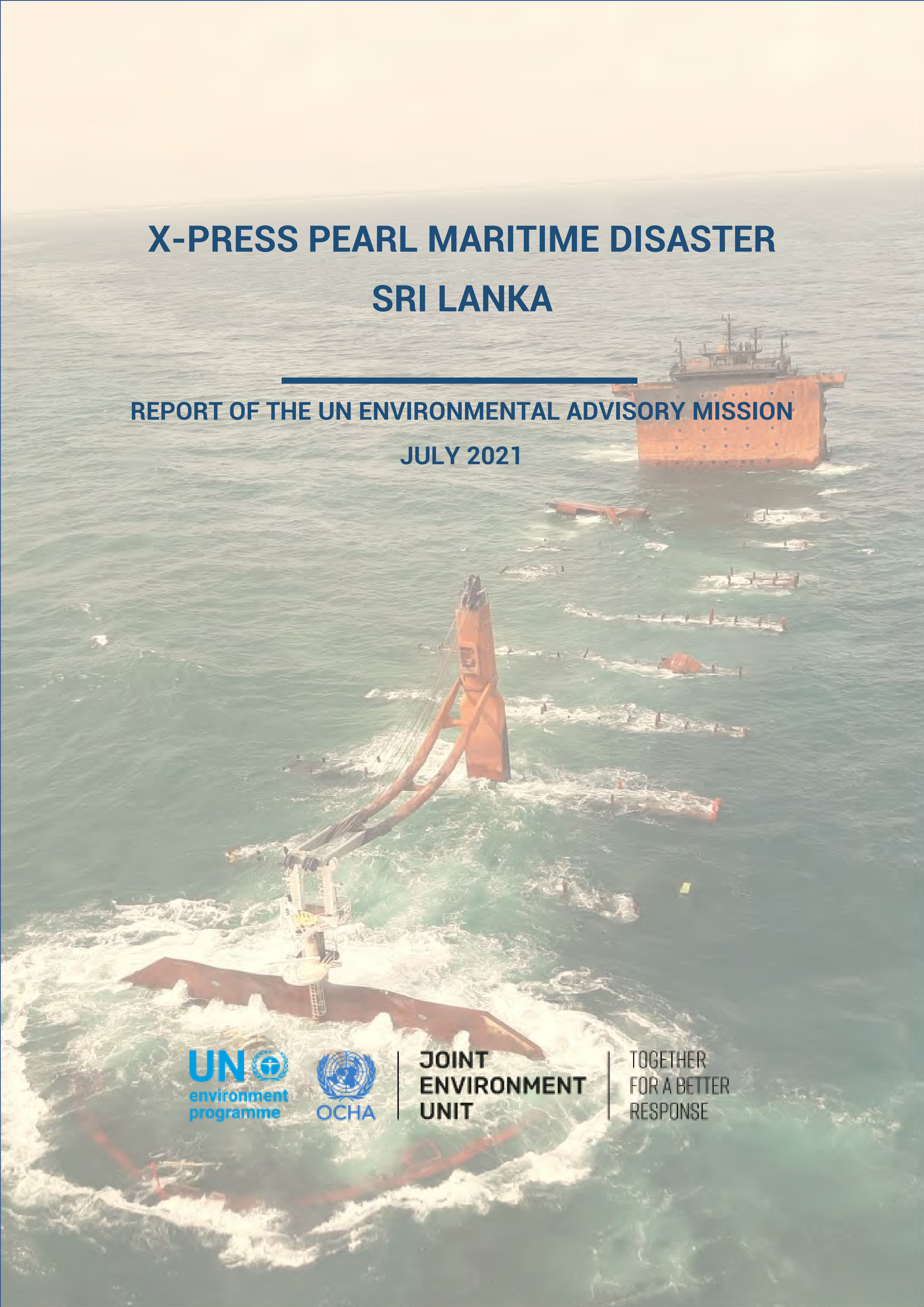
X-PRESS PEARL MARITIME DISASTER
SRI LANKA

REPORT OF THE UN ENVIRONMENTAL ADVISORY MISSION

JULY 2021



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TOGETHER FOR A BETTER RESPONSE

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This report is based on the information received and gathered during the mission and therefore cannot be seen as exhaustive, but can be considered as representative of the existing situation. All information has been compiled by the experts on mission based upon best available knowledge when drafted.

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List of Abbreviations

BAOAC	Bonn Agreement Oil Appearance Code
CEDRE	Centre of Documentation, Research and Experimentation on Accidental Water Pollution (France)
CEFAS	Centre for Environment, Fisheries, and Aquaculture Science (UK)
DWC	Department of Wildlife Conservation
ECHO	European Commission's Directorate-General for Civil Protection and Humanitarian Aid
HDPE	High Density Polyethylene
HFO	Heavy Fuel Oil
HNS	Hazardous and Noxious Substances
IFO	Intermediate Fuel Oil
IMT	Incident Management Team
IMDG	International Maritime Dangerous Goods
ISPRA	National Institute for Environmental Protection and Research (Italy)
ITOPF	International Tanker Owners Pollution Federation
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
MEPA	Marine Environment Protection Authority
NARA	National Aquatic Resources and Development Agency
NBRO	National Building Research Organisation
MV	Merchant Vessel
NM	Nautical Mile
NOSCP	National Oil Spill Contingency Plan
NGO	Non-Governmental Organization
OCHA	(UN) Office for the Coordination of Humanitarian Affairs
OSRL	Oil Spill Response Limited
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
PPE	Personal Protective Equipment
SACEP	South Asia Co-operative Environment Programme
SASP	South Asian Seas Programme
SLPA	Sri Lanka Port Authority
UN	United Nations
UNEP	United Nations Environment Programme

Executive Summary

The X-Press Pearl incident is the worst maritime disaster to have struck Sri Lanka. It has had a significant impact on Sri Lanka's sensitive coastal environment, local communities and the economy. Moreover, the event continues to unfold, and its active pollution generation phase will only come to closure with the elimination of the risks from the wreck and containers lost at sea.

Along with uncertainties of cascading environmental damage, the incident's complexity stems from the range of pollutants involved - oil, hazardous chemicals and plastics – and the lack of clarity regarding the nature and status of a substantial part of the vessel's cargo. Moreover, the growing geographic extent of the plastic spill - the largest on record - is expected to have transboundary impacts further compounding the problem.

There are two immediate risks from the incident that need to be eliminated as soon as possible:

i) a sudden major spill of the fuel oil aboard the ship; and
ii) pollution and navigational hazards from the wreck and lost containers.

Proactive and vigilant surveillance are required to mitigate these risks. With the development of offshore and shoreline clean-up plans, as well as the deployment of response equipment, key actors are now relatively well pre-positioned to deal with a possible oil spill. Action to contain and recover the limited but continuous release of oil from the wreck should be taken as soon as conditions allow.

Similarly, planning needs to be initiated to remove the wreck, lost containers and debris as a matter of priority. A detailed roadmap for this major decommissioning project needs to be developed immediately in a consultative and transparent manner, and independently from current concerns over monsoon related weather challenges. Government sanctioned oversight is imperative to ensure accountability for the satisfactory conduct of the work and instilling public confidence in the wreck and debris recovery process.

Despite the operational constraints of COVID-19 lockdown restrictions, Sri Lanka's authorities are implementing a commendable and efficient clean-up campaign of the plastic spill. Nevertheless, several key actions need to be carried out to enhance its effectiveness including:

i) contamination analysis of the plastic waste to determine if it is hazardous or not;
ii) refining and scaling-up clean-up techniques that minimize sand abstraction and recover small burnt particles; and
iii) establish technical specifications for completion of microplastic clean-up operations while minimizing inadvertent environmental damage.

Environmental assessment of the incident needs to focus on pollution 'hot spots'; namely the area of the wreck and impacted shoreline sites. The investigation strategy should be directed at resolving several key questions with significant socio-economic implications and to allay public concerns, notably:

i) is the fish inside/outside the designated 'no fishing area' safe to eat?
ii) when should the moratorium on fishing be lifted?
iii) is the reported spike in turtle and marine mammal deaths linked to the incident?

A biomonitoring programme is recommended as a relatively simple and cost-effective option to monitor the situation around the wreck, including the status of sensitive marine ecosystems (i.e. coral reefs) in the wider incident area.

While extensive sampling has been conducted, it is now important to focus the analysis on key parameters and expedite laboratory testing to generate scientific results for decision making and assess the actual damage from the incident. The results should also help inform the design of a longer-term monitoring programme of the marine environment. This is vital not only to track this disaster's ecological impacts, but also to obtain insight on baseline conditions which are essential for conducting scientific assessment and remediation of future maritime incidents. A sound knowledge base is also a central requirement for litigation and damage and loss assessments.

Beyond short-term remedial counter measures, ultimately real progress is for Sri Lanka to emerge from this traumatic experience with a more resilient system for preventing and responding to future maritime disasters. This would require a multi-year initiative that would include:

i) development of a maritime disaster plan (building on the existing NOSCP);
ii) strengthening the institutional basis for its implementation; and
iii) a capacity building and training programme.

An initiative of this scale hinges on forging a solidarity coalition between the Government of Sri Lanka and its international friends and partners. Success will ultimately depend on coordinated action between diverse actors and hence the importance of a designated mechanism to organize international support. Thereby reinforcing Sri Lanka's efforts to consolidate its position as a global maritime and logistical hub, while assuring greater protection of ocean health, fishery resources and world trade.

1. Mission Background and Scope

On 20 May 2021, chemical fume emissions erupted on the Singapore-flagged MV X-Press Pearl containership as it anchored around 9 nautical miles (17 kilometres) northwest of the Port of Colombo in Sri Lanka national waters. An unknown number of containers, some of which carrying dangerous chemicals and plastic pellets, reportedly fell overboard as an intense fire broke out and explosions occurred on 25 May. Once the fire was under control around a week later, an effort to tow the vessel on 2 June to a deeper water refuge failed and resulted in partial sinking of the vessel. An oil slick emanating from the ship was visible by satellite from 8 June. And by 17 June the entire vessel had settled on the seabed at a depth of about 21 meters, with only its castle and some of its cranes partially visible. The crew were safely evacuated from the ship and no human causalities were deplored from the incident.

The principal environmental issues arising from this incident include:

1. A large black smoke plume created by the fire extending inland;
2. Potential spill of 15 products classified as Dangerous Goods aboard the ship into the sea, including 25 metric tonnes of nitric acid;
3. Large quantities of plastic pellets, cargo and other debris from the vessel washing ashore along the west coast of Sri Lanka; affecting most notably the Negombo beaches and lagoon - a prime fishing and tourist sector north of Colombo; and
4. A long but limited oil slick continuously leaking from the ship raising concern over a major sudden spill of the 348 tonnes of bunker fuel aboard the ship.

The Marine Environment Protection Authority (MEPA) activated the National Oil Spill Contingency Plan (NOSCP) and manages the incident as it continues to unfold; in collaboration with the Sri Lanka Armed Forces, technical government departments, local authorities and other key stakeholders.

On 4 June the UN Resident Coordinator in Sri Lanka received an official request from the Ministry of Foreign Affairs for technical support. And on 10 June the UN Environment Programme (UNEP) Executive Director received a similar request for assistance. In response to this request and in coordination with the UN Resident Coordinator, the UNEP/OCHA Joint Environment Unit mobilised a team of four experts to advise the Government of Sri Lanka primarily on:

1. Designing and implementing an environmental assessment;
2. Preventing, mitigating and responding to risks from the incident;
3. Strengthening national capacities to deal with future maritime disasters.

The four-member team deployed by the UNEP/OCHA Joint Environment Unit included two oil/chemical and marine litter experts from the Centre of Documentation, Research and Experimentation on Accidental Water Pollution (CEDRE) in France and a marine environment expert from the Italian National Institute for Environmental Protection and Research (ISPRA). The experts were mobilised through the European Commission's Directorate General for European Civil Protection and Humanitarian Aid Operations/Emergency Response Coordination Centre (DG ECHO/ERCC). The team was led by an environmental assessment specialist from the UNEP Resilience to Disasters and Conflicts Global Support Branch and was in Sri Lanka from 16 – 30 June.

The UN team worked closely with MEPA on daily basis, who organised consultation meetings with members of the Environmental Damage Assessment committee and facilitated site visits to the shipwreck and impacted shoreline sites. Furthermore, members of the UN team also received remote backstopping from their respective head offices and networks on technical questions that arose during the mission.

1.1 Context

Although historically Sri Lanka has experienced relatively limited maritime disasters, over a period of nine months the country suffered two major incidents namely that of the: i) MT New Diamond crude oil carrier in September 2020, and ii) MV X-Press Pearl cargo vessel in May 2021. Both incidents were caused by fire aboard the ships. Located on a major East-West shipping route and with major investments underway to build a regional maritime and logistical hub, the prospect of similar accidents occurring is expected to increase in the future.

The Sri Lanka authorities describe the MV X-Press Pearl as the "worst catastrophe in its maritime history"[1]. It is evident that this is a complex and multi-dimensional incident encompassing a spectrum of environmental issues with potentially serious consequences over both the short and longer term. The key risks arise from:

1. Bunker fuel oil spill (348 tonnes);
2. Hazardous and noxious substances (of the vessels 1,486 containers, 81 were carrying dangerous goods including 25 tonnes of nitric acid, caustic sodic, methanol. In addition, there was 9,700 tonnes of potentially toxic epoxy resins on board[2]);
3. Recovery and decommissioning of the shipwreck wreck and lost containers;
4. Microplastics (nurdles or plastic pellets < 5mm). In total, there were 87 containers carrying several types of plastic pellets aboard the ship. The overall quantity of plastic pellets is estimated at around 1,680 tonnes;
5. Macro plastics (5-50 mm);
6. Fire residues (micro to macro);
7. Assorted bulk debris (cargo, pieces of damaged containers); and
8. Air pollution

A gradually developing incident with transboundary impacts

First, it is important to underline that this is a dynamic and evolving disaster, which is not over yet. While the initial emergency response phase has subsided, there is always a residual risk of bunker oil escaping from the vessel and/or hazardous chemicals and plastic pellets being released from containers on the ship or lost at sea. In the short term, the active (pollution generation) phase of the incident will only come to closure when the shipwreck and all the containers are fully removed and safely decommissioned. Over the medium-term, offsite clean-up of the plastics and other waste mixed in beach sand and deposited in sensitive environments (e.g. reef structure) will need to be carried out to a reasonable level; knowing that total recovery is impossible.

At the time of writing, the geographic bounding of the incident remains unknown givens its developing nature. A substantial proportion of the plastic pellet pollution will remain mobilized in the ocean for decades and will take many years to recover which may never be

[1] Letter from Sri Lanka Foreign Secretary to UNEP Executive Director dated 10 June 2021.
[2] While the epoxy resin was not classified as a dangerous good on the cargo list, its toxicity is pending confirmation of its formulation as liquid epoxy is classified as harmful for the aquatic environment.

fully possible. Indeed, modelling studies suggest that the pellets will make landfall across Indian Ocean coastlines from Indonesia and Malaysia to Somalia[3]; further highlighting the potential transboundary impacts of the event. Hence, it would be premature to conclude an environmental assessment of this incident during the current emergency phase. Any assessment of environmental impacts at this stage should therefore be considered an interim or provisional evaluation.

Unprecedented plastic spill

The most immediate and significant impact of the incident so far are the waves of industrial nurdles (raw material plastic pellets) and other debris washing ashore several days after the outbreak of the major fire on 25 May. The fire and explosions had caused cargo to fall aboard, including containers of nurdles. A massive accumulation of plastic pellets, reportedly reaching up to two meters deep in certain locations on Negombo beaches, is the hallmark of the incident which captivated public attention both in Sri Lanka and internationally.

Indeed, the incident is reportedly the single largest plastic spill on record. The event is also exceptional in that a considerable proportion of the stranded plastics on the shoreline are burnt fragments of various sizes and mixed with various types of debris from the ship and its cargo. Both the combustion of the plastics and presence of hazardous chemicals raises important questions over their potential contamination.

Strained incident response capacity

The Marine Environment Protection Authority (MEPA), as the mandated institution dealing with marine pollution in Sri Lanka, activated the National Oil Spill Contingency Plan (NOSCP) to deal with the incident. MEPA is also applying the same organisational procedure laid down in the NOSCP to clean-up the plastic pellet pollution. The plastic pellet clean-up overseen by MEPA is a massive operation, which has been primarily conducted by the Sri Lanka Armed Forces (Navy, Army, Coast Guard, Airforce) in a timely and highly effective manner [4,5]. Furthermore, the International Tanker Owners Pollution Federation (ITOPF) and Oil Spill Response Limited (OSRL) are providing substantial technical advisory support to MEPA in designing and implementing shoreline clean-up operations on behalf of the shipowner and the P&I Club (maritime insurance).

In addition to the substantial demands created by the massive plastic pellet clean-up campaign, the response capacity of MEPA and other government agencies is challenged by the multiple dimensions of the incident which notably includes:

- dealing with oil and chemical spills;
- coordinating emergency support from neighbouring and other countries (e.g. India);
- surveillance and salvage of the wreck and containers;
- assessing the environmental damage over the short and longer-term;
- support to impacted economic sectors, particularly coastal fishing communities and tourist industry;
- legal investigation of the incident; and

[3] X-Press Pearl Disaster: An Oceanographic Perspective (06/08/2021), Prof. Charitha Pattiaratchi and Dr. Sarath Wijeratne, Oceans Graduate School and the UWA Oceans Institute, The University of Western Australia.
[4] Due both to concerns over public safety and the COVID-19 lockdown restrictions participation of the public and civil society organisations in clean-up operations has been limited.
[5] In addition, the Navy conducts surveillance of oil pollution emanating from the wreck and supports the taking of samples by government agencies. For its part, the Airforce is conducting aerial surveillance and operating helicopter reconnaissance visits for experts monitoring the status of the oil slick.

- ➢ filing of compensation claims.

The Cabinet of Ministers appointed an Inter-Ministerial Committee[6] of senior government officials headed by the Minister of Justice for an overall coordinated response to the incident. Five sub-committees have been created thereunder dealing respectively with: i) legal action; ii) compensation claims; iii) environmental impacts; iv) fisheries impacts; and v) economic damages.

Furthermore, the high visibility, public panic and media scrutiny created by the incident (e.g. due to concern over fish contamination, loss of livelihoods, spike in turtle deaths) has created a significant crisis communication and public relations challenge for government officials. Not only has it placed a substantial demand on government institutions to generate information and raise public awareness of potential dangers on regular basis, but also to counter misinformation and maintain public trust in public institutions.

COVID-19 operational and logistical constraints

Despite the important achievements of the government's clean-up campaign to date, it faced significant operational constraints due to the strict COVID-19 lockdown in effect in Sri Lanka during the time of the incident. The COVID-19 pandemic not only impacted the capacity to mobilise manpower on a large scale for clean-up work but supply chain disruptions are causing delays in procurement and transport of clean-up equipment (e.g. PPEs, buckets, sieves, drums, decantation tanks and waste storage containers) both from local manufacturers and international suppliers.

Challenging weather and sea conditions

The incident occurred during the Southwest monsoon which takes place between May to September. In addition to heavy rain, the strong south-westerly winds create rough sea conditions which may make it difficult to deploy offshore oil spill response equipment (booms, skimmers) to contain oil spills. Nevertheless, a lull in weather conditions could make it feasible to use specifically designed equipment such as current busters. Furthermore, the monsoonal winds and swells would mainly drive any spill, debris and cargo from the wreck towards the shoreline. Highlighting thereby the importance of taking necessary measures to protect sensitive coastal environments, particularly the Negombo lagoon and other estuaries and inlets.

The key point to emphasize here is that while difficult weather and sea conditions may impede oil spill response and wreck and container recovery, it does not prevent detailed planning and preparedness in dealing with risks from the incident which should start immediately. Furthermore, it should be feasible to initiate inspections of the wreck and to locate the lost containers with best available surveillance technologies.

[6] Members of the Inter-Ministerial Committee include the Attorney General; the Minister of Ports and Shipping; the Minister of Urban Development, Coast Conservation, Waste Disposal and Community Cleanliness; the Minister of Fisheries and Aquatic Resources; and the Minister of Wildlife Protection.

Table 1: Timeline of the Incident

1) MV X-Press Pearl departs from the port of Hazira, India, on 15 May.

2) The containership anchors within the jurisdictional limits of the outer harbour of Sri Lanka Port Authority (SLPA) at 00:30 AM, 20 May 2021. At 16 hrs of same day, emissions of yellow and brownish fumes began to appear from the ship.

3) At 18 hrs 20 May, the Incident Management Team (IMT) comprising MEPA, SLPA, Navy and Coast guards was activated and held its first meeting.

4) On 21 May, representatives of the four-member IMT undertook an inspection visit to the MV X-Press Pearl. Fires were reported on deck. A directive was issued to the shipping company to take remedial action, who responded by sending a tug operated by the salvage company SMIT.

5) On 22 May, explosions were heard in the cargo hold and the ship catches fire.

6) On 24 May, the salvage company boards the MV X-Press when the situation was still under control and tries to control the fire.

7) Around 12 noon on 25 May, loud explosions occur, and the fire engulfs the entire ship. Multiple containers reportedly fell overboard. All personnel are evacuated.

8) Several firefighting boats from Sri Lanka and the Indian Coastguards are deployed on the scene to fight the fire. A 'boundary cooling' technique is applied initially with foam, but when the foam ran out replaced it with water. A dry chemical powder is also dropped by air to extinguish the fire. As the fire raged, an unknown number of containers continue to fall overboard.

9) At the same time, the IMT activates its NOSCP and mobilize 15 stakeholders who had oil spill response assets (booms, absorbents, etc.) to be on standby. The equipment, however, is considered inadequate to contain an eventual spill, and its usability is reportedly compromised by compatibility issues between the different equipment (e.g. booms).

10) By 31 May, the fire situation is under control. A decision is made to tow the boat to a refuge site located 50 NM west of the coastline to minimize impacts on other maritime shipping and the coastal environment.

11) On 1 June, four salvers were able to board and inspect the ship.

12) On 2 June, after towing the MV X-Press for nearly 1 NM, the ship's aft sinks around 9 NM (17 km) from the Colombo harbour and 4.5 NM (8 km) from the coastline. The forward section remains afloat and the bridge section is above water.

13) The vessel's bow which was initially buoyant continued to settle down, and on 17 June sank completely on the seabed at a depth of about 21 meters. Only the upper forecastle deck and one of the cranes is currently visible.

14) The approximately 100 kilometre stretch between Negombo and Kalutara is the most impacted by the plastic spill from the ship. Plastic pellets and other debris continue to strand on the shoreline.

15) Eight containers have reportedly so far been found on shore. MEPA estimates that a quarter of the containers may still be on board, the rest being either burnt or on the seafloor.

1.2 Mission objectives

The objectives of this environmental emergency mission were to support to the Government of Sri Lanka in responding to the MV X-Press Pearl incident. Specifically, key aims of the mission include:

1. Advise the Environmental Damage Assessment team coordinated by MEPA on the design and implementation of an environmental assessment over the short and longer terms;

2. Advise MEPA on the measures to be taken to prevent, respond and mitigate risks from the incident including from:

    a) bunker fuel oil spill containment and clean-up;
    b) shoreline clean-up of plastic pellets and other debris; and
    c) salvage of the ship wreck and lost containers.

3. Provide longer-term recommendations on strengthening national preparedness and incident management capacity to deal with future maritime disasters;

4. Identify additional expertise needed to address the impacts of the incident and link national counterparts with relevant networks and partners including accredited international laboratories.

5. Brief the government and international partners on the evolving situation and needs for immediate emergency response and longer-term recovery.

The UN mission to Sri Lanka took place from 16 – 30 June 2021. The team operated under a ‘bio-secure bubble’ protocol due to COVID-related restrictions and was thereby able to hold meetings and conduct site visits almost immediately on arrival (Annex IV – Key Stakeholders Consulted).

2. Key Activities and Findings

2.1 Key Activities

The UN Team's mission was formally launched with a multi-stakeholder briefing meeting chaired by the Ministry of Foreign Affairs on 17 June involving around 20 key government stakeholders engaged in the incident response. The meeting allowed the UN team to obtain an initial overview of the roles and mandates of key national institutions in relation to the incident; what actions were carried out or planned so far; inform about the mission's objectives; and exchange views on the challenges encountered and the way forward.

Prior to the abovementioned meeting, the UN Team had held a series of informal meetings with the UN Resident Coordinator for overall guidance on the mission, as well as connected with several other international partners supporting the incident response. Furthermore, a preliminary walkover survey of the most impacted site by the pellet spill at Sarakkuwa beach was carried out, and the designated central warehouse for storage of collected waste were carried-out. This enabled the UN Team to quickly obtain an initial appreciation of the scale and nature of the incident.

A one-day meeting was subsequently organised with MEPA leadership on 18 June to obtain a detailed understanding of how the incident unfolded and the key response actions undertaken. This was followed by an introductory meeting with the 'Expert Committee on Environmental Damage Assessment' coordinated by MEPA and comprising ten thematic teams[7] to understand the assessment approach for evaluating the incident's environmental impacts over the short and long term. A separate meeting was also held with Dr. Nalaka Godahewa, State Minister of Urban Development, Coast Conservation, Waste Disposal and Community Cleanliness, which oversees MEPA, to obtain a better understanding of the Government's expectations from the UN mission.

A series of dedicated meetings were then successively organised with each of the relevant expert thematic working groups to better understand their environmental assessment method including sampling plans and provide advise as appropriate. Bilateral meetings were specifically held with the teams responsible for conducting the following thematic assessments: i) identifying the root cause of the incident, and chemicals and oil assessment; ii) environmental impacts; iii) air pollution; iv) water and seashore; iv) biodiversity; v) aquatic resources; vi) socio-economic impacts (tourism); and vii) damage and economic valuation. Towards the end of the mission a meeting was reconvened with the lead persons of the key thematic teams to exchange views on strengthening the focus of the environmental assessment.

In parallel to the abovementioned meetings, the UN team undertook boat and aerial reconnaissance surveys of the shipwreck with the assistance of the Sri Lanka Navy and Airforce. Oil pollution samples were also collected. Walkover surveys were carried out to several of the most impacted sites by pellet pollution north of Colombo (Sarakkuwa, Dungalpitiya, Negombo Beach) to assess the situation, review clean-up techniques and collect samples for laboratory analysis. Similar site visits were also made to several impacted beaches between Matara and Gurubebila in the south. A boat survey of the

[7] An eleventh team on 'Restoration impact assessment' was established after the mission had ended.

Negombo lagoon and its inlets was also carried out to examine the extent of pellet pollution. In addition, visits to several laboratory facilities (NARA, MEPA) to obtain an appreciation of existing capacities and to the Bellanwila wildlife hospital to inspect the dead turtle specimens were conducted.

During the mission, the UN team submitted a series of advisory notes to MEPA concerning its main observations and recommendations. The key recommendations focused primarily on mitigating the key risks identified including:

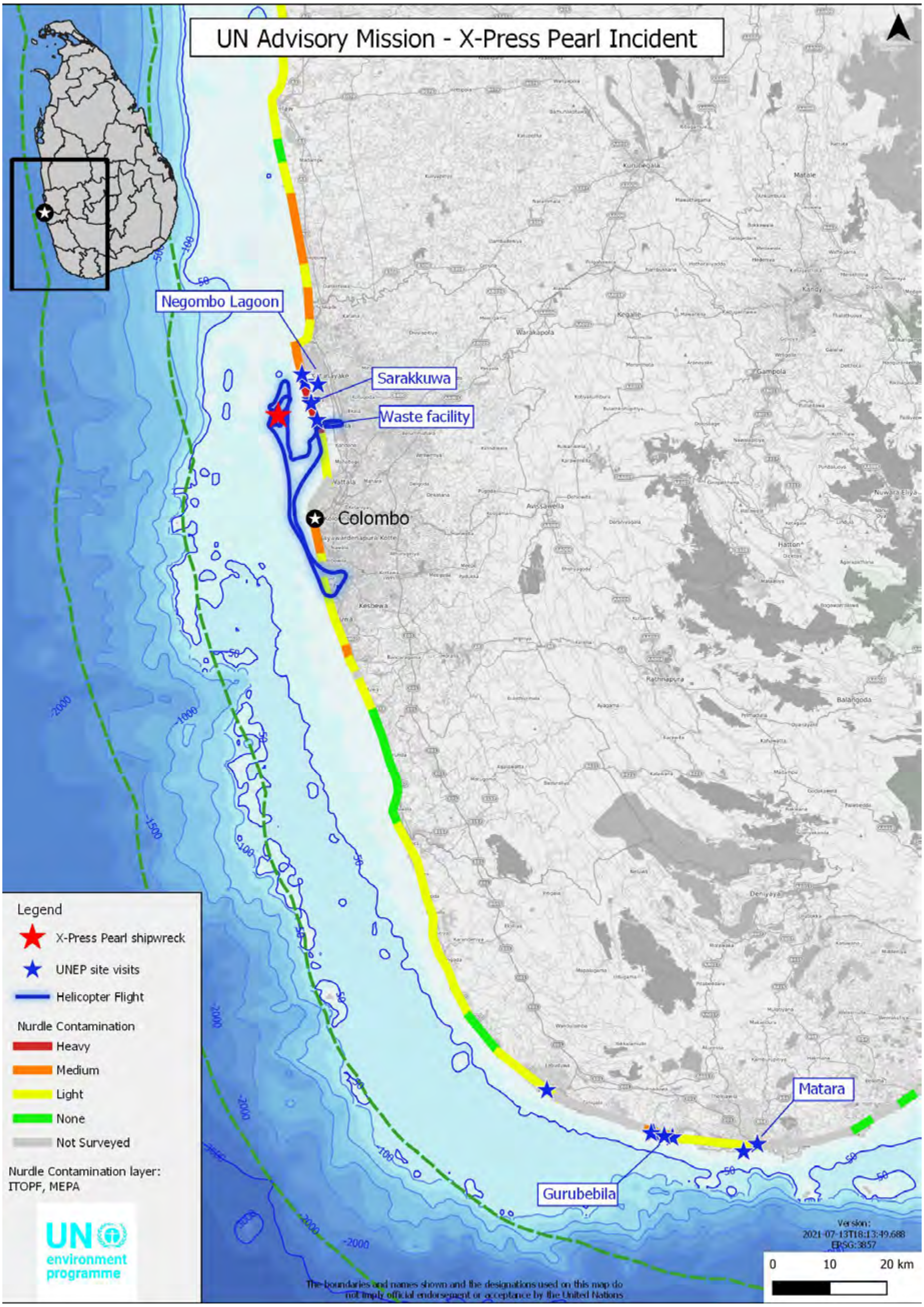
i) the oil slick emanating from the wreck including a potential major sudden release of bunker oil (‘worst-case-scenario’);
ii) on-shore oil spill response planning;
iii) development of a detailed plan to remove the wreck and containers lost at sea;
iv) the shoreline pellet clean-up strategy; and
v) focusing the environmental assessment on key hotspot areas to support decision-making in the emergency phase.

The UN Team also participated in meetings chaired by MEPA involving representatives of ITOPF, OSRL, the salvors and the P&I Club to discuss several of the abovementioned issues which notably led to the development of two separate offshore and onshore oil spill response action plans. This consequently led to the deployment of oil spill response equipment by OSRL which arrived in Colombo on 2 July 2021 and includes provision of oil spill clean-up training for relevant stakeholders.

Furthermore, the UN team held meetings with several other stakeholders including the Ministry of Environment's ‘Mangrove Working Group’, NGOs and development partners to exchange information about the situation and the challenges encountered with incident response.

At the conclusion of the mission on 30 June, the UN Team presented their main findings and recommendations to the Inter-Ministerial Committee on X-Press Pearl incident chaired by the Minister of Justice, Mr. Ali Sabry, development partners and other senior government officials.

Figure 2.1: Meeting of UN Team with Environmental Damage Assessment Committee.



Map 1: Sites visited by the UN Team.

2.2. Key Findings

The main findings of the mission are grouped in the following main topics:

1. Oil pollution;
2. Chemical pollution;
3. Risks arising from the shipwreck and lost containers;
4. Plastic pollution;
5. Strengthening the environmental assessment and monitoring plan;
6. Impacts on wildlife and sensitive environments;
7. Impacts on fishery resources;
8. Air pollution.

2.2.1 Oil Pollution

Satellite and on-site observations

The sinking of the MV X-Press on 2 June, raised alarm as to whether the bunker oil aboard the vessel would spill in the sea, especially as a sheen could be observed soon after the major fire outbreak according to MEPA. An oil slick of an approximate area of 0.51 km^2 and a length of 3.23 km was detected near the ship on 8 June with RADARSAT 2 satellite imagery by the European Maritime Safety Agency. The length of the spill extended to around 4.3 km on 14 June 2021 based on analysis of Sentinel 1 satellite imagery by *Collecte Localisation Satellites* (CLS) (Figure 2.2). Furthermore, Sentinel-1 SAR satellite imagery from 26 June and 4 July showed a long plume heading northeast towards the coast.

On 20 June, the UN team conducted a boat surveillance with the Sri Lanka Navy of the wreck site and within the slick area to ground-truth the satellite image analysis with a closer inspection of the oil at sea. The UN team was able to observe heavy brown patches of oil amidst a metallic sheen on the water surface (Figure 2.3) and to collect samples of the oil. Furthermore, floating pellets were observed in the slick area.

Subsequently on 22 June, aerial reconnaissance by helicopter was conducted to obtain a better overview of the extent and character of the oil slick. The aerial survey confirmed the presence of an oil slick emanating from the ship and which extended for several kilometres.

Based on the satellite imagery and field observations, the UN team concludes that:

- A continuous release of oil is flowing from the ship for nearly one month (8 June – 4 July);
- Based on the Bonn Agreement Oil Appearance Code (BAOAC), the oil observed from the aerial survey on 20 June is classified as ‘discontinuous true colour’ (code 4) of 50-200 µm thickness, and in some segments ‘continuous true oil colour’ of over 200 µm thick (code 5). This situation should normally trigger deployment of oil spill response equipment;
- Furthermore a ‘sheen’ (code 1) of 0.04-0.3 µm thickness can be seen to be surrounding the main oil slick.

Figure 2.2: Sentinel 1 satellite image (2021-06-14 / 00H24 UTC) processed by CLS and highlighting extent of spill.

Figure 2.3: The slick originating from the wreck observed by helicopter (2021-06-20).

Figure 2.2: Water sampling around the wreck.

Figure 2.5: Sample of oil and pellets collected on 21 June 2021.

Effect of fire on heavy fuel oil

Based on its physical appearance and properties, the oil slick released from the vessel appears to derive from bunker oil rather than diesel or other refined products. The bunker oil of the MV X-Press Pearl is an Intermediate Fuel Oil 380 (IFO 380). This type of oil is obtained by mixing approximately 95% of Heavy Fuel Oil (HFO) with 5% gasoline. Laboratory analysis of the oil sample collected near the wreck by CEDRE confirmed it to be IFO (Annex II).

HFO is a category of fuel oil having a tar like consistency. It is the residual fraction of the oil distillation and cracking process. In other words, it is the ultimate residue which stays behind after the oil is distilled at over 600°C. This oil residue is mainly composed of asphaltenes, resins, solid particles and low concentrations of heavy metals. HFO is used primarily by the shipping industry due to its relatively low cost compared with lighter marine fuels. HFO is also the main component of bitumen which is used in road construction due to its physical properties including impermeability, elasticity and fire resistance. In comparison, gasoline is a light oil fraction containing a high percentage of aromatic compounds. This fraction is obtained in the early stages of the petroleum distillation process and therefore has a relatively low boiling point.

As a bunker oil, IFO 380 therefore has a limited propensity to burn. Nevertheless, considering that the gasoline fraction could burn or evaporate, this would result in the density and viscosity of the remaining IFO 380 to increase in the event of fire.

Furthermore, given that the bunker oil tanks are located in the vessel's lower part and below the waterline, the probability that the whole of the IFO aboard the MV X-Press Pearl would have burnt during the incident is almost nil. It is therefore reasonable to conclude that a substantial residual quantity of oil is still present in the vessel's fuel tanks.

Fate and behaviour of heavy fuel oil at sea

The behaviour of oil at sea is directly linked to: i) chemical and physical properties of the oil; and ii) environmental conditions at sea (e.g. temperature, salinity, wave-mixing energy). In this relation, it is important to note that the vessel sank close to the shoreline; that is 4.5 NM from the coastline at a depth of about 21 meters. Given that with the ongoing monsoon season, river discharge would be at a high level – indeed intense rains are causing major flooding since May – and further noting that river outlets (e.g. Kelani River) flow in the area of interest, implies that water salinity and therefore density around the wreck would be lowered to that of nearly brackish/freshwater. This was confirmed by water density measurements in the wreck area conducted by the National Aquatic Resources Research and Development Agency (NARA) which was found to be close to freshwater ($d \approx 1$).

The fact that the density of the seawater is close to 1 raises the question of whether the oil would sink since it would be denser than brackish/freshwater. Even though the oil may sink, it would still not settle on the seafloor. The rough sea conditions and low water level means that the risk of oil re-surfacing is high. This in turn raises the risk of tar balls stranding on the shoreline. In addition, once the salinity and therefore the seawater density returns to its normal condition at the end of the monsoon season the sunken oil would likely resurface and spread based on the current direction.

The drifting slick is essentially composed of brown patches of oil surrounded by grey sheens. Chemical analysis of oil samples performed at CEDRE show that this slick is originating from a discharge of the bunker oil (mixture of HFO and gasoline). While sheens can easily evaporate due to weather conditions (wind and sunshine), the brown patches will persist and drift with the current towards the shoreline, given that it is presently dominated by a northward current. At the same time, it will be difficult to observe the stranding of tar balls on the shoreline due to the high energy dynamics of the beaches. These tar balls will therefore most probably be mechanically eroded by friction with the sand grains, if not totally buried in the sand. Some of the tar balls are also likely to sink as their density increases when sand and other particles are incorporated.

In sum, this situation underlines the need to undertake all necessary measures to recover the fuel oil in the bunker tanks, and the oil slicks at sea to the extent possible.

2.2.2 Chemical Pollution

Of the 1,486 containers on board the MV X-Press, at least 81 containers were carrying 15 different types of dangerous goods according to the International Maritime Dangerous Goods code (IMDG Code). Analysis of the cargo manifest allowed the identification of the Hazardous and Noxious Substances (HNS) that could pose a major problem. These chemicals were transported in different types of packaging and likely to have fully burnt in the fire. Consequently, it is likely that the HNS were released into the environment; at least the HNS transported in containers on the upper deck of the vessel where the fire raged. Assessing the fate and behaviour of these chemicals is essential to understanding their potential impact on marine life.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Bay	Operator	POL	POD	Final destination	Serial	STATUS (EMPTY/ LADEN)	I	R	SizeType	Pos.	W	Type	Spec.	IMDG	UN	CARGO DETAILS
7	9	RSL	AEJE1	LKCMB	LKCMB	BLKU2604634		x		20TK	90182	23,3	2270	I	3	1301	Vinyl Acetate, stablised
8	9	MSK	QAHMD	LKCMB		TEMU1537704				20ST	90184	19,2	22G1				Epoxy Resin, plastic
14	9	MSK	QAHMD	LKCMB		MSKU5030739				20ST	90382	19,3	22G1				Epoxy Resin, plastic
20	9	GENIO	AEJE1	SGSIN	MYPKG	PCIU2585635				20ST	90582	15,2	22G1				FOOD PRODUCTS
21	9	BLPL	AEJE1	SGSIN	MMRGN	TRHU1928620				20ST	90584	4,4	22G1				RECONDITIONED -WAGON (LEFT HAND DRIVE)
22	9	BLPL	AEJE1	SGSIN	IDJKT	BSIU2108497				20ST	90586	5,6	2200				FIRE PUMP (BRAND NEW FIRE PUMPSET WITH COMPLETE ACCESSORIES)
23	9	BLPL	AEJE1	SGSIN	BDCGP	BLZU2105581				20ST	90588	3	2200				NEW ELECTRIC DRIVEN FIRE PUMP
24	9	ACAP	AEJE1	LKCMB	LKCMB	CRSU1059592				20ST	90590	2,4	2210				2600 CARTONS + 1700 PAILS OF LUBRICATING OIL OF CASTROL BRAND
34	10	MSK	QAHMD	LKCMB		MSKU6597780				40ST	1E+05	29,7	42G1				Epoxy Resin, plastic
35	10	MSK	QAHMD	MYTPP		MRKU5224434	E			40HC	1E+05	3,7	45G1	H			EMPTY
37	10	MSC	QAHMD	LKCMB	BDCGP	MSCU5745728				40ST	1E+05	29,9	42G1				1020 BAG(S) of HIGH DENSITY POLYETHYLENE (HDPE)
38	10	MSK	QAHMD	LKCMB		MRKU0170891				40ST	1E+05	29,6	42G1				Epoxy Resin, plastic
39	10	MSK	QAHMD	MYTPP		MRKU3306132	E			40HC	1E+05	3,7	45G1	H			EMPTY
43	10	EVG	AEJE1	MYTPP	MYPKG	GAOU6303031	E			40HC	1E+05	4	45G1	H			EMPTY
44	10	EVG	AEJE1	MYTPP	MYPKG	EGHU9190706	E			40HC	1E+05	4	45G1	H			EMPTY
45	10	EVG	AEJE1	MYTPP	MYPKG	EGHU8216880	E			40HC	1E+05	4	45G1	H			EMPTY

Figure 2.6: Excerpt of the vessel manifest.

Behaviour and fate of HNS in the marine environment

The environmental hazard of the cargo was assessed by examining the physical properties and short-term behaviour of the chemicals. Most of the identified HNS were either flammable and/or soluble substances (nitric acid, caustic soda, methanol, sodium methoxide, sodium methylate, vinyl acetate). This suggests that they were burnt during the fire, dissolved in the water, are still inside the ship or lost containers.

Special attention should be given to nitric acid (25 tons) and caustic soda (1,040 tons). Whereas both these products dissolve in water, their density is significantly higher than that of seawater. This means that they will sink in the seawater column. Thus, it is possible that a highly corrosive plume of nitric acid and caustic soda would have formed on the seabed. This sinking behaviour may explain observations of the “burnt” and “bleached” carapaces of some of the dead turtles found on the beaches. Their shells and skin may have disintegrated on contact with the moving plume of nitric acid and/or caustic soda.

Containers of methanol (210 tons) located on the upper deck probably burnt during the fire, which may also explain the reported explosions. If the methanol spilt into the sea, it would likely float on the subsurface forming a plume of contaminated seawater from which evaporation processes could occur leading to the formation of a toxic vapour cloud above the water surface. A methanol plume just below the surface may adversely impact pelagic marine organisms.

Figure 2.7: Damaged containers washed ashore (credit: MEPA)

Quantities of the content belong to each category in MT (Total)									
Cargo detail in brief	Plastics and Polymers	Cargo detail in brief	Chemicals	Cargo detail in brief	Metals	Cargo detail in brief	Food items	Cargo detail in brief	Other
Epoxy resins	9700.8	Urea (Dust, Prilled, ...)	1843.3	Aluminium stuffs	2202.2	Fish, Dry fish, Sprats	1288.6	Paper/Wastepaper items	1705.9
Synthetic resins	177.3	Inorganic Chemicals, nos	495.3	Copper stuffs	474.6	Chicken	370.6	Used Items (Vehicle parts,	263.9
HDPE	747.8	Caustic Soda	1126.9	Iron and steel stuffs	74.8	Shrimp	252	Cartons	105.1
LLDPE	245.4	Chemical products, nos	160.2	Lead	187	Cuttlefish	33.6	Fabrics, wadding, thread, .	1297.1
LDPE	574	Nitric Acid	28.7	Metal scraps	142.7	Dates	194.6	Tyres (New)	22.8
Packages of PS pellets	31.9	Perfumery products	8			Raisin	88	Furniture	11.1
Bare foam pig	1.9	Assorted perfumes	16.8			Alchoholic	34.4	Waterproof materials	23.4
Packaging materials	22.8	Quicklime lumps	1196.4			Chocolates	24.5	Pharmaceutical packing	16.5
Polycarbonate	60.9	Sodium Methylate	57.3			Honey	11.1	Carpets	46.2
Plastic pellets	81.3	Methanol	235.6			Fruit Juice	29.1	Aseptic pack	29.5
Polymeric beads	19.3	Bright Yellow Sulphur	562.4			Fresh Orange	120.6	Personal cargo, effects, ..	310
Polymers of propylene	57.3	Molybdic Oxide	48			Jam and Pistachio	48.9	Scoured Goat hair	22
PVC film	20.4	Env. Hazardous subs.	10.6			Oats	26	Crushed Stone	22.5
ALKYD resin	19.5	Pharmaceutical stuffs	7.5			Other food stuffs	259.5	Fire Protective Equipment	109.3
Unsat. Polyester resin	21	Paints	21.2					Automotive, vehicle parts (New)	126.3
Vinyl copolymer	18.6	Colors for ceremic ware	15					Wagon Models	28.9
Vinyl Acetate	46.3	Shampoo	16.3					Exhaust stack anchor bolts, nuts, ..	16.1
Polybutadiene	92.7	Cement conforming	1154.8					Consol Cargo	43.6
		Modified Asphault	205.2					Mobile and Stationary Accessories	26.7
		Silicon sealant	12.5					Empty	1114.3
		Engine coolant and grease	16.9						
		Liquid Paraffin	130.2						
		Brake fluid	34.7						
		Lubricating oil	387.8						
		Base Oil	47.6						
		Pails of lubricants	145.9						
Total : Plastics	11939.2	Total : Chemicals	7985.1	Total : Metals	3081.3	Total : Food items	2781.5	Total:other	5341.2

Figure 2.8: Table summarizing the type and quantities of goods aboard the X-Press Pearl (credit: NARA).

One important unresolved question concerns epoxy resin; especially as it accounts for almost one-third of the cargo onboard the vessel (9,700 tonnes loaded in 349 containers). While not classified as a dangerous good in the cargo manifest, epoxy resin can be harmful to the environment depending on the type of formulation (liquid, solid, paste and gel). The liquid form is the most dangerous to the environment. Assessing the potential impact of the epoxy resin, however, is not currently feasible as the ship manifest does not provide adequate detail about the product.

If the epoxy cargo is indeed in liquid form, it would sink and create a plume close to the seafloor as it has a higher density than seawater. The plume would drift depending on the currents and interact with suspended particles in the sea. Epoxy resin is toxic to aquatic life and can have long lasting effects on marine fauna. It is also harmful if ingested and can cause severe skin and eye burns. Therefore, it is important that complementary information is obtained about the epoxy resin shipment (e.g. product C.A.S number or material safety data sheet) to confirm the absence or presence of chemical risk.

The lack of information on the state of the containers remaining on the wreck especially on its lower deck, as well as those lost at sea, and whether they are damaged or not, means that the risk of future pollution releases is an issue of concern. Leaks from damaged HNS containers, either sudden or continuous, remains a constant threat until removed.

2.2.3 Risks arising from the Shipwreck and Lost Containers

The present location of the shipwreck – which is not fully submerged - close to the approaches of Colombo harbour constitutes a maritime danger (Figure 2.10). In effect, the wreck is a navigation hazard to the dense and growing traffic around the Port of Colombo, which is one of the top 20 busiest ports in the world. As such, it also constitutes an additional risk of business interruption.

There is also a high probability that many containers were lost at sea between the outbreak of the fire and explosions on the vessel on 20 May and its final sinking on 17 June. These lost containers, whose location remains unknown, also constitute a navigational risk. Indeed, the containers may drift below the sea surface and collide with merchant ships. Notably, one container had drifted over 100 kms south before stranding on an island near the city of Galle. Furthermore, and as mentioned above, the wreck and containers also pose an environmental hazard due to their potential release of bunker oil and chemical pollutants.

The presence of the wreck in a rich fishing ground is also impacting the livelihoods of local fishing communities. The Sri Lankan authorities have banned fishing in the area around the wreck, although some fishing vessels could be observed. In line with the precautionary principle, the mortarium on fishing should be maintained until the wreck and containers are removed and until the seabed has been investigated for the presence of contamination as described above.

The multiple navigational, environmental and livelihood hazards from the wreck and lost containers highlight the need for their prompt removal. And while recognizing that the monsoon season may impede recovery of the wreck and lost containers, and that the safety of salvage personnel is of foremost priority, weather conditions are not an impediment to undertaking swift and detailed planning and initiating the tendering process for the wreck and container recovery, as indicated earlier.

Figure 2.9: The Port of Colombo is one of the top 20 busiest ports in the world.

Figure 2.10: Illustration of the traffic intensity in the vicinity of the wreck.

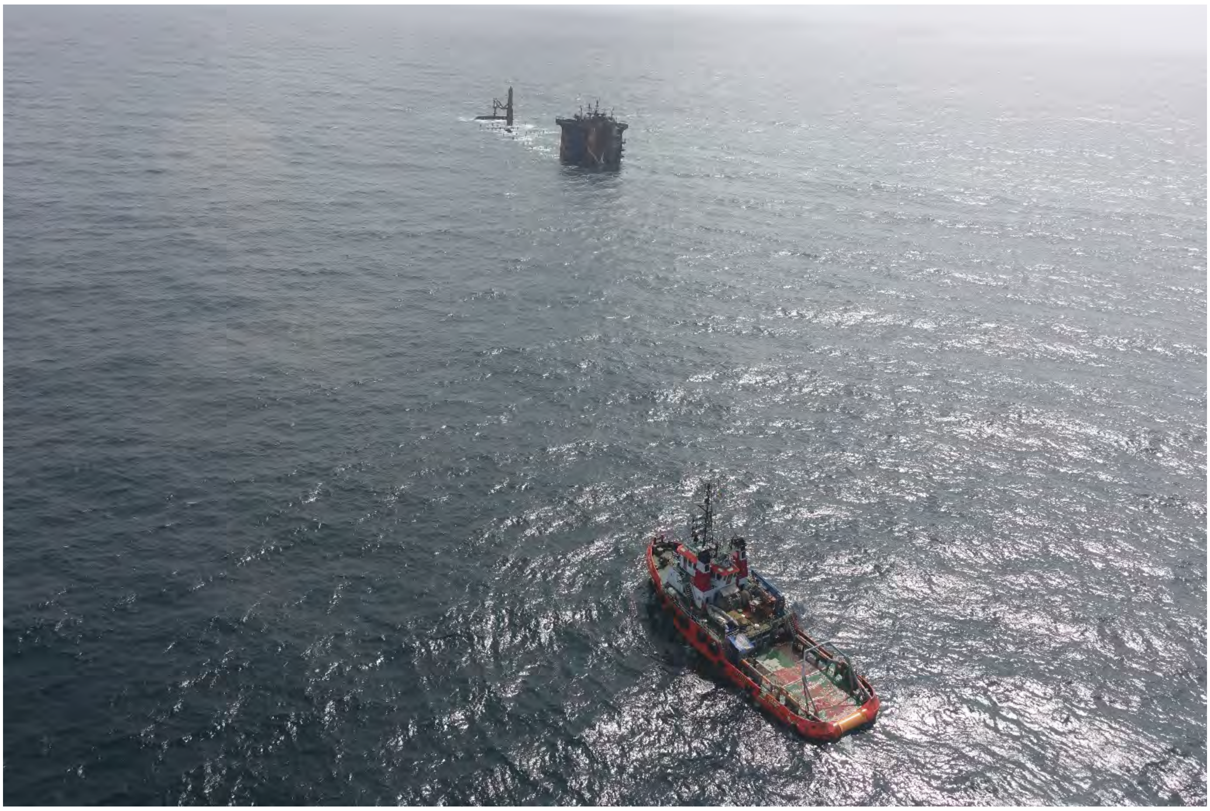


Figure 2.11: A caretaker ship circles the X-Press Pearl 24 hours a day, monitoring the wreck for an oil spill.

Figure 2.12: Current status of the wreck.

2.2.4 Plastic Pollution

Nature and scale of contamination

While the plastic pellets have captured media and public attention, it is important to recognize that a wide assortment of plastics of different sizes and conditions were in fact washed ashore. It would be inaccurate and an oversimplification to refer to the contamination as plastic pellets; even though they comprise the main component of this pollution. Hence the use in this report of the generic term plastic pollution. Specifically, the arrivals coming directly from the wreck as well as lost containers are composed of:

i) various types of plastic pellets (Linear Low Density Polyethylene (LLDPE), Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE);
ii) burnt plastic fragments of various sizes (micro < 5mm to macro > 5mm);
iii) other debris and cargo;
iv) foam and sludge of unknown composition were also reported in the first days following the incident.

Plastic pollution and other debris have so far been found along a ~300-km stretch of Sri Lanka's western, southern and northern coastline transported by prevailing currents. Preliminary modelling results by experts suggest only part of the pellets spilled has reached the Sri Lanka coastline, and that most of the pellets remain at sea. Furthermore, the modelling projects that the extent of this pollution will continue to spread and that as the south-west monsoon becomes established, the nurdles could be transported around Sri Lanka and impact its east coast and reach up to Indonesia. As the monsoon currents reverse, the pellets will be carried westward and may beach in the Maldives and Somalia[8].

Gampaha, the closest district from the incident scene, is the most impacted by mass shoreline stranding of debris. The plastic spill is concentrated around a five-kilometre coastal stretch north of Colombo of which Sarakkuwa beach is its epicentre. Most of the arrivals washed ashore within a limited time period following the fire taking hold of the vessel on 25 May. However, new arrivals are continuously reported although in small quantities. This fits with the UN team's observation during the boat survey on 20 June when floating pellets could be seen in the oil slick coming from the wreck indicating a continuous release

[8] X-Press Pearl Disaster: An Oceanographic Perspective (06/08/2021), Prof. Charitha Pattiaratchi and Dr. Sarath Wijeratne, Oceans Graduate School and the UWA Oceans Institute, The University of Western Australia.

Figure 2.13: Massive arrival of plastic pollution on the west coast of Sri Lanka following the incident (credit: MEPA).

Figure 2.14: Plastic pellets floating in the oil slick near the wreck, boat survey on 20 June.

On the other hand, the situation differs significantly on the southern coast in Matara and Galle districts. The plastic pellets are not emanating directly from the wreck but from a single container that drifted over 100 km south and stranded on an island near the coastline. Only one type of pellets (LDPE) was spread as a result. Pollution on the southern coastline is consequently limited to intact LDPE pellet bags, LDPE pellets and pieces of melted pellet bags. No black burnt plastic residues were observed on the shoreline.

Figure 2.15: Large items collected on the coastline in Sarakkuwa and Dungalpitiya, Gampaha district.
A and B: pieces of burnt plastic pellet bags; C: cardboard roll and D: Intact plastic pellet bag.

Although mainly deposited on the sand surface, the small plastics easily mix with sand due to tidal changes, trampling by workers and heavy machinery during clean-up operations. Buried plastic pollution is also caused by high wave energy and sand movement, most notably in Sarakkuwa beach; where the UN team observed layers of plastic pollution embedded in several dozen centimetres of sand. On the backshore, pellets were found mixed with coastal vegetation making their recovery more complicated (Figure 2.17).

Figure 2.16: Pellets and small burnt plastic pieces deposited in recent strandlines or mixed in the first layer of sand in Sarakkuwa beach, Gampaha district.

Figure 2.17: Left: buried pollution in Sarakkuwa beach;
right: pollution in the vegetation, Dungalpitiya Gampaha district.

Clean-up operations

A massive clean-up operation to collect the plastic pollution is being implemented by the Sri Lanka Armed Forces (Navy, Coast Guard, Airforce) under the overall supervision of MEPA. In total, 48 sites along a 180 km impacted costal stretch have been targeted so far. These sites are classified as being of high, medium and low contamination. Around 500-1,000 personnel were deployed per day in the initial clean-up phase. During the UN team's visit this number had dropped to around 250-300 persons per day. In total, 18,973 participants are reported to have been involved in 385 clean-up events as of 14 July 2021.

On the coastline, the larger debris has been removed and the bulk of the plastic pellets (70-80% by one estimate) has been largely recovered. By 14 July 2021, approximately 1,610 metric tonnes of plastics, other debris and contaminated sand had been collected (equivalent to 53,677 bags). Indeed, by the time of the UN team's visit, the remaining pollution comprised a mix of various types of pellets and small burnt plastic fragments deposited along strandlines formed by recent wave action or mixed in the first layer of sand.

Clean-up of the southern coast and Negombo lagoon

Along the southern coast, the larger debris has been collected and remaining pollution is constituted of virgin LDPE pellets and fragments of melted pellet bags. Though exposed to massive pellet arrivals, the situation along the southern shorelines is relatively less challenging due to the limited diversity of pollutants and absence of burnt plastic pieces.

Figure 2.18: Melted pellet bags and LDPE pellet on the Matara coastline.

The inlets of the Negombo Lagoon – a major fishing ground situated near the most impacted sites – were partially protected by the deployment of booms along the two entrance channels. It is estimated that the booms may have prevented up to 80% of the plastic pollution from entering the lagoon. These booms had been removed by the time of the UN team's visit. Though clean-up campaigns have been conducted, the UN team was able to observe patches of pellets and burnt plastic fragments during a boat survey in the lagoon on 24 June. Recovery of floating plastic pollution in the lagoon inlet (e.g. using small meshed nets) should be considered before it disseminates deeper in the lagoon or enter mangrove stands. Chronic pollution of lagoon water may also make the microplastics a long-term hazard as pollutants adsorb on them and enter the food chain.

Figure 2.19: Floating pollution in inlets connecting Negombo lagoon with the ocean; pellets and burnt plastic fragments, Gampaha district.

Plastic pellet recovery

A phased approach is being applied to plastic pellet recovery. Bulk arrivals of nurdles mixed with other debris was initially hauled manually using large baskets and heavy equipment. As the clean-up progressed and reached an advanced stage, the quantity of nurdles collected decreased while that of sand increased, especially when shovels are used to scoop up the pellets. It was observed that a substantial number of bags contain a large proportion of sand, which in some cases can reach up to 80 percent. Additional treatment will be required to separate the sand from the pellets.

Figure 2.20: Evolution of bag content on Sarakkuwa beach, Gampaha district. On the left, content of bags at the beginning of the clean-up campaign, and on the right after several weeks.

The two main methods being used to separate the plastic pollutants from sand are: i) manual sieving and ii) flotation in seawater. Both methods are highly labour intensive. Manual sieving is applied under dry sand conditions, while flotation is used for wet or coarse sand. Of the two clean-up methods, manual sieving is very time consuming and hence its cost effectiveness is questionable, especially when dealing with light pellet accumulations. Indeed, in cases of low pollution, workers estimated that to produce one bag of plastic pellets, 20 bags of sand mixed with plastic pellets need to be sieved.

Flotation appears to be the more effective option, reduces the volume of sand collected, and offers the possibility of separating and recovering small burnt fragments. Guidance on scaling-up this density-based separation method is needed.

Figure 2.21: Left: Manual sieving, Right: flotation in seawater. Sarakkuwa beach, Gampaha district.

Trialling of mechanical recovery techniques is underway or planned including use of vacuum cleaners, mechanical sieving, trommels and beach graders. Furthermore, especially designed equipment is being piloted by local entrepreneurs to clean-up beaches with deeply buried plastics as in Sarakkuwa.

Figure 2.22: A central storage facility for the collected waste in Pamunugama has been hired, where scaled-up mechanical waste segregation operations are also to be implemented.

Burnt plastic clean-up

The burnt plastic fragments represent a challenge for the clean-up as they appear to be very brittle and easily breakdown into small irregular shaped particles; whereas pellets are solid, round and of standard size. Significantly, the degradation of the burnt fragments can be augmented by mechanical clean-up techniques. Moreover, the smaller particles with an irregular shape and a size inferior to pellets (3 mm) are generally not recoverable with techniques such as manual flotation or sieving due to large mesh size. Methods to recover these small burnt plastic flakes need to be developed. Furthermore, the extent of the remaining burnt plastic pollution in the sand is currently unknown and needs to be assessed.

Figure 2.23: Burnt plastic particles left after flotation that are too small to be recovered with existing sieves.

Clean-up targets and environmental impacts

A critical question for any decontamination operation is to define the level of clean-up required. The question of 'how clean is clean' is particularly relevant for this incident as there is no established specification on the clean-up of pellet pollution. Recognising that it will not be possible to recover all microplastic pollution, it will be important to set a standard to guide the clean-up effort. In setting the amount of clean-up required, it will also be important to consider the net environmental benefit of the different clean-up techniques and prevent any additional damage to the impacted coastline (e.g. increase in erosion). In this relation, it should be pointed out that the clean-up itself with personnel and machinery on the shoreline is having adverse impacts on the sensitive environment.

Secondary pollution

Contamination is being created during the clean-up work itself particularly during: i) storage; and ii) transport. Currently, bags are being gathered in small piles at the point of collection, then transported by heavy equipment (excavators, trailers) to an intermediate storage pile located at the backshore of the beach. The polyweave bags used are fragile and break-up easily causing the pellets to spread especially as they are placed directly on the sand without any protective cover. As a result, relatively important secondary contamination can be observed at these intermediate storage sites on the beach.

Inadvertent release of pellets during transport is another problem. Specifically, leakages during bag transport from the beach to the main road - where continuous traces of plastic pellets could be observed along footpaths and in the vegetation, including in private residences – is an issue of concern. Improvement of on-site storage and proofing of transport methods to avoid contamination is therefore needed.

Figure 2.24: Secondary pollution on the backshore of the beach, on paths used to transport bags and along the road, Sarakkuwa and Dungalpitiya beach, Gampaha district.

Chemical contamination and waste classification

Although an inert material, as the pellets and other plastics have been impacted by combustion and given the risk of adsorption of chemicals from the spill, they may potentially be contaminated. No analysis, however, has so far been conducted to identify the contamination and risks associated with the burnt plastic fragments and pellets collected on the coastline. Consequently, the risk of this potential pollution is currently unknown and needs to be assessed as a matter of priority including its environmental effects on heavily affected shoreline sites.

Preliminary analyses of grab samples collected by the UN mission and analysed by CEDRE (Annex III) reveals that:

i) only polyethylene is found in the pellets which accords with the pellet composition in the cargo that was largely made of polyethylene;

ii) three pieces of burnt plastics analysed showed various compositions with different polymers identified, suggesting burnt residues are not all the same. This is consistent with the diversity of products in the cargo and the large extent of the fire.

Ecotoxicity testing of the plastic material is currently underway at CEDRE, and the results will be shared with the Sri Lanka authorities when available.

At the same time, nurdle samples have been shipped by the Sri Lanka authorities to the Centre for Environment, Fisheries, and Aquaculture Science (CEFAS[9]) in the United Kingdom for analysis. CEFAS plans to conduct analysis of nurdle composition in a range of states from intact to burnt pellets and will be analysing chemical concentrations of the nurdles, the adjacent sediment and biota.

Figure 2.25: Burnt plastic pieces and pellet samples collected on different beaches.

On precautionary basis, the pellets have been classified as hazardous waste by the Sri Lanka authorities since the start of the clean-up operation. This has important implications on clean-up activities and particularly on: i) health and safety of workers; and ii) waste disposal.

In terms of health and safety, it means that workers are required to wear personal protective equipment (PPE) – notably impervious plastic suits and goggles - which under the tropical climate of Sri Lanka can lead to heat stress and dehydration; an important consideration which should not be underestimated. Furthermore, in certain locations such as along the southern coastline, where the plastic pellets are intact and have not been burnt or in contact with the rest of the cargo, the risk of chemical contamination is considered limited. It is therefore advisable to reconsider hazardous waste classification on a site-specific basis to avoid unnecessary hardship to workers.

[9] CEFAS is an agency of UK Government's Department of Environment, Food and Rural Affairs (DEFRA) and is providing this technical support under the Commonwealth Litter Programme (CLiP).

With regards to waste disposal, the classification of the plastic pellets and other plastics as hazardous waste will have a major bearing on waste stream segregation operations and their ultimate disposal; especially given the limited hazardous waste treatment facilities in-country.

The significant implications of whether the plastic waste should be classified as hazardous or non-hazardous further underlines the urgency of conducting chemical laboratory analysis as soon as possible. If the plastics are found to be uncontaminated, then the potential for their reuse and recycling should be favoured as the preferred solution to the extent possible.

2.2.5 Environmental Assessment and Monitoring Plan

One of the main aims of the UN Mission was to exchange views and advise the 'Expert Committee on Environmental Damage Assessment' coordinated by MEPA on the assessment approach including the sampling plan. The Committee comprises of eleven thematic working groups focusing on the following topics: i) identifying the root cause of the incident, and chemicals and oil assessment; ii) environmental impacts; iii) air pollution; iv) water and seashore; v) health; vi) biodiversity; vii) aquatic resources; viii) socio-economic impacts; ix) waste management; x) restoration; and xi) damage and economic valuation. Forty-one experts from 14 government ministries, institutes and universities are involved in the expert committee.

Despite the complexity of the incident and the wide spectrum of issues it raises, the UN team is of the view that a more targeted assessment approach is required during this emergency phase. In this context a phased assessment strategy is suggested with the aim of:

i) providing guidance to decision-makers on pertinent questions arising directly from the incident; and
ii) evaluating the incident's broader and longer-term environmental effects.

Similarly, the proposed sampling plan is likely to result in a very large number of samples and data sets that would likely be challenging to manage and interpret. Indeed, the volume and frequency of sampling as well as the wide range of parameters to be analysed may be overwhelming to conduct. And while the results may be useful for understanding baseline environmental conditions, it is unclear whether they would provide greater insight on the wreck's impacts. Indeed, a large set of samples has already been collected by several institutions. However, limited analysis appears to have been carried out so far. Consequently, with the available data it may not be feasible to gain an initial understanding of the current environmental situation and to support the necessary decision making. This situation again highlights the need for a more focused approach targeting priority geographic areas and parameters of interest.

In this context, it is recommended that the environmental assessment plan be adjusted to follow a stepwise approach that would consist of:

i) Snapshot assessment[10]: a one-time campaign of measurements that would screen for a relatively broad range of parameters to obtain an overview of the environmental situation and establish a baseline;

ii) Pollution hotspot assessment focusing on: a) the area of the wreck; ii) around lost containers; and c) shorelines with high plastic and debris pollution loads; and

[10] A substantial part of the snapshot assessment has already been carried out except for laboratory analysis.

iii) Longer-term environmental monitoring: the geographic scope of longer-term environmental monitoring would include the entire shoreline impacted by plastic pellet pollution, with a focus on environmentally sensitive areas (e.g. lagoons, mangroves, estuaries, coral reefs, turtle nesting sites). This can be subsequently expanded to build a sound environmental baseline which will be critical for conducting scientific assessment of and remediation of future incidents. A collaborative institutional programme is needed involving all key relevant agencies including *inter alia* NARA, MEPA, Navy, Coast Conservation and Coastal Resource Management, Dept. of Wildlife Conservation, Coast Guard, and Central Environment Authority.

This three-tiered approach is considered more practical and useful; enabling efficient use of available human and financial resources to deliver results in a time sensitive manner. It also provides a reasonable margin to adapt the assessment strategy to an evolving emergency characterised by considerable uncertainty. Additional information on the environmental assessment and monitoring approach is provided in Annex I.

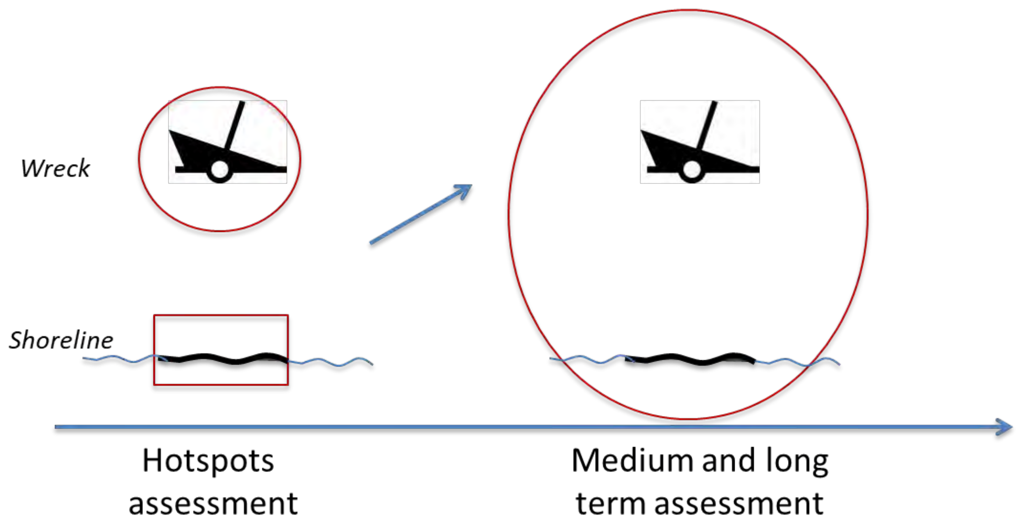


Figure 2.26: Phased assessment approach focusing on areas with the highest pollution loads.

2.2.6 Impacts on Fishery Resources

The X-Press Pearl disaster has had a substantial impact on the incomes of Sri Lankan coastal fishing communities, particularly those whose livelihoods are dependent on fishing grounds that were (or are suspected) of being impacted by pollution from the incident. More broadly, the Sri Lankan consumer has been affected by the reduction in food supply (fish, shrimps, crab, etc.). Furthermore, the public panic from consuming "contaminated fish", which has been exacerbated by a major spike in turtle and dolphin deaths, has reportedly significantly dented consumer confidence particularly in the first weeks of the incident. As a result, seafood sales and consumption apparently plummeted across the country. This has important implications on food security and malnutrition in a country where 70% of the animal protein intake comes from seafood consumption[11].

Following the spill, coastal fishing was initially banned along an 80-kilometre liitorall stretch adjacent to the incident. In addition, fishing in the highly productive Negombo lagoon was suspended where aquaculture is also practiced (e.g. seabass). The area subject to the fishing ban was subsequently reduced and restrictions lifted in Negombo lagoon. It is estimated that the livelihoods of 20,000 fishing families were impacted as a result. In addition, many others whose livelihoods are dependent on allied fishing activities from net manufacturers to boat owners are also affected to varying degrees. Each impacted family is to receive a compensation of 5,000 Sri Lankan Rupees (USD 25) from the government as a single down payment. While fisherman, are demanding 3,000-4,000 SLR (USD 15-20) per day.

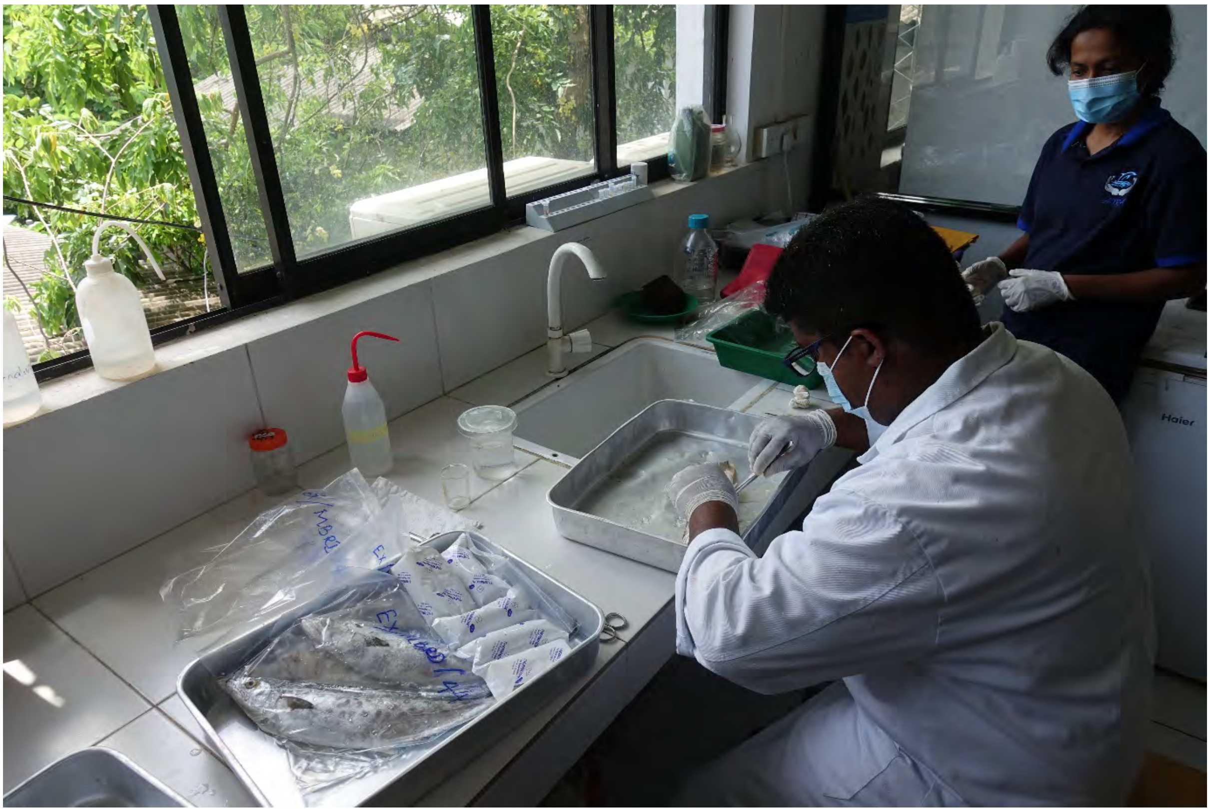
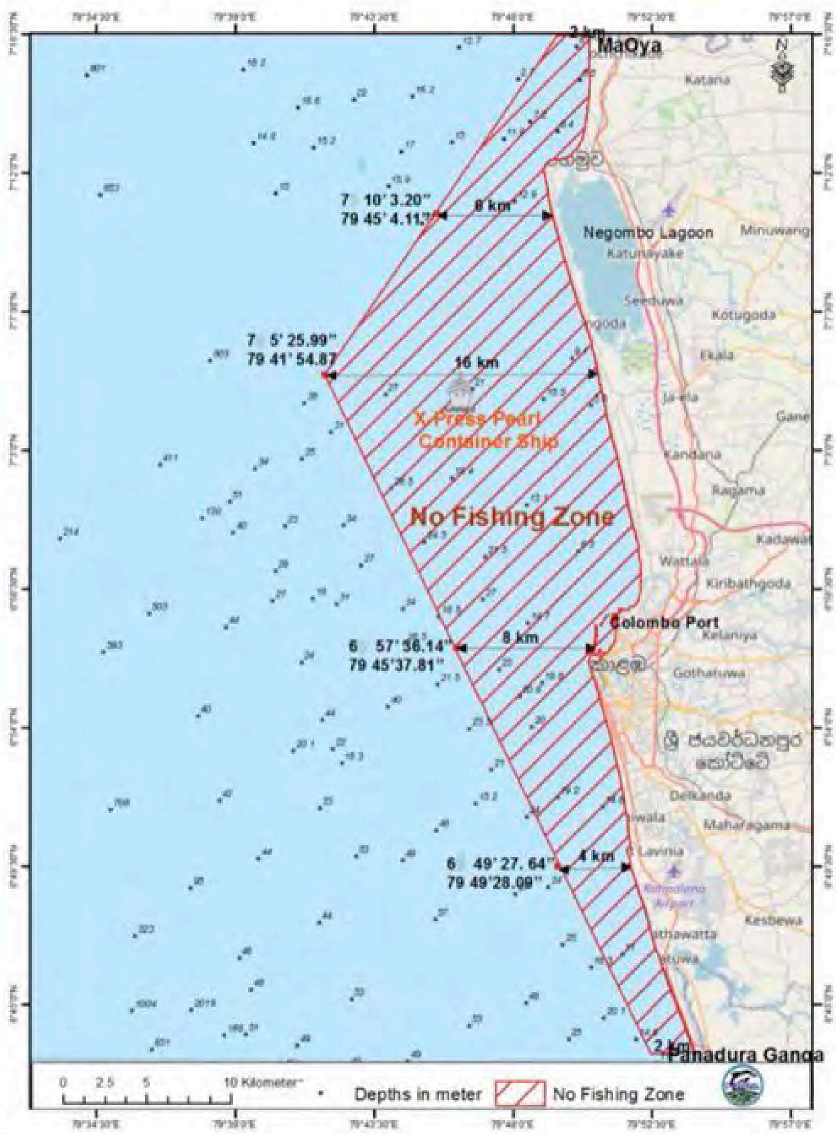


Figure 2.27: Fish analysis at NARA laboratories.

[11] Sri Lanka J. Aquat. Sci. 18 (2013): 1-15. Fisheries resources in alleviation of hunger and malnutrition in Sri Lanka - accomplishment and challenges1



Map 2: No-fishing zone imposed following the MV X-Press Pearl incident (credit: Ministry of Fisheries).

Chemical pollution and debris from the incident have created the following direct risks on the fishing sector: i) seafood safety; ii) damage to fishing gear and other assets; and iii) risk to fisherman from debris at sea.

Seafood safety is currently a major public health concern for the Sri Lankan authorities, fishing communities and the general public. Although the risks have been well identified, the absence of scientific evidence to assess seafood health risks has helped create a state of uncertainty and suspicion. While test results to evaluate chemical contamination levels is reportedly ongoing, it is notably lacking to determine: i) seafood safety inside the no-fishing area; and (ii) seafood safety outside the no-fishing zone. This data is essential to support critical decisions on maintaining, adjusting or lifting the fishing ban, and to inform and reassure the general public on the safety of seafood consumption.

While there is a potential risk of fish accidentally feeding on pellets, there is limited evidence so far that this has occurred. Analysis of dead fish found ashore and live samples collected through experimental fishing by the National Aquatic Resource Agency (NARA) have so far found few specimens with pellets lodged around their gills.

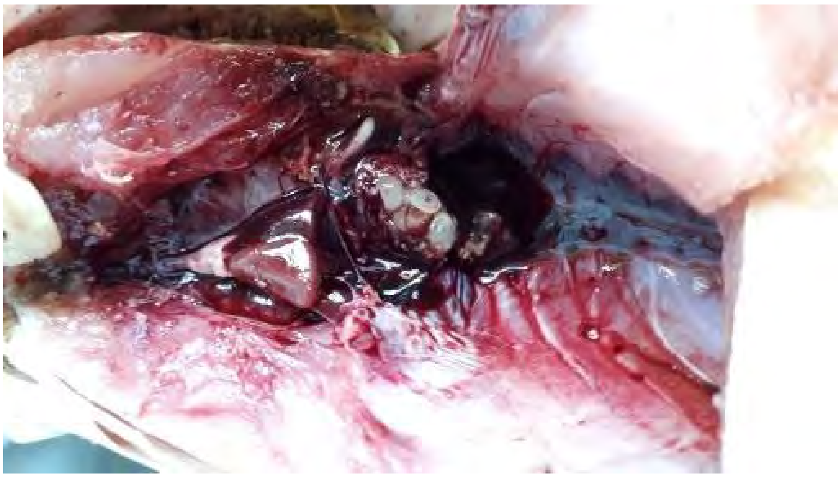


Figure 2.28: Giant trevally (*Caranx ignobilis*) with plastic pellets in pharynx (credit: NARA).

Figure 2.29: Gold silk sea bream (*Acanthopagrus berda*) with plastic pellets in opercle (credit: NARA).

Surface fishing nets being damaged by debris or dissolved by chemicals from the incident have been reported. This includes several reports of nets being entangled with fibres from the cargo, resulting in damaged and unusable nets. The fibres were analysed by CEDRE laboratory (Annex III), and appear to be at least partly made of polyester, confirming their synthetic nature.

There are also reports of dissolved nets, which the UN team was not able to directly verify. If this is confirmed, then damage to other shipping assets (e.g. boats) may have also occurred. In addition to the replacement cost of the nets, their loss can heavily impact fisherman earnings for the whole season

Figure 2.30: Nets entangled with synthetic fibres (left, credit: MEPA).

While it does not appear that sea salt production pans on the west coast of Sri Lanka have been impacted by incident, microplastic contamination may emerge as an issue over the medium to longer-term and should be monitored.

2.2.7 Impacts on Marine Wildlife and Sensitive Environments

Turtle and marine mammal deaths

One of the key environmental questions arising from the X-Press Pearl incident is whether the reported spike in turtle deaths is linked to the event or a coincidental occurrence. According to the Department of Wildlife Conservation (DWC, Ministry of Wildlife and Forest Conservation), 251 dead turtles had washed ashore since the incident as of 17 July. And carcasses continue to be collected on daily basis. In addition, 33 marine mammals – 28 dolphins and 5 whales – have also washed ashore since the incident.

DWC experts distinguish turtle mortality into main stages: i) an initial phase during the first week where turtle carapaces (shells) appear to have been bleached or sheared off; suggesting signs of potential chemical burns; and ii) a larger wave of mainly juvenile turtles with no sign of damage to the carapaces, and investigations showing them to be in apparently good health with their guts full of food. The two main species impacted are the green turtle (*Chelonia mydas*) and Olive Ridley (*Lepidochelys olivacea*).

While the high mortality of turtles and marine mammals is a cause of concern, the UN team cautions on causal attribution to the incident without scientific evidence. Two qualifications are worth noting here: i) the deaths coincide with the start of the monsoon season which typically witness a high number of turtle stranding as carcasses are washed ashore by rough western currents; and ii) the increased reporting of turtle deaths may be due to a 'heightened awareness situation' and increased surveillance by both government institutions and the public.

Figure 2.31 (left): Turtle with bleached shell suggesting potential burn (credit: Department of Wildlife Conservation).
Figure 2.32 (right): Turtle with intact carapace (credit: NARA).

It is also noteworthy that in such high mortality events, turtle experts typically first screen for biotoxins. This has not been done so far, but this is particularly relevant in this case as monsoonal upwellings may have generated harmful algal blooms – a phenomenon that has been observed in several instances before.

As potential sources of chemical and oil pollution, it is important to underline that until the shipwreck and lost containers are recovered, they represent a risk to marine wildlife. Moreover, plastic pellets, polyester yarns and other debris from the incident could affect marine wildlife through their ingestion or by entanglement. According to marine wildlife experts, plastic pellets may also represent an additional risk for turtle reproduction as their presence in nesting sites may alter sediment temperature; a key parameter in determining the sex of turtle offspring. In this relation, the occurrence of the plastic spill during the sensitive nesting season (April-May) - when the numbers of turtles in Sri Lanka's coastal waters are highest - is noteworthy.

Environmentally sensitive areas
The incident occurred in shallow waters (<25m) endowed with high biodiversity, namely reefs and soft bottom habitats. The entire coastal area near the incident is economically important for fisheries and tourism.

Galmaga is a long coral reef a few kilometres to the west of the incident which marks the beginning of the continental slope; dropping steeply over a short distance to below 350 meters. Large pods of Spinner dolphins are known to patrol this region. In addition, there are many other reef areas that parallel the coast. All these reefs are highly important breeding and nursery grounds for fish, spiny lobsters, shrimps, crabs as well as marine aquarium fish. There are no significant seagrass meadows, other than in the Negombo lagoon.

Figure 2.33: Typical coral reef structure in the vicinity of the shipwreck (credit: Arjan Rajasuriya, IUCN Sri Lanka Country Office).

Figure 2.34: A specimen of Panilurus homarus on a coral reef (credit: Arjan Rajasuriya, IUCN Sri Lanka Country Office).

The ship is suspected to be sitting on a muddy soft bottom, but this is not entirely confirmed. No monitoring of underwater habitats has so far been performed due to safety concerns for divers. A survey of sensitive benthic ecosystems (coral reefs, soft bottom) by marine ecologists will be important to undertake when conditions allow. In investigating the impact of the wreck on the seabed, special attention should be given to the section along which it drifted and was towed from the beginning of the incident until it sank; as containers and other debris may have fallen overboard during this period.

Other environmentally sensitive areas impacted by the incident include mangroves – particularly in the Negombo lagoon – and turtle nesting sites. During the UN teams boat survey of the Negombo lagoon, plastic pellets and burnt fragments were observed floating on the sea surface as well as large quantities of chronic marine litter pollution entangled in mangrove stands.

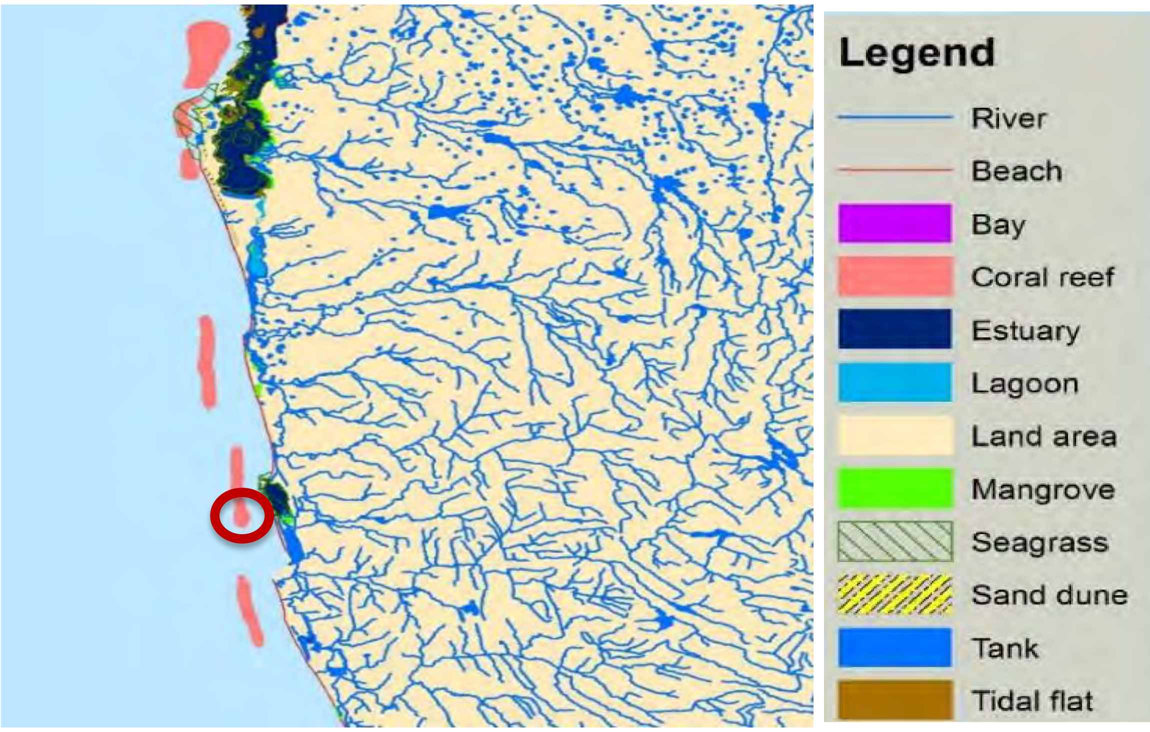


Figure 2.35: Environmentally sensitive coastal areas of western Sri Lanka.
Red circle indicates position of shipwreck.

Mangroves and benthic communities are particularly vulnerable to a heavy fuel oil spill. The mangroves dense network of aerial roots acts as a trap for floating pollutants (hydrocarbons, plastics, chemicals) whose removal is extremely difficult. Therefore, every effort should be made to protect them from contamination.

Figure 2.36: Toque macaque (*Macaca sinica*) an endemic species to Sri Lanka observed in the Negombo lagoon.

2.2.8 Air Pollution

The massive fire and explosions on the ship caused significant air pollution. Lasting for around 10 days, the smoke plume created by the fire extended for several kilometres and was a highly visible impact of the incident. The plume rose and dispersed depending on weather conditions reaching inland when the prevailing winds blew from the west and southwest. By the time the UN team arrived in Sri Lanka, however, all the primary pollutants had disappeared, limiting an appraisal of the issue.

Figure 2.37: The smoke from the incident reached several kilometres inland (credit: AP Photo: Eranga Jayawardena).

In view of the cargo and dangerous goods on board the ship, the smoke itself would have contained a toxic mix of pollutants including nitrogen oxides, sulphur dioxide, soot, particulate matter, carbon monoxide, a range of hydrocarbons as well as dioxins, furans, and heavy metals. The combination of these combustion products represents a substantial environmental pollution load that could potentially generate respiratory problems on arrival on-shore.

Limited primary data was gathered by the National Building Research Organisation (NBRO, Ministry of National Security and Disaster Management) which conducted air quality monitoring using photoionization detectors (PID) about 50 meters from the ship on 23 May. As expected, the results indicated high levels of air pollution within this direct fire zone as shown in Table 2 and Figure 2.38.

Table 2: Air pollution levels (credit: NBRO).

Parameter	AQ1	AQ2	AQ3	SL Standard
PM2.5 (mg/m3)	24	10	210	50 (24 hours)
PM10 (mg/m3)	30	11	270	100 (1 hour)
CO2 (ppm)	1011	1400	5200	
CO (ppm)	2	1	530	30 (1 hour) 50 (any time)
VOC (ppm)	0.3	0.3	0.5	
NO (ppm)	<1	<1	62	
NO2 (ppm)	<1	<1	43	0.13 (1 hour)
SO2 (ppm)	<1	<1	5	0.08 (1 hour)

Figure 2.38: Air Quality Monitoring Locations.

Based on simulation modelling of the fire plume zone by NBRO an area of about 120 km^2 was identified as vulnerable in terms of short-term exposure, which includes a highly populated region. The modelling revealed that while nitrogen oxides would have exceeded national ambient air quality levels, the methanol and vinyl acetate would have dispersed below safety thresholds on reaching inland. Despite this important modelling effort by NBRO, the results should be considered with caution due to the lack of adequate primary data including on the volumes of chemicals and other cargo that burnt.

As the identified vulnerable area does not have continuous air quality monitoring stations, NBRO carried out several air quality monitoring campaigns to control for particulate matter ($PM_{2.5}$ and PM_{10}). Overall, the ground level measurements did not record significant levels of pollutants and were within the standard levels. This is expected as the plume had risen considerably higher above the ground on reaching the land. And while the fire does not appear to have resulted in air pollution over and above that expected during a typical day, it should be noted that pollutant levels were generally very low due to the COVID-19 lock down restrictions. Therefore, the pollution load created by the incident may have been concealed as a result.

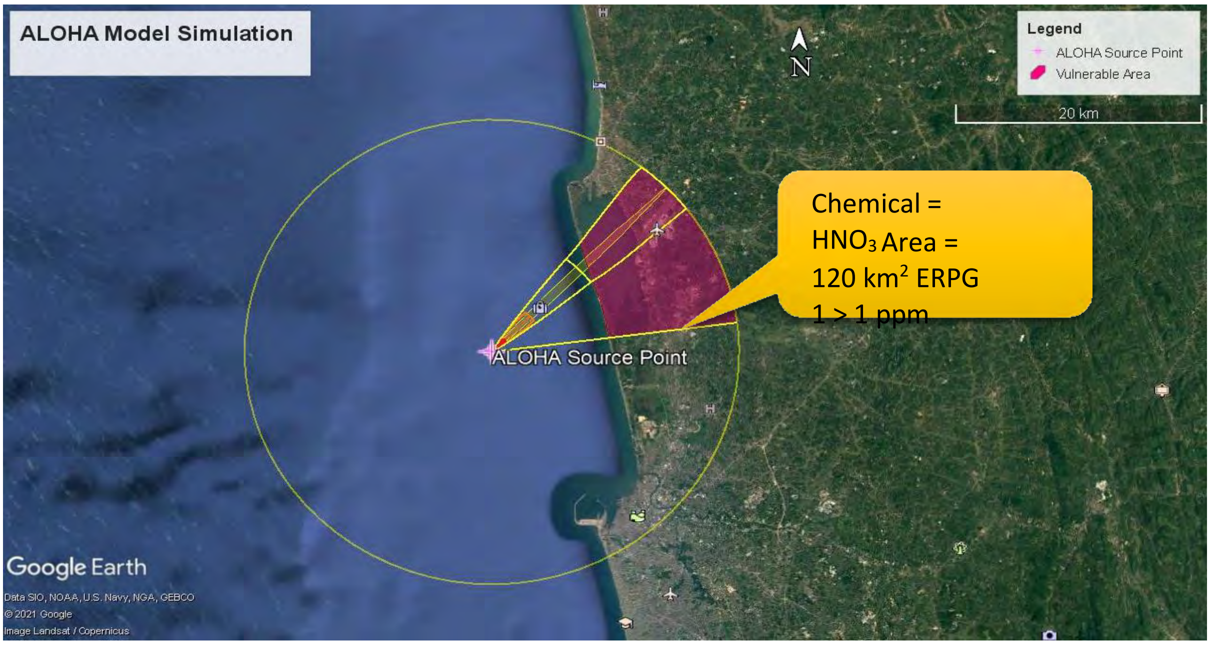


Figure 2.39: Identified vulnerable area for nitric acid according to simulation modelling (credit: NBRO).

The deposition of fire residue on the sea and on land is one of the important hazards that has not been evaluated. To assess the impact of the soot fallout from the fire, a limited survey of soil quality, smear samples, rain and groundwater within the defined vulnerable area could have been carried out to determine if some of the air pollutants that reached the upper atmosphere may return in the form of precipitation. As one of the main components in the soot, polycyclic aromatic hydrocarbons (PAH) is a key parameter that should be analysed as it is both carcinogenic and mutagenic. Given the lapse of time since the incident, however, the value of conducting such an assessment is now likely to be limited; especially as there are many other sources of pollutants (e.g. combustion engines, stove, waste burning, etc.)

Figure 2.40: Depositor of fire residue on the shoreline (credit: NBRO).

Determining the extent and impact of atmospheric pollution from fire incidents is a complex scientific undertaking. It is therefore important that the national air quality monitoring system - including simulation modelling capacity - be strengthened in order to be better prepared to assess and deal with such incidents in the future.

3. Conclusions and Recommendations

The MV X-Press Pearl incident has had a significant and direct impact on Sri Lanka's sensitive coastal environment, local communities and economy. Furthermore, many environmental issues continue to unfold as the active pollution generation phase of the incident will only come to closure with the elimination of the risks from the wreck and containers lost at sea. Recovery from the incident provides an opportunity to enhance the country's institutional and technical capacity to prepare and manage maritime disasters.

As the mandated institution dealing with marine pollution, the Marine Environment Protection Authority has a central role to play in the implementation of the proposed recommendations in cooperation with other relevant government agencies and key stakeholders. Technical and financial assistance from Sri Lanka's friends and international partners is needed to strengthen its capacity to effectively address maritime disasters and protect ocean health, fishery resources and global trade.

The UN team's recommendations are grouped in four areas:

1. Mitigating and eliminating risks from the incident;
2. Plastic pollution clean-up;
3. Environmental assessment and monitoring; and
4. Strengthening maritime disaster management capacity

3.1 Mitigating and eliminating risks from the incident

i) Oil spill surveillance and recovery

The limited but continuous release of oil from the wreck represents an evolving threat to the marine environment and necessary control measures should be put in place for a 'worst case scenario' of a sudden release of a large volume of bunker oil. The shipowner and maritime insurance (P&I Club) have through OSRL deployed oil response equipment to Sri Lanka to respond to such an event.

Specific actions include[12]:

- Daily surveillance of the wreck by boat and helicopter should be maintained to monitor oil discharge. This should be complemented with analysis of satellite images to observe the extent of the oil slick on the sea surface and drift direction.

- Modelling of the oil spill trajectory should be reinforced to obtain a more accurate projection of its trajectory and fate (i.e. where and when the oil may wash ashore). The shoreline should also be regularly surveyed for tar ball arrivals based on aerial observations and modelling results.

- As described in the offshore containment and recovery plan prepared by OSRL, two current buster systems should be deployed to recover the oil slick and sheen as soon as weather and sea conditions allow.

[12] The UN team confirms that oil dispersion using water lances should be avoided as it promotes the spread of the slick on the water surface through disintegration. Chemical dispersion does not appear to be suitable, given that the shallow depth of the sea will likely have impacts on fisheries and coral reefs, which are already under stress. In addition, the high viscosity of the oil will limit the effectiveness of the dispersant.

- An inspection of the vessel fuel tanks should be conducted, and the oil leak stopped as soon as the situation permits. Planning for the evacuation of the oil on the ship should commence as soon as possible.

ii) Chemical pollution monitoring

A plan should be developed and implemented to setup a monitoring to detect the release of chemical pollutants from the wreck and lost containers in its vicinity. This is also needed to ensure the safety of divers and underwater surveillance equipment before initiating the wreck inspection.

For this purpose, a biomonitoring programme using caged marine organisms (e.g. bivalves) is recommended as a relatively simple and cost-effective option. In addition, monitoring of standard water quality parameters (pH, dissolved oxygen, nutrient concentration) should be regularly conducted to control for stratification in the water column (see Annex I).

iii) Removal and decommissioning of the shipwreck and lost containers

The wrecked MV X-Press Pearl and the lost containers at sea pose the most immediate risks of this gradually unfolding incident. A plan to eliminate these risks by the removal of the wreck and containers, and their eventual decommissioning, should be prepared as soon as possible. The plan should be subject to a peer review process and approved by government. Key issues to be addressed include:

- Inspection and examination of the wreck including survey of its immediate vicinity;
- Recovery of the bunker fuel oil, before removal of entire wreck;
- Surveying to locate the containers and other debris on the seafloor using best available technologies (magnetometers, sonars and remotely operated vehicle);
- Recovery of the wreck and the containers;
- Onshore decommissioning of the wreck and containers, including establishment of a dedicated inland decommissioning site (unless the plan is to remove the recovered wreck/containers outside of Sri Lanka);
- Final inspection and project closure including restoration of the decommissioning site (if used); and
- Time schedule of the above operations.

The Government of Sri Lanka should nominate a qualified representative/team to oversee the work of the company that will be commissioned to remove and decommission the wreck and the containers. Oversight duties of the Government's representative/team should include inspection of the wreck, containers and debris removal, and confirmation that all work areas are returned in a clean and satisfactory condition to their owners. A stakeholder consultation process involving *inter alia* representatives of coastal fishing communities and environmental NGOs should be established to ensure public confidence in the wreck and container recovery project.

3.2 Plastic pollution clean-up

Several actions are suggested to improve clean-up, classification and disposal of the plastic waste including:

- Chemical analyses of the pellet and burnt plastic mix to assess the level of their contamination should be conducted as a matter of priority;
- The results of the chemical assessment should inform the characterisation of the plastic waste as hazardous or non-hazardous;

- If found to be hazardous, additional waste criteria testing (e.g. leachate analysis) should be carried out to determine the appropriate disposal method;
- If found to be non-hazardous, then the potential for the reuse and recycling of the plastic waste should be prioritized;
- On-site separation of the plastic waste should be maximized to reduce sand collection, transport and storage;
- Beach sediment analysis should be conducted to quantify the presence of small burnt plastic particles (<3 mm) that may not be recovered during clean-up operations;
- Develop clean-up methods to recover small burnt plastic particles (<3 mm) (e.g. adaptation of the flotation method to capture small burnt particles);
- Recover floating pellet and burnt plastic pollution in the inlet channels of Negombo lagoon to prevent incoming pollution dissemination deeper in the lagoon and mangroves;
- Improve pellet storage at the backshore of the beach to avoid secondary pollution (e.g. protecting the temporary storage areas by placing a tarpaulin or equivalent under the bags),
- Improve handling and transportation of pellet bags particularly from the beach to the main road to avoid secondary pollution (e.g. establish defined routes, use wheelbarrows for transportation);
- Set specifications to guide the microplastic clean-up effort and help assess the environmental impact of clean-up techniques to determine when to stop cleaning and prevent additional environmental damage;
- Develop a long-term plastic beach clean-up programme along the coastline to collect chronic beach pollution by plastic debris, including that from the X-press Pearl. A community-based approach for waste collection should be considered.

Finally, as the single largest plastic spill, it would be valuable for Sri Lanka to document its clean-up experience and share its learnings with the international community. The event could also serve as an opportunity to call for a review of international regulations on plastic pellet packaging, storage and maritime transportation with relevant international organisations.

3.3 Environmental assessment and monitoring

i) Marine pollution assessment

The environmental assessment plan should be organised into a two phased approach comprising of: i) pollution hot spot assessment; and ii) long-term environmental assessment and monitoring.

The pollution hot spot assessment should focus on three areas: i) the area of the wreck; ii) around lost containers; and c) shorelines with high plastic and debris pollution loads. The following activities should be carried out as a matter of priority:

- verify the epoxy resin formulation aboard the vessel (CAS number/MSDS);
- regular water quality analysis (pH, PAH and heavy metals) around the wreck;
- bottom sediment analysis (PAH and heavy metals) around the wreck and lost containers;
- benthic organism analysis (PAH and heavy metals) and use of biomarkers (if feasible) to detect release of chemicals around the wreck;
- an assessment of seafloor integrity around the wreck including the section along which the vessel drifted and was towed from the beginning of the incident until it sank;
- shoreline sediment analyses (PAH and heavy metals) in highly impacted sites;
- pellets and burnt plastic mix analyses (PAH and heavy metals); and
- awareness campaign to educate public and officials on the relevant findings.

In conducting the assessment, it will be important to accurately document the methodology and sampling plan and to keep duplicate samples in safe storage.

Based on the findings of the hot spot assessment, design a long-term monitoring program of the marine environment which would include the entire shoreline impacted by plastic pellet pollution, and with a focus on environmentally sensitive areas (e.g. lagoons, mangroves, estuaries, coral reefs, turtle nesting sites). This program could investigate as a priority sand contamination by chemicals and plastics and their impacts on shoreline species (e.g. crabs), as well as ecological status of main sensitive biota.

It is important to underscore that a long-term environmental monitoring programme is necessary for a better understanding of baseline conditions and the deployment of credible scientific plans to assess impacts and remediation approaches of future maritime incidents. A sound knowledge base is also a central requirement for litigation and damage and loss assessments.

ii) Fisheries assessment

To clarify the status and alleviate concerns over seafood safety, the following actions are recommended:

- assess for chemical contaminants (PAH and heavy metals as a priority) in seafood both in the: i) no-fishing area to determine if the ban should be maintained or lifted; and ii) outside the no-fishing zone to reassure the general public on the safety of seafood consumption;
- maintain the mortarium on fishing in the vicinity of the wreck until the wreck, containers and other large debris are removed;
- conduct a risk assessment of sea salt microplastic contamination before the production season starts; and
- disseminate relevant information among technical agencies, media and public with adequate explanations.

iii) Marine wildlife assessment

An assessment to determine the cause of the mass turtle and other marine mammal mortalities should be carried out by qualified medical veterinarians. The diagnostic investigation should prioritize the following actions:

- conduct necropsies of specimens to detail all lesions including ingestion of pellets, fibres and other debris;
- test for biotoxins to determine if deaths may be linked to harmful algal blooms;
- screen for algal blooms along the coastal zone including by analysing satellite imagery;
- good quality photo documentation of specimens; and
- toxicological analysis to identify presence of chemicals (PAH and heavy metals) in body fluid and tissues.

Surveys of sensitive benthic ecosystems (coral reefs, soft bottom habitats) should be planned by marine ecologists. This should include underwater investigations (e.g. using Remotely Operated Vehicle) to assess the health status of biota and the presence of debris from the wreck.

iv) Air pollution assessment

Air pollution was an important and visible impact of the incident including the generation of large quantities of particulate matter and fire residues. However, only limited analysis of air pollution could be performed due to limitations in technical capacity and available monitoring equipment. It is therefore important that the national air quality monitoring system - including simulation modelling - be strengthened in order to be better prepared to assess and deal with such incidents in the future.

3.4 Strengthening maritime disaster management capacity

As with the Tsunami of 2004, if there is to be any upside from this incident, it would be by serving as a catalyst or window of opportunity for building a more resilient system to prevent and respond to maritime disasters in the future. Taking this aspiration forward would essentially mean prioritizing maritime emergency preparedness and management through: i) development of a maritime disaster plan; ii) strengthening the institutional basis for its implementation; and iii) undertaking a capacity building programme.

To realize this considerable and long-term proposition, a collective initiative by the Government of Sri Lanka and its international friends and partners is needed. Coordination will be pivotal to a successful outcome. To ensure that support is delivered efficiently, a mechanism needs to be setup for accepting and facilitating international assistance to avoid overlaps and that key gaps are left unaddressed.

The key building blocks of the proposed maritime disaster management institutional and capacity building programme would include:

- Review of institutional arrangements;
- Preparation of a disaster management plan;
- Capacity building and regular training on maritime emergencies (oil and chemical spills, fires, collisions, wrecks, ballast water);
- Emergency response assets;
- Coastal and marine environmental monitoring programme using state of the art technologies (upgrade laboratories, remote sensing, real-time sensors, underwater survey equipment);
- An integrated marine information management system to support environmental monitoring and intervention operations; and
- Cooperation with regional and international partners including the South Asia Co-operative Environment Programme/South Asia Seas Programme (SACEP/SASP) (e.g. mock drills, training)

To reinforce Sri Lanka's maritime disaster management capacity, it will be important that a comprehensive review of relevant international maritime conventions and protocols be carried out to determine those which it would be beneficial to accede to, update national laws accordingly and train staff on their implementation (e.g. Nairobi Convention on Wreck Removal, 2007; additional protocols of the Intervention Convention, 1969)

4. Annexes

Annex I: Key Considerations in Developing an Environmental Monitoring Plan of the MV X-Press Pearl Incident – UN Team Advisory Note

1. Background

Costa and Teixeira (2014) define **biomonitoring** as the "systematic measurement of compounds and/or detection of cell or cell molecules alterations in living organisms with the purpose of identifying or assessing potential hazardous exposure and effects to chemicals. Biomonitoring presents a wide range of advantages over environmental monitoring and has been considered to be a valuable tool for both ecological and human health surveillance. Cautious interpretation of data is one of the most sensitive issues on this matter. Still, the development and application of biomonitoring lead to improved knowledge of the effects of chemicals on living organisms and at the same time to increased protection of public health and environment."

In the context of the X-Press accident, the consideration should be given to two biomonitoring programs, namely ():

- **Biomonitoring of the wreck** itself to determine its hazardousness (does the wreck continue to release hazardous products into the environment);
- **Environmental biomonitoring program** to evaluate environmental consequences of MS X-Press Pearl incident and the extension of its effects both in space and in time.

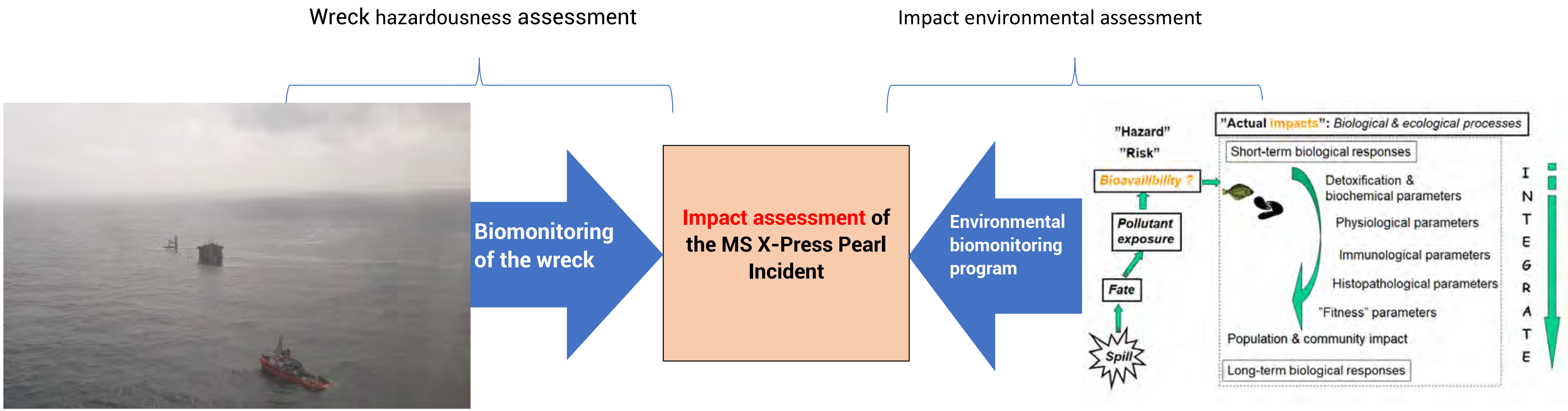


Figure 1: Two independent and complementary approaches to determine the impact of the MS X-Press Incident.

Each programme includes specific measures and they are independent of each other. However, the results obtained are complimentary and can be jointly interpreted.

2. Biomonitoring of the wreck

Until salvage operations begin, it is essential to assess the risk of the wreck, particularly with regard to hazardous substances that may be released over time. Does the wreck release substances that could potentially impact marine life?

A monitoring programme, inspired by those used to assess the possible impact of industrial sites on the quality of the marine environment (Mussel Watch Programme), could be judiciously implemented. Environmental quality is described using measurements to assess the health status of caged marine organisms.

2.1 What is a cage?

The cage could be made with fishermen net (preferably), or with seawater resistant wire fencing, in fact, with "something" **as simple as possible**.

For each monitoring point, 2 cages are placed at different depth to better monitor situation along water column (on the bottom and at 3-5 m depth). Cages are connected to ballast that will be deposited on the bottom, and to a buoy on the surface.

2. 2 Where cages must be placed?

Given the position of the wreck on the site and the main environmental parameters (current and wind), cages must be placed as follow:

- Depending of the direction of the main current, 4 cages should be placed upstream (2 monitoring points, around 50 meters) and 4 other cages should be placed downstream of the wreck (2 monitoring points, around 50 meters). Current seems to be always in the same direction during a season.
- 2 cages must be placed directly in the wreck as deep as possible.
- 2 cages must be placed close to the shoreline and will serve as "control organisms" (reference site, without contamination).

Then, 6 monitoring points will be used, and, at each point, 2 depths will be controlled. **In total, 12 cages are needed.**

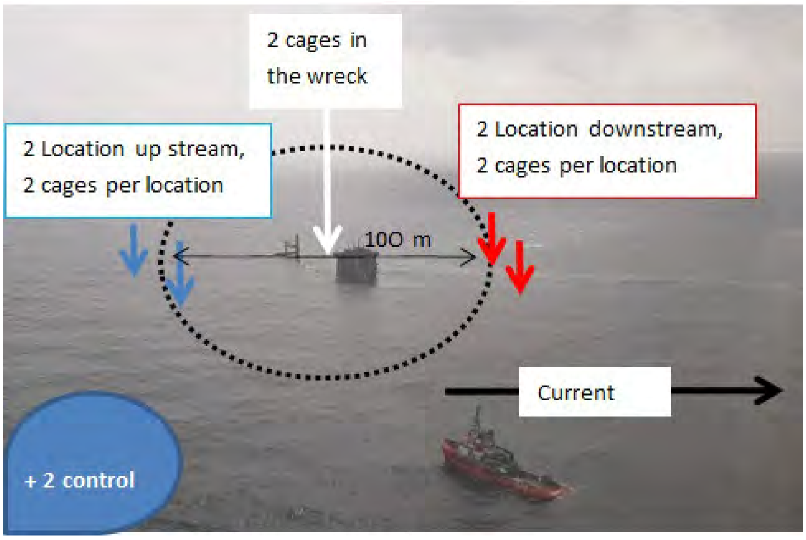


Figure 2: Allocated cages in the vicinity of the wreck plus control site.

2.3 Duration, frequency of samplings and number of organisms

The number of organisms needed is directly related to the duration of the biomonitoring program, the frequency of the sampling and the number of organisms sampled at each time (Lacroix et al., 2015).

Duration of the whole programme: from "as soon as possible" to the end of the wreck recovery (January 2022?).

Frequency of the samplings: at least, one sampling per month must be done (**6 sampling dates** until the wreck recovery).

Number of organisms: at least, **10 organisms** must be sampled per cage and per sampling date (this number takes into account the need for replicates and the fact that pooling of samples may be necessary to quantify possible pollutants).

In this respect, 10 organisms per sampling date x 1 sampling per month x 6 months = **60 organisms per cage**. Ideally, **80 organisms** can be placed in each cage in case of an over mortality is observed.

In total, **12 cages x 80 organisms = 960 organisms.**

2.4 Which type of organisms?

The biomonitoring program can be implemented using bivalves (mussels or oysters) as is being done in other environmental programs (Lacroix et al., 2014; Kazour and Amara, 2020).

2.5 Which type of measurements on organisms?

In the context of this accident and taking into account the lack of analytical equipment of Sri Lankan administrations involved, we propose to perform **measurements as simple as possible**. For example, the condition index or "survival on air" are very good candidates; these indicators are relatively simple to measure, and they provide relevant information on physiological stress and, consequently, on the state of health of bivalves (Albentosa et al., 2012). These measurements must be done on individual organisms. Evaluation of mortality in different cages could also highlight acutely toxic effects if appropriate statistical analyses are applied (ANOVA test).

Bioaccumulation measurements in bivalve tissues can provide useful help in the results interpretation. The compounds to look for in priority are PAHs (US EPA list of 16 PAHs), halogenated hydrocarbons, standard trace metal (Al, As, Cd, Cr, Cu, Hg, Ni, Pb, V, Zn) and possibly microplastics. These measurements can be made on samples of 3 pooled organisms. There are many internationally accredited labs which can conduct these analyses including, for example:

- ALS which has laboratories in Thailand and Singapore: https://www.alsglobal.com/en-sg#chooser-section;
- A lab run by IAEA: https://www.iaea.org/services/laboratory-services

Additional biomarkers measurements can be performed depending on analytical equipment available. Specific tissues can be sampled like haemolymph and digestive glands to perform measurements which will allow providing relevant information on key toxicological pathways, including neurotoxicity, genotoxicity, biotransformation and oxidative stress (Regoli et al., 2014). It is also recommended to monitor the sediment contamination in the vicinity of the wreck, and the potential bioaccumulation of pollutant by benthic organisms (Benedetti et *al.*, 2014).

3. Environmental Monitoring Programme

The monitoring strategy should prioritise the survey of media that characterize environmental conditions, and which are presumably most at risk of impact (Neuparth et al., 2012; Kirby et al., 2010, 2014 and 2018). For this reason, **analysis of marine sediments is a priority** representing a key medium for assessing chemical pollutants; especially when compared to contaminants in water and air that are diluted and transported by sea currents and winds**. Organisms are** also **critical** for evaluating both **bioavailability of released compounds** and their **toxicological hazard.** Thereby, allowing an assessment not only of short-term but also medium and long-term consequences (IMO and UNEP, 2009). Bioindicator organisms to be sampled must be representative of the sampled area, i.e. specimens that live in close contact with the sea bottom (sedentary species with a small home range) compared to species that have a more erratic behaviour (e.g. pelagic fishes).

The investigation should take into consideration the following aspects:

- Chemical analysis of sediments samples and biota;
- Biological assays on sediment and water samples;
- Ecotoxicology on specimens of sedentary marine organisms;
- Assessment of ecological status around the impacted area
- Interest of data provided by the biomonitoring of the wreck (see chapter 2).

An environmental monitoring programme around the MS X-Press wreck would help to determine the:

- Potential impact of the wreck on marine ecosystem in particular on organisms;
- Longer-term impacts on the food chain and the risk for humans.

Important: Direct observation of the seabed using a ROV (Remotely Operated Underwater Vehicle) is an integral part of an environmental monitoring plan. This activity must be carried out as soon as possible and should be done with the support of marine ecologists, with expertise in tropical environments. The seabed surrounding the wreck should be surveyed as a priority, probably characterized by typical ecosystems of mixed seabeds (soft bottom assemblages), and the closest coral reefs. Thus, it will be possible to observe any signs of damage that can be attributed to the presence of the wreck and associated sources of pollution.

3.1 Key points for biota monitoring plan

The pollution can be monitored by following its impact on the biota, i.e. marine organisms (Alcaro et al., 2012; Cunha et al., 2017).

Where collect biota samples?

Bioindicator organisms will be sampled in the area of the incident, approximately within 1 nautical mile from the wreck. A similar sampling campaign will be carried out in a reference area, with similar environmental characteristics but not affected by the wreck or other sources of pollution.

Which species?

Organisms should be sedentary, with a limited home range, living in close contact with the seabed (benthic) and possibly being used for human consumption, to assess any risks to humans. Excellent candidates are specimens of *Conger conger* or species belonging to the Muraenidae family.

How to collect fish samples?

Fishing equipment, mainly pots (i.e. stationary traps) or seafloor longlines, can be used. It is preferable to use pots to limit the stress on the specimens.

Number of samples? With which frequency?

To obtain statistically robust results, a minimum of 15 specimens should be collected in each fishing campaign, from both the reference site and the area around the wreck, for a total of 30 specimens (Della Torre et al., 2005). Sampling can be repeated 2-3 times until December 2021, with 60-90 specimens to be analysed.

What kind of analyses? Which tissues?

Analyses should be primarily carried out on liver which represents the most important target tissue, with the more elevated metabolic and biotransformation activity (Della Torre et al., 2008). Additional analyses will be considered for selected samples of gills (reflecting exposure through water), and muscles to evaluate possible risk on edible portion of fishes.

Chemical and toxicological analyses include:

- Bioaccumulation of PAHs, halogenated hydrocarbons, trace metals and possibly microplastics.
- Health Assessment Index (HAI), macroscopic evaluation of the state of the sampled organisms and their internal tissues.
- Histopathology
- Analysis of cellular damages, such as lysosomal stability, lipid peroxidation, typical biomarkers of detoxification and oxidative stress processes, immune responses, neurotoxicity and genotoxicity.

3.2 Key points for sediments monitoring plan

Where to collect sediment samples?

Sediment samples will be collected around the wreck in different directions and at different distances. When the precise distribution of sunken containers will be known, specific collection will be performed around these potential sources of pollution.

As preliminary design, sediments will be collected at 100 and 1000 meters from the wreck: for each distance 2 upstream and 2 downstream sampling sites will be considered for a total of 8 sampling points. At least 2 additional sites will be selected with similar characteristics but far from the source of pollution (reference area).

For each site, sediments will be collected in triplicate: considering 10 sampling sites, **a total of 30 sediment samples** will be available for chemical and ecotoxicological analyses**.**

Which sampling frequency? Number of samples?

Sediment sampling campaign can carried out 2-3 times until December 2021, determining a total collection **of 60-90 samples**.

How to collect sediment samples?

Sediment can be collected using a Day grab / Van Veen grab or a Box corer. The Box corer guarantees a more precise analysis of the upper layer (where it is more likely that released contaminants are present) but, on the other hand, it may be more logistically complex to use. (EPA/USACE, 1995).

What kind of analyses?

Both chemical and ecotoxicological analyses should be performed (ASTM, 2004).

Chemical analyses

Considering the wide range of pollutants that might be released from the wreck (contaminants present in the cargo, fuel oil, combusted products), a full screen, un-target measurement would be advisable to investigate the overall presence of contaminants. Analyses should include PAHs, halogenated hydrocarbons, trace metals and possibly microplastics.

Ecotoxicological bioassays

The ecotoxicological potential of sediments will be evaluated with a battery of standardized ecotoxicological bioassays, typically used to analyse the quality class of sediments. The battery includes different biological endpoints and organisms of different Phyla and trophic level (Beiras, 2002).

Recommended species and test include:

- the bacterium *Vibrio fischeri* (Microtox®) (variation of bioluminescence);
- the algae *Dunaliella tertiolecta* or *Phaeodactylum tricornutum* (algal growth);
- the oyster *Crassostrea gigas* (embryotoxicity)
- the crustacean *Tigriopus fulvus* (its larval development)

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Annex II: Chemical analyses of oil samples

A chemical characterisation of the oil slick coming from the wreck is deemed necessary as the oil slick was observed for several days and it is considered important to know whether it was bunker oil or a product (e.g. lubricants) coming from the cargo. This information should also be factored when planning the removal operation of the wreck (chemical composition of the propulsion fuel, still present or not on board) and in order to better assess the risks associated with this drifting oil slick. Indeed, heavy fuel oil presents high risks in terms of toxicity and impact on marine organisms.

In this respect, two samples were analysed by CEDRE:

1. An oil sample taken by MEPA immediately after the vessel sank (very black liquid, very viscous, appearance and smell of weathered oil)
2. An oil sample taken by the UN team during their vessel survey around the wreck. This sample was taken on 20 June.

Both samples were received at CEDRE on the 1 July 2021 and analyses were performed the same day. Samples were analysed by gas chromatography coupled with a detection by mass spectrometry (GC-MS) in order to characterize them by their constituent molecules separated according to their boiling point. The objective was to compare the samples based on the methodology described in the CEN guidelines "CEN/TR 15522-2:2012 - Oil spill identification - Waterborne petroleum and petroleum products - Part 2: Analytical methodology and interpretation of results based on GC-FID and GC-MS low resolution analyses".

The analyses lead to the following conclusions:

1. The bunker oil has the characteristics of a heavy Fuel oil (Figure 1). Three chromatographic features allow this conclusion to be drawn: the presence of an unresolved complex mixture (UCM), the absence of retene (heavy fuel oils are generally liquefied by a cut resulting from catalytic cracking which destroys this molecule) and the presence of 2-methylanthracene which is produced by catalytic cracking.
2. To match the two oil samples, different compounds were analysed to characterize each oil sample. From these compounds, various ratios were calculated and then compared. The comparative analysis shows a concordance of biomarkers abundance (surrounded by a red circle). Comparison of samples does not show significant differences. Conclusion: match between these two samples (Figure 2).

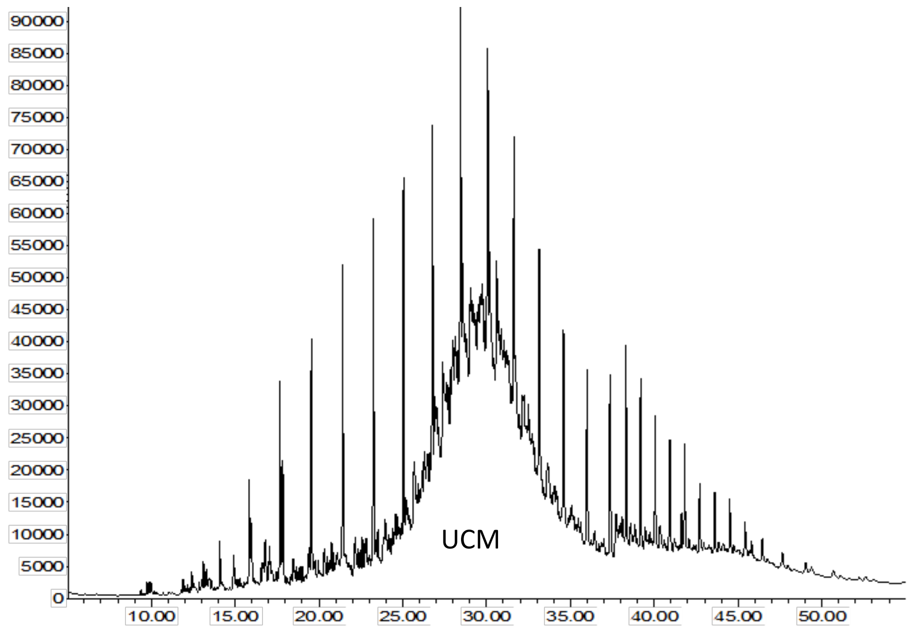


Figure 1: Chromatogram of oil sample taken on 20 June, which is typical of a heavy fuel oil.

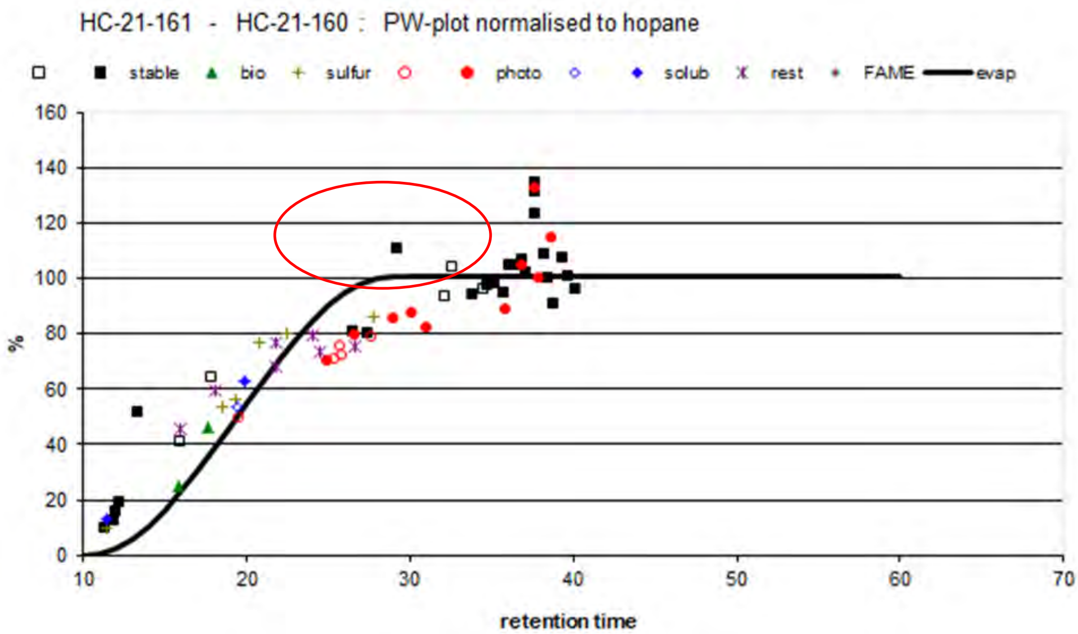
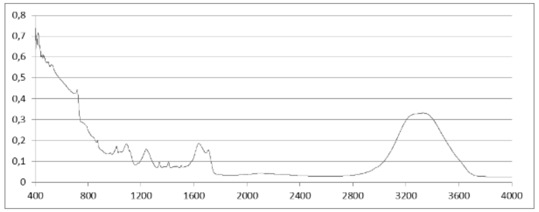
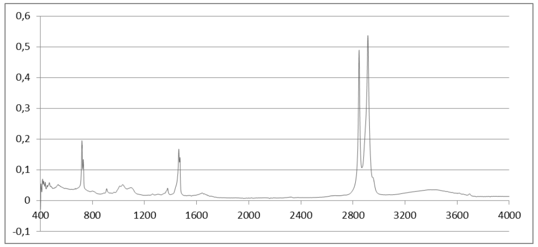


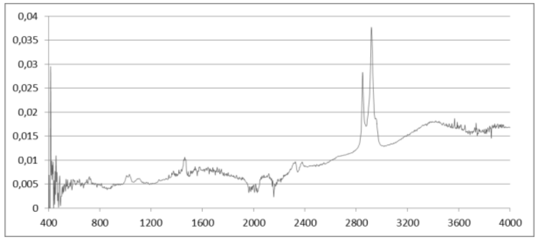
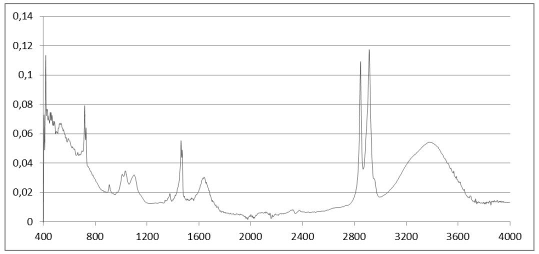
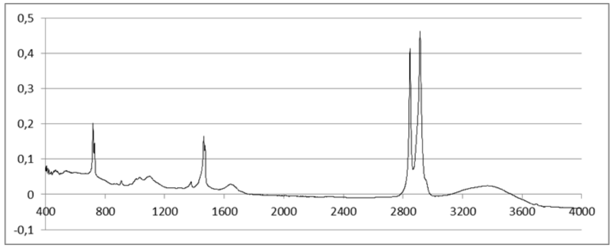
Figure 2: Full concordance for compounds in the red circle. The statistical treatment of analysis does not show significant difference between the two oil samples taken.

Annex III: Preliminary results of plastic analyses performed by CEDRE using Fourier transformed infrared spectrometry (FTIR)

Analyses were performed in CEDRE laboratory using an ATR Nicolet Summit FTIR spectrometer (Thermofisher). Samples analysed and results obtained are detailed in the table below.

Table 1: Results of plastic analyses samples.

Sample name	Sample picture	FTIR spectra	Substances matching and % of match
Fibres provided by MEPA			1. Polyethylene terephthalate (CEDRE spectrum bank) 81.98% 2. PBAT (CEDRE spectrum bank) 48.49%
Burnt plastic collected on Sarakkuwa beach - Piece 1			1. Polyethylene (CEDRE spectrum bank) 94.88% 2. Polyethylene 93.10% 3. Natural vegetable wax from Mexican shrub 85.68% 4. Natural vegetable wax from Brazilian palm trees 83.43% 5. Oxidized polyethylene 79.23%

Burnt plastic collected on Sarakkuwa beach - Piece 2			1. Poly(ethylene :propylene :diene) 73.25% 2. Poly(ethylene :propylene :diene) 62.78% 3. Docosanoic alcohol 61.13% 4. Heneicosanol 60.20% 5.Poly(ethylene :propylene :ethylidenenorbornene) 59.76%
Burnt plastic collected on Sarakkuwa beach - Piece 3			1. Polyethylene 87% 2. Natural vegetable wax from Mexican shrub 84% 3. Natural vegetable wax from Brazilian palm trees 83% 4. Oxidized polyethylene 81% 5. Polyethylene oxidized by heat 69%
Small Burnt plastic pieces collected in a flotation tank on Sarakkuwa beach			1. Polyethylene (CEDRE spectrum bank) 97,34% 2. Polyethylene 92,90% 3. Natural vegetable wax from Mexican shrub 85,79% 4. Natural vegetable wax from brazilian palm tres 83,76% 5. Oxidized polyethylene 79,87%

Annex IV: Key Stakeholders Consulted

Name	Designation	Agency/Ministry
Hon. Dr. Nalaka Godahewa	State Minister	Urban Development and Coast Conservation, Waste Disposal and Community Cleanliness
Ms. Dharshani Lahandapura	Chairperson	Marine Environment Protection Authority (MEPA)
Dr. Terney Pradeep Kumara	General Manager /CEO	Marine Environment Protection Authority (MEPA)
Ms. Hasanthi Urugodawatte Dissanayake	Director General/Ocean Affairs, Environment and Climate Change	Foreign Ministry
Dr. Sugath Yalegama	Additional Secretary	State Ministry of Urban Development, Coast Conservation, Waste Disposal, and Community Cleanliness
Mr. Jagath Gunasekara	Deputy General Manager	Marine Environment Protection Authority (MEPA)
Prof. Ajith de Alwis	Head, Department of Chemical and Process Engineering, and co-chair of Environmental Damage Assessment Committee	University of Moratuwa
Professor A. Navaratnerajah	Chairman	National Aquatic Resources and Development Agency
Dr. Palitha Kithsiri	Director General	National Aquatic Resources and Development Agency
Dr. A. A. Deeptha Amarathunga	Senior Scientist Environmental Studies Division	National Aquatic Resources and Development Agency
Dr. Tharaka Prasad	Director, Wildlife Health	Department of Wildlife Conservation
Mr. Manjula Amararathna	Director, Protected Area Management	Department of Wildlife Conservation

Name	Designation	Agency/Ministry
Dr. Ananda Mallawatantri	Country Representative	International Union for Conservation of Nature
Dr. Arjan Rajasuriya	Marine and Coastal Expert	International Union for Conservation of Nature
Dr. (Eng.) Asiri Karunawardane	Director General	National Building Research Organisation
Mr. H.D.S. Pemasiri	Director, Environmental Studies and Service Division	National Building Research Organisation
Mr. W.K.N. Chandrasena	Scientist/Engineer, Environmental Studies and Service Division	National Building Research Organisation
Ms. Dhammika Wijayasinghe	Director General	Sri Lanka Tourism Development Authority
Prof. Ruchira Kumaratunga	Emeritus Professor in Fisheries Biology	University of Ruhuna
Mr. A.W.M. Rifa Wadood	Director/International Relations	Ministry of Environment
Ms. Pathma Abeykoon	Director/Biodiversity	Ministry of Environment
Prof. Sevvandi Jayakody	Senior Lecturer, Department of Aquaculture & Fisheries, and Chairperson, National Mangrove Expert Committee	Wayamba University of Sri Lanka
Prof. Prasanthi Gunawardena	Department of Forestry and Environmental Science Department	University of Sri Jayawardanapura
Mr. Ajith Weerasundera	Director, Chemical and Hazardous Waste Management	Central Environmental Authority (CEA)
Mr. Muditha Katuwawala	Co-ordinator	The Pearl Protectors
Mr. Sena Peiris	Sri Lanka Coordinator, CounterMEASURE project	UNEP

Name	Designation	Agency/Ministry
Mr. Ranjan Marasinghe	Director, Operations	Department of Wildlife Conservation
Mr. Lalith Kumara	Assistant Director (Western Region)	Department of Wildlife Conservation
Dr. Suhanda Jayawardane	Veterinary surgeon	Department of Wildlife Conservation
Dr. Pramuditha Dewasurendra	Veterinary surgeon	Department of Wildlife Conservation
Mr. Saman Liyanagama	Wildlife Ranger (Bellanwila-Attidiya)	Department of Wildlife Conservation
Mr. M.M.K.Moratanna	Wildlife Ranger (Kalpitiya)	Department of Wildlife Conservation
Dr. Jagath Rajapakse	Remote Sensing	Ocean University of Sri Lanka
Mr. A.B.A.K. Gunaratne	Director / Monitoring and Evaluation	National Aquatic Resources and Development Agency
Dr. K Arulananthan	Head / National Institute of Oceanography Marine Sciences	National Aquatic Resources and Development Agency
Mrs. K.W.S.Weerasekara	Head / Environmental Studies Division	National Aquatic Resources and Development Agency
Dr.K.W.S.Ariyawansa	Head / Institute of Post Harvest Technology	National Aquatic Resources and Development Agency
Dr. H.S.S.K.Haputhantri	Head/ Marine Biological Resources Division	National Aquatic Resources and Development Agency
Dr. P.P.M Heenatigala	Head / Inland Aquatic Resources and Aquaculture Division	National Aquatic Resources and Development Agency
Mr. K.H.M.L. Amaralal	Head / Socio Economics & Marketing Research Division	National Aquatic Resources and Development Agency

Name	Designation	Agency/Ministry
Dr. Aravinda Abeygunasekera	Material Science and Engineering	University of Moratuwa
Prof Shantha Egodage	Chemical and Process Engineering	University of Moratuwa
Mr David Campion	ITOPF Ltd	Senior Technical Advisor
Dr. Conor Bolas	ITOPF Ltd	Technical Advisor
Gabriel Gyamfi	OSRL	Duty Manager, Senior Response Specialist
Mr. Daniel White	OSRL	Response Readiness Manager/Incident Manager
Ms. Natalie Kirk	OSRL	Oil Spill Responder
Mr. Paul Irving	Senior Advisor, Strategic Risk and Science Repsonse	Australian Maritime Safety Authority
Mr. Nicholas Hardman Mountford	Head of Oceans and Natural Resources	The Commonwealth Secretariat
Dr. Sue Ware	Monitoring Group Manager & PREMIAM Monitoring Coordination Cell Chair	Centre for Environment, Fisheries and Aquaculture Science
Ms. Dinusha Panditaratne	Adviser & Head, Asia Governance and Peace Directorate	The Commonwealth Secretariat

Annex V: UN Team Members

The mission was conducted under the overall guidance and facilitation of the UN Resident Coordinator in Sri Lanka, Ms. Hanna Singer Hamdy.

Name	Role	Organization
Hassan Partow	Team Leader	UNEP
Camille Lacroix*	Marine litter and chemical expert	CEDRE
Stephane Le Floch*	Oil and HNS expert	CEDRE
Luigi Alcaro*	Oil and marine environment expert	ISPRA

** (deployed through EU)*

The UN team was provided with administrative support by the UNDP office in Sri Lanka.

Remote advisory support to the UN field mission was provided by:

Name	Role	Organization
Muralee Thummarukudy	Acting Head Resilience to Disasters and Conflicts Global Support Branch	UNEP
Olof Linden	Senior environment advisor	UNEP
Margherita Fanchiotti	Focal Point for Response	UNEP/OCHA Joint Environment Unit
Yves Barthelemy	Senior GIS and Data Management Expert	UNEP
Dawit Yared	Administration	UNEP/OCHA Joint Environment Unit

Annex VI: References

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13. Sri Lanka J. Aquat. Sci. 18 (2013): 1-15. Fisheries resources in alleviation of hunger and malnutrition in Sri Lanka - accomplishment and challenges1

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2. EU/UN/World Bank. Post Disaster Needs Assessment guidance documents available at:

   https://www.westmopoco.rempec.org/en/project/specific-objectives-and activities/hns-marine-response-manual

   https://www.gfdrr.org/en/damage-loss-and-needs-assessment-tools-and-methodology