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ABSTRACT
Feeder vessels are the necessary part of the transport system that mother vessels can't reach. In contrast, the frequent transmittable feeder vessels can affect the environment drastically and shift the factors of environmental catastrophe entirely. This shift can be stopped with reasonable restrictions in light of MARPOL and other regulations. Through data-driven strategy and state legislation, laws regarding the movement of the feeder vessels and other factors can be controlled and bought to a minimum. Proper strategy execution is also a major part of making an efficient route system and reducing the Hydrometeorological environmental catastrophe.

Keywords: Disaster, Environmental Catastrophe, Feeder Vessel, Hydrometeorological, Route, Strategy.

Introduction

80% of the volume of international trade in goods is carried by sea, and the percentage is even higher for most developing countries (*Review of Maritime Transport*, n.d.). Along with the rapid increment of shipping via sea, the environment is also affected. The environmental effects of shipping include air pollution, water pollution, acoustic, and oil pollution. Ships are responsible for more than 18% of some air pollutants. As for greenhouse gas emissions, the International Maritime Organization (IMO) estimates that carbon dioxide emissions from shipping were equal to 2.2% of the global human-made emissions in 2012 and expects them to rise 50 to 250% by 2050 if no action is taken (*Environmental Effects of Shipping*, n.d.). That has led to a rapid increase in environmental catastrophe. Ocean passages go through various routes for fuel efficiency, safety and trade advantages. For centuries, these routes got changed and modified for better communication. As ships before the establishment of the Suez Canal, they had to go around South Africa's cape town to move Between continental Europe and Asia. On the other hand, before the establishment of the Panama Canal, ships had to go around South America or to the Arctic Sea to move from one coast cost to another in the USA. After establishing new canals and with the rapid advancement of ships, these routes have become shorter or spat, or traffic went low. Therefore, they introduced the feeder vessels, which help the port move tankers from the mother vessels to shore, and in many cases, it has shown great economic benefits. Generally, the Feeder vessel is normally smaller than the Mother vessel. Feeder vessels serve in between smaller ports and major ports. In other words, feeder vessels feed cargo to the mother vessel from smaller ports to large ports for exports and major main ports to smaller ports for imports (*Difference between Mother Vessel and Feeder Vessel*, 2022).

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However, these various routes have come up with a new issue where they are increasing the average global temperature, and also, they are making the ocean's water more polluted with its spilt garbage and oil. Earth's temperature has risen by 0.14 °F (0.08°C) per decade since 1880, and the rate of warming over the past 40 years is more than twice that: 0.32 °F (0.18°C) per decade since 1981. 2020 was the second-warmest year based on NOAA's temperature data, and land areas were recorded warmly (Dahlman & LuAnn, 2022). This one can potentially bring the Tsunami and many more environmental catastrophes that might not be thought able and in upcoming sections, the whole issues and factors will be discussed.

As the trade and environmental catastrophes have increased, it has led to the formation of international law for making the sea environment clean and clear to avoid accidental ecological disasters. The world knows this convention as MARPOL- International Convention for the Prevention of Pollution from Ships. In brief, MARPOL has six annexes dealing with the Prevention of Pollution by Oil, Pollution by Noxious Liquid Substances in Bulk, Pollution by Harmful Substances Carried by Sea in Packaged Form, Pollution by Sewage from Ships, Pollution by Garbage from Ships, Air Pollution from Ships (International Convention for the Prevention of Pollution from Ships, n.d.).

By overviewing these segments, this paper will aim to evaluate the whole paper in three-part. Feedering Route Around the world will be discussed in Part I. The factors affecting the environment during the feedering supply chain will be discussed in Part II, Strategies to reducing environmental catastrophe by implementing MARPOL Convention and Local Regulation in Part III. After evaluating these three parts, the paper will provide recommendations for building up supply chain efficiency and Environmental Catastrophe reduction.

Literature Review

Part I: Feedering Route Around The World

Humankind divided the whole landmass and water areas into seven and five parts and named their continents and oceans. Trade often take place between these vast areas divided by water. Nevertheless, the largest passage goes through the vast ocean areas through various ships and vessels for thousands of years. Major Ports named used as the satellite ports- A satellite port can exist or be created near a port reaching capacity. Satellite ports help overcome issues such as limited land availability and draft adequacy, which is the depth of water to which a ship sinks according to its load (Sood & Bhaskar, 2017) - and other small to medium ports where the draft is so low to welcome large ships there, they introduced the feedering vessel systems.

According to Figure 1, ships sail globally; generally, all the ships first come to the satellite ports of each continent. Japan, China and Singapore hold the most container vessels in eastern Asia. In South Asia, mostly Singapore and the South Indian ports act as the satellite ports; In the Gulf countries, the Strait of Hormuz surrounding ports are the key points for the oil tankers.

In continental Europe, many major ports reside among those ports from the UK, Netherlands, France, Spain and Portugal, holding the key satellite stations. Despite having vast natural and mineral resources, moving Africa does not hold any major satellite port. However, Gibraltar, Suez Canal and Durban hold the most prominent ports.

Across the Atlantic Sea, North, South, and Latin America hold few prominent satellites port due to their inclusive trade routes. New York, Huston, Vancouver, Los Angeles and New Orleans seem prominent in North America, covering the Atlantic and Pacific oceans along with the Panama Canal, Itaqu and Tubarao holds a significant place in South America. As we know about the major places where the state satellite ports reside (See Table 1), it also says about the surrounding areas where the ports may have the feedering vessels' routes.

The feeder vessels are a small and relatively low amount of container carriers and can sail in relatively short distances, so their route is determined based on the surrounding conditions. One condition can be the most understanding: Feeder vessels are loaded or unloaded in the port, and then it goes to the mother vessel already in the satellite ports in the nearby area and gets unloaded or loaded. Sometimes, the mother vessel comes around the shoreline till where the draft allows and then gets the goods for a ship from the feeder vessels that came from the surrounding port with low draft. So, feeder vessels can have various types of route types. We have gathered a few feeder vessels International Shipping Route data from a littoral country Bangladesh which requires feeder vessels for the Trade. (See Figure 2).

Methodology

Part II: The Different Factors Affect The Environment During Feedering Supply Chain. The environment is getting worse with the rapid increase in environmental factors. With these rapid changes, many environmental catastrophes as arisen and are known by various names like wildfires, landslides, floods, earthquakes, droughts, tornadoes, tsunamis and volcanic eruptions ("Environmental Disasters", n.d.). These catastrophes are classified under geophysical, meteorological, hydrological, and climatological (Stanton-Geddes et al., 2013). As the concern of this paper is all about the sea's environmental catastrophe, especially by the shoreline, we will mostly focus on the Hydrometeorological disaster subset. Hydrometeorological disaster includes Tropical Cyclones, i.e., Typhoons and Hurricanes, Heatwaves and cold spells, Coastal storm surges, strong wind and rain, Tsunami, Biological Hazard, and Volcanic Eruption. (Wu et al., 2016) As all disasters are natural, the factors based on the catastrophes can be manipulated, and, in our findings, we have identified the most effective factors that arise from the feeder vessel movement in the Territorial Sea. It includes pollution, temperature rises and salinity, sea current movement change, and the chemical balance of the sea.

Factor I: Pollution

Feeder vessel movement affects the land, air and water simultaneously and in various ways. As mentioned in the introduction, feeder vessels mostly run in developing countries, and they have little protection against it. They cannot do something efficient to take immediate action against this pollution.

Land Pollution

Land Pollutions are the indirect effect of the feeder vessels as they move the goods from the small ports to larger satellite ports, so they have to take these goods from the dock. In the time of taking these goods, the ships saw an inefficiency in passing those as those products had to wait in the port for so long and therefore heavy metal from the industry, and oils, logging etc., make a crucial effect in the polluting the land. This is making the land base weak, and in return, when any Hydrometeorological catastrophe hits the shore, it cannot stand against it. Building and other important things built on it collapse easily and make the most devesting outcome in terms of causalities and economic losses. Also, it is needed to be mentioned that 80% of marine pollution comes from land (VanderZwaag & Powers, 2008).

Air Pollution

According to experts, "Commercial ships burn fuel for energy and emit several types of air pollution as by-products. Ship-source pollutants most closely linked to climate change and public health impacts include carbon dioxide (CO_2), nitrogen dioxides (NO_2), Sulphur dioxides (SO_2) and particulate matter (*Air Pollution & Marine Shipping | Clear Seas*, n.d.). These have become prominent globally (See table 2).

In terms of impacts, CO_2 increases the average temperatures, rainfall patterns, and hazardous elements in the air. Also, it becomes more acidic if it is sucked into the water. NO_2 mostly harms humans directly rather than creating a disaster. However, as this NO_2 reduces the ground level Ozon, it threatens food security (*Air Pollution & Marine Shipping | Clear Seas*, n.d.). SO_2 is the sole cause of acidic rain, and if it starts for a long time for the temperature void, then it becomes a catastrophe, and other effects of SO_2 are directly related to humans.

Moreover, SO_2 as a toxic gas is also harmful to human health directly. Humans can feel suffocated if they go around an SO_2 concentration of more than 500 ppb. If the level is not high, they can feel chest pains, breathing problems, eye irritations, and long-term lung diseases. Ill effects of SO_2 become visible when the concentration is more than 20ppb in the normal air. Asthma Attacks and Raspatory problem can be seen when the attack of SO_2 and NO_2 works together in the air. It also damages the environmental p^H by making it acidic with a pH of 5 (What Are the Effects Of Sulphur Oxides On Human Health And Ecosystems? 2022).

Water Pollution

Feeder vessel directly pollutes the sea waters and inland water indirectly. These vessels generate garbage like plastics, packages, cleaning materials, paper products, food waste, ship paint, chemicals and oils (Singh, 2021). These directly harm marine life and weaken the shores. Coral reefs can be used as a shield against a cyclone, but if these feeder vessels harm those by water pollution, it makes the shore vulnerable. Moreover, with the increased plastics, chemicals, and paper products, the sea currents, chemical balance directlybecomes affected and also shows how it can manipulate nature to bring the catastrophe

Factor II: Temperature Rise & Salinity

With the increase in temperature, the salinity also increases. Moreover, the dissolved oxygen rate decreases with the increased salinity representing the perfect relation between temperature, salinity and oxygen (*Environmental Conditions Affecting The Sea*, 2022). Because of Factor I, the temperature is rapidly increasing; the ice of the north and south poles started melting, which also increased the sea level. It can buy many littoral developing countries underwater, which run feeder vessels unrestrictedly (Bappy *et al*., 2021). Moreover, with the increase of salinity, much marine life will go extinct because no perfect environment creates an imbalance among every other species, bringing an ecological disaster.

Factor III: Sea Currents

Hydrometeorological disasters, tsunamis and hurricanes are the effects of changes in the sea currents based on many sub-factors. These changes in sea currents include subfactors like wind, the density of different water masses, temperature, salinity, gravity, earthquake & other disasters. (Ocean Exploration, 2022). As the temperature and salinity changes have been shown in factor II, if it continues, then changes in sea currents also start to see more often and these sea currents, in return, become a disaster if it only increases by 3 meters and devastating disasters can take place if that sea current length become more than 200-300 meters (*Tsunamis: Facts About Killer Waves*, 2005).

Factor IV: Chemical Balance and P^H

Sea water is composed of different elements like Na, Mg, Ca, K, Cl, SO_4, HCO_3, etc., and it mainly distinguished itself from the sea seawater's increased amount of NaCl compared to River water's Ca and HCO_3 (See table 3). Most of the induvial element's ratio differences are seen in the Na, Mg, Cl and Sr, Br is completely absent in the river water (See Figure 5). In terms of pH, seawater has 7.8-8.4 pH, so it is mildly acidic. (*Seawater*, 2022) Wikipedia: A slight change in factors I, II, and III directly affect the seawater's chemical balance; in return, the most fundamental chain broke. So, as Factor II is responsible for changing the ecosystem, Factor IV will act the same. All the marine life that is well adapted to the NaCl quantity of the seawater might disappear with the change in the chemical, and also, if with feeder vessels, any waste or any chemical regularly gets dumped, then these ratios will change and in return makes the most of the Part of that territorial sea water point of marine ecology disaster.

Results and discussion

Part III: Strategies for Reducing Environmental Catastrophe by Implementing MARPOL Convention And Local Regulation

In Parts I and II, we have discussed the shipping routes of the feeder vessels and the factors based on the environmental catastrophe. Also, in Part II, we have discussed a summary of the displaced factors and what kind of situation can occur. Evaluating the regions and water range of the feeder vessels and the factors from Part II, we have identified two core problem fields that need to be solved, and other allied problems will go away along it. To solve the problems, we will take help from conventions like MARPOL, Emission Control Area, and other common local regulations of the territorial seas.

Problem Field I: SO_2 and NO_2 Reduction

In factor I, it is well discussed what SO_2 and NO_2 are and what damages it carries in catastrophes, including factors like factors II and IV. After the intensive evaluation, it has come up as the most prioritised problem as if it got solved, the temperature rise will reduce, the sea's chemical balance will stay intact, and pH level will also reduce or at least stay stable with the less acid rainfall. Globally IMO, other local and global authorities have introduced three major provisions to keep it stable.

Provision I: Annex VI of MARPOL (Prevention of Air Pollution from Ships)

The provision I was introduced to set a limit on sulphur and nitrogen oxide emissions. The limit will only be on ships with a marine diesel engine with more than 130 kW power output (MARPOL Annex VI And The Act To Prevent Pollution From Ships, 2022). Also, from 1 January 2020, ship fuel cannot contain more than 0.1% Sulphur than 1.00% before, and outside of Emission Control Area, this limit is 0.5% than 3.5% before (IMO Web Accounts, 2020). However, this provision is open to the municipal law as to how they will make this provision more intact based on their territorial sea's need. All feeder has to follow them strictly.

Provision II: Emission Control Areas

International Maritime Organization (IMO) introduced Emission Control Area in 2012 (Air Pollution & Marine Shipping | Clear Seas, n.d.). Its main goal is to minimise the emission of NO_x, SO_x and particulate matter in the Baltic Sea area; the North Sea area; the North American area (covering designated coastal areas of the United States and Canada); and the United States Caribbean Sea area (around Puerto Rico and the United States Virgin Islands) (Network 2021).

In the Emission Control Area, ships should use fuels from International Code for Ships using Gases and other Low Flashpoint Fuels (IGF Code) and are encouraged to use Marine Fuel as it has no Sulphur. If the ship is carrying the fuel according to the IGF code, then the Port Authority will issue International Air Pollution Prevention (IAPP) Certificate to the ship. If they are not, then it is over to the state to penalise the ship at their will (Network 2021).

Strategy Suggestion for Problem Field I: Widening the Emission Control Area

From provision II, we have understood that the emission control area is narrow and mostly covers North America. Nevertheless, the NO_x and SO_x issue is a global problem and has to solve globally as our concern is about developing countrie's feeder vessel-generated catastrophes. Therefore, we need to enlarge this Emission Control Area or introduce a new area for these states still using feeder vessels. Because despite having Annex VI of the MARPOL, they are allowed to use 0.5% Sulphur content in ship fuel (See provision I), whereas, in ECA, the use is below 0.1%, which is much more effective in the long run. Marine fuel with 0% Sulphur might cost a little more, but when greater impact comes into consideration, their increase in freight cost does not affect that much because as the developing countries will see fewer catastrophes, the cost of the introduction of a new area like ECA will eventually become worth its price.

Problem Field II: Garbage, Harmful Substance and Waste Dumping Reduction

Factor I, II, III, and IV are directly connected to this reduction process. Centuries ago, when people did not have ships and did not use anything artificially, the structure of the sea and the surrounding environment remained stable and went on the natural order. However, when people started to use ships, the amount of garbage, harmful substance and waste started increasing, affecting the territorial sea. IMO introduced four provisions to fight against these issues.

Provision I: Annex V (Prevention of Pollution by Garbage from Ships)

Annex V of MARPOL deals with all the garbage generated from food and domestic and operational waste. (Pandi, 2013). Its main highlighted Part was that the disposal of plastic in the sea is prohibited according to Annex V. Also, it has introduced special areas where the garbage should be disposed of in the coastal water.

Provision II: Annex IV (Prevention of Pollution by Sewage from Ships)

Sewage products' main source is human, mostly land-based. Nevertheless, the ship's sewage must be maintained as it is an undetachable part of every species on the earth. However, if that raw sewage gets discharged into the sea, it can bring health hazards. Moreover, this can lead to oxygen depletion and visual pollution in the coastal area (MARPOL IV | Prevention Of Pollution By Sewage From Ships | Tradebe Marpol, 2022). Therefore, Annex VI was introduced and says, "Annex IV of MARPOL prohibit the discharge of sewage into the sea within a specified distance of the nearest land, unless they have an approved sewage treatment plant in operation." But in high seas, assimilation of raw sewage is possible through natural bacterial action.

Provision III: Annex III (Prevention of Pollution by Harmful Substance) & Annex I (Prevention of Pollution by Oil)

Annex III and Annex I of MARPOL work hand in hand by maintaining the chemical balance of the sea by preventing the chemical substance. Annex III deals with the harmful substance according to Intentional Maritime Dangerous Goods Code (IMDG Code). If any of the substances escape, then the marine diversity will see dangerous effects, which is why Annex I is introduced. All ships containing oil should have double hulls (International Convention for the Prevention of Pollutionfrom Ships, n.d.). If no ship contains oil, maintain this provision, then it will not get the clearance.

Strategy Suggestion for Problem Field II: Strengthening the Execution of The Provisions

Annex V's plastic prohibition, Annex IV's special zone, Annex III's restrictions on goods and Annex I on a ship designed already built a base. If everything can be properly monitored through state law, executive, and port authority, nothing can bypass the garbage dumping provisions. As the feeder vessels regularly come to the territorial seas, therefore, their garbage dumping rate is higher, but if it can be ensured that it is dumping its garbage and sewage in Annex IV's special area, then everything will stay in order and Factors of environmental catastrophe will not change that much. Eventually, everything comes to the point of proper execution, and for that, a separate department can be introduced in every coast guard and port.

Conclusion and Recommendations

Feeder vessels worldwide have come to a prime point where it is needed to be restricted because the environmental catastrophe factors are not getting influenced by the actions of these feeder vessels. Throughout this article, we have understood the shipping route of the feeder vessels in Part I, and in Part II, we have seen what bought the environmental catastrophes and found out the factors of Hydrometeorological catastrophes. Lastly, we have found all the provisions regarding restricting the factors to prevent the disaster as we cannot control a natural disaster but can somehow affect it by controlling the factors. After a brief analysis of the provision, a strategy suggestion was introduced. It is suggestive that all the law-enforcing authorities, port authorities, state executives and parliament members can follow these suggestions to make regulations to protect the country where feeder vessels are being operated.

As mentioned in the introduction, the paper's secondary concern was providing suggestions for making an efficient route system for the feeder vessels based on Part I and II. After analysing the scenarios, we have found two effective recommendations that can change the feeder vessel's transition time and cost efficiency and increase supply chain efficiency.

Recommendation for Feeder Vessels

As shown in figure 2, avoiding the transit points should be the major concern for the feeder vessels. As they are meant for short passage with little goods compared to mother vessels, they should only be dedicated to one satellite port rather than turning around several major ports. As they move between them, the probability of damaging existing goods on ships becomes higher, and the transition cost also adds up with the port fees and duties.

Recommendation for Ports

Ports should introduce green channels with a feeder vessel that can reduce the time for clearance as the ship stays in the port. The various extra costs might not be added up if it had to stay a short amount of time. With the introduction of the green channel, the port will also see a quick turning back time rate, making the port's traffic efficiency high and ship occupancy low.

Table 1: World's Major Satellite Ports

No.	Name of Port	Country	Coordinates
1.	Shanghai Port	China	30° 37′ 35.54″ N, 122° 3′ 53.85″ E
2.	Port Klang	Malaysia	3°0′0″N 101°24′0″E
3.	Singapore Port	Singapore	1.264°N 103.840°E
4.	Port of Rotterdam	Netherlands	51.8850°N 4.2867°E
5.	Port of Hamburg	Germany	53.551086°N 9.993682°E
6.	Port of Barcelona	Spain	41°20′15″N 2°9′8″E
7.	Port of Houston	USA	29.7300° N, 95.2724° W
8.	Port of New York	USA	40.6840° N, 74.0062° W
9.	Port of Chennai	India	13.0815° N, 80.2921° E
10.	Port of Cape Town	South Africa	33.9043° S, 18.4301° E

(Source: Developed by Authors)

Table 2: Shipping Industry Emissions Compared to Global Emissions

Shipping Industry Emissions	
CO_2	2.2% Per Year
NO_2	15% Per Year
SO_2	13% Per year

Table 3: Elements of the Sea and Ocean Water

Elements	Sea Water (mmol kg-1)	River Water (mmol kg-1)
Na	468.0	0.26
Mg	53.1	0.17
Ca	10.3	0.38

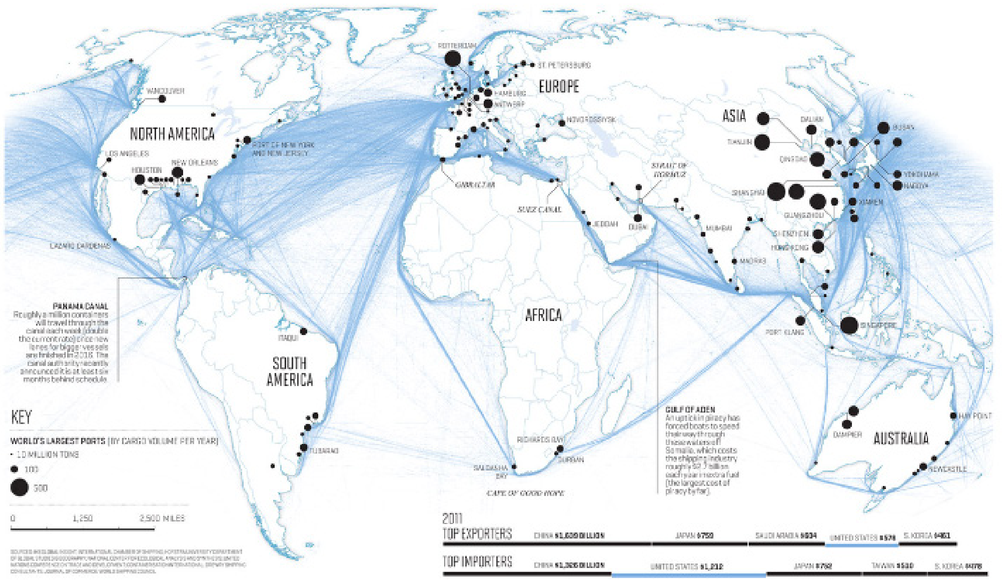

Figure 1: World shipping route.

(Source: Pittman, n.d.)

Chittagong to Singapore Route   Colombo to Chittagong Route

Figure 2: Feeder vessel route overview

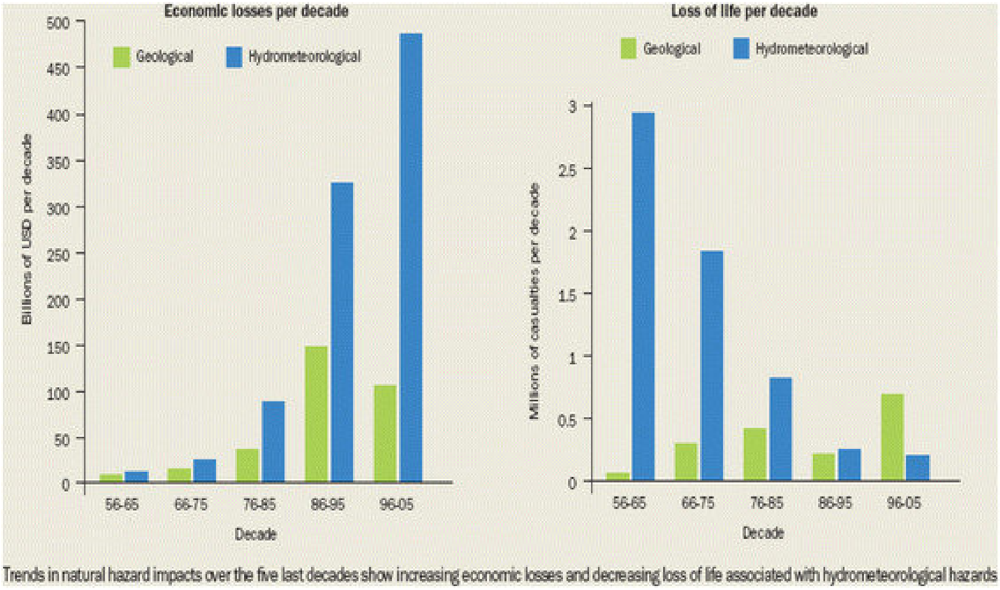

Figure 3: Economic losses and loss of life from hydrometeorological and geological disasters by decade.

(Source: Andrews & Quintana, 2015)

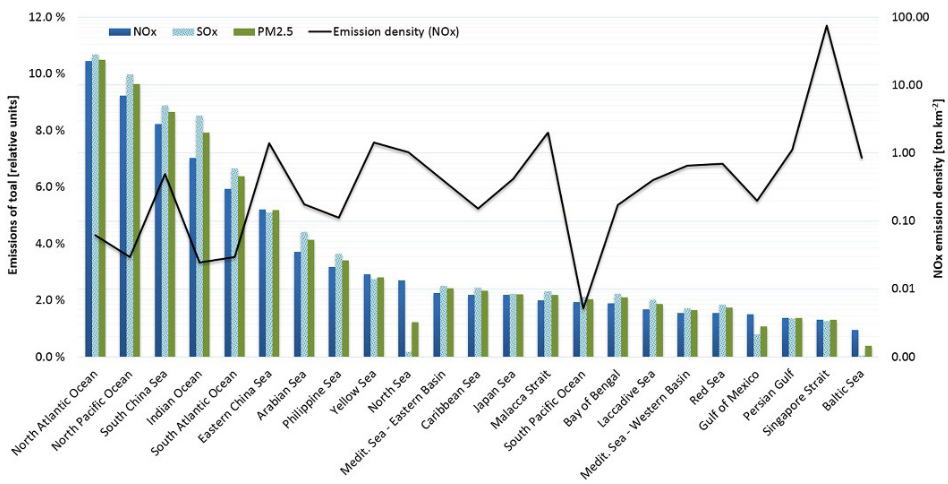

Figure 4: Relative share of NO_x, SO_x and $PM_{2.5}$ from the total global shipping emissions (bar graph). The emission density for NO_x emissions is presented with a black line using a logarithmic scale.

(Source: Johansson *et al.*, 2017)

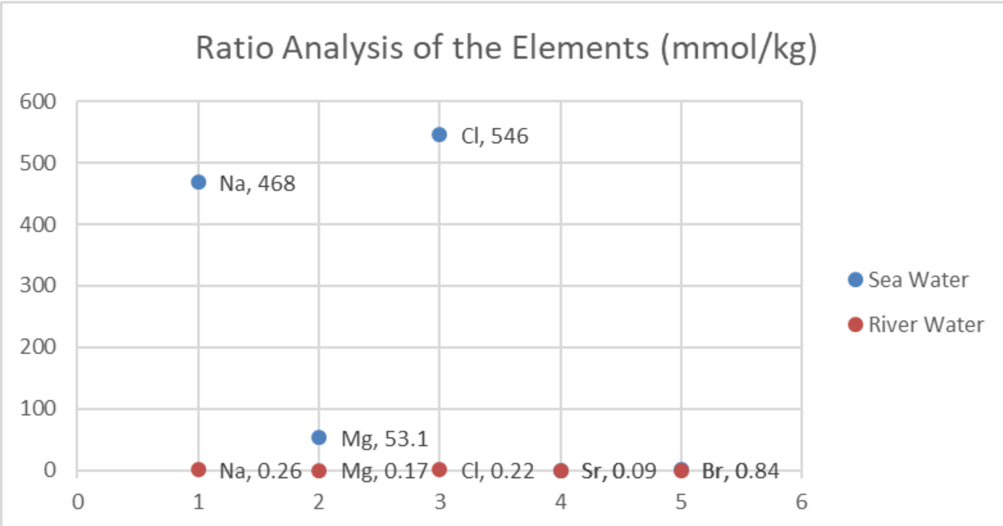

Figure 5: Ratio analysis of the major elements of river and seawater

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