X-PRESS PEARL: A 'NEW KIND OF OIL SPILL'

A TOXIC MIX OF PLASTICS AND INVISIBLE CHEMICALS

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CEJ Centre For Environmental Justice

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IPEN is a network of over 600 non-governmental organizations working in more than 120 countries to reduce and eliminate the harm to human health and the environment from toxic chemicals.

www.ipen.org

Centre for Environmental Justice (CEJ) is a public interest environmental organization based in Sri Lanka, established in 2004. CEJ engages in environmental awareness, litigation, and advocacy, and promotes citizens science.

https://ejustice.lk/

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ABSTRACT

In May 2021, the cargo ship X-Press Pearl caught fire outside of Sri Lanka. After the first wave of air pollution, the second wave of pollutants hit the beaches. It consisted of lost cargo, including billions of plastic pellets (microplastics used to produce plastics). Through summarizing the events leading up to and following the fire, analyzing plastics found on the beaches for toxic chemicals, and interviewing 107 fishermen and other locals, this report looks at 1) the chemical pollutants and their potential consequences 2) the socio-economic impacts and 3) how to move forward to mitigate the situation and to prevent future similar disasters.

Throughout the study it has been evident that the consequences from the fire on board X-Press Pearl are, however, far more complex than just the visible debris found on the beaches. The analytical results tell a tale of pollutants matching the complexity of the cargo on board the ship, confirming that the consequences don't only consist of the physical pollutants, but also chemical ones. The fishermen tell of lost income, destroyed nets, decreased catch, changes in the sea, and in some cases allergic symptoms following the accident.

If all the different types of chemicals, metals, and hazardous cargo leached out, the consequences are comprised of a mix of endocrine-disrupting bisphenols, metals that don't have exposure limits that can be considered safe, cancer-causing PAHs, toxic plastic additives, and corrosive caustic soda. With increasing shipping, complex mixtures of chemicals, and regulations that have not caught up with the currently prevalent massive container ships, accidents like this must be considered the oil spills of our time. It is therefore crucial that prevention, mitigation, and regulatory measures are adapted to today's shipping patterns to protect coastal communities and prevent similar disasters in future.

Firefighters trying to control the fire on board X-Press Pearl outside Sri Lanka.
Photo: Nilantha Ilangumuawa/Unsplash

BACKGROUND

On the 20th of May 2021 a fire erupted on X-Press Pearl, a container ship anchored outside of Colombo, the commercial capital and largest city of Sri Lanka. As the world watched the ship burn for 13 days, Sri Lanka braced itself for the inevitable environmental disaster that has later been described as the worst in Sri Lanka's history [4].

On board the three-months-old ship [4] were 1,486 shipping containers. Of those, 81 were classified as dangerous goods [2], such as nitric acid and caustic soda. The others have been reported to contain a mixture of several tonnes[1] of potentially toxic epoxy resin, plastics, and oil, as well as metals such as lead and copper [5].

Following the fire, the contents of the containers started to leak out into the environment. This led to fishing being prohibited in large areas along the coast, hundreds of dead turtles floating ashore, and tonnes and tonnes of waste filling the beaches.

This accident illustrates a new type of oil spill where coastal communities are deeply impacted by a toxic mix of oil, chemicals, plastics, and other wastes. This story is far from over, and on the following pages we will take you through how this event has impacted Sri Lanka's coastal communities, how it can come to impact the local marine environment, how there seems to be a lack of accountability, and how this, in many ways, is the result of a legislation that has not been adequately adapted for today's container ships.

1 A tonne is equivalent to 1 metric ton.

Shipping of dangerous goods at sea is primarily regulated by the International Convention for the Safety of Life at Sea (SOLAS) in connection with the provisions of the International Maritime Dangerous Goods (IMDG) Code, the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78), and the United Nation's Convention on the Law of the Sea (UNCLOS).

SOLAS regulates dangerous goods in chapter VII, which also regulates chemicals packaged in solid form and bulk (solids, liquids, and liquified gases). SOLAS, which was signed in 1914, was last amended in 2016 when new rules on the weighing of containers were added, with the intention of decreasing spills, since misdeclared weights have previously resulted in losses at sea [6]. Chapter II-2 of SOLAS includes provisions on fire protection, fire detection, and fire extinction. In the wake of the accident on X-Press Pearl, these provisions of SOLAS have been criticized as outdated, and Bozzi (2021) states that "they need to be amended to suit the current era of large and ultra-large vessels, like X-Press Pearl".

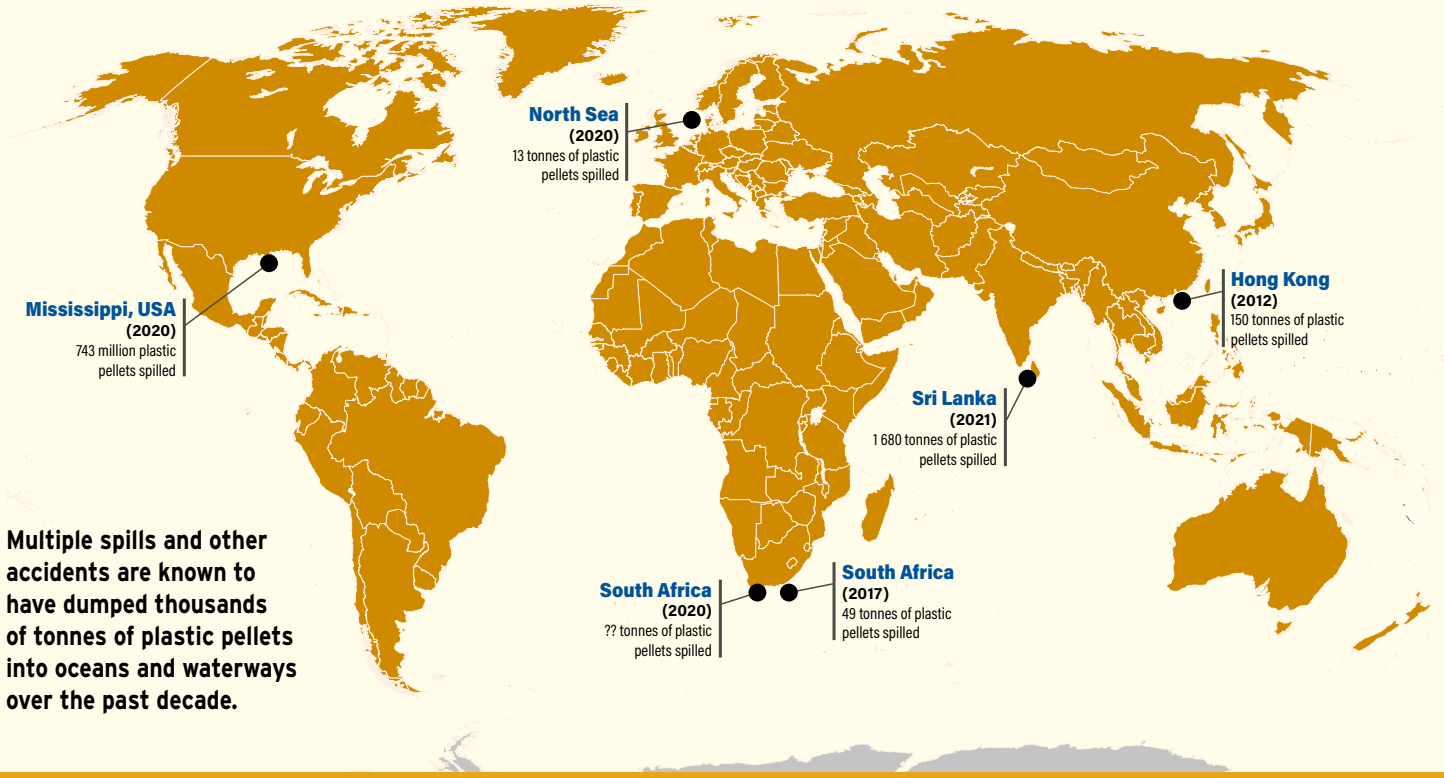
The carriage of chemicals in packaged form must comply with the provisions of the International Maritime Dangerous Goods (IMDG) Code, which is directly linked to the provisions of SOLAS chapter VII. Chapter 1.4 of the IMDG Code concerns security provisions and general provisions for companies, ships, and port facilities. In 1.4.1.4 it states that all port facility personnel "having specific duties, engaged in the transport of dangerous goods, should also include elements of security awareness related to those goods".

In MARPOL the prevention of pollution by packaged harmful substances is regulated in Annex III, where "harmful substances" are those that are identified as marine pollutants in the International Maritime Dangerous Goods (IMDG) Code. In the case of X-Press Pearl, it is important to note that MARPOL also states that every flag state (i.e., the country where the ship is registered) has the duty, according to article 12, to perform investigations on any maritime casualty of its ships, if it has caused a "major damaging effect upon the marine environment" [7].

MARPOL was originally created to prevent oil spills. For compensation following oil spills that have not been prevented there are two specific relevant conventions, namely a convention for civil liability (the CLC convention) and a convention on the establishment of an international fund for compensation for oil pollution damage (the 1971 Fund convention).

For hazardous and noxious substances (HNS) on the other hand, there is a protocol on preparedness, response, and co-operation to pollution incidents by hazardous and noxious substances (the OPRC-HNS Protocol 2000), which entered into force in 2007 [8]. There is also an international convention on liability and compensation for damage in connection with the carriage of hazardous and noxious substances by sea (the HNS Convention), which was adopted in 1996, superseded in 2010, but has not yet entered into force. The definition of HNS can differ depending on which of these contexts it is considered in. For the purposes of the 2000 OPRC-HNS protocol, HNS is defined as a substance, other than oil, that can create hazards for human health, harm living resources and marine life, damage amenities, or interfere with other legitimate uses of the sea [9]. For the purposes of the 2010 HNS convention, which is more designed for compensation, a HNS is a substance that is identified in one or more lists in the International Maritime Organization's conventions and codes [10]. Regardless of which definition is used, it is important to note that several of the substances carried on board X-Press Pearl would be included.

In addition to international conventions and regulations, there are also local regulations that apply to ships. In Sri Lanka, the Marine Pollution Prevention Act No. 35 2008 is the legal background to Sri Lanka's national jurisdiction for the enforcement of UNCLOS and MARPOL. This act also considers the precautionary principle [7]. It is administered by the Marine Pollution Prevention Authority. According to this act, the owner or the operator of a ship is liable for any pollution caused by the discharge, escape, or dumping of any oil or other pollutant into Sri Lankan waters [7].



Multiple spills and other accidents are known to have dumped thousands of tonnes of plastic pellets into oceans and waterways over the past decade.

SPILLS OF PLASTICS AND CHEMICALS AT SEA

Due to a wide range of preventive measures oil spills have decreased globally, but simultaneously the amount of hazardous and noxious substances (HNS) that are being transported at sea have increased, which can lead to spills that are more complicated from a mitigation perspective as well as from a risk assessment perspective. Several of the substances carried on board X-Press Pearl would be defined as HNS (See "Shipping Regulations" above).

HNS spills differ from oil spills in that whereas the oil is expected to float on the surface, other chemicals can sink, creating toxic, moving underwater plumes, or float on the subsurface. These differences mean that the spills require other types of mitigation and remediation strategies. It also complicates risk assessment, especially in cases such as X-Press Pearl where it is not fully elucidated what has leaked out.

Spills of plastic pellets at sea are also frequent, and plastic pellets have been found in the environment since the 1970s. In recent years these spills have received more attention, which has also led to increased discussions on accountability, still the local communities often end up paying most of the cost.

In 2012, 150 tonnes of plastic pellets were spilled outside of Hong Kong [11]. Volunteers spent three months cleaning up beaches, still big mounds of pellets were found along the beaches six years later [12].

In 2017, following a storm, 49 tonnes of plastic pellets were spilled from a container ship outside South Africa [13], and the partial clean-up of the spill (estimated to 10% of the total spill) was then paid for by the cargo owners, the Saudi Basic Industry Corp [14].

In 2019, following spills linked to a shipping facility in South Carolina, the organizations Charleston Waterkeeper and the Coastal Conservation League reached a $1 million USD settlement with Frontiers Logistics, that were the suspected source of nurdles found along Sullivan's Island [15].

In 2020, again in South Africa, another plastic pellet spill of unknown size was reported. It was confirmed by Plastics SA that the spill came from a vessel that lost its cargo [16]. In 2020, a big plastic pellet spill occurred in the Mississippi River (USA), estimated at 743 million nurdles. The ships operator CMA CGM group hired a small clean-up crew after the spill but six months after the spill pellets kept washing up on the beaches along the river [17]. In the North Sea, the same year, 13 tonnes of pellets were spilled from a ship operated by SeaTrans Ship Management due to a storm. Four months later 700 locations were reported to be affected by the spills and only one of the 13 spilled tonnes of plastics had been collected [12]. The insurance of the ship's owners covered some of the cost of the partial clean-up [12].

Unfortunately, most spills of plastics and chemicals tend to fly under the radar, especially if the spills occur further out at sea. Lydon calculated that between October 2020 and January 2021, 3,000 containers were lost in the Pacific [18], and according to the World Shipping Council the annual average is 1,382 containers [6]. In 2019, following another shipping accident where 280 containers were lost at sea, a draft proposal for a new IMO rule that would require better reporting of containers that are lost at sea was submitted by Vanautu [19]. In 2021, the Maritime Safety Committee of IMO agreed to include new output regarding containers lost at sea, noting the need for continued work during the two upcoming sessions [20]. Such a rule could address some of the issues related to lack in transparency during shipping [18].

A container ship leaving Colombo in June 2021.
Photo: Nilantha Ilangamuawa, Unsplash

SHIPPING IN SRI LANKA

Sri Lanka is a land of water. The country's exclusive economic zone is bigger than its land area and it has been a key connecting point for shipping since ancient times [21]. Since then, Sri Lanka has remained an important connecting spot. In 2018, it had the 15th highest liner shipping connectivity index in the world [22]. The port of Colombo is the only commercial deep-water port in South Asia, where every day roughly 300 ships pass through [23].

Today, approximately 90% of world trade goods are transported by shipping [3] and IMO has estimated that more than half of the packaged goods and bulk cargoes that are transported at sea can be regarded as harmful to the environment [24]. Shipping accounts for approximately 33% of all trade-related emissions from fossil fuel combustion, emissions that are continuously increasing [25].

Container fires exacerbate the pollution, cause severe environmental disasters, and risk the lives of crew members. Still, they are quite common. According to the Claudio Bozzi, Lecturer in Law at Deakin University [5], insurers are notified of fires every two weeks, and of major fires every 60 days. Historically, engine-fires have often been the cause of fires, but nowadays they are just as likely to start due to the cargo itself, often because it has not been properly declared or stowed, which can lead to leakage or other damage that can then lead to fires. Annually, over 150,000 cases of undeclared or misdeclared goods are estimated to be capable of causing fires.

In the case of X-Press Pearl it is thought that the fire was caused by a leaking container of nitric acid. The details are not published, but nitric acid is a strong oxidizing agent which can cause combustible materials, including paper, wood and oils, to ignite spontaneously. Leaking containers are common on-board ships. In fact, just a few months after the fire, another ship in Port Colombo also had a leak of nitric acid, which was discovered on its way to the harbor. In that case the disaster could be prevented as the captain notified the local agents of the leak, who notified the harbor master. To prevent further leaks and associated risks the nitric acid was moved into a new container [26].

X-Press Pearl

Flag: **Singapore**
Built: **2021**
Capacity: **2 756 TEU**[1]
Draught: **11.4 m**
Length: **186 m**
Beam: **34 m**

X-Press Pearl is owned by X-Press Feeders, one of the 20 largest container ship operators in the world. [3]

1 TEU - Twenty-foot equivalent units, a measure of how many 20-foot containers that fit.

Moreover, less than 2 months after X-Press Pearl caught fire, another container ship, MSC Messina, caught fire 480 miles outside Sri Lanka's coast [27]. And the year before X-Press Pearl caught fire, a fire erupted on board MT New Diamond, 38 nautical miles from the Sri Lankan shoreline. The fire was controlled, but approximately 1,700 million tonnes of fuel leaked into the ocean [28].

It is therefore clear that Sri Lanka's position as an important hub in international shipping puts the country at risk for future environmental disasters, wherefore it is crucial that the events surrounding X-Press Pearl are thoroughly investigated to prevent history repeating itself yet again.

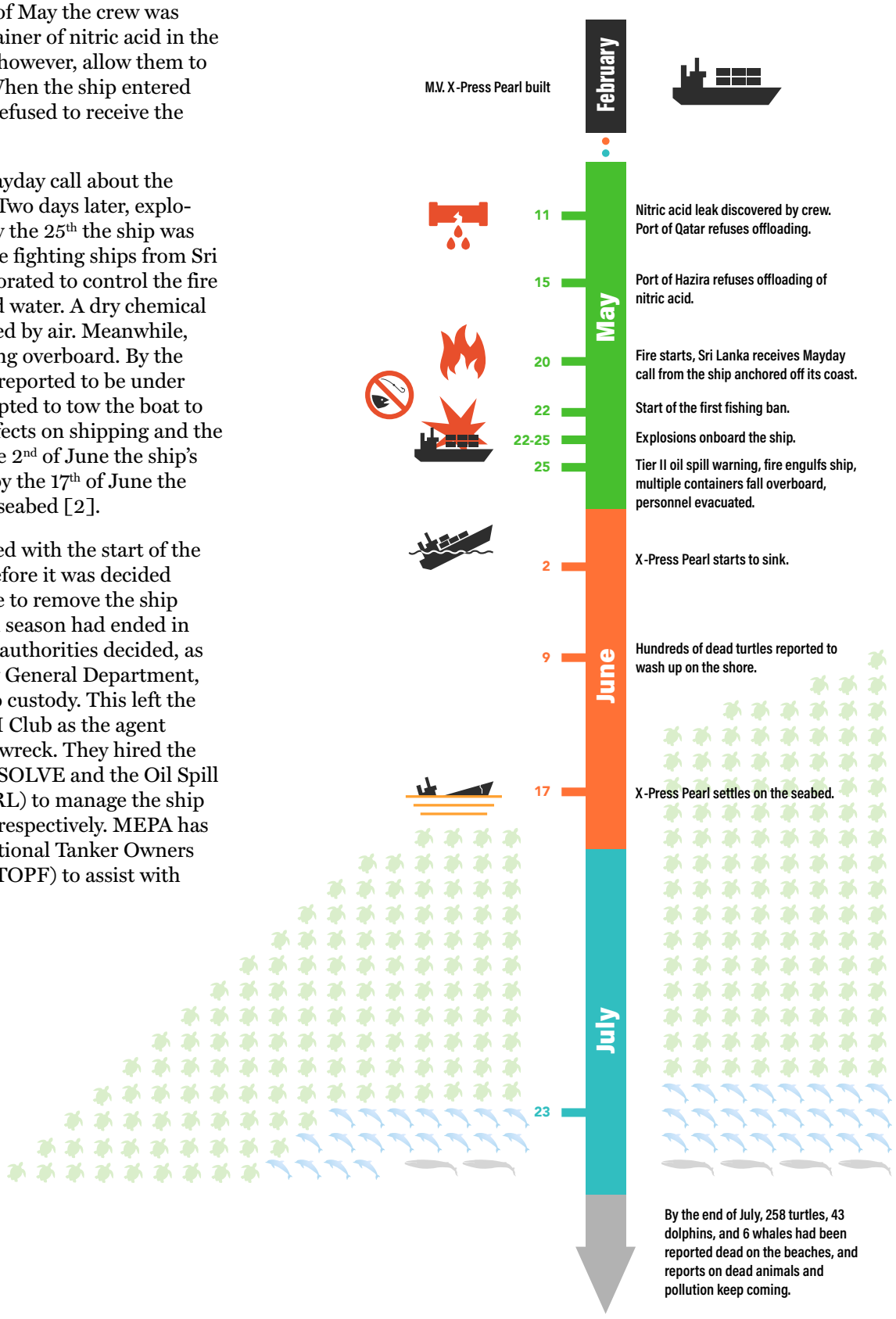
EVENTS LEADING UP TO THE FIRE

It has been reported that already in Port Hamad, Qatar, on the 11th of May the crew was aware of a leaking container of nitric acid in the hold. The port did not, however, allow them to offload the container. When the ship entered Hazira, the port again refused to receive the container [5].

Sri Lanka received a mayday call about the fire on the 20th of May. Two days later, explosions were heard and by the 25th the ship was engulfed by the fire. Fire fighting ships from Sri Lanka and India collaborated to control the fire through using foam and water. A dry chemical powder was also dropped by air. Meanwhile, containers kept on falling overboard. By the 31st of May the fire was reported to be under control, and they attempted to tow the boat to port to minimize the effects on shipping and the environment, but on the 2nd of June the ship's aft started to sink and by the 17th of June the ship was settled on the seabed [2].

The accident co-occurred with the start of the monsoon season, wherefore it was decided that it would not be safe to remove the ship until after the monsoon season had ended in September. Sri Lankan authorities decided, as advised by the Attorney General Department, to not take the ship into custody. This left the insurance company P&I Club as the agent responsible for the shipwreck. They hired the American company RESOLVE and the Oil Spill Response Limited (OSRL) to manage the ship and potential oil spills, respectively. MEPA has also invited the International Tanker Owners Pollution Federation (ITOPF) to assist with damage control [29].

Timeline of the events between the 11 May and 23 June 2021.



AFTER THE FIRE

A disaster of this magnitude and complexity is bound to have a lot of unknowns. It is still not known what or how much of the cargo has leaked out and the details of the cargo are not available. However, even if those details were known, the cargo included such a complex mixture of pollutants that it would still be hard to predict the risks. Nonetheless, this accident has had, and will continue to have, grave, long-lasting impacts.

AIR POLLUTION

The first wave of pollution consisted of the smoke plume originating from the burning ship and spreading over Sri Lanka. The smoke plume lasted for approximately 10 days [2]. The national Building Research Organization conducted measurements of the air pollution and identified an area of 120 km^2 as vulnerable to high exposure with an estimated 8,000-13,000 tonnes of air pollutants being released [30]. These pollutants may, considering the mix of hazardous materials on board, have contained a toxic mix of soot, particulate matter, nitrogen oxides, sulphur dioxide, carbon monoxide, a range of hydrocarbons, dioxins, heavy metals, and furans [2].

MARINE AND COASTAL POLLUTION

The second wave of pollution was the cargo that leaked out from the containers and was found along the beaches. On board the ship was a wide array of potentially harmful substances and although it is not known how much has leaked out from the ship, the following section goes through some of the potential consequences that the cargo could have.

Early observations paint a bleak picture. By the 23rd of July, 307 marine animals had been found dead along the coast of Sri Lanka, including 258 turtles, 43 dolphins, and six whales [31] and since then the reports of dead animals along the beaches keep on coming [29].

The dead turtles have in several cases been reported to have "burnt" or "bleached" carcasses [32], which can have been caused by corrosion from the chemicals [2]. Moreover, there have been unverified reports of dissolved nets, wherefore the potential occurrence of damage on boats cannot be disregarded [2]. Other sources have reported that concentrated sludge collected from the beaches have made the containers warm, which is indicating a chemical reaction in the sludge [29].

PLASTIC PELLETS

According to the UN environmental advisory mission the ship carried 1,680 tonnes of plastic pellets. With a weight of approximately 0.02 g per pellet [33] that equals roughly 84 billion pellets. It is not yet known what quantity of it has leaked out, but by all indications, this is the largest spill on record, ever.

Based on previous consequences from plastic spills it is reasonable to assume that the plastic pellets on board X-Press Pearl will have far-reaching consequences for a long time and initial modelling suggests that it would reach coastlines in the region reaching from Indonesia and Malaysia to Somalia [2].

By the fourth of August, 899 tonnes of waste had been collected [4], but to date waste such as plastic bags, pellets and macro plastics are still being collected. In some places, the plastic pellets have accumulated to reported levels of two meters and the geographic extent of the plastic spill has been reported to be the largest on record, and growing [2].

Despite massive clean-up efforts, it will not be possible to remove all the pellets from the environment and they are expected to have far-reaching consequences. However, it is not

Fumes from leaking nitric acid on board X-press Pearl.
Photo: Isuruhetti, Wikimedia Commons

only the physical impact of the plastic pellets that is worrying. With them they carry plastic additives as well as sorbed chemicals and metals.

To make matters worse, the pellets are in the same size as what a lot of marine animals and birds eat, and several marine species and birds are known to ingest plastics, including over 180 species of birds. For some this can lead to a false sense of satiation, or it can block their gastrointestinal tract, leading to starvation.

Following the accident documentations have been made of fish with plastic pellets lodged in their gills. Studies of the effects of plastic particles on fish have shown effects on several endpoints, including disruption of the endocrine system, and interference with the immune system, as well as blockage of gills and the gastrointestinal tract [34].

In the cargo manifest several different types of plastics are listed. Although the majority are polyethylene, the list also includes polystyrene, polypropylene, polybutadiene rubber, expandable polymeric beads, and polycarbonates. The form that these plastics were packaged in is not known but polyethylene pellets have been frequently reported on the beaches. Polystyrene is listed as pellets in the cargo list but both polystyrene and polycarbonate have a density higher than seawater so they would be presumed to sink and thus be more frequent in the sediment than on the beaches. Additionally, the ship carried several types of plastic resins, including epoxy which is discussed further below. Different plastic types have different properties, such as density, which means that the way that they would spread in the water would be different. They also vary in chemical composition which means that their inherent toxicity varies.

The potential effects of the plastics become even more complex if we include the many different chemicals that are used in them. A recent review showed that over 10,000 substances are used in plastics and of those 2,400 are substances of concern, of which 50% are not regulated at all [35]. Some chemicals used in plastics are also known to leach from the plastics and induce toxic effects [36]. One type of plastic additive is benzotriazole UV stabilizers (BUVs). This is a group of chemicals often used in plastic products that is found in plastics all over the world [37, 38]. BUVs have been shown to leach out from plastic pieces and accumulate in birds upon ingestion [39]. Several BUVs have been shown to have toxic effects on humans and animals. They can also act as endocrine disruptors and disrupt the hormonal balance [40].

Toxic additives are, however, general concerns with plastics because they lead to negative effects on human and environmental health throughout their life cycle. In the context of X-Press Pearl, it is, however, even more complicated, because once the pellets are in the water, several different chemicals can sorb (attach themselves) to the plastics. In fact, plastics are such good passive samplers that scientists that study environmental contaminants often use pieces of plastics to sample what type of pollutants there are in the water, meaning that, aside from the physical impact of the plastics, and the potential effects of the wide array of chemicals that are used to produce the plastics, the spilled plastics can also have adsorbed other chemical contaminants. This is of course extra concerning in the case of X-Press Pearl, since the ship carried many different chemicals and on top of that went through a fire where different fire suppression techniques were used, some of them making use of substances that also often contain toxic chemicals, such as PFAS.

Mirissa harbor May 30th. Photo: Sören Funk/Unsplash

These chemicals, along with toxic chemicals in the pellets themselves, can then leach into animals that feed on the pellets [38, 39], the beach sand [41, 42], and the surrounding water [43, 44]. As the pellets spread vertically in the beach sand and the water column, horizontally with currents, and as they are ingested by marine animals and birds, it therefore poses a substantial risk that they bring toxic chemicals with them.

Following the accident, plastic pellets and burnt plastic lumps are continuously making landfall. Adults and children are collecting and selling the pellets for LKR 60 per kg (approximately 0.3 USD). No one knows where the sold pellets are ending up, and no one knows what hazards the adults and children sit-

ting in the sand, collecting the pellets without any protective clothing, are exposed to [29].

FIREFIGHTING FOAM

Attempts to control the fire on board the ship included using foam, dry chemical powder, and water. The chemical content in the powder and the foam is not known, but it is worth noting that firefighting foams are often associated with adverse effects on human health and the environment. It is likely that the foams contained per- and polyfluoroalkyl substances (PFAS), which are built up of very stable molecules rendering them the nickname "forever chemicals". PFAS are often found in humans [45-47] and have been associated with several negative impacts on human health, such as impairments on thyroid hormone function [48] and foetal development [49].

BUNKER FUEL OIL

The X-Press Pearl carried 348 tonnes of bunker fuel oil [2] and already on the 25th of May a Tier II oil spill warning was issued [50]. Based on satellite imagery it was concluded that oil was continuously flowing out of the ship for nearly a month. The oil thickness was considered thick enough to, normally, trigger the deployment of an oil spill response [2].

It is unknown how much oil has leaked out at this point, but until the sunken ship and its content has been salvaged the concerns for a more extensive leak of oil and other pollutants remain. Since the fire started in the same season as the southwest monsoon, which typically occurs between May and September, this further complicates any mitigation efforts, such as oil spill containment. Additionally, the ship carried gear oil and lubricating oil that could also leak out.

In the aquatic environment PAH pollutants are mainly considered to be derived from fuel (petrogenic) or incomplete combustion (pyrogenic) [51]. Polyaromatic hydrocarbons (PAHs) are organic compounds with two or more condensed aromatic rings. They are ubiquitous in the environment and are known to sorb to plastic particles. After an accident such as that of X-Press Pearl, which combined both an oil spill, fire, and floating plastic particles to which the PAHs can adhere, PAH pollution is also a highly likely consequence.

NITRIC ACID

The fire started due to a leakage of nitric acid, and it is likely that most of the nitric acid on board was consumed in the fire. However, any nitric acid that may have leaked out into the water remains a cause of concern, especially together with the caustic soda, since their density is higher than that of seawater and the chemicals are therefore expected to sink. Mixed nitric acid and caustic soda would generate heat [24].


Photo: Rinson Chory/Unspash

SUMMARY OF X-PRESS PEARL CARGO MANIFEST

- 348 tons of bunker fuel
- 9,700 tons of epoxy resin
- 1,680 tons of plastic pellets [2]
- 81 containers carrying dangerous goods, including: 25 tons of nitric acid, 1,040 tons of caustic soda, and 210 tons of methanol

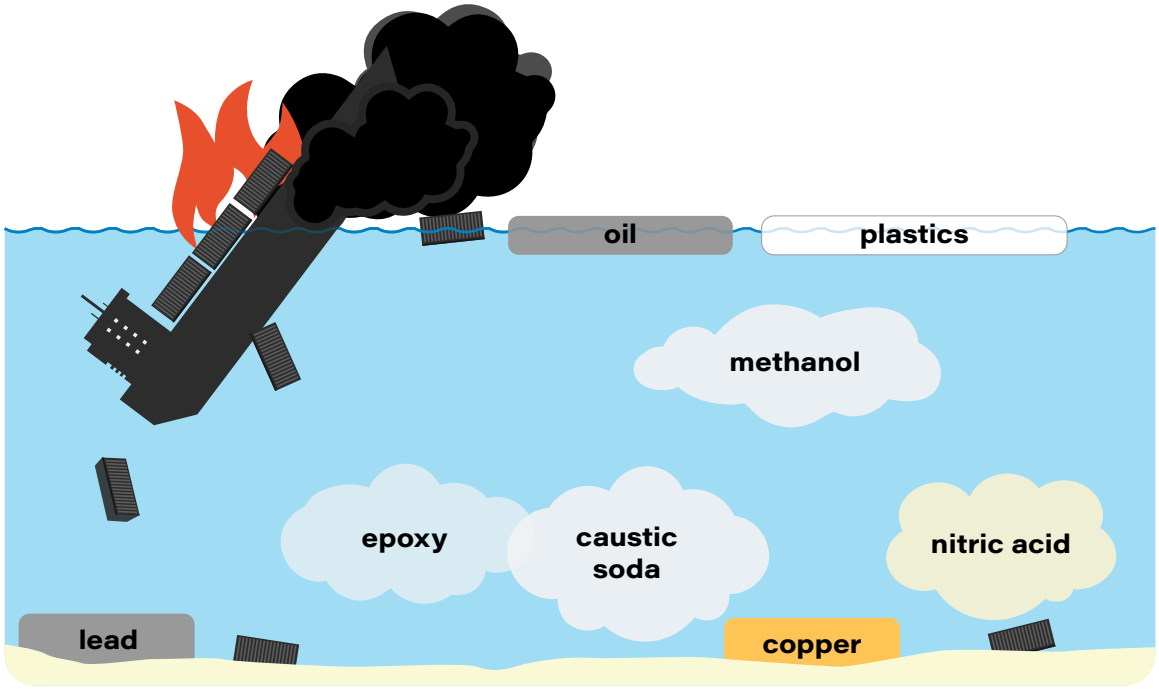
CAUSTIC SODA

On board were also 1,040 tonnes of caustic soda (sodium hydroxide). Caustic soda causes chemical burns and historical releases into rivers have led to mass deaths of fish and other aquatic organisms. Although caustic soda typically dissolves in sea water [52], the UN advisory mission group indicates that it remains possible that a highly corrosive, moving, plume of nitric acid and caustic soda has formed on the seabed [2].

Previous spills of caustic soda have had devastating impacts on river ecosystems. In 2006, 42,000 gallons (pprox.. 170 tonnes) of 50% caustic soda was spilled into a river in the USA. Following the spill, hundreds of thousands of dead fish were soon observed and subsequent analysis indicated a total kill of fish for 11 miles downstream and a 98% loss of aquatic invertebrates [53]. The year before, 41,000 liters of caustic soda was spilled into a Canadian river and it was estimated that 90% of the free-swimming fish in the river was killed following the spill (reported in [54]).

EPOXY RESIN

Almost one third of the cargo on board was epoxy resin. Epoxy resin is toxic to aquatic life. There is not enough information in the ship's manifest to assess the risks, but if it leaks out in liquid form, the epoxy resin can sink and create a moving plume on the seafloor [2]. It was however packaged in container types made for dry bulk. Epoxy resin is also a common cause of occupational contact dermatitis



Conceptual image of the possible pollution that may have leaked out from the ship during and after the fire and how it could distribute in the water column.

[55]. It is also important to note that most epoxy resins are made from bisphenols, such as bisphenol A which is a known endocrine disruptor. Bisphenol A can leach out from epoxy resins [56] and in aquatic environments it can cause developmental and reproductive effects on non-mammalian vertebrates. Moreover, it can affect immune function and metabolism [57]. It has also been associated with abnormalities, behavioral changes, and negative effects on the cardiovascular system, development, growth, and survival of aquatic organisms [58]. Exposure to BPA has also been linked to several adverse health effects in humans such as cancer, infertility, diabetes, and obesity [59, 60].

METHANOL

The 210 tonnes of methanol from the ship can, if spilled into the sea, float on the subsurface creating a toxic vapor cloud. This may adversely impact pelagic marine organisms [2]. Even if the concentrations do not reach lethal levels, tests on the marine fish *Florida pompano* show that methanol can have adverse effects on swimming behavior at sublethal concentrations [61].

METALS

On board were also several metals, including copper, lead, and aluminum, as well as lithium batteries. The ship also carried 474 tonnes of copper "stuff", further defined as scrap and slag [29]. Copper slag is a by-product of copper extraction that can be used as abrasives or fillers in materials [62]. Copper is toxic to a wide range of aquatic organisms [63]. It is however hard do elucidate the potential effects of the copper on board X-Press Pearl as it is unclear in what form it was and if it has been spilled, and therefore if it is bioavailable or not.

Lead

There were also 187 tonnes of lead on board the ship. Lead is a toxic metal that accumulates in teeth and bone tissue after exposure through ingestion, inhalation, or across the placenta. There are no known levels of exposure in children that can be considered safe, and the health effects are generally irreversible and can have life-long impacts [64].

Even low levels of childhood lead exposure can cause developmental impacts on the central nervous system and the brain, leading to lower IQ and neurological conditions, but lead can also affect the circulatory system, the kidneys, and the skeleton [65]. Lead is also categorized as an endocrine-disrupting chemical [40].

Lead exposure can also cause health impacts in adults, including increased risk of high blood pressure and kidney damage. Even low-level exposure in adults has been shown to be an important risk factor for cardiovascular disease mortality in the USA [66]. One key element in lead toxicity is its capacity to replace calcium in neurotransmitter systems, proteins, and bone structure. This alters function and structure, which leads to health impacts [67].

CLEANUP AND MITIGATION EFFORTS

According to the Marine Environment Protection Authority (MEPA) in Sri Lanka, cleaning operations have been carried

out together with volunteers, Sri Lankan Tri-Forces, and government officials. By the 25th of June they had cleaned up around 250 locations from Mannar to Kirinda [68].

During the initial clean-up phase 500-1,000 people per day were deployed. By the 14th of June 18,973 persons had participated in the clean-ups [2] and together they had removed massive amounts of litter from the beaches.

The most polluted beach was observed in the coastal zone of the Gampaha and Colombo districts, which could be explained by their proximity to the accident and a northward oceanic transport of the pollutants along the coastline. Less pollution was observed in the Puttalam and Kalutara districts [69].

The huge scale of the pollution was further highlighted by the results achieved by the "Blue machine", operated by a local inventor, Mr. Chinthaka Waragoda. His machine could separate six distinct kinds of contaminants from the beach sand, ranging from large burnt plastic pieces to fine foam. The machine used fresh water, which was mixed with sand excavated from the beach, to achieve gravity separation of different kinds of substances, from large plastic pieces to fine foam, from the sand. Despite the promising results from his approach the machine was only operated in one location (Sarakkuwa). MEPA asked him to stop this initiative, saying that more strategic methods would be necessary. They then employed women and people from the community, said to be trained to handle the cleaning. A previous report by CEJ however, has disclosed that the women employed did not know how much they would be paid and feared that they might not receive any payment at all for their clean-up efforts [29]. In addition, the Sri Lankan Red Cross trained and employed around 2,650 people in beach cleanup efforts under a "cash for work" program in the Gampaha, Puttalam, Kalutara, Galle, and Matara districts [69].

The use of protective equipment during cleaning has varied over time and has also differed between the different groups. In the beginning, people that were deployed to clean the beaches used protective suits and gloves, but later on this changed, and some of the people that are currently tasked with the clean-up do not even use gloves, even though there is yet no available data on the potential toxicity of the debris washing ashore from X-Press Pearl.

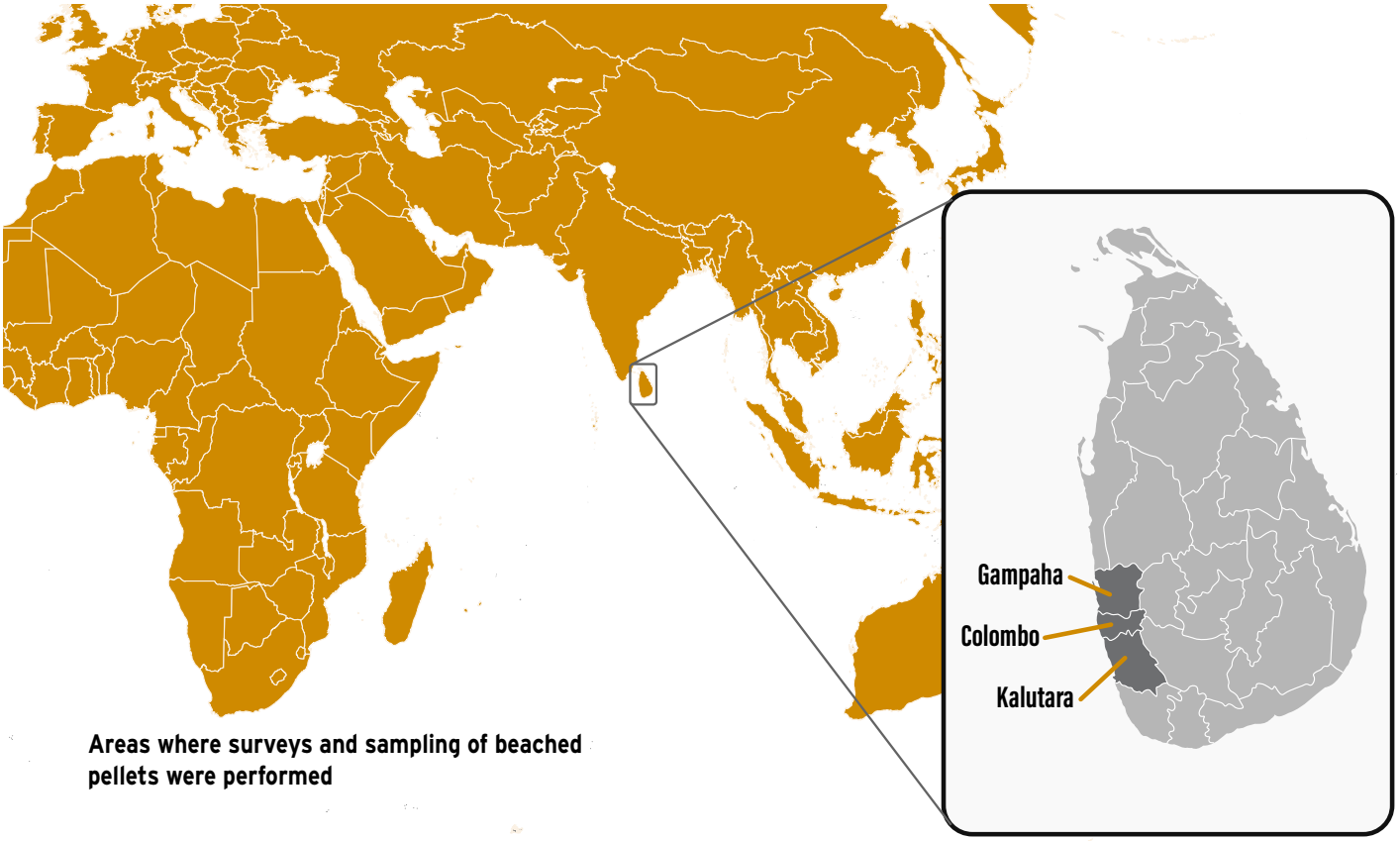
The UN advisory group suggested a scaled-up floatation approach [2] to separate the pellets from the sand. Currently trommels are used instead and only the upper layer of the sand is targeted [70]. It is likely that this method leaves pellets that are buried deeper into the sand behind, where they will continue to pollute the environment. Moreover, despite the massive clean-up efforts, the enormous scale of the spill will unfortunately likely mean that plastics will continue to wash up on the beaches for a long time ahead.

The blue machine operated by Mr. Chinthaka Waragoda that separates out six distinct types of contaminants. The last picture also shows the final cleaned-up sand, and sand with seashells that will go back to the beach. Photos: Panduka Rubesinghe, Harshani Abayawardhana

ANALYSIS AND SURVEYS

To better understand the impact that this accident has had, two different types of investigations were performed in the three regions closest to the shipwreck – Gampaha, Colombo, and Kalutara:

1. Plastic pellet samples and burnt lumps were collected from beaches and analyzed for heavy metals, polyaromatic hydrocarbons (PAHs), per- and polyfluoroalkyl substances (PFAS), benzotriazole UV stabilizers (BUVs), and bisphenols.
2. Surveys and interviews with people working in the affected areas were performed.



Areas where surveys and sampling of beached pellets were performed

Plastic pellets were still dispersed along the coast in September 2021, 5 months after the accident. Photo: Harshani Abayawardhana

Plastic pellets and burnt lumps dispersed on the beach at Sarakkuwa, Gampaha district, Sri Lanka.
Photo: Harshani Abhayawaradhana

SAMPLING AND ANALYSIS OF BEACHED PLASTICS

To better understand the potential toxicity of the plastics, CEJ sampled plastic pellets from four locations along the coastline for analysis of their heavy metal and toxic chemical content.

The samples, consisting of pellets and burnt lumps, were collected along the coastline from Negombo to Kalutara along the western province coastal zone (Appendix 1, Table 1).

ANALYTICAL METHOD

Metals

Heavy metals in beached pellets (six subsamples from four locations) and burnt lumps (eleven subsamples from 3 locations) were screened using Niton XL3t XRF Analyzer (in calibration mode "consumer products") at the Arnika office in Prague and using Niton XL5 Handheld XRF Analyzer (in calibration mode "plastics") in the Laboratory of X-ray Diffractometry and Spectrometry at the University of Chemistry and Technology Prague, Czech Republic.

Chemicals

Chemicals were analyzed in pellets from four locations and burnt lumps from three locations. Analyses of benzotriazole UV stabilizers (BUVs), per- and polyfluoroalkyl substances (PFAS), bisphenols, and polyaromatic hydrocarbons (PAHs) were performed at the Department of Food Analysis and Nutrition at the University of Chemistry and Technology Prague, Czech Republic.

BUVs and PAHs were extracted from the pellets using an ultrasonic extraction into a mixture of hexane:dichloromethane. BUVs were determined using ultra-high performance liquid chromatography coupled with tandem mass spectrometry (UHPLC-MS/MS). PAHs were analyzed using high performance liquid chromatography coupled with fluorescence detection (HPLC-FLD).

PFAS and bisphenols

The analysis of PFAS and bisphenols involved an ultrasonic extraction into a mixture of methanol: ethyl-acetate, followed by determination using UHPLC-MS/MS for bisphenols and PFAS. FTOHs were analyzed using gas chromatography coupled with tandem mass spectrometry operated in positive ion chemical ionization (GC-PICI-MS/MS).

RESULTS FROM THE BEACHED PLASTICS ANALYSES

Summary of the analytical results

The plastic pellets and burnt lumps collected were analyzed for several different toxic chemicals and metals. Overall, the results show that there are several contaminants of concern associated with the plastic debris from the accident, especially the burnt lumps.

Several metals, including copper, were present in the samples. In the burnt lumps, lead and cadmium were also detected. The beached plastics also contained bisphenol A, benzotriazole UV stabilizers, and polyaromatic hydrocarbons (PAHs).

For the benzotriazole UV stabilizers, four out of six analyzed BUVs were identified. UV-326 was found in all analyzed samples.

Bisphenol A was present in all burnt lumps. It was also present in one of the pellet samples, however at a lower concentration than in the burnt lumps. Its presence is likely linked to the 9,700 tonnes of epoxy resin that the ship carried.

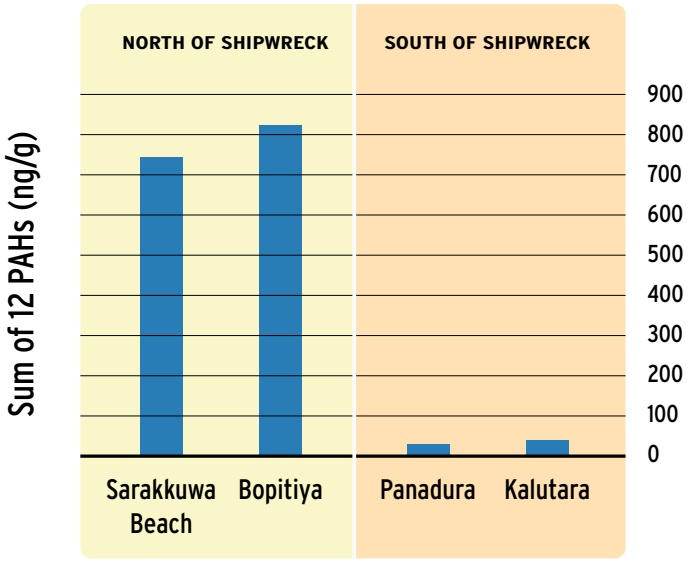
The total concentration of the twelve measured PAHs in the pellets was more than 20 times higher in samples collected north of the accident compared to the samples collected south of the accident.

The concentrations were however even higher in the burnt lumps (more than a hundred times higher than in the pellets), where the concentrations for several individual PAHs surpassed the limit values for consumer products established in the EU. The concentrations in the lumps were also higher than concentrations that have been associated with negative effects on several organisms in sediment and soil studies.

Pellets

On board the ship was several tons of metals such as copper, aluminum, and lead. In the marine environment, metals can sorb to natural particles, and to a lesser extent, to microplastics [71]. Research has also indicated that the co-occurrence of metals, such as copper, and microplastics can both decrease [72] and increase [73] the negative effects of the compounds for marine organisms. Chemical analysis of the samples showed that the plastic pellets and burnt lumps of plastics contained several different metals. Calcium, copper, iron, titanium, and zinc were all detected in all pellet samples. 83% of the analyzed samples also contained barium and 50% of them contained bromine. Mercury, manganese, antimony, tin, and strontium were detected in 17% of the samples (Table 1).

In comparison to previous studies of chemicals sorbed to microplastics, copper was found in a similar range here as in plastic samples from Guadeloupe [74].



Graph 1. Concentrations of PAHs on pellets from different locations.

All pellet samples contained UV-326 in concentrations ranging from 31-270 ng/g. BPA was found in one pellet sample (58 ng/g).

Of the analyzed chemicals, PAHs were the most frequent. Samples taken north of the accident location typically had higher concentrations than the samples from beaches located south of the accident location. For the PAHs this means that north of the accident the concentrations were more than 20 times higher than south of the accident (Graph 1). This matches previous reports of higher levels of visible pollutants to the north of the accident, which has been linked to the predominant direction of the currents after the accident [69].

For the PAHs, Benzo[a]anthracene and Benzo(k)fluoranthene were found in three out of four samples, and the remaining ten PAHs were found in all samples. The concentrations for most of the measured PAHs on the pellets are comparable to other studies of PAHs on microplastics [75, 76]. One difference that is interesting to note is the higher occurrence of the cancerogenic PAH benzo[a]pyrene. In this study it was present in all four samples at concentrations ranging from 0.1-57 ng/g. In Gorman *et al.* [76] it was found in 2/12 microplastic samples and in Lozoya *et al.* [75] the concentrations found were all below 5 ng/g.

Burnt lumps

The burnt lumps consisted of melted pollutants, including plastic pellets, and tell a story of a complex pollution pattern.

The burnt lumps had higher concentrations and higher detection frequencies of metals than the pellet samples. Eleven

TABLE 1 ANALYTICAL RESULTS FOR METALS AND OTHER ELEMENTS IN THE BEACHED PLASTIC PELLETS.

	Min (ng/g)	Max (ng/g)	Average (ng/g)	Detection frequency (%), n=6
Barium (Ba)	<LOD	164	88	83
Bromine (Br)	<LOD	7	2	50
Calcium (Ca)	119	824	318	100
Cadmium (Cd)	<LOD	<LOD	<LOD	0
Clorine (Cl)	251	3993	1278	100
Cobalt (Co)	<LOD	<LOD	<LOD	0
Cromium (Cr)	<LOD	<LOD	<LOD	0
Copper (Cu)	8	20	14	100
Iron (Fe)	120	597	243	100
Mercury (Hg)	<LOD	2	0	17
Manganese (Mn)	<LOD	36	6	17
Nickel (Ni)	<LOD	<LOD	<LOD	0
Lead (Pb)	<LOD	<LOD	<LOD	0
Antimony (Sb)	<LOD	12	2	17
Selenium (Se)	<LOD	<LOD	<LOD	0
Tin (Sn)	<LOD	14	2	17
Strontium (Sr)	<LOD	6	1	17
Titanium (Ti)	<LOD	87	31	100
Vanadium (V)	<LOD	<LOD	<LOD	0
Zinc (Zn)	7	62	26	100

TABLE 2. ANALYTICAL RESULTS FOR METALS AND OTHER ELEMENTS IN THE BURNT LUMPS

	Min (ng/g)	Max (ng/g)	Average (ng/g)	Detection frequency (%), n=11
Barium (Ba)	<LOD	1235	353	91
Bromine (Br)	<LOD	30	11	91
Calcium (Ca)	94	4625	1799	100
Cadmium (Cd)	<LOD	10	2	27
Clorine (Cl)	337	7460	2459	100
Cobalt (Co)	<LOD	163	35	45
Cromium (Cr)	<LOD	48	8	36
Copper (Cu)	<LOD	68	23	18
Iron (Fe)	1200	13765	4790	100
Mercury (Hg)	<LOD	<LOD	<LOD	0
Manganese (Mn)	<LOD	163	38	55
Nickel (Ni)	<LOD	14	1	9
Lead (Pb)	<LOD	7	2	45
Antimony (Sb)	<LOD	18	2	9
Selenium (Se)	<LOD	16	2	36
Tin (Sn)	<LOD	11	2	18
Strontium (Sr)	<LOD	20	8	82
Titanium (Ti)	229	5127	1931	100
Vanadium (V)	<LOD	64	10	27
Zinc (Zn)	34	5960	1558	100

Burnt lumps with pellets as found on the sampled beaches.

subsamples of the lumps were analyzed and in addition to the metals detected in the pellets, the burnt lumps also contained cadmium (27%), cobolt (45%), chromium (36%), nickel (9%), lead (45%), selenium (36%), and vanadium (27%). Notably, the detection frequencies for mercury (0%), copper (18%), and antimony (9%) were lower in the burnt lumps than in the pellets (Table 2).

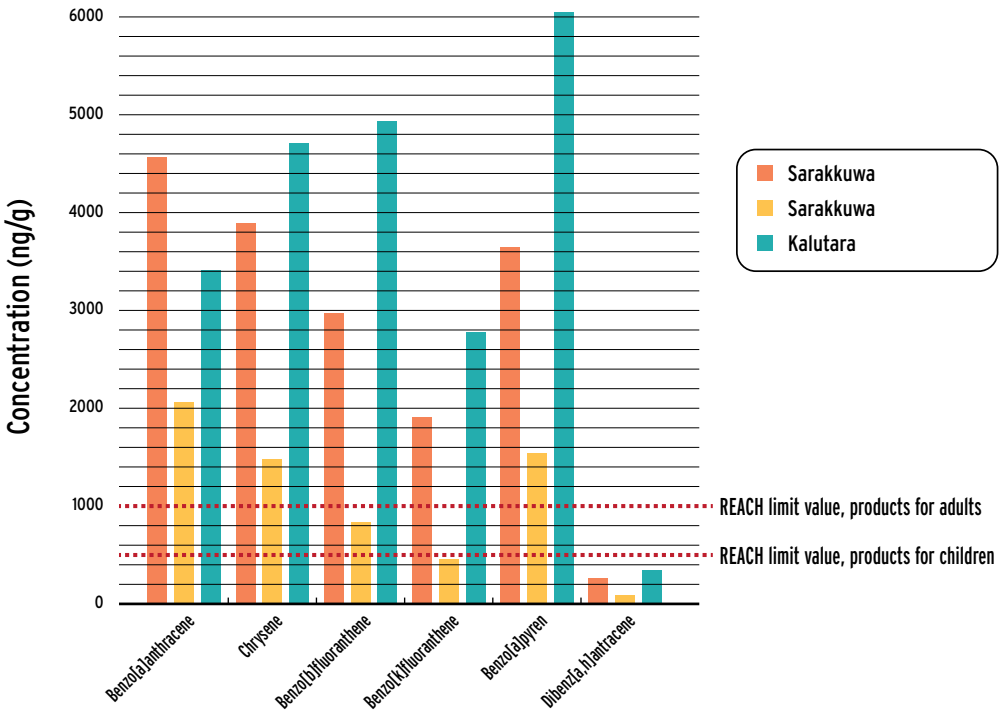
The copper, lead, cadmium, and chromium were all within a similar concentration range as previously found in plastic samples from Guadeloupe [74].

Chemicals were measured in three samples of burnt lumps and all contained bisphenol A in concentrations between 36.2-504 ng/g. The absence of BPA in all but one pellet sample, combined with the overall higher concentrations found in the burnt lumps, indicates that it was not used in the pellets as an additive. The most likely explanation of the prevalence of BPA in the burnt lumps is that it originated from the epoxy resin that was carried on board the ship. This indicates that the epoxy has leaked out into the environment and can now be found on the beaches and likely also in the water.

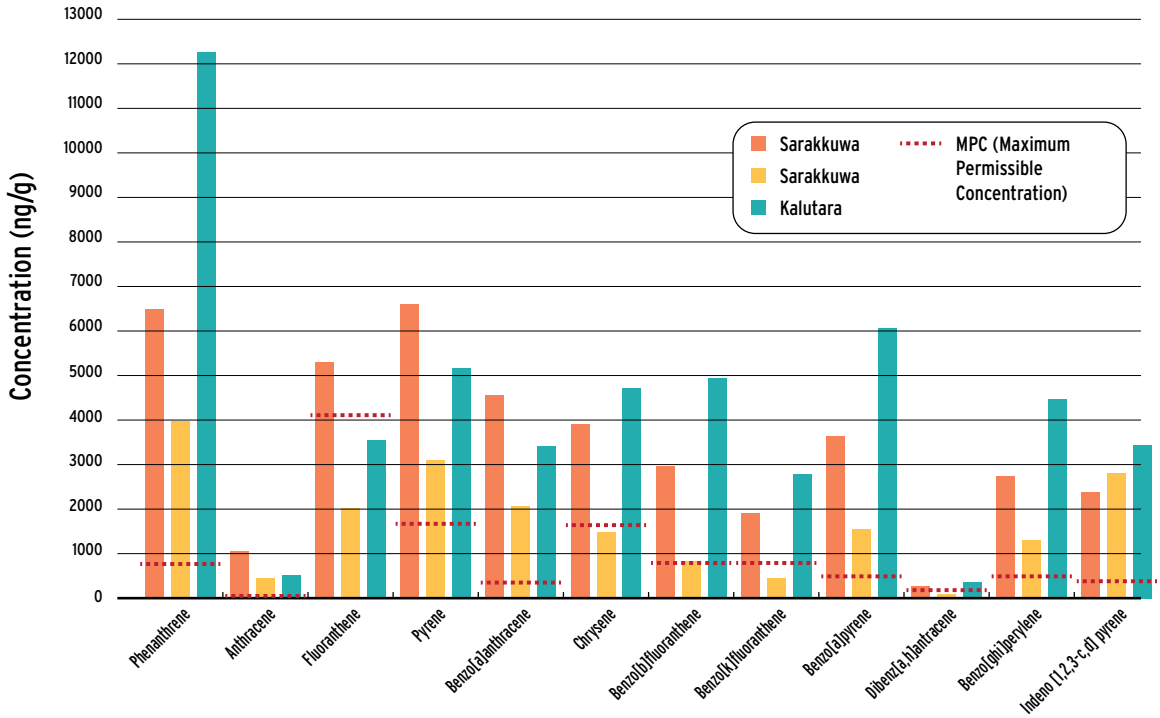
Four different benzotriazole UV stabilizers were found in the burnt lumps. Three of them (UV-328, UV-329, and UV-234) were however only found in concentrations below 10 ng/g. UV-326 was found in all three samples in concentrations ranging between 69 – 26 665 ng/g.

All twelve analyzed PAHs were present in all three samples of burnt lumps. The total concentrations of PAHs were approximately 100 times higher in the burnt lumps than in the pellets. The average concentrations for the individual PAHs were however up to 200 times higher in the burnt lumps than in the pellets.

For consumers products, the EU has set limit values for six of the PAHs measured here [84]. For the individual PAHs these are set at 1000 ng/g for adults and 500 ng/g for products directed towards children. The measured concentrations in this study exceeded these values for five out of six PAHs (Graph 2).



Graph 2. Concentrations of PAHs in the burnt lumps compared to REACH limit values in consumer products for children and adults.



Graph 3. Concentrations of individual PAHs in the burnt lumps compared to maximum permissible concentrations (MPC) for sediments as identified by Verbruggen *et al.* (2012).

In fact, here the concentrations were so high that they were up to six times higher than the REACH limit values for individual PAHs in products for adults and twelve times higher than the limit values for products for children, meaning that any direct or repeated contact with these lumps should be avoided, especially since seven of the PAHs found in these samples are listed as possibly carcinogenic or carcinogenic to humans according to lists maintained by the International Agency for Research on Cancer [77].

There is limited knowledge on the toxicity of PAHs associated with plastics in the environment. Some comparisons could however be made with toxicity studies on PAH concentrations in sediment and soil. In the Netherlands, they have established maximum permissible concentrations for individual PAHs in sediment [78]. Maximum permissible concentrations (MPCs) are used as limit values under which negative effects are not expected for 95% of the species in the sediment ecosystem. When the values measured in the lumps are compared to the maximum permissible concentrations for sediment, 12/12 PAHs are above the MPC in one of the samples from Sarakkuwa, and 8/12 in the other sample. In the sample from Kalutara, 11 out of 12 PAHs were found at concentrations above the maximum permissible concentrations for sediment (Graph 3).

For some of the PAHs the measured concentrations were in the same size range as the serious risk concentrations. Serious risk concentrations (SRCs) correspond to concentrations where negative effects are expected amongst 50% of the species. Phenanthrene was found at a maximum concentration of 12 254 ng/g and the SRC is at 63 000 ng/g. Anthracene was found at a maximum concentration of 1052 ng/g and the SRC value for sediment is 3000 ng/g. Benzo[ghi] perylene was found at concentrations up to 4463 ng/g and the SRC is 10 000 ng/g.

Several of the measured concentrations also surpass concentrations that, in studies on spiked sediment, has negatively affected several organisms (summarized in [78]). For example, for pyrene and phenanthrene the observed effects include decreases in chlorophyll a levels and cell density for microalgae [79]. Similarly, benzo[a]pyrene surpassed the no-effect concentrations in soil for some crustaceans [78]. Moreover, fluoranthene concentrations were in 2/3 samples higher than concentrations that have been associated with an increased mortality for some amphipods in sediment [80].

Even if the numbers measured in the pellets and burnt lumps in this study are not directly comparable to toxicity studies in sediment or limit values in consumers products, these high concentrations are still very concerning.

Overall, the results show that the samples analyzed here contain a wide range of pollutants, mirroring the complexity of the cargo on board X-Press Pearl. It is therefore important to maintain a precautionary perspective when handling any debris from the ship.

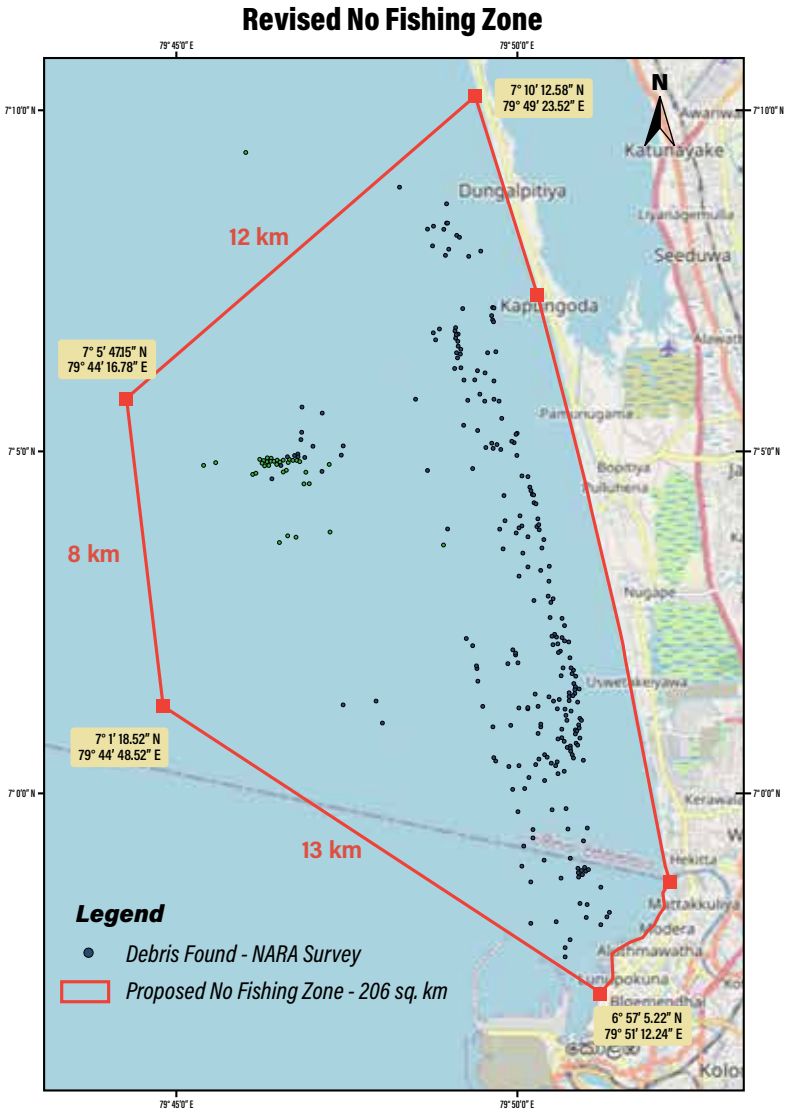
IMPACT ON LOCAL COMMUNITIES

"We were out fishing at sea, when we saw yellowish fumes coming from a ship anchored in the outer harbor. We knew that is unusual. We saw it for 2-3 days. After that, when we came back to shore, we found out from the media that the ship had caught fire. We became very worried because it was in a critical zone for our fishing where there are coral reefs. We were not informed, but we were afraid to go fishing there. Then suddenly they imposed a fishing ban."

—Fisherman from Negombo, Gampaha district.

Fishing is the backbone of Sri Lanka. The contribution to Sri Lanka's GDP is 1.3% (the Fisheries Department, 2020) and approximately 583,000 persons are employed in the fishing industry, with a supporting workforce of 2.7 million (Azmy *et al.* 2021). Additionally, 60% of all animal protein consumed in Sri Lanka is fish, which is the main source of protein among low-income groups (Azmy *et al.* 2021).

On the 22nd of May, 2021, the first fishing bans were issued. The extension of the fishing ban area has varied, but at one point more than 175 square miles were closed to all fishing activities (The Maritime Executive 4/8 2021). It is unclear exactly how long the fishing ban lasted and in what area. According to reports, the no fishing zone was restricted to a smaller area on the 1st of June and after that it was only banned between the Pandura river and Ma Oya and up to 16 km off the coast (Warawita, 2021).



No fishing zone revised and in place from 1st December, 2021.
Source: Ministry of Fisheries, Sri Lanka

In conversations with fishermen during October of 2021, it was evident that they thought the ban was no longer in place and that they had therefore resumed fishing in the area. In international news outlets people talked about a fishing ban existing, but on the official web pages of Sri Lankan authorities (such as MEPA, or the Ministry of Fisheries) there was no information about any such ban. However, later in December, the previously marked fishing ban area was revised, and a new ban was introduced, and the following map was obtained from the Ministry of Fisheries.

The impact of the X-Press Pearl incident on the marine environment in Sri Lanka is evident and obvious, but its impact on the lives of everyone in the coastal communities and the livelihood of the fishing community is yet to be identified. Within the fishing community, there are different kinds of livelihoods all being affected, including:

- Boat rentals
- Owners of beach seines (a type of large-scale fishing net operated from the beach)
- People sorting fish from nets
- Multi-day boat operators
- One-day boat operators
- Traditional Theppam (raft) fishing gear operators
- Lagoon fishermen
- Fish sellers – small scale
- Fish sellers – stocks / large scale
- Tour guides – Snorkelers / Divers
- Ornamental fish sellers

CEJ took several measures to assess the impact of the X-Press Pearl ship accident on the coastal com-

munity, with a special focus on fishermen. These included focus group discussions, interviews with fishermen/ fisherwomen and a survey with 107 representatives of the coastal community in Gampaha, Colombo, and Kalutara within the Western province.

A convenience sampling method was used since the timing of this event overlapped with a heavy spread of the COVID-19 pandemic, when strict travel and gathering restrictions were imposed. The interviews with the participants were conducted by persons residing in each district. Some initial results from the interviews can be found in a recently published CEJ report [81]. Below, a more detailed analysis of the different districts is presented, since the pellet sampling revealed large local differences in pollution levels.

COLOMBO

Twenty individuals were interviewed from the Colombo district. The majority of the respondents (65%) were depending on fishing. The other categories of employment were (each person could indicate more than one occupation): producing beach seines or other types of nets (35%), productions related to fishing boats (35%), mobile vending at the beach (15%), government jobs (5%), hotel jobs (15%) and work in the informal sector (5%) (Graph 4).

The respondents were also asked whether any struggles that they had experienced related to their income were due to the COVID-19 pandemic, or the accident. It became clear that both incidents have impacted their income, but in different ways. For people engaged in activities related to fishing this was especially evident. Whereas the pandemic affected the access to the market, the accident led to a decrease in access to the fishing areas and a decreased interest in buying and consuming fish overall. Before the accident 30% of the respondents reported a monthly income above 26,000 LKR. After the accident only 10% of the respondents reported a monthly income above 26,000 LKR. One of the respondents went from earning over 201,000 to earning between 86,000-120,000 LKR (Graph 7).

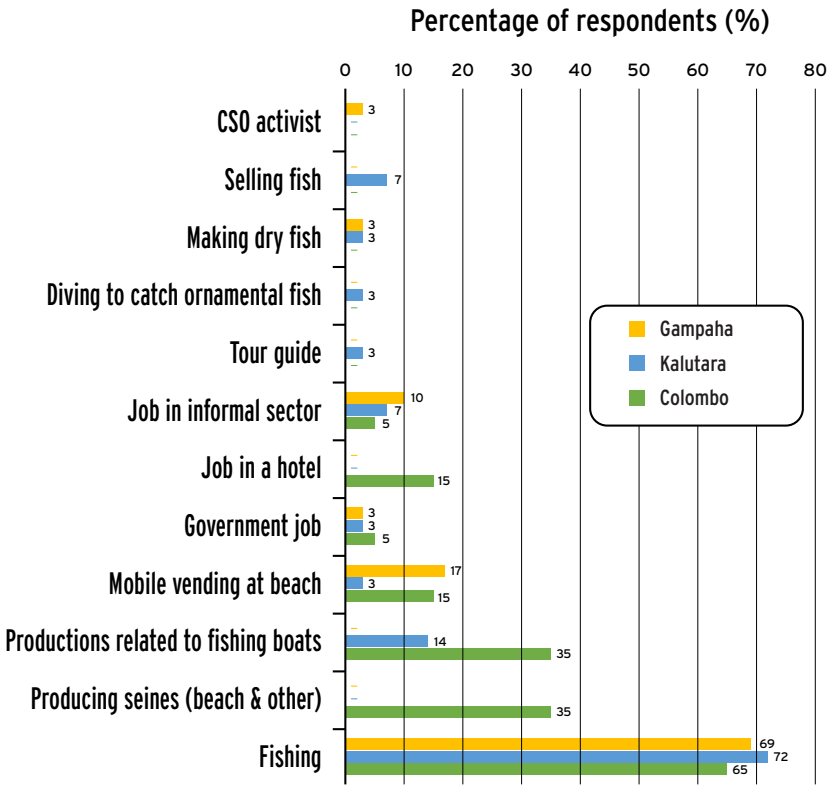
Reported impacts included a complete loss of income, difficulty to sell products, loss of daily income for some time, destruction of equipment, and a reduction in consumers / tourists, such as people rejecting to buy fish due to fear of chemicals in them (Graph 5). Only one person, who works in a hotel, indicated that his income had not been affected by the accident.

Additionally, some of the respondents indicated that they had experienced symptoms of chemical poisoning such as skin irritation and allergies. Some also reported that they suffered from depression due to the impact that the accident had on their income.

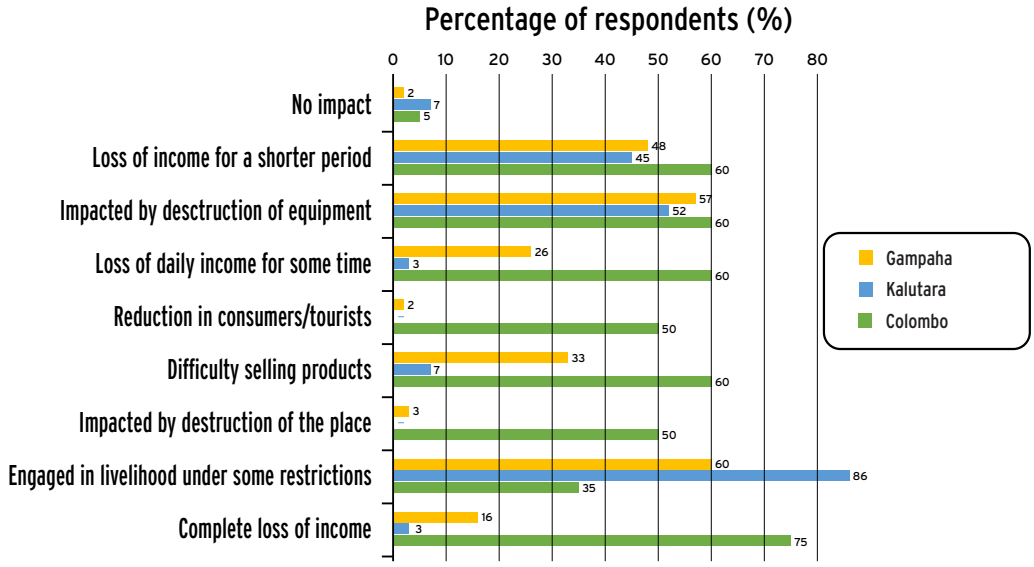
"We only got to know about the sinking ship through television. We don't know what was in there or what will happen in the future. After the accident we saw a lot of dead turtles and dolphins floating by the beach. We also saw those plastic-like beads on the shore. But we don't know anything about any chemicals."

— Rohitha, owner of a beach seine (Sinhala: Maa dala), Wadduwa beach, Colombo

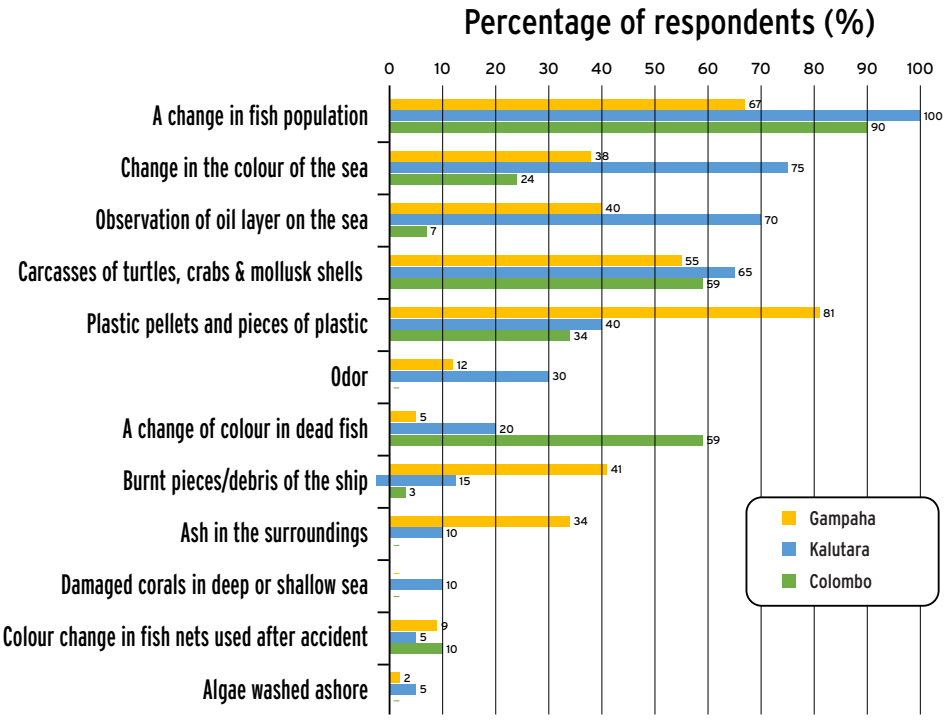
Regarding observed changes in the environment, the respondents in Colombo reported four main observations: a change in fish population, a change in the color of the sea (becoming blackish), observations of a layer of oil on the surface of the sea and on the carcasses of turtles, fish, crabs, and mollusc shells (Graph 6). Additionally, a few said that they had also observed plastic pellets and pieces of plastic, unusual odors, a change of color in dead fish, burnt pieces/debris from the ship, ash in the surrounding area, and damaged corals in deep or shallow sea. One respondent also reported a change of color in fish nets used after the accident.



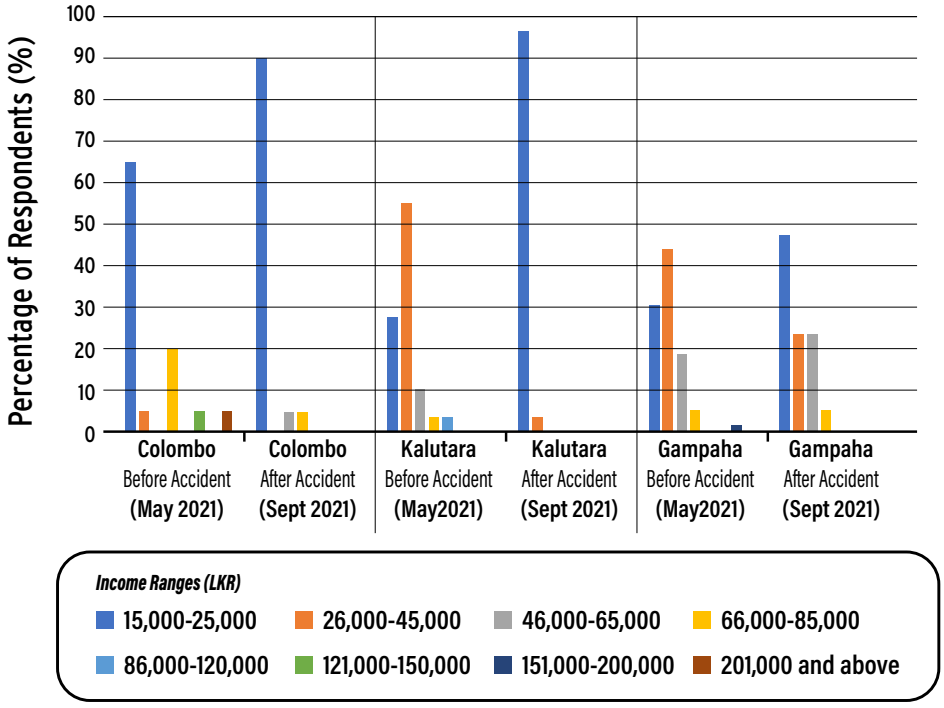
Graph 4. Percentage of respondents engaged in each job category in three districts.



Graph 5. Types of impacts on income levels and livelihood.



Graph 6. Environmental impacts as reported by the respondents.



Graph 7. Ranges in income in LKR before May and in September.

KALUTARA

A total of twenty-nine persons, including three women, participated in the survey from the Kalutara district. The majority were involved in activities related to fishing; 72% were fishermen (Graph 4), 15% were involved in production activities related to fishing boats, 7% were selling fish, 3% diving to catch ornamental fish, and 3% were occupied in making dry fish. Others reported occupations in the informal sector (7%), working with mobile vending of items such as clothes, toys, food, etc., at the beach (3%), having government employment (3), or working as tour guides (3%).

In the Kalutara district, the changes in income before and after the accident were quite clear. Before the accident, 28% of the respondents were in the lower-income range of LKR 15,000-25,000. After the accident, however, a total of 97% of the respondents were in that same income range. Since the majority of the respondents were fishermen, this clearly reflects the drop in fishing industry activities in the area (Graph 7).

> *"Fishermen usually do not depend on anyone. They can usually sustain themselves very well through their work. 30-35 years ago they even lived quite prosperously, but then came first the tsunami which dragged them down to some extent, then with the coastal erosion their difficulties increased, and then this ship sank and fish worth 7,000 to 8,000 rupies could not even be sold for 100 rupies. Even if it was given away for free, no one would eat it, because of the rumors saying that it was contaminated with chemicals and people might end up dead."*
>
> *— K.A. Karunarathne, Fisherman, Kalutara North*

On the topic of the different types of economic impacts, the majority said that they had faced a complete loss of income, could only engage in their livelihood under some restrictions, or were impacted by a destruction of their work location (One such example was given by a person whose work was drying fish on the beach. After the accident, the drying location had been totally ruined due to the plastic pellets and other debris that had washed ashore, and could therefore no longer be used) (Graph 6). Some of the respondents also said that they faced difficulties in selling their products, experienced a reduction in consumers /tourists and a loss of daily income for some time, as well as being impacted by equipment being destroyed.

> *"People say that even today (October 2021), there are no fish that could be caught with a fishing line here. We used to fish in the area around 3 km from the beach and the harvest was good. We used to use floating nets to fish there, but after this incident the harvest became very scarce and nowadays people have given up on floating nets, which usually catch torpedo scad fish, frigate tuna, yellowfin tuna, small Seer fish, etc. There is almost no harvest now, not even 2 kg of squid. My neighbor also said that there wasn't even a Pony fish in the net that usually catches fish like Silver-bar fish, Indian herring, etc."*
>
> *— K.A. Karunarathne, Fisherman, Kalutara North*

In this district one person indicated that they had experienced health effects consisting of difficulty breathing and having headaches.

For the environmental observations in the Kalutara district a majority mentioned a change in the fish population, seeing

Photo: CEJ, Sri Lanka

carcasses of turtles, fish, crabs and mollusc shells, a change of color in dead fish, and plastic pellets and pieces of plastic being washed ashore (Graph 6). A few also reported that they had observed a change in the color of the sea, as well as observations of a layer of oil on the surface of the sea and on the burnt pieces and debris from the ship. At Kalutara, three persons also reported fishing nets having changed color after the accident.

> *"No one told us about the possibility of fishing gear being damaged. We experienced it ourselves. We only observed that after fishing. When we took the nets off, we observed some whitened fibers in them, but nothing worked when trying to remove them. We could not use those nets anymore and some fishermen even burnt them. Officers only came to observe, no one offered us any compensation."*
>
> *— K.A. Karunarathne, Fisherman, Kalutara North*

GAMPAHA

The Gampaha district was represented by 58 respondents, including 26 women and 32 men, living in and around Negombo. As in Kalutara and Colombo, the majority of the respondents were working in jobs related to fishing and fisheries. 69% worked with fishing and 3% made dry fish. The others worked with mobile vending at the beach (17%), had jobs in the informal sector (10%), or worked with civil society organizations (3%).

"This accident has affected around 7,000 families engaged in fishing. They lost their livelihoods. Not only fishermen, but also those attached to the fishing sector such as people making dry fish, and people selling fish, were affected."

— Reverend Sarath Iddamalgoda, Negombo, Gampaha

A change in the income levels towards low-income ranges were observed in the Gampaha district as well (Graph 7). The story in Gampaha was however quite unique, as there are many strata of income generation. When a boat sails out to go fishing, there are many that depend on it. Apart from the owner of the boat, the income from a catch is also divided among the boat crew, people who sort the fish from the nets, vendors of fish stocks, and retail vendors, which mostly includes women. The income share for each of these groups would of course vary. In addition, this industry is connected to several other businesses, such as making dry fish, like Jadi, the Sri Lankan style dry fish, making and mending nets, etc., that provide employment to the coastal community.

In Gampaha, the respondents emphasized that although there was already a local impact from COVID-19, people could still go fishing, and the industry survived even after going through people's fear of eating fish due to a spread of COVID-19 in a local fish market. The impact following the X-Press Pearl accident, on the other hand, prevented them from fishing altogether, created a huge vacuum in the fish consumption, and thereby also in the sales. Even the fishermen were afraid of consuming fish as no authority or research were providing clear recommendations as to whether the fish was safe to eat.

"When this accident happened, there were dead fish on the shore and when we opened their mouths we saw tiny balls of plastics, like pearls, inside their mouths. They did some research on it, but we were never informed whether the fish was safe to eat or not. So, as we don't know, people are afraid to eat it."

— Merina Roshanthi Fernando , Kuda paduwa, Negombo, Gampaha

According to the interviews given by the community in Negombo, before the accident a boat trip would sometimes earn them around LKR 50,000 to 300,000 per week, while a small-scale fisherman could earn LKR 7,000 to 10,500 per week, depending on the catch.

Some of them completely lost this income when they were unable to go fishing after the accident, especially the operators of small-fishing gear that operate within 8 km from land. Some also highlighted that the debris, such as shipping containers scattered on the seabed, could even damage their fishing nets. Moreover, some of the respondents explained that the fish catch dropped very clearly after the accident.

"There were around 14 big fishing nets that were lost due to the accident, which means a loss of some hundred thousands of rupies."

— Merina Roshanthi Fernando, Kuda paduwa, Negombo, Gampaha

In Gampaha, the majority of the respondents were impacted through a restriction on their livelihood (60%), destruction of equipment (57%), and loss of income for a shorter period of time (48%) (Graph 7). Several respondents also reported that they experienced difficulties selling their products (33%), loss of their daily income for some time (26%), and some even reported a complete loss of income (16%). Only a few mentioned being impacted by destruction of the location where they worked (2%) or a reduction in the number of consumers/tourists (2%).

Relating to health symptoms, one of the respondents mentioned skin irritation and allergic reactions.

In Gampaha, the respondents highlighted the damage on the environment made by the plastic pellets, the effects on fish population, observations of carcasses of turtles, fish, crabs and molluscs, burnt pieces and debris of the ship washing up on the beach, observations of a layer of oil on the sea surface, a change in color of the sea, and ash landing in the surroundings and on the beach (Graph 6). A few respondents mentioned noticing an odor, and a change of color in dead fish. Five respondents reported damage to the fishing nets consisting of a change of color in fish nets used after the accident.

LACK OF INFORMATION

Several of the respondents highlighted a lack of information regarding fishing bans, a need for protective equipment during beach clean-ups, a lack of information on the safety of eating marine catch, and a risk of damage to fishing nets and other property.

Regarding the awareness about the potentially hazardous nature of the debris that drifted ashore, the responses show that the respondents were unaware of it. Most of them had participated in beach clean-ups without any personal protective equipment, PPE, (67%), because they thought PPEs were not necessary (15%), they didn't know if they were necessary (15%), or because PPEs were not provided to them (62%). Some of them avoided going to the beach at the time of the accident (17%) and refrained from touching things that had washed ashore from the accident (94%), while others collected those items (6%) and went to the beach specifically to watch the accident (63%), thereby potentially exposing themselves to toxic fumes and compounds being transported by water and air.

Traditional small-scale artisanal fisheries such as Theppam (raft-fishing) were the most affected by the fishing ban, as they were not able to travel outside the fishing-ban zone.

LEGAL AFTERMATH

It is not yet fully elucidated who bears the responsibility for the accident on board the X-Press Pearl and the following events. Sri Lanka has submitted claims and launched investigations, but the outcome of these is still not known. However, from initial reports it seems that there were many culprits along the way and that the accident could and should have been avoided. Who bears the responsibility for which part is important to assess, not only for issues related to compensation for the local communities, but also to prevent future accidents. There are currently several ongoing legal cases concerning the accident, both on a national and an international level.

Furthermore, following the accident Sri Lanka called on the International Maritime Organization (IMO) to classify plastic pellets as hazardous substances, in consideration of the impact caused by the spills in Sri Lanka [82]. During the IMO's Marine Environment Protection Committee (MEPC) 77th meeting the proposal was subsequently referred to the Sub-committee on Pollution Prevention and Response (PPR) [83].

ONGOING CEJ WORK

Under the case no. CA/WRT/383/21, CEJ has filed a lawsuit with a plea towards the authorities involved in the mitigation responses. In the case they are, among other things, requesting the authorities to:

- Conduct an independent and impartial investigation into the fire to ascertain the cause and parties responsible.
- Assess the environmental damage caused by the accident
- Assess the damage caused to the fisheries industry, fishing communities and the tourism industry
- Assess the health impacts
- Income loss compensations for people involved in the fishing and tourism industries.

Furthermore, the case pleads the Honorary Attorney general to take necessary actions to obtain compensation in terms of the provisions of the Marine Pollution Prevention Act No. 35 of 2008 or any other applicable laws, and to dispose of the plastic pellets/nurdles and other debris of X-Press Pearl, which are collected and stored in containers, in an environmentally friendly manner. Within the case they further plead the respondents to formulate a national policy and/or contingency plan to augment marine safety.

CEJ has also filed the case SC FR 168/21, representing the fishing communities. In this case they evoke the fundamental rights of the communities and the right to equal protection by the law for all citizens and future generations, as stated in the Sri Lankan constitution Furthermore, they request the responsible authorities to conduct an independent and impartial investigation and to assess the damage caused to the fishing industry, the fishing community and the tourism industry. They also ask that the affected communities be compensated for the damages suffered. The case further requests the respondents to make a preliminary and a final report on the damage and health impacts caused by the X-Press Pearl incident and also that they formulate a National Policy and/or Contingency Plan to augment maritime safety.

STEPS FORWARD

Although we wish that this story would end here, the reality is that the environmental disaster along the coast of Sri Lanka will continue unfolding for a long time to come. Many question marks remain on what kind of consequences this will bring, both in the medium and long term. From the events as described here, there are however a set of lessons that ought to be learnt and several immediate steps that need to be taken to mitigate the damage, support the local community, and prevent future similar disasters.

The accident in Sri Lanka is extraordinary in its size and impact, but it is not an isolated event. With increasing shipping across the world, coastal communities, already exposed to effects from climate change and the transboundary marine circulation of waste and chemicals, are extremely vulnerable and there is an unforgivable lack of accountability for companies that transport hazardous waste at sea.

The events leading up to and following the accident include several key moments when the disaster could have been minimized or prevented if the people involved would have assumed their responsibility.

Notably, in the case of X-Press Pearl, the leak was known nine days prior to the fire, and two ports have been reported to deny the ship offloading the leaking containers. This inaction and passive stance shown by several of the involved parties will, if left unresolved, continue to cause catastrophes putting the lives of crews, coastal communities, and marine ecosystems at risk.

These issues also need to be addressed on an international level. With more and more shipping taking place by sea, over 1,000 shipping containers being lost at sea every year and ship fires being reported every second week, the current system is not fit to prevent accidents and environmental pollution on this scale.

Several of the accidents that have occurred during the last few years have been linked to poor cargo lashing, which has also been suspected in the case of X-Press Pearl. This means that current conventions need to be better enforced, SOLAS needs to be updated to match today's large container ships and there is an urgent need for more transparency so that when accidents happen, risk assessments and suitable mitigation measures are possible to roll out quickly.

The plastic spills following X-Press Pearl are the largest ever recorded, to date. Plastic pollution spills at sea are however common and historically they have been seen as inert/harmless. With the research that has emerged during the last decades, showing that plastic pollution causes a wide range of negative effects on the environment, it is important that regulations for shipping at sea reflect this improved understanding.

Historically, a lot of shipping regulations have been directed towards the prevention and mitigation of oil spills. Considering that today's container ships are transporting more and more complex mixtures of chemicals and plastics it is crucial that the convention for the new time reflects these challenges and is enforced in a way that actively prevent spills of toxic chemicals, plastics, and oil, to avoid the ecological disasters that these mixtures can cause on coastal and marine ecosystems.

Photo: Jalitha Hweage/Unsplash

RECOMMENDATIONS

LOCAL COMMUNITY

Take a precautionary approach to any debris on the beach potentially originating from the ship. Avoid touching it without gloves until potential risks can be ruled out.

REGULATORY BODIES IN COASTAL COMMUNITIES/ NATIONS

The frequency with which containers are lost overboard and with which fires are reported on container ships indicates that these types of accidents can easily happen again. Coastal countries, especially those that are close to major shipping lanes or serve as crucial shipping hubs, such as Sri Lanka, need to ensure that they are sufficiently prepared in the case of a spill of hazardous and noxious substances. Some aspects to consider in preparing for the future is:

- Ensure that proper information dissemination and clear communication channels are established.
- Develop both preventive and mitigation strategies to respond to future spills/accidents within your exclusive economic zone and ensure that each port has designated persons with adequate knowledge on hazardous and noxious substances.
- Develop strategies on fishing zone bans, when to start, what parameters to measure to decide the extent in time and space, and what are suitable communication channels for them.
- Ratify the hazardous and noxious spills convention (HNS convention).
- Determine how to best support the affected local communities as soon as possible.

INTERNATIONAL AGREEMENTS

Considering that shipping is in its nature connected to transboundary movements of goods, it is however crucial that the international community works together to prevent and mitigate risks related to shipping accidents. To do so, it is important that:

- Safety of life at seas (the SOLAS Convention) is adequately adapted to today's large container ships.
- There is a clear responsibility for harbors involved in handling dangerous goods to help prevent accidents and that there are designated persons with adequate knowledge on hazardous and noxious substances in the harbor.
- A compensation program for spills of plastics and chemicals is put into place and that the HNS convention is ratified.
- Setup strategies for monitoring of pollutants after spills of plastics and chemicals spills, to make it possible to provide early advise on suitable restrictions for different activities such as fishing.
- A system for reporting lost containers and their content is adopted to facilitate mitigation and prevention strategies.
- Plastic pellets are classified as hazardous substances.
- Sri Lanka receives support in investigating the consequences of the accident, as well as the issues related to responsibility and accountability.
- Sri Lanka receives support in mitigating the effects of the accident on human health and the environment.

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APPENDIX 1. DESCRIPTION OF SAMPLING LOCATIONS

TABLE 1. DESCRIPTION OF BEACH SAMPLING LOCATIONS

Coordinates	Brief description of beach location (mainly in relation to the pollution source)	Other comments
7° 6′41.61″N 79°50′32.46″E	Sarakkuwa, the sampling location is considered the most affected by plastic pellets, which was evident when observed. It's a sandy beach and along the tide line and towards the land the pellet contamination was immense. Pellets could be observed in an excavated pit to a depth of around 1.5- 2 meters.	Along the beach towards the south there is a rocky reef where a large number of shells of dead small mussels were found, along with some dead crabs.
6°42′38.00″N 79°54′6.00″E	In Panadura, the presence of pellets even on a day with rough sea and frequent swash, was obvious. Most often, they were found among other debris on the shore. The location is originally a beach park maintained by the municipal council of Panadura, but due to the pandemic there were no people, except for a few coming to jog or catching sand fleas (mole crabs or sand crabs). The beach seemed relatively polluted with plastics, slippers, fishing nets, and other general waste that comes with the swash motion of the waves. There was also an abandoned vessel, partly scrapped, on the beach.	There was a warning sign indicating, "Danger: strong currents" at the location. Even so, pellets were abundant at the site as they often are washed ashore with the swashing of the waves.
6°36′24.00″N 79°56′55.00″E	At Kalutara North, the pellets were abundant among the debris. On the day of sampling, a dead turtle was found washed ashore. At a glance, the amount of plastic debris seemed comparatively low, but it wasn't hard to find a discarded tungsten bulb and some mobile phone batteries, among other household waste.	Except for very few coming to take a walk or bathe their dog, the beach area looked empty. There were however a number of hotels and lodges by the coastline.
	At Kalutara North, this piece of burnt plastic was found among the debris. We also found a discarded phone battery among the debris.	
7° 3′55.00″N 79°51′8.00″E	Bopitiya, a sandy beach with a rock reef almost inundated in waves. Pellets were abundant at one side of the beach. Two dead turtles were observed. One seemed to have died a long time before. People seemed quite indifferent towards the dead turtles, yet their opinion was that these turtles had died because they had fed on algae on the ship. Two fishing vessels were observed in the near shore area. The beach seemed to carry a lot of debris, both plastic and plant debris. Among it, plastic pellets as well as small pieces of burnt plastics were identified. We also observed a log with burnt plastic pellets.	We observed three women collecting firewood on the beach. We could observe algae on the inundated rock reef. Also, there were rock crabs in a rock wall built at some portions of the beach.

APPENDIX 2. ANALYTICAL RESULTS

TABLE 1 CONCENTRATION OF ANALYZED METALS (NG/G)

Location	Sample type	Ba	Balance	Br	Ca	Cd	Cl	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Se	Sn	Sr	Ti	V	Zn
Sarakkuwa	Pellets	97	999229	<LOD	128	<LOD	251	<LOD	<LOD	15	124	<LOD	36	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	40	<LOD	62
		75	999007	<LOD	221	<LOD	526	<LOD	<LOD	8	120	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	14	<LOD	14
		94	998562	2	388	<LOD	576	<LOD	<LOD	15	272	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	41	<LOD	29
	Burnt lump	1222	979474	16	4625	<LOD	337	<LOD	48	<LOD	5004	<LOD	<LOD	<LOD	<LOD	<LOD	16	<LOD	15	3243	<LOD	5960
		1235	980182	22	1933	<LOD	3509	35	<LOD	20	5689	<LOD	<LOD	<LOD	6	<LOD	4	11	20	2427	<LOD	4848
		<LOD	991937	3	1003	7	400	<LOD	<LOD	12	5362	<LOD	54	<LOD	2	<LOD	2	<LOD	5	411	<LOD	787
		158	992985	1	1632	<LOD	1070	<LOD	<LOD	20	3192	<LOD	32	<LOD	4	<LOD	<LOD	<LOD	<LOD	229	<LOD	650
		106	994423	<LOD	1112	10	1152	<LOD	19	26	1809	<LOD	<LOD	<LOD	<LOD	18	<LOD	<LOD	3	1166	<LOD	114
		506	982439	30	2922	<LOD	2588	110	12	<LOD	7298	<LOD	95	14	<LOD	<LOD	<LOD	<LOD	19	2427	18	1462
		160	992936	7	1233	<LOD	803	58	<LOD	22	3278	<LOD	30	<LOD	2	<LOD	<LOD	<LOD	11	824	<LOD	585
Panadura	Pellets	99	998533	<LOD	119	<LOD	992	<LOD	<LOD	20	208	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	6	<LOD	11
		164	994216	7	824	<LOD	3993	<LOD	<LOD	19	597	2	<LOD	<LOD	<LOD	12	<LOD	14	6	87	<LOD	32
Kalutara	Burnt lump	104	981542	4	3266	<LOD	7141	<LOD	<LOD	68	1200	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	5127	<LOD	1511
Bopitiya	Burnt lump	<LOD	998213	1	228	<LOD	1327	<LOD	<LOD	8	137	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	7
	Pellets	190	981323	14	94	<LOD	1388	163	<LOD	54	13765	<LOD	163	<LOD	<LOD	<LOD	<LOD	<LOD	4	2428	64	263
		63	995008	3	776	7	1206	<LOD	<LOD	10	1850	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3	1008	<LOD	34
		140	983893	20	1192	<LOD	7460	22	8	19	4246	<LOD	47	<LOD	7	<LOD	2	9	8	1951	31	926

APPENDIX 2 TABLE 2 CONCENTRATION OF ANALYZED CHEMICALS (NG/G)

	Location	Sarakkuwa			Panadura	Kalutara		Bopitiya
	Sample type	Pellets	Burnt lump		Pellets	Pellets	Burnt lump	Pellets
PFBA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFPeA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFHxA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFHpA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFOA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFNA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFDA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFUnDA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFDoDA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFTrDA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFTeDA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFHxDA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFODA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFPrS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFBS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFPeS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFHxS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05

	Location	Sarakkuwa			Panadura	Kalutara		Bopitiya
	Sample type	Pellets	Burnt lump		Pellets	Pellets	Burnt lump	Pellets
PFHpS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
br-PFOS	ng/g	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
L-PFOS	ng/g	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04	<0,04
PFNS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFDS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFUnDS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFDoS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFTrDS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
PFOSA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
N-MeFOSA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
N-EtFOSA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
HFPO-DA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
NaDONA	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
9Cl-PF3ONS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
11Cl-PF3OUdS	ng/g	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
FBET	ng/g	<0,80	<0,80	<0,80	<0,80	<0,80	<0,80	<0,80
FHET	ng/g	<1,60	<1,60	<1,60	<1,60	<1,60	<1,60	<1,60
FOET	ng/g	<1,60	<1,60	<1,60	<1,60	<1,60	<1,60	<1,60
FDET	ng/g	<16,0	<16,0	<16,0	<16,0	<16,0	<16,0	<16,0
4:2 FTS	ng/g	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
6:2 FTS	ng/g	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
8:2 FTS	ng/g	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
10:2 FTS	ng/g	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10
6:2 PAP	ng/g	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0
8:2 PAP	ng/g	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0
6:2 diPAP	ng/g	<0,50	1.1	<0,50	<0,50	<0,50	<0,50	<0,50
6:2 8:2 diPAP	ng/g	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50
8:2 diPAP	ng/g	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50
PFBPA	ng/g	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0
PFHxPA	ng/g	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0
PFOPA	ng/g	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0
PFDPA	ng/g	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50
UV-234	ng/g	<0,25	1.8	<0,25	<0,25	<0,25	<0,25	<0,25
UV-326	ng/g	149.1	571.9	68.6	69.0	31.1	26664.6	270.0
UV-327	ng/g	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50	<0,50
UV-328	ng/g	<0,50	<0,50	2.0	<0,50	<0,50	<0,50	<0,50
UV-329	ng/g	<0,25	<0,25	6.9	<0,25	<0,25	<0,25	<0,25
UV-P	ng/g	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0
BPA	ng/g	<1,25	36.2	176.8	<1,25	<1,25	503.6	57.8
BPB	ng/g	<1,25	<1,25	<1,25	<1,25	<1,25	<1,25	<1,25
BPF	ng/g	<1,25	<1,25	<1,25	<1,25	<1,25	<1,25	<1,25
BPS	ng/g	<1,25	<1,25	<1,25	<1,25	<1,25	7.3	<1,25
PHE (phenantrene)	ng/g	122.2	6478.8	3979.4	5.0	17.8	12254.0	315.9

	Location	Sarakkuwa			Panadura	Kalutara		Bopitiya
	Sample type	Pellets	Burnt lump		Pellets	Pellets	Burnt lump	Pellets
AN (anthracene)	ng/g	7.0	1052.1	450.6	0.4	1.1	514.7	13.2
FLT (fluoranthene)	ng/g	152.3	5293.4	2027.3	6.4	7.6	3548.1	89.2
PY (pyrene)	ng/g	166.6	6595.9	3098.5	1.1	5.7	5155.6	106.2
B[a]A (benzo[a]anthracene)	ng/g	72.3	4561.8	2063.9	<0,10	2.8	3408.0	53.5
CHR (chrysene)	ng/g	42.9	3893.3	1475.3	0.1	1.3	4703.7	44.3
B[b]FA (benzo(b)fluorantene)	ng/g	26.4	2969.8	830.3	1.5	0.3	4932.0	25.9
B[k]FA (benzo(k)fluorantene)	ng/g	18.7	1907.6	450.4	1.0	<0,05	2775.1	20.6
B[a]P (benzo(a)pyren)	ng/g	57.0	3643.8	1534.8	0.9	0.1	6049.2	50.1
DB[ah]A (dibenz(ah)antracene)	ng/g	1.8	263.0	91.8	2.8	1.1	345.5	2.7
B[ghi]P (benzo(ghi)perylene)	ng/g	36.9	2731.2	1288.1	1.1	0.6	4462.5	46.7
IP (Indeno [1, 2, 3-c, d] pyrene)	ng/g	40.2	2382.6	2800.8	0.3	0.4	3438.5	54.0

APPENDIX 3. DATA FROM SURVEYS

TABLE 1 EMPLOYMENT TYPES AMONGST RESPONDENTS

Employment type	Colombo	Kalutara	Gampaha
Fishing	13	21	40
Producing beach seines or other types of seines	7	0	0
Productions related to fishing boats	7	4	0
Mobile vending at beach	3	1	10
Government job	1	1	2
Job in a hotel	3	0	
Job in informal sector	1	2	6
Tour guide	0	1	
diving to catch ornamental fish	0	1	
Making dry fish	0	1	2
Selling fish	0	2	
CSO Activist			2

TABLE 2 CHANGES IN RANGE OF INCOME

	Colombo- Before Accident (May 2021)	Colombo- After the Accident (September 2021)	Kalutara- Before Accident (May 2021)	Kalutara- After the Accident (September 2021)	Gampaha- Before Accident (May 2021)	Gampaha- After the Accident (September 2021)
15,000 - 25,000	13	18	8	28	18	28
26,000 - 45,000	1		16	1	26	14
46,000 - 65,000	0	1	3		11	14
66,000 - 85,000	4	1	1		3	3
86,000 - 120,000	0		1			
121,000 - 150,000	1					
151,000 - 200,000	0				1	
201,000 and above	1					

TABLE 3 IMPACTS TO LIVELIHOOD

	Colombo	Kalutara	Gampaha
Complete loss of income	15	1	9
Loss of income for a shorter period	7	25	35
Loss of daily income for sometime	10	0	2
Undergo the livelihood under some restrictions	12	2	19
Impacted by destruction of equipments	10	0	1
Impacted by destruction of the place	12	1	15
Difficulty to sell products	12	15	33
Reduction in consumers/ tourist	12	13	28
No impact	1	2	1

TABLE 4 ENVIRONMENTAL IMPACTS REPORTED BY RESPONDENTS

	Colombo	Kalutara	Gampaha
A change in fish population	18	29	39
Change in colour of the sea	15	7	22
Observation of oil layer on the sea	14	2	23
Carcasses of turtles, fish, crabs and mollusk shells	13	17	32
Plastic pellets and pieces of plastic	8	10	47
Odor	6		7
A change of colour in dead fish	4	17	3
Burnt pieces/ debris of the ship	3	1	24
Ash in the surrounding and on the beach	2		20
Damaged corals in deep or shallow sea	2		
A change of colour in fish nets used after the accident	1	3	5
Algae washed ashore	1		1

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