Fig. 1. Outdoor air pollution is classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans. There is no safe level of air pollution and even exposure to levels below the WHO recommendations pose a risk to human health (see also Section 5.0, Health impacts).

The impact of the risks to air quality from burning oil will be influenced by factors that include the time of year in which the event takes place (ocean currents and winds differ in winter and summer), the duration of the spill, whether there was a slow or rapid leak of oil or a sudden explosion, and the extent to which mitigation efforts succeed in recovering any spilled crude oil.

Figure 1: Simulated air pollution following a spill from the FSO Safer.



a-d *Projected 24-hour average air pollution concentration at the end of spill in the winter (**a**,**b**) and summer (**c**,**d**) for fast release spills (**a**,**c**) and slow release spills (**b**,**d**).*

e *Population density plot*

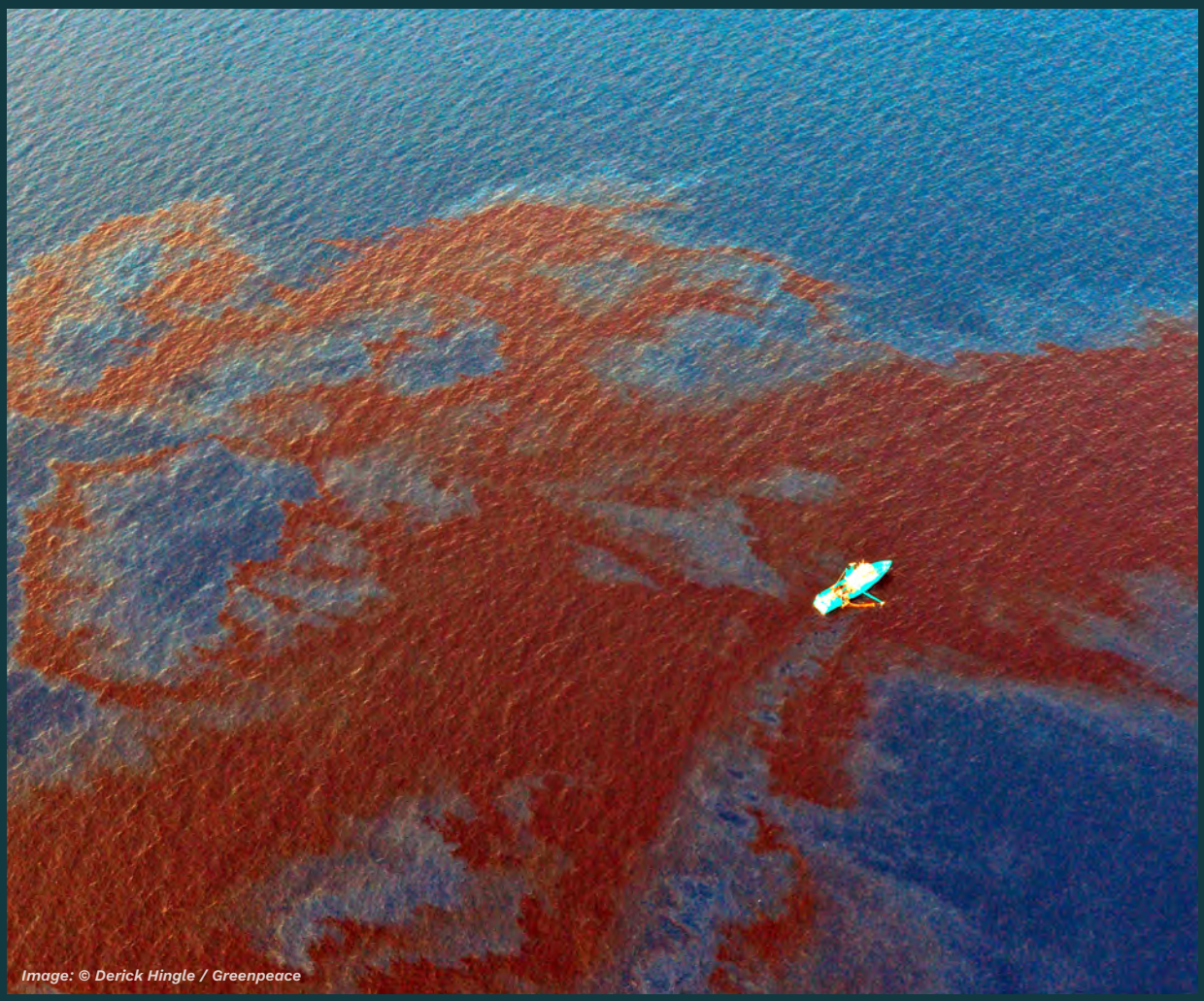


Image: © Derick Hingle / Greenpeace

Oil on the sea surface

The risk of the spill causing widespread environmental damage is very high. No technique to date has been successful in recovering all oil from a large spill. Techniques that have been used to mitigate the impacts of spills in the past include booms to contain the oil, with skimmers, chemical dispersants such as Corexit, and using fire to burn the spilled oil. Some oil removal or recovery methods create different problems: burning oil causes air pollution; booms are ineffective in the event of wave action; and chemical dispersants are both toxic and fail to eliminate the presence of oil-related toxic chemicals making them more available in the marine food chain.

Oil spill modelling scenarios undertaken by Oil Spill Response Ltd. (OSRL) on behalf of International Maritime Organisation (IMO) found that in the worst-case scenario, oil will negatively affect Eritrea, Saudi Arabia and Yemen in all seasons, with Djibouti and Somalia being affected for part of the year (excepting Jan–March). The extent of oil spread is predicted, again in a worst-case scenario, to impact the immediate vicinity up to 300 km away with heavy to moderate amounts of oiling, and possibly some light oiling spreading to Aden 500 km to the south. The OSRL worst-case scenario involves all 1.14 million barrels of oil being rapidly released over a period of seven days. Other scenarios that were modelled considered different quantities of oil leaking over a period of 2 days, 21 days and 60 days. In all scenarios, oil is expected to reach the coastline of Yemen within 3-4 hours of release (Ballard, 2021).

In the days following the 2010 Deepwater Horizon spill, the air quality analysis found the main pollutants were hydrocarbons, particulate matter, ozone, carbon monoxide and nitrogen oxides. Some pollutants were because the oil was on fire, as explained in the previous section, but the biggest source of primary air pollutants were the hydrocarbons (which include harmful compounds such as benzene, toluene and naphthalene) that evaporated from the oil on the sea surface. After evaporating, the primary air pollutants reacted with other compounds in the atmosphere to form secondary pollutants, such as ozone. The key take-home message is that it is not only pollutants from the oil spill that can be toxic, but products of reactions between toxic chemicals in the oil and compounds in the atmosphere (Middlebrook et al., 2012).

Even in the most favourable conditions, oil recovery efforts only remove an estimated 10-20% of spills because of the complexities involved, which means that in reality almost all contents of an oil spill are left to disperse into the environment (Nikiforuk, 2016).

Image: © Paksi Sandang Prabowo / Kaltim Post / Greenpeace

2.1 Local (Yemen) Risks

- Disruption to Yemeni ports including Hudaydah and Salif: 68% of aid brought into the country is through these two major hubs. Yemen imports up to 97% of fuel, although since 2020 this has been primarily through its southern coast ports at Aden and Mukalla, and 90% of Yemen's food supply arrives through the sea ports. Following an oil spill, food supplies and aid for up to 8.4 million people could be disrupted (Huynh et al., 2021).
- Three weeks after an oil spill, the desalination plants on Yemen's coast at Hudaydah, Salif and Aden could be affected and that, combined with disrupted fuel supply, could disrupt the drinking water supply for up to 10 million people (Huynh et al., 2021).
- Yemeni fisheries (as well as those of neighbouring countries) could be completely closed by an oil spill. These fisheries support 1.7 million people and closures would be necessary to ensure that no contaminated commercial fish enter the human food chain (Huynh et al., 2021). The most serious risks are to the livelihoods of the fishing communities.
- Crude oil contamination to Yemeni marine ecosystems and coastlines due to oil and tar balls washing up on the shore. This could contaminate marine sediments and smother marine animals with oil.
- Major concerns are attached to the capacity of vulnerable coastal communities – predominantly people on low incomes who rely on fishing to earn a living – to cope with the environmental and health impacts following an oil spill or an explosion, and whether there is adequate infrastructure to provide alternative access to essential food, water, medical and fuel supplies. Without such supplies, the humanitarian crisis will be exacerbated.

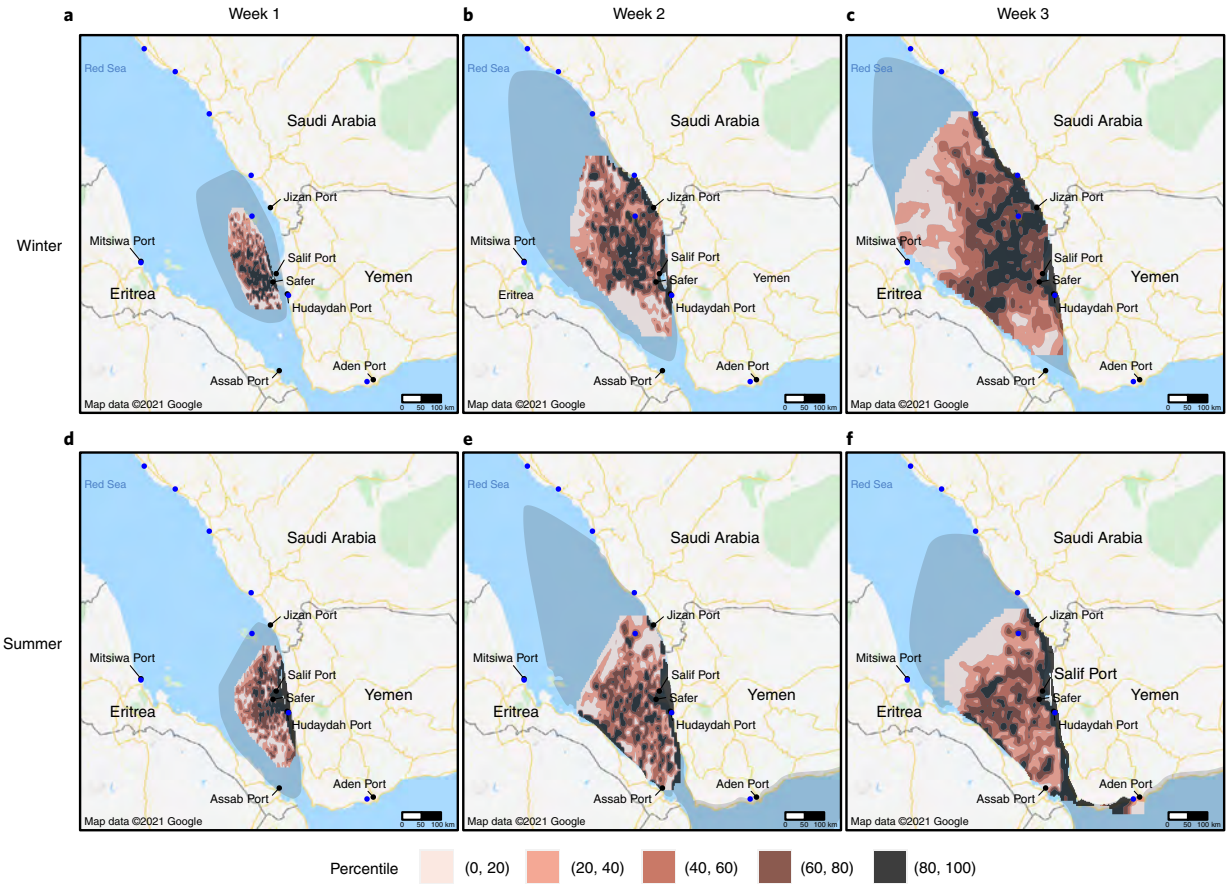
Image: KHALED ZIAD/AFP via Getty Images

2.2 Regional (Red Sea) Risks

- In the event of a spill or explosion, a substantial portion of the Red Sea region's clean water supply could be contaminated by oil. Modelling projections suggest that desalination plants on the coasts of Yemen, Eritrea and Saudi Arabia could be affected by oil in just three weeks following a spill disaster (Huynh et al., 2021).
- An oil slick or weathered oil could drift to the coastline of Yemen's neighbouring countries of Djibouti, Eritrea and Saudi Arabia (Fig. 2). The timing of a spill will have an impact on the oil's immediate direction of travel and distance of spread because of the seasonal nature of sea surface currents. Computer modelling projections by Kleinhaus et al. (2020a) suggest that in summer, the oil is projected to spread in a southerly direction. In winter, the oil will spread much further and with a northwards trajectory – over a period of 30 days in winter the oil is projected to reach the centre of the Red Sea. The model did not include wave action, which could act to spread the oil further north/south (depending on the season) than the projections actually suggest. The implications of an oil spill in winter, when oil spreads northwards, is that oil will remain within the Red Sea basin for a longer period of time, increasing the likelihood of closed fisheries, contaminated desalination plants and severe damage to plant and animal communities (Kleinhaus et al., 2020a).
- Fishing communities in Saudi Arabia, Eritrea and Djibouti could be affected if fish caught for commercial or subsistence purposes become contaminated with crude oil.

Image: KHALED ZIAD/AFP via Getty Images

Figure 2: Simulated surface oil concentration following a spill from the FSO Safer.



a-f *Average surface oil concentration of 1,000 simulated spills in the winter (**a**,**b**,**c**) and in the summer (**d**,**e**,**f**).*

*Columns denote progress of the 1,000 spills after one week (**a**,**d**), two weeks (**b**,**e**) and three weeks (**c**,**f**).*

Coloured contours represent percentiles of average surface concentration over 1,000 simulated spills and can be interpreted as the expected surface concentration relative to other grid cells in the exposed area.

Shaded region represents the area within which approximately 90% of spill trajectories are expected to fall. Blue dots represent desalination plants.

2.3 International Risks

- The Red Sea coral reef ecosystem is of high international scientific significance because the scleractinian corals[1] have demonstrated unusual resilience to increasing sea temperatures. Across the world, coral reefs are at risk from climate change and other human stressors such as coastal development and pollution – an estimated 70–90% of coral reefs could be degraded by 2050. By studying the Red Sea reefs, scientists hope to understand more about how the unique corals that grow there can withstand increasing sea temperatures. The Red Sea reef systems will be important to marine scientists to help them understand if or how other reefs may adapt to climate change, or the Red Sea corals could become an important surviving marine ecosystem (Kleinhaus et al., 2020a; Kleinhaus et al., 2020b).
- Research has found that the reef systems in the north Red Sea and the southern part (divided at around 19° N) are genetically different and support different species of corals, fish and sponges. An explanation for the unique southern Red Sea biodiversity is a connection to areas outside of the Red Sea in the Gulf of Aden and remote parts of the Indian Ocean, as currents flow between these regions enabling the movement of marine animals and nutrients for the coral reefs (Wang et al., 2019).

Image: © Axel Heimken / Greenpeace

1 *Scleractinian corals are hard corals that form the base of the reef and are important because they act as a shelter for fish and invertebrates and are, therefore, a key part of the rich and diverse marine food web in the tropics.*

Image: Greenpeace/Marco Care

3.0 TEMPORAL RISKS

Image: Oleg Znamenskiy/Shutterstock

3.1 Short-term (up to a few weeks) Risks

Short-term modelling of oil spills takes into account the dispersal through wind and wave action and can be very useful in understanding the extent of a slick and help organisations involved in mitigating impacts in the hours and weeks afterwards (Huynh et al., 2021; Solo-Gabrielle et al., 2021). Huynh et al (2021) limited the simulations of a Red Sea oil spill to three-week timelines because of the lack of data available to inform the modelling beyond this time horizon, partly due to what they describe as "uncertainty in clean-up efforts".

The computer modelling by Huynh et al. (2021) focused on the potential impacts most closely related to public health within the first three weeks of a Red Sea oil spill. The key projections from this exercise were:

- Disruption of coastal desalination plants by oil contamination alone would affect the supply of clean, fresh drinking water for 1–1.9 million people in Yemen, Eritrea and Saudi Arabia;
- Yemeni Red Sea fisheries would probably be completely closed for food safety reasons within the first three weeks of a spill;
- Disruption to the delivery of fuel to Yemen would cause the closure of hospitals and desalination plants. Additionally, an estimated 8 million people would be expected to lose water supply from fuel shortages because the water supply depends on fuel-powered pumps and trucks that transport the water locally (note that the 8 million figure is in addition to the 1–1.9 million figure directly affected by contaminated desalination plants) (Huynh, B., personal communication);
- Air pollution would increase the risk of hospitalisation for cardiovascular and respiratory conditions. People directly exposed to oil, such as workers involved in the removal or recovery of spilled oil, would probably be worst affected unless full personal protective equipment (PPE) is used, although the disruption to the ports would be likely to prevent delivery of PPE supplies. The air pollution projections shown in Fig. 1 suggest that the WHO guidelines are at risk of being breached over the land, depending on the season and weather conditions at the time of an oil spill/fire.
- Port closures in Yemen would cause disruption to the delivery of food aid and essential medical supplies.

Researchers have urged that immediate action is needed to prevent the existing humanitarian disaster in Yemen getting worse and creating widespread environmental damage. Kleinhaus et al. (2020a) highlight the immediate risks to Red Sea countries in the form of air pollution and contaminated food and water supplies, and to the fragile coral reef and other coastal ecosystems that line most of the Red Sea's 4,000 km coastline.

Image: © Daniel Beltrá / Greenpeace

3.2 Long-term (years and decades) Risks

Long-term modeling of oil spill impacts is interdisciplinary – and therefore complex – because it takes into account various sectors: ocean systems (for example, ocean currents); biological ecosystems (including organisms in the food chain); socioeconomics (industry and market sectors); and human health (physical and mental) (Solo-Gabrielle et al., 2021).

The Red Sea is enclosed by land with only the Suez Canal to the north and the Bab-el-Mandeb strait, which is 20 miles (32 km) wide, to the South and connects the Red Sea with the Gulf of Aden and the Arabian Sea (Britannica, 2006). The physical geography dictates that impacts could be long lasting if crude oil persists in the Red Sea basin because there is no seawater flow through the Suez Canal, only through the southern section. For example, PAH compounds were found on the Louisiana coastline up to two years after the 2010 Deepwater Horizon disaster in the Gulf of Mexico (Turner et al., 2014), an area of open sea with greater circulation than the Red Sea. The implication is that toxic oil and oil-associated chemicals following an FSO Safer spill could persist for years.


Image: © Greenpeace / Richard Smith

In short, although the precise nature of long term impacts is uncertain, it is highly probable that they would persist over many years as has been noted in the case of many previous oil spills. For example, oil, including chemicals toxic to animals, from the 1989 Exxon Valdez oil spill in Alaska was found to have persisted on gravel beaches in Prince William Sound 20 years after the event (Li & Boufadel, 2010). In another example, heavy metals were found in the feathers of seabird chicks (European shags and yellow-legged gulls) after the 2002 MV Prestige spill in the Atlantic off the north-west coast of Galicia, Spain, indicating that oil pollution can persist in the marine environment and in the food chain for at least three years after the Prestige was wrecked and spilled its cargo (Moreno et al., 2011).


Image: © Mikhail Pyzhov / Greenpeace

4.0
ENVIRONMENTAL RISKS

Image: Greenpeace/Marco Care

This section considers some of the marine birds, animals and plants that inhabit the immediate vicinity of the FSO Safer in Yemen waters, as well as in other parts of the Red Sea, or what the possible impacts might be if and when the FSO Safer leaks oil/explodes.

Compounds in oil are toxic to marine animals such as plankton, fish, invertebrates and mammals, and can cause disease, slowed growth, reproductive problems and death – oil physically smothers marine organisms and habitats. The impact of exposure to oil and associated toxic chemicals on a marine species will depend on the duration and extent of contact, and the type and state of oil – light crude oil can be highly toxic after just a brief period of exposure because of the compounds (benzene, toluene, ethyl benzene and xylene) it contains (Chapter 4 in Lee et al., 2015).

Studies of past oil spills such as the Deepwater Horizon and Exxon Valdez disasters help us to understand the behavior of oil in the immediate aftermath of a spill, the impact on biota (plants and animals), and the potential risks to the wider environment. Studying the short, medium and longer-term impacts from the Deepwater Horizon disaster are particularly relevant because the Macondo crude oil from this spill has similar properties to the Marib light crude on board the Safer. The use of satellite imagery to identify the immediate extent of an oil spill is an important capability to have on hand and provides key information for organisations involved in mitigating the impacts of the spill, but it might not show the full extent of the spill and its subsequent spread (Berenshtein et al., 2020). Removal of oil from habitats can be as damaging as the spill: the physical presence of workers and machinery can be harmful; the use of chemical oil dispersants is potentially toxic to marine species (Ch 4 in Lee et al., 2015).

An oil spill from FSO Safer is projected in the immediate weeks afterwards to impact sizeable sections of the coastlines of Yemen (which has 700 km of coast along the Red Sea), Saudi Arabia (which has 2,000 km of Red Sea coast) and Eritrea (which has 2234 km of Red Sea coast). However, five other countries have coastlines on the Red Sea – Egypt (1,600 km), Israel (14 km), Sudan (853 km), Djibouti (314 km) and Jordan (26 km) – that may all, to some extent, be impacted by an oil spill or explosion if, for example tar balls wash up on beaches or if fisheries or desalination plants are contaminated.

Yemen's marine environment comprises lagoons, sandy and rocky beaches, dunes,

mangroves, wetlands, coral reefs and seagrass beds – these environments are highly valued by the country (see Section 6.0) (Republic of Yemen, 2017). In the event of an oil spill, these could be severely damaged and degraded.

In summary, the long-term impacts of an oil spill from FSO Safer could be much more extensive than projected in the short term modeling scenarios presented in Huynh et al (2021) and ACAPS (2021).

4.1 Coral reefs

The Red Sea is regarded as a global biodiversity hotspot, in part because it contains more than 16,000 km^2 of coral reef that supports a high number of endemic species (i.e. occurring nowhere else). Coral reefs are found throughout the Red Sea basin – its coastline amounts to around 4,000 km, almost all of which has coral reefs, making the Red Sea reefs one of the longest continuous living reefs in the world (Kleinhaus et al., 2020a; Kleinhaus et al., 2020b). Such reefs are essential habitats for fish and invertebrates.

- The detrimental effect of crude oil on coral reefs has been recognized for decades. A large oil spill, while initially highly visible, is also extremely detrimental to the environment in both the short and the long term. A slow 'invisible' leak can cause chronic crude oil pollution that can also have severe biological consequences on coral reefs, including damage to corals' reproduction, damage to the coral tissues and slowing the growth rate. Also, after the visible effects of an oil spill have gone, oil accumulated in sediments can exert longer term impacts (Loya & Rinkovich, 1980).
- The Red Sea is home to around 365 scleractinian coral species, of which 19 (5.5%) are endemic (DiBattista et al., 2016). Some of the Red Sea corals are very unusual because they can withstand relatively wide fluctuations in sea temperature. The ability to adapt to an increase in sea temperature, a result of the Earth's changing climate, could be important for the survival of the Red Sea reef system. Coral reefs across the world are at risk of bleaching (which causes corals to die) because of increasing sea temperatures and increased frequency and intensity of natural climatic events such as El Niño (Hughes et al., 2018). Studying the unique corals of the Red Sea and the Gulf of Aqaba could help researchers to understand how these organisms survive increased heat. Importantly, the heat-resilient Red Sea corals could be one of the only reef ecosystems to survive if other reefs are badly affected by warming ocean temperatures (Savary et al., 2021).
- Coral reef cover along the Saudi Arabian coastline has declined over the past four decades. A study comparing the coastal flora and fauna along the Saudi Arabian coastline in 1980 and 2010 suggests that corals have been put at risk from human development, such as construction, and from pollution sources, such as sewage outlets (Price et al, 2014). Contamination by an oil spill would risk further, serious, damage to the southern Red Sea coral reefs.

Image: © Chuck Cook / Greenpeace

Image: Greenpeace/Marco Care

4.2 Fish, invertebrates, mammals, reptiles and birds

A major oil spill in the Red Sea, a marine biodiversity hotspot, would significantly jeopardise the integrity of its ecosystems (Roberts et al., 2002).

4.2.1 Fish

- The Red Sea region has more than 1,000 species of fish, of which 14% are unique. In detail: the Red Sea has 1,071 recorded fish species (there are 1,760 in the Arabian Peninsula region), of which 138 (12.9%) are endemic to the Red Sea and 189 (14.1%) are endemic to the Red Sea and Gulf of Aden (DiBattista et al., 2016).
- 15% of Red Sea crustaceans are endemic (only found in the Red Sea) (DiBattista et al., 2016).
- A crude oil spill releases toxic polycyclic aromatic hydrocarbons (PAHs) into the water. Research into fish caught in the Gulf of Mexico after the Deepwater Horizon found that fish had been contaminated with PAHs. Laboratory analysis concluded that it was highly likely that the PAH contamination of the fish came from the spill (Murawski, et al. 2014).
- PAHs and other hydrocarbons are toxic to fish, and in the short term can cause skin lesions; long-term exposure can affect fish reproduction, slow their growth and increase the risk of disease. Combined, these impacts can negatively affect fish population numbers (Berenshtein et al., 2020).
- The combination of exposure to crude oil and natural sunlight can increase the toxicity of polyaromatic hydrocarbons (toxic chemicals found in crude oil) to fish, invertebrates and marine plants, which will, ultimately, affect the entire marine ecosystem. Embryos of commercially caught mahi-mahi fish had a decreased hatching rate following exposure to oil from the Deepwater Horizon spill because of exposure to toxic chemicals in oil combined with ultraviolet light from the sun (Alloy et al., 2016).

4.2.2 Invertebrates

- Of the invertebrates, there are approximately 211 described echinoderms (starfish, sea urchins and sea cucumbers), of which 17 (8.1%) are known only from the Red Sea and 21 (10%) only from from the Red Sea to the Gulf of Aden (DiBattista et al., 2016).
- Even a small-scale crude oil spill will have a detrimental effect on the marine ecosystem. After a small-scale experimental crude oil spill with a volume of $5m^3$, oil contamination was found up to 500 metres away on the sea surface and at least 8 metres deep. In particular, the number of zooplankton (microscopic animals that are important food sources for larger animals) decreased by half in just one day in the water beneath the oil (Brussaard et al., 2016). Even if the Safer develops another small oil leak, as it did from the engine room in May 2020, the consequences can still be widespread and long-term.


Image: Jina Tally / Greenpeace

4.2.3 Mammals

- 16 species of cetacean (whales and dolphins) have been recorded in the Red Sea, although only nine have been observed regularly. These are: Bryde's whale, false killer whale, Risso's dolphin, Indian Ocean humpback dolphin, Indo-Pacific bottlenose dolphin, common bottlenose dolphin, pantropical spotted dolphin, spinner dolphin and Indo-Pacific common dolphin (Notarbartolo di Sciara et al., 2017).

- Dugongs can be seen throughout the Red Sea – these shy, plant-eating mammals graze on the region's seagrasses. Dugongs are listed as vulnerable to extinction on the International Union for Conservation of Nature's Red List because they get caught in fishing nets and also because they feed on seagrasses, a habitat that is under threat from coastal development (Nasr et al., 2019).

4.2.4 Reptiles

- Five of the world's seven species of turtle are found in the Red Sea. These reptiles play an important part in maintaining the ecology of both seagrass beds and coral reefs. The five turtle species are: the green, the hawksbill, the loggerhead, the olive ridley and the leatherback. The presence of turtles is valued by the tourist industry as they are a key attraction for divers and snorkelers and often easily seen from the shoreline. Populations of marine turtles in the region are already under threat because of habitat destruction and pollution (Mancini et al., 2015).

4.2.5 Birds

- High-volume oil spills are highly detrimental to seabirds by coating their features in thick oil and exposing them to toxic chemicals. When a bird's feathers are coated in oil, it cannot regulate its temperature or fly, and is at high risk of death. Studies on birds exposed to past oil spills suggest that ingesting toxic chemicals found in oil can negatively affect the bird's hormone and circulatory systems (King et al., 2021).


Image: © Jose Luis Magana / Greenpeace

4.3 Coastal wetlands

- The Red Sea has important coastal wetlands – mangroves and seagrass beds. They are important for storing carbon, protecting the beach and coastline from storm surges, helping to filter water and providing important habitats for fish and mammals such as dugongs. Mangroves are also important habitats for marine birds (Price et al, 2014).
- The Red Sea mangroves are some of the northernmost in the world and are an important habitat, particularly towards the southern part of the Red Sea along the coasts of Saudi Arabia and Yemen. The Red Sea mangroves have actually increased in extent since 1972, in contrast to global trends. Currently, they cover an area of around 120 km^2. Although the mangroves in Yemen continue to be impacted by human activity, they are found both to the north and the south of the location of the FSO Safer. (Price et al, 2014; Republic of Yemen, 2017).
- Seagrass beds are a coastal wetland ecosystem found throughout the Red Sea including on the coast of Yemen and Saudi Arabia. Globally, there are around 60 species of seagrass – 12 are found in the Red Sea. The highest number of seagrass species are in the central Red Sea region where they provide important habitats for fish, turtles and dugongs. However, this fragile habitat is under threat from climate change, pollution and coastal development. The added risk from an oil spill would be highly destructive (El Shaffai et al., 2011; Price et al, 2014; Republic of Yemen, 2017).

Image: Roberto Sozzani/Greenpeace

4.4 Ecosystem-wide risks

- Oil spills can be larger than they appear because some of the oil from a spill is 'invisible' and not seen on satellite imagery. The extent of the Deepwater Horizon spill from the deep sea, 1,522 metres below the sea surface, extended well beyond its satellite footprint. The key point to note here is that if satellite imagery is used to determine the extent of an oil spill it could be misleading if there is 'invisible' oil present in areas that cause toxicity in areas of water. The Deepwater Horizon spill extended beyond the closed fisheries – in other words, some fisheries that were not closed could have been contaminated by 'invisible' oil that had not been detected on the satellite images (Berenshtein et al., 2020). If satellite images are relied on in the event of a spill from FAO Safer, contaminated water could unwittingly be used in Red Sea desalination plants to provide drinking water, or could contaminate commercial fisheries. Similarly, fisheries that are at risk of contamination from toxic oil could remain open.
- Toxicity tests to determine whether water is safe must be sensitive enough to detect low levels of contamination or there could be a risk to human and environmental health (Berenshtein et al., 2020).
- Spilled oil could contaminate beaches and sediment. Contamination was found more than 500 km from the Deepwater Horizon site over an area of approximately 110,000 km^2 (McDaniel et al., 2015; Romero et al. 2017).

Image: : © Greenpeace / Jim Hodson

5.0 HEALTH RISKS

Image: © Daniel Beltrá / Greenpeace

An element of unpredictability exists in attempting to project potential health impacts.

The reason is that short-term impacts, such as the temporary closure of ports, desalination plants and fisheries, and exposure to air pollution, could have long-term impacts such as displacement of people following fishery closures (if those people seek employment elsewhere) or lack of food, water and/or fuel; and the health effects of air pollution exposure might not be evident for years. Regional instability could escalate resulting from the spill as parties blame each other; the war/blockade could be prolonged as a result of the spill, perpetuating the humanitarian disaster in Yemen (Huynh, personal communication, 2021).

- Crude oil contains chemicals that are carcinogenic to humans and animals. One family of toxic chemicals is the polycyclic aromatic hydrocarbons (PAHs). The International Agency for Research on Cancer has classified some PAHs as 'carcinogenic to humans' and some as 'probably carcinogenic to humans' (IARC, 1983). Crude oil also contains volatile organic compounds such as benzene (classed as a human carcinogen by the IARC), toluene and styrene (classed as carcinogenic to humans by the IARC), and heavy metals, which are toxic to human health. Metals commonly found in crude oil are nickel, vanadium, copper, cadmium and lead (Osuji & Onojake, 2004).
- The health impacts from direct exposure to crude oil will vary depending on factors that include the amount of time the oil has been exposed to the atmosphere, the extent to which the oil has mixed with water, and whether any chemical dispersants have been used (Levy & Nassetta, 2011).
- Negative health impacts from exposure to oil spills on workers and local communities include headache, nausea, dizziness, itchy eyes, cough or sore throat, rashes and skin irritation. Some people have reported psychological disorders (such as anxiety, stress and depression) following exposure to oil spills. Crude oil contains volatile organic compounds that can irritate the skin and the respiratory system (Levy & Nassetta, 2011). Human exposure to crude oil risks exposure to carcinogenic compounds such as benzene, toluene, ethylbenzene and xylenes, and to polycyclic aromatic hydrocarbons (commonly abbreviated to PAHs) (Levy & Nassetta, 2011).
- If dispersants are used there may be health hazards from exposure to these chemicals and mixtures of detergents and oil (Levy & Nassetta, 2011).

- Exposure to crude oil can be toxic to the human endocrine system and interrupt the metabolism of some hormones (Pérez-Cadahía et al., 2007).
- Medical evaluation of people exposed to an oil spill requires taking a detailed medical history, a physical examination together with specific laboratory tests (Levy & Nassetta, 2011). Yemen is in the midst of a six-year armed conflict and a humanitarian crisis (Human Rights Watch, 2021) now into its seventh year. A valid concern is whether a medical protocol to assess acute and chronic exposure to spilled crude oil is in place and whether workers and people affected will have access to adequate medical care.
- A concern is the supply of adequate personal protective equipment to workers and locals who could come into contact with oil spilled from the FSO Safer and are involved in attempts to remove oil from beaches or marine animals.
- There is not enough evidence to assess the potential impacts on human health of consuming seafood contaminated with PAH or compounds formed when PAHs are partially degraded by ultraviolet light (Berenshtein et al., 2020).
- Exposure to air pollution is covered in section 2.0, above.

Image: © Giorgos Moutafis / Greenpeace

Image: © Sean Gardner / Greenpeace

6.0 ECONOMIC RISKS

Image: AFP via Getty Images

The spilled oil has the potential to contaminate water in an extensive area of the southern Red Sea, and possibly further north, which will severely impact low-income coastal communities.

- Yemen's marine and coastal ecosystems – coral reefs, mangroves, seagrass beds and turtle nesting sites – have been valued at approximately US$541 million. These ecosystems are already under threat from various human activities, but an oil spill would severely damage and degrade these environments (Republic of Yemen, 2017).
- Yemen has plans to foster ecotourism to its coastal zones and islands (Republic of Yemen, 2017) but those plans will be compromised by any form of oil-related pollution.
- Traditional fisheries would be impacted by a spill; fisheries on the Saudi Arabia coastline have a combined net value (estimated in 2012) of up to Saudi Riyals 111 million (US$29.6 million) (Jin et al., 2012). An oil spill risks jeopardising livelihoods and income in Saudi Arabia – and neighbouring countries including Yemen, Sudan and Eritrea – as those fisheries close because of oil contamination.
- Economic impacts would be costly to the global shipping trade that passes through the Suez Canal. The temporary closure to international shipping routes through the Suez Canal will have global economic impact. An example of the potential disruption was the impact of the six-day-long blockage of the Suez Canal in 2021 by the container ship the MV Ever Given, which reportedly cost an estimated $9.6 billion in trade along the canal each day. An estimated 12% of global trade passes through the Suez Canal daily (Russon, 2021).
- Further disruption to shipping routes through the narrow Bab el-Mandeb Strait could also result (Huynh et al., 2021).
- Red Sea tourism to the coral reefs is an important part of economic income for several Red Sea countries, notably in the northern part of the Red Sea on Egypt's coastline, but Saudi Arabia has plans to increase coastal tourism by 2030 that could be jeopardized by oil contamination (Fine et al., 2019). Yemen also has plans to develop a sustainable ecotourism business (Republic of Yemen, 2017).

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