

Impact of Fuel Waste Emission on Pollution of Ocean Water

Leyang Yu *

Shanghai united international school, 201103, Shanghai, China

* Corresponding Author Email: julia.yu@newlinker.net

Abstract. As ocean is taking about 70% of the whole globe, the pollution problem of earth is severe and should be drawn more attention to. With this research paper, it can inform the readers on how severe the problem is, what is the cause of the global issue—ocean pollution and how to improve, modify and change. This research paper discusses about the issue existing nowadays—ocean pollution and analyze it from the perspective of fuel wasted emission. The cause is analyzed from mainly two angles, the wastes generated by shipping industry and the waste generated by coal burning industry. Furthermore, the process of waste emitted from engines and the process of burning coal and the component of heavy fuel oil discharged is explained. Moreover, the negative impact on various aspects is explored and several possible solutions are provided, for example limiting the polluting components in a commonly used fuel—HFO and developing machineries to reduce and eliminate the smoke produced during process. The paper wants to gather readers attention, raise awareness on this global issue and make suggestions that can make a change.

Keywords: Fuel waste emission; pollution; ocean water.

1. Introduction

The background of the research topic is the global issue of ocean pollution. As ocean is taking about 70% of the whole globe, the pollution problem of earth is severe and should be drawn more attention to. With this research paper, it can inform the readers on how severe the problem is, what is the cause of the global issue—ocean pollution and how to improve, modify and change. The goal of this research paper is to find the relationship between fuel emission and ocean pollution issue. This paper wants to discuss about where are the fuel wastes generated, from which of the human activities, how are they generated and what waste specifically, what component of the waste is generated into the ocean that's occupying most areas of the globe we live in. Setting research in this topic is important as there is a lack of awareness in this issue right now, most of the people, even the people who work in the industries that generated tons of fuel wastes did not pay much attention to the problem. The paper wants to gather readers attention, raise awareness on this global issue and make suggestions that can make a change.

There had been a lot of people who wrote on the topic of ocean pollution and less on the topic of fuel wastes' impact on the issue. There are a lot more of research on fuel wastes generated by shipping industry's impact on ocean comparing to other ways of fuel wastes generated, for example, from coal burning industry. In this research paper, it includes not just the part of impact of fuel wasted caused by shipping industry, but also provides knowledges on the carbon cycle, how ocean helps absorbs a lot of fuel wastes, and additionally, it would be discussing the fuel wastes' impact from the coal burning industry. It is more comprehensive, specific, and written in various perspectives comparing to other papers and research. The best way to help minimize pollution problem generated in this paper is to set limitations on the mostly commonly used fuel—the heavy fuel oil by the ships and vessels. This method is chosen as it would not make a change in the choice of fuel the shippers are used to using. By changing the polluting components quantity is the most efficient and cost-efficient way.

This research paper discusses about the issue existing nowadays—ocean pollution and analyze it from the perspective of fuel wasted emission. With more detail, the cause is analyzed from mainly two angles, the wastes generated by shipping industry and the waste generated by coal burning industry. Furthermore, the process and component of wastes discharged is explained. Moreover, the negative impact on various aspects is explored and several possible solutions are provided.

2. Fuel Emission

For the past years, pollutions had been a major issue leaving negative impacts to the environment and perplexing people. Fuel emission is working as one of the main contributing factors to pollution issues. As fuels are released from human activities, such as shipping and factories, negative impacts had been caused leading to a mass decline in the quality of ocean water, causing pollution and many health concerns for the ocean water.

2.1. Fuel Released by Ships

Shipping is one of the essential transportations means humans rely on. It carries more than 10 billion metric tons of cargos each year, including clothing, foods, necessities, electronics, toys, beauty products and are not limited to just these aspects. Anything can be carried by shipping around the world and as shipping costs lower than airway, it is a priority of choice for a considerable percent of import and export market. Since almost all of these ships and steamers run on fossil fuels, a large amount of fuel wastes is released during the process of shipping. A lot of the greenhouse gas had been emitted by shipping. Research has shown that maritime shipping caused about 3% of global greenhouse gas emissions which is surprisingly even more than airplanes [1].

2.1.1 Types of Ships Emitting in Ocean Water

It is unavoidable for ships to emit fuel wastes to ocean water when activating and employing. The common types of ships and vessels that works in seas are cargo ships, which transfer goods and merchandises; passenger ships, which carries passengers on leisure trips; fishing vessels, which are used to catch fishes and other seafoods. These goods can be sold for a living; Specialty ships, that are designed for specific purposes like ice breaking and mapping the ocean floor. They can be used for research usage; Some other types that are not so common but could be mentioned are tugboats, yachts and ferry [2]. The types of ships work in specialty in different fields, but all generates fuel wastes to the ocean.

2.1.2 Function of Fuel in Ships

Fuel mainly works as helping the engine of ships function which leads to the activation and movement of the ship. The engine is an essential component of the ships. It is compulsory for the following reasons: it provides the power the ship needs for progressing, the thrust to steer ships in tight spaces such as when navigating through narrow tunnels and uses the fuels in an efficient way [3]. During the process of the engine generating fuels into energy, wastes are released by the ship and out into the ocean water causing a pollution problem.

2.1.3 Process of fuel working in engines

The structure of engines is complicated therefore the process of fuel functioning in engines is very complex, it contains several steps. Firstly, fuel enter the engine through the fuel injectors and is mixed with air in the chamber of combustion. Secondly, the mixture of fuel and air is lit by a high-pressure compression and an explosion takes place. Thirdly is that the explosion creates a force, and this force pushes the piston. As the piston is connected to a crankshaft, the crankshaft is turned, and the fuel and air mixture is generated into mechanical power. The mechanical power is transferred to a propeller. The propeller turns and sets the ship in motion and pushes it into the water [3]. This is the basic procedure of how fuel functions in the process of energy generating of the engine. A boat often has multiple engines which operate at the same time to provide further energy needed or to maintain the ship driving when repair works take place. During the process of the engine transferring fuels to energy, many fuels are used for maintaining the boats' progression, therefore emitting an uncountable measure of fuel waste, decreasing the ocean water quality to an unlimitedly low scale. To sum up, the fuel oil releases energy to rotate the ship propeller by burning fuel inside the combustion chamber of the engine or to generate steam inside the boiler.

2.1.4 Mechanism of the heavy-fuel oil and impact of components

The heavy-fuel oil is the most commonly used fuel of ships in oceans. Starting from year 1950s, people's need for heavy fuel oil had started to increase [4]. Today, more than 60,000 vessels use heavy fuel oil for propulsion [5]. With this large amount of heavy fuel oil released into the ocean, getting to know the component of this type of commonly used fuel is important. The heavy fuel oil, HFO, is a complex group of hydrocarbon products. It is a tar-like residual waste produced in an oil refining process. This most commonly used, and most polluting ship fuel is typically consisting of bitumen, asphaltenes and long chain polycyclic aromatic hydrocarbons. It also includes large quantity of mineral pollutants such as sulphur and heavy metals (vanadium, nickel etc.) which are derived from the baseload crude oil [6]. From its components, we can tell how dirty and polluting this fuel is. Firstly, the bitumen content. Asphalt, or bitumen is a major pollution source, especially in sunny and hot space. Research shows total emission of bitumen doubled when the temperature rose 20°C, from 40°C to 60°C [7]. This is a concerning problem as ocean floor is exposed to sunlight. Once the fuel emitted into the ocean, the bitumen part getting attached to sunlight would release a large amount of carbon-based waste, often with 12 to 25 carbon atoms per molecule. Another concerning part of the component of the heavy fuel oil is the large-scale elements of sulphur and heavy metals. The element of sulphur can release large amount of sulphur oxide and sulphur dioxide waste. Moreover, heavy metal pollution is already a noticeable existing issue. Heavy metals have an irreversible biotoxicity to living organisms. As heavy metal particles are released into the ocean water from fuels and most of the living things, especially us humans cannot live without water, creatures attaching or exposed to the ocean would be inevitably negatively affected. With chronic exposure to heavy metals, even at low concentrations, negative effects and sequela like teratogenic and carcinogenic effects would occur and remain [8]. Furthermore, heavy metals are not biodegradable, therefore, they tend to bioaccumulate. This leads to another drinking issue. In some of the countries around the world, the average concentrations of heavy metals found in surface water bodies are well above the maximum allowed values for drinking water boundaries [9]. Overall, the components of a commonly used fuel in ships and vessels—the heavy fuel oil all have a high toxicity and a severe negative effect to environment, either contributes to air pollution or causes danger in ecosystem's health issue.

2.2. Coal Industry's Fuel Waste Emission

Coal mining operations wash toxic residues into streams and into the ocean. The vast amount of unwanted rock and soil are being scoured into the water system. The oil leaks happening during transport can severely pollute drinking water sources and threaten the entire ocean ecosystem. Despite from the leak of the harming substances into the ocean, when coal is burnt, the fuel waste of burning coal would change the ocean's basic combination, making it more acidic. Almost a quarter of artificial fuel waste is absorbed by the ocean, transforming the ocean's Ph value 30 percent more acidic [10].

2.3. Ocean Absorbing Fuel Waste Emission

The global ocean has had absorbed 34 billion metric tons of carbon from fossil fuels emissions from year 1994 to year 2007. The amount increased 2.6 billion metric tons per year when compared to the previous period starting from the industrial revolution in 1800 to 1994 [11]. Ocean's carbon dioxide (fuel waste) concentration has risen and continue to rise. Carbon dioxide concentration levels naturally rise and fall in cycles over long periods of time, however, they are higher now than they have been in the past 400,000 years, as shown in the graph below, and this is caused by the fuel emission brought by the human activities. Fig. 1 is the stop to a regulation of carbon dioxide rise and fall cycle, carbon concentration in the ocean soars in present years.

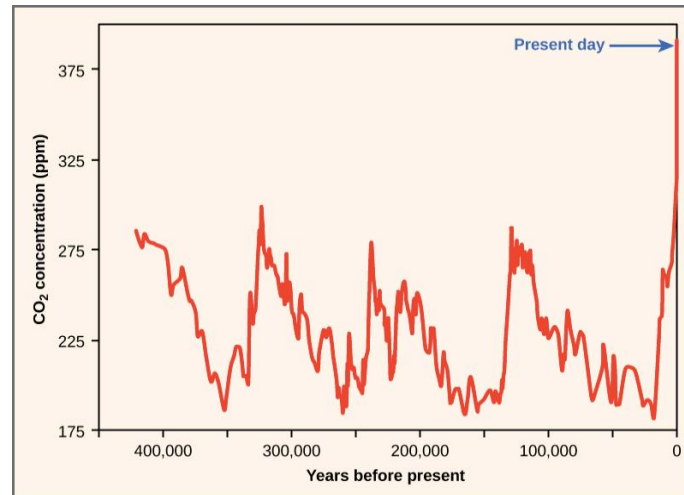
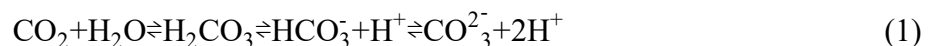


Fig. 1 The stop to a regulation of carbon dioxide rise and fall cycle, carbon concentration in the ocean soars in present years [12]

Ocean actually works as an essential role in holding the responsibility of minimizing fuel emission's harm to earth, it is humans' greatest ally in stopping pollution, but with a serious consequence. When fuels wastes are emitted from human activities, about 25% of them is absorbed by the oceans [13]. Furthermore, the ocean captures 90 percent of the excess heat generated by fuel emission [14].

2.4. Process of Ocean Absorbing Fuel Waste

Ocean helps absorbs and resolves one-third of the total carbon dioxide generated from burning fuel. And the action takes place in a regulation process of carbon cycle. Carbon cycle is the movement of carbon from reservoir to reservoir as carbon released, especially from fuel emission can be stored in varieties of reservoirs. These reservoirs include plants and animals. They are named as carbon life forms. Carbon can also be stored in atmosphere in the form of gases, such as carbon dioxide. More importantly, it can be stored in oceans, either in the deep ocean or be captured by many types of marine lives and organisms. Carbon cycle happens when carbon stored in these reservoirs transferred between each other. For example, carbon in atmosphere can be captured by plants and be made into food during the process of photosynthesis. This food can be ingested by animals. When animals died, they decompose and the remain sediments would trap the stored carbon. This trapped carbon would eventually turn into minerals and form fossil fuels, which release carbon back into the atmosphere when fuel is burned [15]. Furthermore, the level of CO₂ in atmosphere is influenced by the reservoir of carbon in oceans. The equation of CO₂ dissolves and reacting with water molecules when entering ocean is written as equation (1) [12].



The carbonate released in this process when combining with Ca ions can make calcium carbonate. Calcium carbonate has the key role of helping partial marine animals make shells. This would be elaborated in the section of 3.2 marine life. Fig.2 is the process of carbon cycle [16].

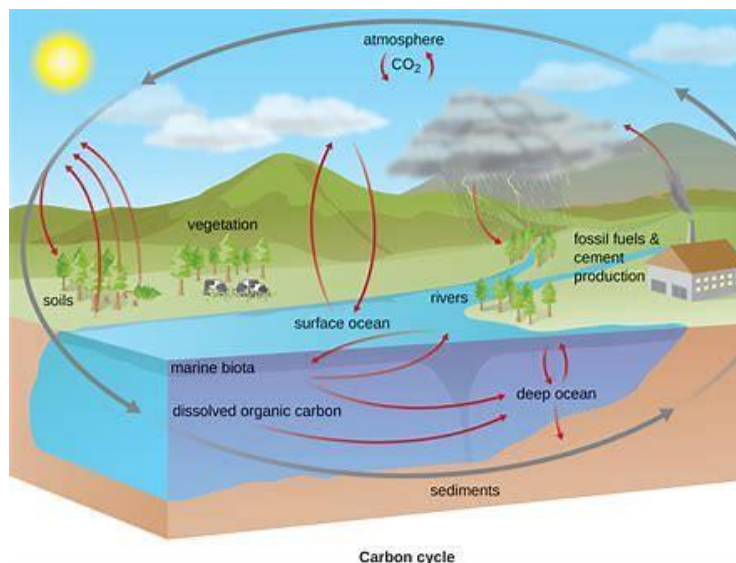


Fig. 2 Process of carbon cycle [16].

3. Impact on ocean water

3.1. Ocean Acidification

With more and more fuel wastes emitted into the ocean water, the Ph value have been dropping a lot, causing the problem of ocean acidification.

Ocean acidification is when carbon dioxide (CO_2) reacts with the water (H_2O) to form bicarbonate (HCO_3^-) and hydrogen (H^+) ions. The course can be seen on the increase in acidity of the ocean—more H^+ ions are being produced and appearing thus lowers the Ph value. Another part is the salty seawater's components. Overtimes, weathering of rocks adds dissolved ions, salts, to the ocean, including calcium (Ca^+) and carbonate (CO_3^{2-}) originated from the limestones. This leads to the seawater performing a basic PH value—which greatly increases the amount of carbon dioxide that could be dissolved in the seawater [9].

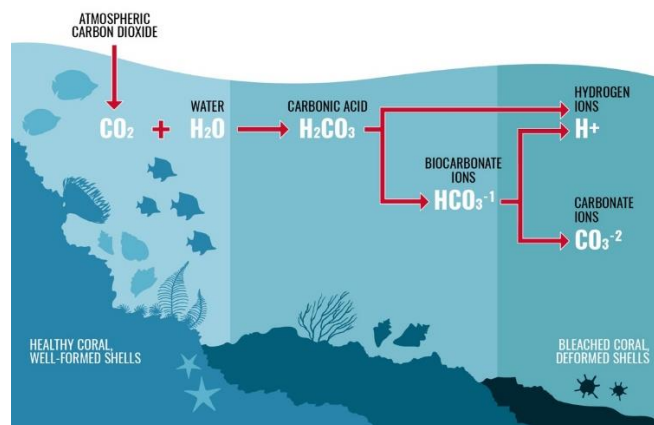


Fig. 3 Process & reaction equation of ocean acidification [17].

Today, ocean waters are up to 30% more acidic than in preindustrial times. Back in the 1950s, levels of ocean water atmospheric carbon dioxide measurement were at 315 parts per million. This was a measurement started by David Keeling when his studies seawater carbon dioxide chemistry took place. Now, a little more than a half-century later, carbon dioxide levels are approaching 400 ppm and continuing to rise as more fuel wastes are generated into the ocean.

3.2. Marine Life

When fuel wastes are dumped into the ocean, ocean becomes more acidic therefore causing the ocean oxygen level to decrease. Ending up leading to the bloom of algae which is not beneficial as the algae live as a threat to the coral reefs [18]. Marine wildlife has been exposed to pollution from fuel wastes of ships for over a century. But as time pushes forward, the pollution becomes more and more intensified, the number of pollutants—fuel wastes dumped into the ocean increased largely. Leading to coral reefs dying. The chemical residue debris are choking and killing turtles, fish, and other oceanic life. Chemicals in those fuel wastes are very harmful to marine life and coral reefs. Once the coral reefs get damaged, the marine life systems would be affected and there would be more species depending on the coral reefs dying even causing extinction.

Additionally, there's this element—carbonate that many species in the ocean depends on living—especially marine life that lives in shells. With the element of carbonate ions, marine animals are able to alter this element as a building block to build hard calcium carbonate shells [14]. This is an essential element compulsory for their living. However, with ocean's acidification caused by the fuel waste emitted, less carbonate ions persist and is threatening these species' life. Marine lives including corals, oysters, shellfish, and some important types of plankton, the small floating organisms that form the base of the marine food web are all getting negatively affected since they need certain carbonate ions condition to grow tough shells and skeletons for living [19].

3.3. Human

Ocean pollution caused by fuel waste emission lead by human activities is also concerning for people's health, environmental, and economic reasons. The increased concentration of chemicals, such as nitrogen and phosphorus, in the coastal ocean promotes the growth of algal blooms, which can be toxic and harmful to humans [20]. Moreover, people are exposed to the fuel waste not just by getting attached to ocean water but also ingesting seafood grown up in a polluted environment. By burning coal, fuel wastes, to be more specific, mercury wastes enter the ocean and causes damages to the marine animals therefore harming people who ingested the seafoods. For example, when a pregnant woman eats mercury-contaminated fish, the mercury can damage the unborn child's brain development resulting in a decreasing in IQ and causing further behavior problems. For adults, intaking mercury contaminated fish can increase the rate of heart diseases and the occurrence of dementia [21].

3.4. Globe-wide

Algal blooms caused by ocean acidification originated by fuel wastes causes negative effects on environment also causes damages to local fishing and tourism industries. As the big algae groups can produce certain toxins that are very harmful to fishes. These toxins can kill fish or shellfish directly. They restricted species of fishes' growth and therefore leads to a negative impact on fishing industries. The effect caused by algal blooms lead from fuel wastes is hard to inverse and leaves a serious economic loss problem in fisheries and aquaculture across the globe.

4. Improving Means

4.1. Fuel Choice

The shipping industry has already raised awareness on the fuel emission pollution issue. Shippers set the goal of working to cut emissions from shipping by at least 40% by 2030 relative to 2008 levels, in keeping with international agreements reached in 2018 by the IMO's member states. (IMO refers to international marine organization) [22]. The industry also plans to switch from standard marine fuels to greener alternatives and by boosting energy efficiency, it can cut emissions of climate-changing gases and air pollutants known to harm human health. The industry is evaluating numerous sources of energy for propelling ships, including liquefied natural gas, methanol, hydrogen, and

ammonia, and it is testing demonstration vessels. However, the heavy fuel oil becomes the top priority choice for most of the shippers for a reason. It is inexpensive and energy dense, this means that a small amount of it can keep the boat in progress for a long distance and it would not cost much. So, a greener substitute for HFO have not yet been emerged.

As the coal industry had been generating a lot of fuel waste to ocean pollution, the severity of the problem had been noticed. This led the industry into putting effort into coming out ways to reduce fuel wastes such as sulfur and other impurities waste caused by burning coal. Some chooses to change the ingredients into low sulfur coal which is an improvement to the origin of the fuel, solving the problem from the root. While some choose to use equipment to clean the gas emitted from burning coal, therefore preventing further damages to the ocean as oceans absorb and store these toxic gases. For example, there's a company that use this equipment of flue gas desulfurization equipment, this equipment benefits people by cleaning the sulfur emitted from coal burnt before the smoke leaves the tubes, leaves the factories and gets absorbed by the ocean. Additionally, another strategy had been used is developing ways to remove the impurities from coal therefore creating the type of coal that is more durable when burning. This type of coal would be more efficient in energy utilization and can therefore lead to the advantage of reducing the amount of coal burnt. This helps to solve the issue of ocean water polluted by fuel waste [23].

4.2. Policies

A new policy came into force in 2020 stipulating that the maximum sulfur content of ship fuel should be lowered from 3.5% to 0.5%. There is a stricter limit with a level of 0.1% sulfur applied in coastal regions and the designated areas. The IMO's (the International Marine Organization) sets that there should be limitations in NO_x (For example, NO₂, which is a severe pollutant released by fuel emission), which varies by the ship's engine size, their operating speed, and construction date. It has grown increasingly restricted and limited in the past decades and can now be as low as 2 g of emissions per KW h of energy output surprisingly [23]. With the amount of NO_x and Sox limited, organizations are wishing that the phenomenon of over polluting the ocean caused by fuel emission can be modified and improved.

5. Conclusion

The research paper explores the negative impact of fuel wastes on ocean water and causes an issue of pollution. The paper wants to discuss about from mainly two angles of where fuel wastes are generated into the sea, one is the wastes generated by shipping industry and the other is wastes generated by coal burning industry. The process of waste emitted from engines and the process of burning coal and the component of heavy fuel oil discharged is explained. In the future, limiting the polluting components in a commonly used fuel—HFO and developing machineries to reduce and eliminate the smoke produced during process are possible, and feasible means to imply in the industries. The goal of this research paper is to gather readers attention, raise awareness on the global issue of ocean pollution, make people pay attention to the source of fuel wastes emitted and imply suggestions and methods that can make a change.

References

- [1] YCC Team, Maritime shipping causes more greenhouse gases than airlines, 2021, <https://yaleclimateconnections.org/2021/08/maritime-shipping-causes-more-greenhouse-gases-than-airlines/>
- [2] SINAY, what are the different types of ships? 2023, <https://sinay.ai/en/maritime-glossary/ship-types/>
- [3] Praneet Mehta, Ship Engine, 2023, <https://www.merchantnavydecoded.com/ship-engine/>

- [4] Takahiro, History and Transition of Marine Fuel, 2021, <https://www.mol-service.com/blog/transition-in-ships-fuel#:~:text=Since%20the%201950s%2C%20the%20use%20of%20marine%20heavy,the%20refining%20process%20of%20oil%2C%20began%20to%20increase.>
- [5] Norwegian, what are the four major types of fuels used in ships? 2021, <https://www.norshipsale.com/what-are-the-4-major-types-of-fuels-used-in-ships/>
- [6] HFO-free arctic, what is heavy fuel oil? 2016, https://www.hfofreearctic.org/hrf_faq/heavy-fuel-oil/
- [7] Michael Marshall, Asphalt on roads may soon be greater source of air pollution than cars, 2020, <https://www.newscientist.com/article/2253470-asphalt-on-roads-may-soon-be-greater-source-of-air-pollution-than-cars/>
- [8] Kosar Hikmat Hama Aziz, Fryad S. Mustafa, Khalid M. Omer, Sarkawt Hama, Rebaz Fayaq Hamarawf , Kaiwan Othman Rahman, Heavy metal pollution in the aquatic environment: efficient and low-cost removal approaches to eliminate their toxicity: a review, 2023.
- [9] Camilo Zamora-Ledezma, Daniela Negrete-Bolagay, Freddy Figueroa, et al., Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods; 2021.
- [10] NRDC, Fossil Fuels: The Dirty Facts, 2022, <https://www.nrdc.org/stories/fossil-fuels-dirty-facts#sec-whatis>
- [11] National Oceanic and atmospheric administration, Global ocean is absorbing more carbon from fossil fuel emissions, 2019, <https://www.noaa.gov/news/global-ocean-is-absorbing-more-carbon-from-fossil-fuel-emissions>
- [12] Khan academy, Biogeochemical-cycles, 2023, <https://www.khanacademy.org/science/biology/ecology/biogeochemical-cycles/a/the-carbon-cycle>
- [13] Monique Curet, Carbon dioxide “is not a problem. The Earth has more than enough land and ocean plant life to metabolize it”, 2021.
- [14] United Nations Climate Action, The ocean – the world’s greatest ally against climate change, unknown, <https://www.un.org/en/climatechange/science/climate-issues/ocean>
- [15] National Geographic Society, The carbon cycle, 2023, <https://education.nationalgeographic.org/resource/carbon-cycle/>
- [16] OpenStax College, Microbiology, Biogeochemical Cycles, 2016, <https://philschatz.com/microbiology-book/contents/m58825.html>
- [17] The California State university, MICHELLE MCCARTHY, Ocean Acidification, 2019, <https://www.calstate.edu/csu-system/news/Pages/breaking-the-seafood-chain.aspx>
- [18] Megan Avakian, New Study Finds Ocean Pollution a Threat to Human Health, 2021, https://www.niehs.nih.gov/research/programs/geh/geh_newsletter/2021/2/articles/new_study_finds_ocean_pollution_a_threat_to_human_health.cfm
- [19] Scott Doney, Oceans of Acid: How Fossil Fuels Could Destroy Marine Ecosystems, 2014, <https://www.pbs.org/wgbh/nova/article/ocean-acidification/>
- [20] National Geographic Society, Marine Pollution, 2023, <https://education.nationalgeographic.org/resource/marine-pollution/>
- [21] Friends of the Earth, Cruise Ship Pollution Effects on Marine Life, 2021, <https://foe.org/blog/cruise-ship-effects-marine-life/#:~:text=When%20cruise%20waste%20is%20dumped%20into%20the%20ocean%2C,by%20the%20ship%20waste%20dumped%20into%20their%20habitat.>
- [22] U. S. Energy Information Administration, Coal and the Environment, 2022, <https://www.eia.gov/energyexplained/coal/coal-and-the-environment.php>
- [23] Chemical and Engineering News, Mitch Jacoby, The shipping industry looks for green fuels, 2022, <https://cen.acs.org/environment/greenhouse-gases/shipping-industry-looks-green-fuels/100/i8>