




Commentary

# The Mauritius Oil Spill: What's Next?

Davide Seveso <sup>1,2</sup> , Yohan Didier Louis <sup>3,\*</sup> , Simone Montano <sup>1,2</sup> , Paolo Galli <sup>1,2</sup> and Francesco Saliu <sup>1</sup>

- <sup>1</sup> Department of Earth and Environmental Sciences (DISAT), University of Milano, Bicocca, Piazza della Scienza, 20126 Milano, Italy; davide.seveso@unimib.it (D.S.); simone.montano@unimib.it (S.M.); paolo.galli@unimib.it (P.G.); francesco.saliu@unimib.it (F.S.)  
<sup>2</sup> MaRHE Center (Marine Research and High Education Center), Magoodhoo Island, Faafu Atoll, Nilandhoo 12050, Republic of Maldives  
<sup>3</sup> Department of Agriculture and Food Science, Faculty of Agriculture, University of Mauritius, Réduit 80837, Republic of Mauritius  
 \* Correspondence: yohanlouis20@gmail.com; Tel.: +39-026-448-2813

**Abstract:** In light of the recent marine oil spill that occurred off the coast of Mauritius (Indian Ocean), we comment here the incident, the containment method used by the local population, the biological impact of oil spill on two sensitive tropical marine ecosystems (coral reefs and mangrove forests), and we suggest monitoring and restoration techniques of the impacted ecosystems based on recent research advancements.

**Keywords:** oil spill; mitigation; restoration; PAHs; Mauritius; marine ecosystem; marine pollution; coral reef; mangrove



**Citation:** Seveso, D.; Louis, Y.D.; Montano, S.; Galli, P.; Saliu, F. The Mauritius Oil Spill: What's Next? *Pollutants* **2021**, *1*, 18–28. <https://doi.org/10.3390/pollutants1010003>

Received: 30 November 2020

Accepted: 26 January 2021

Published: 2 February 2021

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## 1. The MV Wakashio Accident: Consequences and First Containment Measures

On 25 July, a 300 m long Japanese tanker sailing without cargo from China to Brazil, named MV Wakashio, ran aground on a barrier reef off the south-east coast of Mauritius (location Pointe d'Esny). According to official statements, MV Wakashio had on board around 4200 metric tons (MT) of fuel for its own consumption, including low-sulphur fuel oil (3894 MT), diesel (207 MT), and lubricant oil (90 MT) [1]. Inhabitants of the south east of Mauritius and fishermen promptly expressed their concern about the socio-economic and environmental consequences on this incident [2]. The national oil contingency plan was activated by the Ministry of Environment, Solid Waste Management, and Climate Change on the day of the ship's grounding and oil booms were installed [3]. As no fuel leakage occurred immediately following the grounding, salvage teams were optimistic about a recovery of the ship from the reef without spill. Unfortunately, several days of rough seas and battering waves ultimately cracked open the hull of the MV Wakashio and, on 7 August, it began leaking its engine fuel [4] (Figure 1).

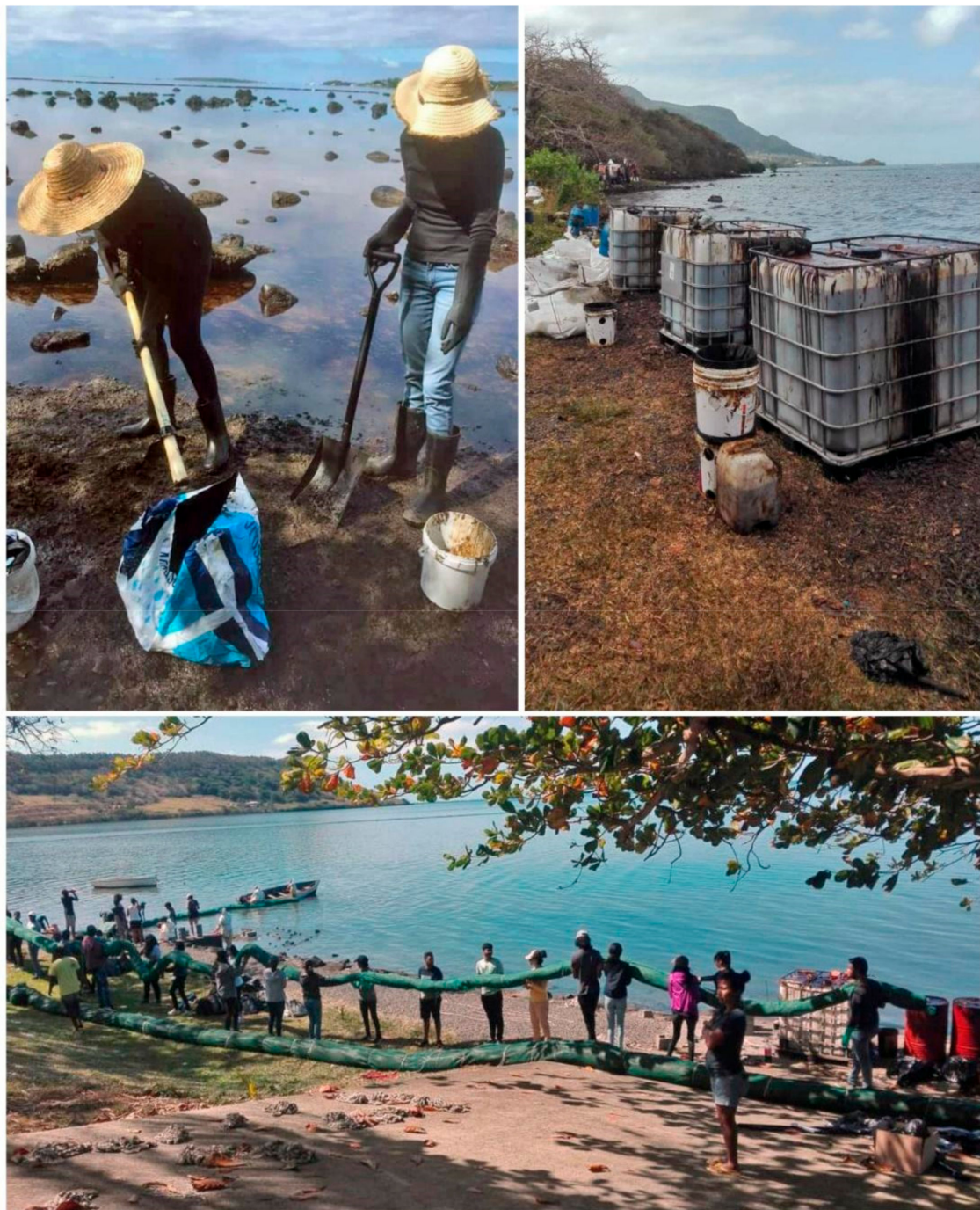
Mauritius declared a “state of environmental emergency” on the same day and requested international help. Local authorities indicated that approximately 3000 MT of fuel was pumped out before the ship broke in two, whereas around 1000 MT leaked into the sea [5]. The local population, non-governmental organizations (NGOs), and community service groups reacted promptly and actively participated in different ways to limit the oil spill spread, using different artisanal methods to contain the spill and in the removal operations of oil from the sea surface and along the coastline (Figure 2). By 24 August, 1122 tons of contaminated liquid waste (oil mixed with seawater) and 792 tons of contaminated solid on the shore had been carted away [6]. Clean-up operations are still ongoing in areas difficult to access such as mangroves swamps. Although the MV Wakashio oil spill is considerably smaller in terms of volume of oil spilled compared with previous oil spill disasters (e.g., 220,880 MT leaked from the sinking of the Amoco Cadiz, off the coast of Brittany, France in 1978, and more recently, on April 2010, 4.9 million barrels of crude oil were released into the Gulf of Mexico after the Deepwater Horizon drilling

platform explosion), it has affected three highly ecologically sensitive sites of one of the most renowned coral reefs of the world, and thus has brought severe economic impacts to the local communities that rely on them; that is, (i) The Marine Protected Area of Blue Bay Marine Park; (ii) the nature reserve Ile aux Aigrettes, which is a coral island hosting rare and endemic birds and geckos; and (iii) a mangrove forest protected under the Ramsar Convention. The oil spill has also affected a fishing reserve, public beaches, and smaller mangroves forests. Fish and crabs were the marine animals found covered in fuel and dead along the shoreline. In total, 36 km of shoreline has been declared off limits, and fishing and recreational activity in those areas was banned [7,8]. The livelihoods of people in affected areas have been strongly impacted, particularly those who rely on fishing. Tourism and the related activities (diving, recreation boat owners, and restaurants) faced a severe drop in revenues. Recreational activities have been re-authorized in November 2020, but fishing in the impacted areas remains banned [9]. So far, according to local observation, there is no visible trace of crude oil on the sea surface, but large accumulation is still present in the mangroves forest. This may have long-term consequences on the ecosystem. Proper monitoring plans and restoration counteraction are required, as severe toxicological effects of oil on the marine communities, from the microbial communities to the mammals, have been already detailed by several studies (reviewed in [10]).



**Figure 1.** The MV Washiko oil spill. In the first photo on the left, the ship MV Washiko appears stranded on a coral reef off the southeastern coast of Mauritius. In the other photos, the oil spots on the sea surface are shown (Credits: Yohan Didier Louis).





**Figure 2.** Citizens of Mauritius helping local authorities to fight the oil spill by collecting the spilled oil by accumulating on their beaches and deploying artisan booms made of dried sugarcane leaves (Credits: Yohan Didier Louis and Rima Beesoo).

## 2. Impacts of the Oil Spill on Marine Communities

The oil toxicity is mainly due to the aromatic hydrocarbons, particularly polycyclic aromatic hydrocarbons (PAHs), which show binding ability to DNA and protein, low water solubility, lipophilicity, and high persistence. Carcinogenic and long-term chronic impacts have been reported even when these compounds were exposed at low levels to marine organisms [11,12]. The oil spill in Mauritius has affected sensitive ecosystems such as mangroves (Figure 3). The consequence for marine life could be disastrous as mangroves are the nursery of the marine environment. Mangrove communities are particularly susceptible to damage from large oil spills [13–16]; when oil is released into coastal waters

and washed ashore, it deposits on sediments that cover the highly sensitive fine feeding roots of mangrove trees. Once deposited, oil adheres and rarely moves, having adsorbed into oleophilic surfaces of plants. Oil coats the breathing surfaces of mangrove roots, stems, seedlings, and surrounding sediments, as well as fauna present in burrows and root hollows (Figure 3). When smothered with oil, shorter plants and animals die mostly within days. By contrast, taller mature trees and shrubbery, oiled only on their exposed roots and sediments, might persist for six or more months before dying [17]. The effects of oil spills on mangrove communities are reviewed in [17].

Together with mangrove, filter feeders, such as corals, crustaceans, and mollusks, are of particular concern. Crabs are mostly exposed to oil toxicity through coating on surfaces and body suffocating, feeding on oil polluted sediments, which causes ensnaring and blockage of the gills, and low feeding [18,19]. Heavy coating of oil on the crab's body has a detrimental impact, such as impaired physiology and behavior, interfering ecosystem roles, and transferring to crab predators. Various studies have recorded a high frequency of death of crabs exposed to oil spills, while surviving members have impaired movement and digging ability [20]. Among mollusks, mussels and other bivalves accumulate oil for a long period through their gills owing to their filter feeding activity [21]. The continuous accumulation of oil generates a reduction in development and DNA impairment within 48 h of exposure with a significant increase in this impairment by 72 h [22]. The cellular immunity of mussels was also disrupted [23,24].

The coral reefs and coral communities in the area have also been severely exposed to the oil spill (personal observation—YD Louis). The acute and chronic effects and injuries of oil pollution on coral species, both on the adult colonies and larvae, have been analysed in previous field and experimental studies [25–32]. These studies have confirmed various lethal and sublethal physiological, behavioral, and ecological responses of scleractinians, including impaired reproduction and fecundity, low larval recruitment and survivorship, decreased growth, increased tissue damage, and bleaching [25–32]. The annual mass spawning of corals was observed in the impacted area at the start of November 2020, similar to previous studies. The oil spill has hence not altered the timing of the release of gametes for this year, at least. However, no information is yet available on the fertilization, survival, and settlement success of coral planula larvae. In the coral reef ecosystem subjected to oil spills, the total coral cover and the species diversity showed a significant decline, leading to substantial changes of the community structure being detectable up to several years after the spill [33–37]. In addition, deep-water coral communities were also found to be affected by oil spill events, and many large octocoral colonies below the oil slick exhibited significantly more injury than in years before the spill [38–42].

Fish at early life stages (eggs and larvae) are highly susceptible to PAHs owing to the lack of developed cell membranes and detoxification structures [43] and may face malformation, circulatory failure, stunted development, and low appetite [44,45]. In adult fishes, PAHs may cause reduced feeding and growth rates, increase vulnerability to predators and starvation [46,47], loss of hatching ability of eggs, fouling of gill structures, impaired reproduction, growth, development, feeding, and respiration [48]. PAHs also interrupt the normal development and role of the heart, which can further cause failure of circulation [44,49]. Noteworthy, significant changes in fish community structure, especially in terms of food web and trophic relationships, as well as a substantial decline in the abundance of demersal reef fish immediately after an oil spill event, have been observed [50,51].

Finally, marine mammals are mostly exposed to oil on the sea surface and shoreline. Dolphins and whales, as well as sea turtles, are mostly affected by oil spills because they breathe at sea surface and ingest oil after an oil spill, resulting in respiratory irritation, inflammation, emphysema/pneumonia, gastrointestinal inflammation, ulcers, bleeding, diarrhea, and possible damage to organs [52–54]. Analysis of live bottlenose dolphin exposed to oil showed that they had lung and adrenal ailments coupled with other poor health disorders [55,56]. Other research confirmed the vulnerability of the dolphins to



bacterial infections and other health ailments that could possibly lead to death [57,58]. In this context, almost 20 days after the oil spill, 51 melon-head dolphins were washed up in Mauritius on the shores in the same region in which the oil spill occurred. During their necrosis, no traces of hydrocarbon were found on their skin, in the digestive and respiratory tract of the animals, thus no direct link with the oil spill has been found yet [59,60]. However, further toxicological analysis revealed the presence of hydrocarbon in 11 of the dead dolphins.



**Figure 3.** The oil spill has heavily affected the mangroves forest. Large and dense oil stains cover the shallow basin where the trees develop and affect a young mangrove propagule as well as the mangrove roots (Credits: Yohan Didier Louis).

### 3. Short- and Long-Term Mitigation Measures

To have an overview of the impact and the damage caused by the oil spill on the ecosystem biodiversity using the ecological approach, as well as the incidence of the oil spill on the different biota and within each biota, the prevalence of the impact at population and community level must be measured. In addition, at the organism level, because the earliest steps of an individual's response to any environmental stress occur at the cellular level, a useful diagnostic tool is the analysis of the expression of cellular and molecular biomarkers (such as stress proteins, enzymes, and gene expression) that reflect changes in cellular structural integrity, as well as in functional cellular pathways and performance. Hierarchially, the organism's physiology is the nexus between the organism and the stressor, playing a paramount role in determining their tolerance and resilience to stressors.

In this context, the efforts to remove the oil should have as a first aim the recovery of a healthy biological community. According to ITOPF (International Tanker Owners Pollution Federation) indication [61], clean-up operation may be delivered following a two stage process: firstly, the prompt removal of the gross contamination, followed by targeted activities to limit the pollution damage and help the natural healing process. Moreover, it should always be taken into account that nature plays a very large part in the cleaning process and that improper clean-up operations may cause additional damage beyond that caused by the oil spill (such as an excessive use of hot water and chemicals to reach a fast and unrealistic last oil drop removal).

To date, clean-up operation can only address the oil that is accessible (stranded on the shoreline/mangroves). The removal of free oil from mangrove stand using a low-pressure high volume of water has already been reported in order to mitigate long-term damage. The use of heavy vehicles and excessive manpower should be monitored in order to avoid damages to rootstocks by trampling. In addition, the chemical and physical characteristics of the oil should be also taken into account, as light refined oils, such as diesels, are less persistent, but more toxic and should be removed firstly from sensitive sites. On the contrary, higher viscosity oil can stick and persist for a longer time, with the possibility that the recovery of the original ecological features of the habitats and ecosystems are reached even without a visible cleanliness of the area.

To the best of our knowledge, dispersants were not applied in the first days immediately following the oil spill. The effectiveness of dispersants to combat oil spill is highly debated in the literature and current reviews focus on the fact that their application should be tailored considering environmental conditions, the chemical profile of the spilled oil, as well as possible counteraction with other clean-up operations. From an ecological point of view, the fact that the oil is removed from the sea surface and moved again to the water column in the form of little droplets can cause more risks, as corals, seagrasses, and fish larvae may be more readily affected. Moreover, even free swimming fish should not be considered safe, as they are able to spot and avoid large oil bulky mass, but not the tiny dispersed droplets.

In a study conducted following an oil spill event in Panama, the short- and long-term effects of floating oil and chemically dispersed oil on mangroves, seagrasses, and corals in sheltered shallow sea areas, similar to those of Mauritius, were analyzed [62]. The study concluded that the dispersed oil initially caused large mortality to invertebrate fauna and seagrass beds and reduced coral cover by approximately 30%. However, within 10 years, the coral coverage had fully recovered to pre-spill levels. In addition, floating oil significantly affected the mangrove forests, with 46% mortality of the adult mangroves and evident signs of coastal erosion. In this case, 20 years after the initial oiling, no significant evidence of recovery of the mangrove forests was detected, as adult mangrove trees were still dying, although new trees were slowly replacing those killed by the oil [62]. Other post-spill assessments suggest that structural recovery of oil-damaged mangrove forests takes place over a period of at least three decades [17].



#### 4. Monitoring and Restoration of Coral Reef and Mangrove Forests

In Mauritius, monitoring of health of mangroves and corals communities started soon after most of the spilled oil had been recovered. Different specialised working groups were set up by the Government consisting of Government officers, university researchers, and scientists from NGOs, as well as foreign scientists notably from Japan and the United Nations (UN). The aim of this working group was to regroup scientists with relevant expertise and local field experience to start a coordinated preliminary ecological monitoring soon after the catastrophe. Monitoring is still on-going.

Coral and mangrove farming and restoration may represent the best, and maybe the only, solution in order to try to restore the pre-oil spill condition and the functionality of coral reefs and mangrove forests, two fundamental marine habitats that provide several ecosystem services to the Mauritian population.

The concept of restoration is connected to that of rehabilitation [63] and it implies “assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed”. To date, coral restoration is still a discipline in development, with a lot of research currently being done to address those challenges and to improve and innovate on the techniques used. Different techniques exist and may be used to enhance the Mauritian coral reefs. Coral transplantation may be used to translocate corals, in whole or in parts, to a denuded or degraded reef, for example, affected by the oil spill [64]. Coral transplantation can be considered particularly effective in the case of physical damages (such as ship groundings or hurricanes) because of the large availability of coral fragments. In the most damaged reefs, artificial reefs can be used aimed at rehabilitating denuded and structurally unstable areas to promote the settlement of various invertebrates. Some examples are represented by Reef Balls™ [65], which are ball-like hollow elements; Coral Spiders, which are metal modules and have been used in a successful project in an Indonesian island [66] to consolidate rubble; or sand-coated metal frames [67], used in sandy environments. However, coral gardening is now one of the most used methods for coral propagation. It is represented by the creation of in situ nurseries (rope nurseries or table nurseries) to grow coral colonies from fragments in areas within the reef, but not affected by human pressure, sedimentation, wave action, and predators [67–69]. On these structures, corals grow to a size suitable to then be transplanted on reefs, including artificial reefs.

Different techniques have also been developed to restore mangrove forests [70–73], and could thus potentially be used for those in Mauritius affected by oil release. Moreover, the operational response guidelines based on actions and response strategies for monitoring and restore mangrove habitats impacted by large oil spills were well developed as standard operational procedures [17]. The types of responses, actions, and their timing depend on four threat phases of the spill incident: “Pre-Spill”, “During Spill Pre-Impact” and “During Spill Post-Impact”, and “Post Spill”. For each phase, specific action and monitoring plans are developed and suggested [17].

Mangrove planting is the most common method of restoring mangrove forests. It basically consists of planting new seedlings or propagules or adult trees in the degraded area previously occupied by the forest. However, work must not be focused only on techniques for growing mangrove trees (a “tree-centered approach”), as attention must be paid to long-term community structure [70]. In addition, the approach is not often successful, especially when the reasons for mangrove degradation were not removed prior to planting. For example, in a previous study, a detached breakwater was erected seaward at the shoreline to shelter the restoration area from wave action; prevent the ongoing erosion; and promote sediment deposition, raising the elevation of the substrate to the target elevation [73].

Currently, in Mauritius, different restoration techniques have been proposed by NGOs and are being discussed with local authorities. These include mangrove and coral farming to restore the respective ecosystems, but to date, discussions are still on-going for a coordinated and efficient restoration program, while funding is being sought.

## 5. Conclusions

Mauritius is one of the most renowned coral reefs on the planet, comprising a wide marine protected area rich in biodiversity, estimated by travelers from all around the world as paradise for leisure, sightseeing, scuba diving, and water sports. Unfortunately, the islands lie near a shipping highway used by thousands of large vessels every year. This represents a hazard for their natural treasures, which the MV Wakashio accident confirmed to be real. Thanks to recent research advancement, the scientific community has gained knowledge about the impacts of oil spill on marine ecosystem, and developed technologies that may limit the ecological damage in the short term and speed up natural self-healing processes in the long term. However, the large differences in the time scale of the events (accident–response–restoration) as well as the irreversibility of a part of the pollution process are, once again, under our eyes; the spill was spread in a few weeks after the vessel ground, the assessment of the impacts on the marina fauna and the action to restore the affected ecosystem are still (after several months) in progress, and will most probably continue for years.

**Author Contributions:** Conceptualization, P.G. and F.S.; Methodology, D.S. and F.S.; Resources, Y.D.L.; Data Curation, F.S.; Writing—Original Draft Preparation, D.S., Y.D.L., S.M. and F.S.; Writing—Review & Editing, D.S., Y.D.L., S.M. and F.S.; Supervision, F.S. and P.G.; Project Administration, F.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

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