https://doi.org/10.22364/atee.2022.50

Promoting Ocean Literacy and Combating Chemical Pollution via Marine Education in Taiwan

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ABSTRACT

In the rapidly industrializing world of the 21st century, the many negative environmental impacts of modern-day human practices are becoming substantially more evident. One such problem not brought into considerable focus is chemical pollution in the oceans. As Taiwan is an island that relies heavily on the surrounding ocean for many economic practices, the harms and preventive measures of ocean chemical pollution must be discussed forthwith. This paper aims to conduct an analysis on the current scientific literature published on the topic of ocean chemical pollution and its various impacts specifically on Taiwan's oceans but also aims to conduct a study on Taiwanese university students to investigate the role the current education system plays in establishing the basic understanding of the risks of ocean chemical pollution. This study was organized by surveying 62 university students from the Tainan National University of the Arts and the National Taipei University of Technology. Results showed that 59.7% of students reported they had never learned about ocean chemical pollution in school before, 17.7% of students reported they were not sure, and only 22.6% of students reported that they did learn about ocean chemical pollution in school. This statistically correlates to how only 25.8% of students answered chemical pollution as the most serious problem Taiwan's oceans are facing. A fundamental understanding of ocean chemical pollution in the upcoming generation of young workers, who ultimately will take part in future governmental decision-making, is necessary in that it leads to:

1) an overall increased public support when the government or other private organizations take charge to implement solutions
2) an ability to develop lifestyles that reduce the risk of man-made ocean chemical pollution
3) a willingness to contribute to preventive measures.

Keywords: education system, ocean chemical pollution, ocean literacy, Taiwan, university students

Introduction

Taiwan is an island where the surrounding oceans have significant economic, political, and cultural value. The oceans play a large biological role in that it helps sustain marine biodiversity, acts as a carbon sink, produces about 50~80% of the oxygen in the Earth's atmosphere, maintains ecosystem resilience, engages in matter and energy cycles such as water, nutrients, and waste cycling, and partakes in climate regulation (National Oceanic and Atmospheric Administration [NOAA], 2022). This paper plans to focus on the negative impacts of marine pollution specifically in Taiwan to better understand the immediate effects ocean chemical pollution can have on the local marine ecosystems and what the response from the public would be. Analyzing the problem on a small-scale first would be beneficial in that it provides a more specific area of study with less overall confounding variables to throw off the end results. This is why this paper will be specifically focusing on Taiwan's oceans to analyze the problem on a local level before applying the knowledge and methodology to an international scale.

Ocean chemical pollution is the dumpage of harmful contaminants into the oceans, commonly originating from man-made sources such as pesticides, herbicides, fertilizers, detergents, oils, industrial chemicals and waste, metals, and sewage (Howard, 2019). Even though ocean chemical pollution poses a great danger to the marine environment, it has long been ignored compared to the other types of pollution in the oceans. Media outlets and current recovery projects only aim to lessen the harms of plastic pollution rather than trying to combat lesser-known problems such as ocean chemical pollution. ENGOs and governmental agencies such as Taiwan's Environmental Protection Administration (EPA) have collaborated to work towards the shared goal of plastic-free oceans by issuing a 15-year ban on plastic and enacting a 10-year Action Plan which would notably advance the limitation and clean-up of plastic waste from the environment (Walther et al., 2021). While these efforts are good indications of sustainable decision-making, this does not change the dire fact that chemical waste in the oceans is still going largely unnoticed and will continue to harm the marine ecosystem's health, human health, and economic strength if overlooked.

Little do people know that plastic pollution is in fact largely linked with chemical pollution, being that plastic pollution plays a key role in the planetary boundary corresponding to chemical pollutants and waste via the discarding of microplastics and other industrial chemicals made during plastic production such as cadmium, phthalates, and lead (Villarrubia-Gomez et al., 2018). Countering both problems concurrently would be beneficial in that effectively resolving two interrelated problems will minimize the chances of one reactivating the other, therefore efforts to combat both must be taken rather than only focusing on plastic pollution. This paper sees that chemical pollution is the most serious problem Taiwan's oceans are facing as of now predominantly because it is being

widely ignored on both the public and governmental level even though it poses the same level of threat as issues such as plastic pollution. In this regard, the seriousness of a problem should be defined with respect to the number of preventive measures taken to combat the problem in the status quo, not only the degree of harm the problem poses.

Problems that do not receive much public attention or governmental involvement tend to root from the lack of prior knowledge or education regarding the basic causes and possible preventive measures concerning the problem. Comparing this study to prior ones conducted by others revealed the proposed need for the increased integration of marine pollution education into school curriculums and expanded public support and inclination to partake in pollution recovery efforts. This paper shows that public support is something people will be willing to give if they are educated about the many harms and potential life risks of the various types of marine pollution from a young age. This tendency to be willing to support recovery efforts will be based on the innate human need to satisfy their protection and well-being by enhancing the health of their environment after having learned about the risks. A similar study done by Liu et al. (2019) examined the educational role of marine pollution prevention by surveying ninth-grade students from a harbor city in southern Taiwan and having them complete a drawing activity and answer several survey questions. After analyzing the students' responses, it appeared that most of the students' mental models of marine pollution were disconnected and lacked the human component of the problem (Liu et al., 2019). Another study done in Taiwan by Tsai & Chang (2018) developed a Chinese scale for measuring high school students' ocean literacy to allow students to reflect upon the reality of marine pollution issues. The personal understanding and mental models people have of problems affect how they perceive the reality of the issue and how willing they are to make efforts to prevent or lessen the harm.

The majority of prior studies discuss the many environmental threats of ocean chemical pollution however don't discuss the importance of the education curriculum in teaching the growing populace about those threats and cease to analyze the problem from its root cause. Even if a few studies do mention the educational aspect of the problem, data has only been gathered from high school students or younger while this paper conducts a study on university students who have already been through the entire school curriculum and have had the chance to be exposed to the reality of ocean chemical pollution and other types of marine pollution via the internet or other external sources. Therefore, gathering data from university students presents a clearer overall picture of the educational environment current students are exposed to, both inside and outside school, and how well it prepares them to better understand local ocean chemical pollution and other marine pollution issues.

Literature Analysis

Ocean chemical pollution harms the marine environment via various different sources and routes. This paper aims to categorize the distinct types of ocean chemical pollution sources and analyze each type separately to better comprehend the whole picture. This paper will prove the dire situation of ocean chemical pollution in Taiwan by analyzing different works and information concerning the situation. For the benefit of establishing a clear analysis, this paper has categorized ocean chemical pollution sources into 4 different components: agricultural, industrial, urban, and maritime transport.

Agricultural Component

The agricultural component of ocean chemical pollution sources includes chemicals commonly found in pesticides, herbicides, fertilizers, fungicides, soil fumigants, harvest aids, etc. Taiwan is a large user of chemical pesticides and other such agricultural chemicals, where the total consumption of agricultural pesticides in Taiwan from the year 2019 to 2020 amounted to about 4.5 billion NTD (Wong, 2021). Chemically consisting of nitrates, abamectin, hydramethylnon, cyfluthrin, bifenthrin, and other such harmful toxins (Srivastava et al., 2014), these chemicals often end up in the ocean as a result of agricultural runoffs and soil leaching. Agricultural runoffs are commonplace if nearby agricultural lands are exposed to intensive irrigation practices and heavy tropical rains, but an extensive reliance on toxic farm chemicals pollutes the water which end up in nearby bodies of water via the runoff. Once these toxins end up in the marine ecosystem, they simply remain trapped in the bionetwork due to bioaccumulation and biomagnification, where the toxic chemicals either gradually accumulate in organisms' fat tissue content or magnify in concentration as one moves up the food chain in the ecosystem. This in turn inhibits certain biological functions of these organisms and threatens the biodiversity of the environment, lessening the overall resilience and resistance an ecosystem has towards external dangers.

The introduction of abamectin into marine environments have resulted in abnormal growth and gill alterations in fish where the epithelial cells of the gill filaments and the secondary lamellae membrane of the gills merge, causing the appearance of aneurysm or bulges in blood vessels which have a high risk of rupturing (Novelli et al., 2016). If the blood vessel is ruptured in the wrong part of the body such as the brain or the heart, there is a risk of death for the organism. Hydramethylnon is also another chemical which gravely harms the fish population if presented in the environment. With an LC50 of 0.16 ppm and 0.10 ppm in rainbow trout and channel catfish respectively, hydramethylnon is highly toxic in fish and often accumulates in the fatty tissue of fish due to its low water solubility, large KOW, and large KOC ratios (Bacey, 2000). Additionally, cyfluthrin is highly toxic to fish species, killing them in LC50s as low as 1 ppb

and also negatively affecting the reproductive success of aquatic invertebrates such as water fleas and mysid shrimp species (Cox, 1994). Moreover, the rapid influx of nitrates into marine coastal ecosystems can result in eutrophication where the abundance of nitrates prompts algae blooms, a rapid accumulation of algae in the ocean, which consumes most of the dissolved oxygen in the waters. This results in extended dead zones where the marine ecosystem has a very low dissolved oxygen content and cannot sustain life for a prolonged period of time.

Industrial Component

The industrial component of ocean chemical pollution sources includes the chemicals that are used in industrial manufacturing processes or used as active ingredients in commercial product manufacturing. Taiwan has a booming chemical industry, boasting approximately 42 member companies of the Taiwan Petrochemical Association and 80 other major chemical companies as of 2010 (Hu & Chen, 2012). Due to the high production capacity, Taiwan exports 50% of its petrochemical products and 70% of its plastic and synthetic rubber raw materials such as polyethylene and styrene-butadiene rubber, with Taiwan's chemical industries making a total of 135 billion USD (Hu & Chen, 2012). These statistics prove that industrial chemical manufacturing in Taiwan is very prevalent and explains how 19.0 million metric tons of industrial waste were generated in Taiwan in 2016 alone (Tsai, 2019). If Taiwan wants to continue its growth in the global chemical industry, proper preventive measures must be taught and understood to restrict the influx of these harmful industrial chemicals into the marine environment.

Industrial chemical wastewater is not only a consequence of fossil fuel mining, powerplants, and chemical manufacturing companies, but also produced as a result of food, beverage, plastic, and clothing processing industries. Chemicals released via petroleum refineries and petrochemical companies comprise of pollutants such as oil, suspended solids, ammonia, chromium, phenols, sulfides, ethylene, propylene, chlorine, nitrates, phosphoric acid, etc (Moore et al., 2021). Fossil fuel power plants, predominantly coal-powered plants, discharge industrial wastewater with substantial amounts of metals such as mercury, lead, cadmium, chromium, arsenic, and selenium (Micronics Engineered Filtration Group, 2021). These metals and toxins, in turn, harm the marine ecosystem into which these industrial wastewaters are dumped into or enter them through wastewater runoff. It has been reported that trace metals such as cadmium, chromium, and lead have been found in marine copepods in northern Taiwan's coastal areas and indicates the high level of contamination in these waters (Fang et al., 2006). High concentrations of selenium, iron, zinc, copper, manganese, and mercury were found in muscle, lung, kidney, and liver tissues of cetacean species such as *Kogia sima*, *Grampus griseus*, *Lagenodelphis hosei*, *Stenella attenuata*, and more in

the marine waters of northern and eastern Taiwan (Chen et al., 2020). Not only are Taiwanese marine biodiversity suffering from metals and industrial chemicals contamination, they are also prone to microplastic contamination where 1,097 microplastic particles ranging from 0.25 mm and more than 4 mm, weighing 0.771 grams were identified in only eight 0.0125 m3 samples of Taiwan's northern beaches and coastal marine areas (Kunz et al., 2016). Industrial chemicals, metals, and microplastics pose a great threat to the marine ecosystems of Taiwan's coastal areas and must be dealt with to lessen the chance of endangerment of marine species.

Urban Component

The urban component of ocean chemical pollution sources include urban wastewaters, sewage sludge, domestic chemical detergents, household chemical products, etc. Municipal wastewater is one of Taiwan's largest sources of water pollution, especially in concentrated urban areas lacking proper sewer systems and sanitation protocols. The Environmental White Paper 2007 presented by the Taiwanese Environmental Protection Administration (EPA) analyzed that inadequately treated municipal wastewater have been continuously contaminating local water bodies and coastal areas, additionally stating that sanitary sewer systems have not been properly augmented to sustain growing city populations, rapid urbanization, and expanding commercial activities (Chou, 2013). Furthermore, it was reported on May 1, 2018, that surfers and tourists at Nanwan Beach in southern Taiwan encountered sludge discharge from a local sewage treatment plant in the coastal area (Everington, 2018). Specialists later analyzed that the sewage sludge had already been spread far enough into the ocean and has a high prospect of disrupting the local marine ecosystem and harming the biodiversity. Additionally, in 2020, the Taiwanese domestic consumption of synthetic chemical detergents measured up to approximately 70,000 metric tons and has shown a positive trend with increasing consumption of household chemical detergents throughout the years (US Environmental Protection Agency, 2000). This proves the dire state of urban ocean chemical pollution in Taiwan, with inadequate urban wastewater disposal systems and the overwhelming domestic consumption of chemical products and detergents.

Chemicals often found in sewage discharges and urban sludges include considerable amounts of nitrates, ammonia, phenols, polychlorinated biphenyls (PCBs), phthalates, volatile aromatic compounds (toluene, benzene, xylene), selenium, etc. (US Environmental Protection Agency, 2000). These toxins inhibit chemical senses of fish species and biomagnify throughout marine ecological food chains. Due to the high affinity for lipids and low elimination rate, PCBs tend to bioaccumulate in the fatty tissue of fish and results in irregular levels of thyroid hormones and neurotransmitters due to disruptions of the endocrine system in

fish (Monosson, 2000). High levels of PCBs also immoderately negatively affects the hypothalamic-pituitary-gonadal-liver (HPGL) axis of fish, a closely regulated feedback loop essential for the supervision of proper reproductive success, which leads to alterations in sex steroid hormones, gonad growth, and embryo yolk production (Monosson, 2000). Ultimately, PCBs are highly toxic to fish and greatly alters the reproductive cycles. Additionally, chemical detergents are proven to harm fish species such as *Ictalurus natalis* by damaging their chemoreceptors revealing erosion of taste buds and impairment of receptor function, affecting ability to feed or swim just after being exposed to only 0.5 ppm of the chemical detergent (Bardach et al., 1965). It was reported that afflicted fish did not recover even after spending 6 weeks in detergent-free waters, demonstrating the long-term negative effects excessive use of chemical detergents can have on the marine ecosystem. Furthermore, the influx of nitrates found in sewage sludges are very likely to result in eutrophication and harmful algae blooms just as discussed earlier in the agricultural component section.

Maritime Transport Component

The maritime transport component of ocean chemical pollution sources involve marine transportation for commerce and global trade via coastal trading vessels, bulk carriers, tankers, container ships, cargo ships, etc. The main link maritime transport has to chemical pollution are the harmful incidents of chemical and oil spills and the degradation they bring to marine ecosystems. This case of ocean chemical pollution is also distinctive to Taiwan due to the previous occurrences of oil spills caused by maritime transport. It was reported in March 2016 that a grounded ship, the T.S. Lines freighter, around Shimen Township in the coastal waters of New Taipei City encountered a breach in the hull which caused flooding in the engine compartment and severe damage to the fuel tank. This resulted in an expansive oil spill, where the local marine ecosystem was greatly threatened due to the fact that the ship was storing 40 tons of diesel fuel, 447 tons of gasoline, and 9 containers of hazardous chemicals (Charlier, 2016).

Additionally, another oil spill took place when the Greek-registered ship, the *Amorgos*, passed by the southern coastal areas of Taiwan and caused a vast oil spill, putting the local marine species in danger due to an accident in the merchant vessel. These occurrences demonstrate the realistic harm oil spills via maritime transport can cause to the environment. Even if people argue that oil spills have a rare occurrence rate, ecologically damaging oil spill accidents have already happened before and especially with heavy maritime traffic where approximately 30,000 tankers travel through Taiwan's coastal waters every year (Chiau, 2005), proper education and development of effective protocols is absolutely necessary to ensure the safety of Taiwan's coastal waters while still allowing for the continuation of economic maritime activities.

Incorporating the Educational Factor

Ocean literacy is a knowledge set that is essential for people to have in a world where sustainable development is constantly being promoted and studied. Historically, ocean literacy has only been something taught to people who have direct exposure or involvement with the ocean and its many commercial practices. However, as the world is growing ever more interconnected, where the actions of people living away from the oceans still have an impact on the health of the oceans, ocean literacy needs to be more than just informally mentioned at schools. Similar to the European Marine Science Educators Association, there is an inherent need for the formation of an organization dedicated to mapping out ocean literacy principles in order to uniformly incorporate marine education into high school curriculums in Taiwan (Worm et al., 2021). For most students, ocean literacy may seem like an abstract term, therefore, in order to incorporate ocean literacy, the practical and cultural connections between the ocean and students' everyday lives must be made so that students can develop a clearer mental map of the importance of the ocean.

Although over the years, Taiwan has gotten more involved in marine protection methods to participate in the UN's Decade of Ocean Science for Sustainable Development, most of these measures are not implemented directly in education. The Taiwanese education system would benefit from incorporating a measurement tool to determine students' ocean literacy levels and thus make changes to the curriculums accordingly. An example would be the International Ocean Literacy Survey which sets a standard for students, however, this kind of survey has never been implemented within Taiwan, thus marking a need for change (Fauville et al., 2018).

Methodology

To better understand the role, the educational curriculum plays in establishing a basic understanding of ocean chemical pollution and other marine issues in students, a survey was designed and given to Taiwanese university students. Participation in this study was voluntary and anonymous. This was a self-administered web-enabled questionnaire, which was estimated to take approximately 5 minutes to complete the survey.

Even if a few studies do mention the educational aspect of the problem, data has only been gathered from high school students or younger while this paper conducts a study on university students who have already been through the entire school curriculum and have had the chance to be exposed to the reality of ocean chemical pollution and other types of marine pollution via the internet or other external sources. Therefore, gathering data from university students presents a clearer overall picture of the educational environment current students are exposed

to, both inside and outside school, and how well it prepares them to better understand local ocean chemical pollution and other marine pollution issues.

Survey Development

The questionnaire was created and administered in both English and Chinese to aid the Taiwanese university students and avoid confounding variables. The survey was designed to gather information about the students' opinions on how well the school curriculum developed their ocean literacy and how confident they are in their personal understanding and knowledge about marine pollution issues in Taiwan.

- Questions 1~3 were designed to ask for basic personal information and demographic data. Information such as age, gender, and highest level of education were asked for.
- Questions 4~5 were designed to directly and explicitly ask what the students' views were on how well the school curriculum prepared their ocean literacy. They were asked whether they had learned about ocean chemical pollution in school before and what they thought the most serious marine pollution problem was after being exposed to the school curriculum and other external sources such as the internet.
- Questions 6~13 were designed to indirectly and implicitly ask what their knowledge about ocean chemical pollution and marine issues were. These questions helped gather objective data on how well the school curriculum developed students' ocean literacy. They were asked questions about certain facts or what they thought about a certain piece of information or statement regarding marine issues.

The majority of the responses were recorded using a 5-point Likert scale, where 1 represented strongly disagree and 5 represented strongly agree. A few of the questions were multiple-choice or free-answer style questions.

Survey Administration

The questionnaire was presented through an online Google forms survey platform. The survey was given specifically to Taiwanese university students, unlike the previous studies that were discussed in the introduction. University students were chosen exclusively due to how their responses would present an overall impression of how well the entire school curriculum and external educational environment prepares students' ocean literacy and gives them the chance to understand marine issues in their country. University students from the Tainan National University of the Arts and National Taipei University of Technology were chosen specifically since the combination of these universities' student populations would have a broader range of professional backgrounds and education specialization areas to avoid results from being deceiving or biased.

Additionally, since the universities are located in different regions of Taiwan, the school curriculums and educational environments of different counties could be taken into consideration in this study. The online questionnaire was distributed to students at the Tainan National University of the Arts and was published on the student website of the National Taipei University of Technology to have students voluntarily fill out and submit responses via the Google forms link. The students were given a period of 6 days to fill out the survey, starting on June 25, 2021, and ending on June 30, 2021.

To take into consideration ethical approval for this study, as an independent research, we received an IRB approval from the Tainan National University of the Arts. Additionally, before administering the survey, it was made clear to the participants that their responses to the survey were for the purpose of this study and that any personal information remained confidential and the survey responses were anonymous. If the participants did not want to take part in the study, then they were free to choose not to participate. Those who agreed and consented to using their answers as data were free to proceed with the survey, thus being voluntary participation after informed consent.

Data Analysis & Discussion

Demographic Data

Out of the university students that were surveyed, 61.3% (38 people) of participants were female, 37.1% (23 people) were male, and 1.6% (1 person) preferred not to say.

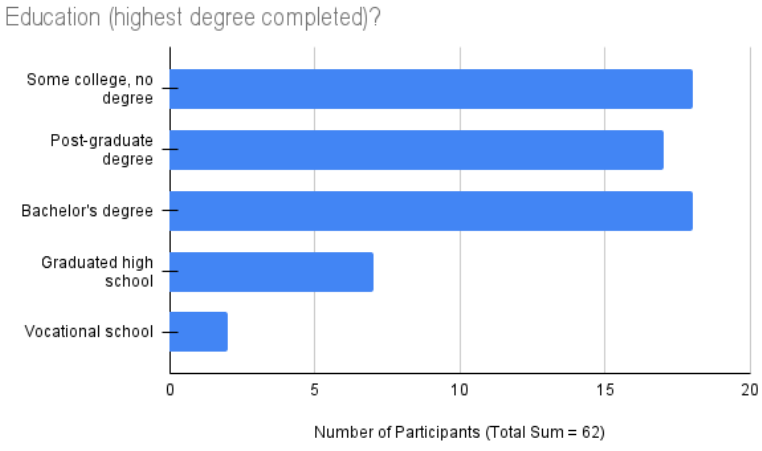

Figure 1. Demographic data on the educational status of the participants

The data on age range was that 62.9% (39 people) of participants were between the ages of 18 and 24, 30.6% (19 people) were between the ages of 25 and 34, 3.2% (2 people) were between the ages of 35 and 44, and 3.2% (2 people) were between the ages of 45 and 54. The data on the highest degree of education completed is shown in Figure 1.

As Figure 1 shows, 11.3% (7 people) of participants had graduated high school, 3.2% (2 people) had completed vocational school, 29% (18 people) had completed some college but had not yet obtained a degree, 29% (18 people) had completed a Bachelor's degree, and 27.4% (17 people) had completed a post-graduate degree. Results show a varied student body allowing for a fair variety of views amongst the participants.

Critical Data Points

In providing the analysis of the survey results, there were a few questions that provided the critical data values for this study. The first question being "Did you ever learn about marine chemical pollution in school before?", this question aimed to explicitly examine what the university students' views were on their own education systems and have them question the role their school curriculums and educational environment played in ensuring students with a basic foundation of ocean literacy for the future. The results for this question supported this paper's claim that there is in fact a lack of proper integration of ocean education, regarding ocean chemical pollution and other such marine pollution issues, into the curriculums of local Taiwanese schools. As shown in Figure 2, the 59.7% majority of students (37 people) answered that they have never learned about marine chemical pollution in school before. Only 22.6% of students (14 people) were absolutely certain when answering that they have in fact learned about these kinds of marine issues in school before, with 17.7% of students (11 people) not being sure.

To provide further analysis, the students' age ranges and levels of education were studied to see if it was possible to derive a correlation between these variables. Out of the 37 people who answered that they have never learned about marine pollution in school before, the majority of the responses came from students who are between the ages of 18 to 24 (19 students; 51.4%) and between the ages of 25 to 34 (15 students; 40.5%), while only the extreme minority of responses coming from older age groups (1 student in the age range between 35 to 44 at 2.7% and 2 students in the age range between 45 to 54 at 5.4%). Therefore, the majority of the students who commented on the lack of ocean literacy in their school curriculums were those from younger age groups, meaning those who were exposed to the most current educational curriculums in Taiwan admit that their curriculums did not do a good job of preparing them and educating them on marine pollution issues. Out of the 37 people who answered

no, when asked for the highest level of education they have been involved in, 14 students responded high school (37.8%), 10 students responded Bachelor's degree (27%), and 13 students responded post-graduate degree (35.1%).

From these specific data points, it can be identified that the responses are divided fairly equally amongst the three levels of education, meaning that the more educated one was didn't really play a significant factor in ensuring whether someone was more educated on marine issues or not. However, looking back at the statistics regarding the ages of people who answered no, the overwhelming majority were those who were from younger age groups, implying that education on all three levels was almost equally bad in ensuring ocean literacy and the trend with age probably meant that students' external learning environments, such as the internet, current news, or the very limited public environmental campaigns, played the biggest factor in the trend of ages observed. In other words, the older the students are, the longer they have been exposed to this external learning environment and thus the more of them that have a better understanding of marine issues. In conclusion, the relative trend of how younger students knew less about these issues could be due to two reasons:

1) the quality of education in this area or the overall integration of marine pollution education into school curriculums decreased or
2) the longer the students are exposed to external factors of education such as the media or already existing public campaigns, which age played a key factor in.

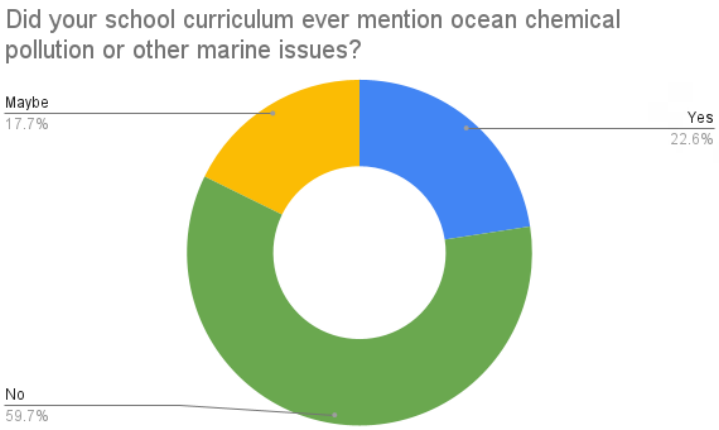

Figure 2. Results on whether students ever learned about marine chemical pollution or other related marine issues in their high school curriculum

The second question being “What do you think is the most serious problem Taiwan’s oceans are facing no?”, this question was meant to test the participants’ knowledge of marine issues and how their educational environments influenced their opinions on this matter. Out of the 5 main types of marine pollution listed, the 3 that were answered the most were plastic pollution, chemical pollution, and solid waste pollution. As illustrated in Figure 3, the responses from the 63 participants showed that the majority 54.8% (34 people) of students stated plastic pollution as the most serious problem, 11.3% (7 people) stated solid waste pollution, 4.8% (3 people) stated thermal pollution, 3.2% (2 people) chose other, and only 25.8% (16 people) answered chemical pollution as the most serious problem Taiwan’s oceans are facing. To put it in other words, only 16 out of 63 people thought that chemical marine pollution, which this paper previously went in depth about its direness and a justification for why it should be considered.

More specifically, out of the 34 people who responded with plastic pollution as the most dire situation in Taiwan, 22 of those participants were those whose high school curriculums didn’t include marine pollution education. Consequently, out of that batch, 6 people answered earlier that their high school curriculum included marine pollution education while the remaining 6 participants were unsure. In comparison, out of the 16 people who answered chemical pollution as the most dire marine pollution situation in Taiwan, 9 of those people have never properly learned about marine pollution in school, while 3 people have learned about it and 4 people were unsure. These numbers show inconsistency in ensuring students with the prerequisite knowledge of marine education, demonstrating how the majority of people whose curriculums had no mention of marine issues were more likely to immediately believe that plastic pollution was more dire than chemical pollution, presumably due to the relatively larger media coverage plastic pollution receives in Taiwan. Comparatively, people who chose chemical pollution as the most dire situation didn’t display a statistically relevant percentage breakdown of people who learned about marine issues in school versus people who didn’t. However, due to the lack of marine pollution education in school curriculums as demonstrated by the statistics shown in Figure 2, only a minority of students realize the real serious nature behind ocean chemical pollution. The majority of students who chose plastic pollution were highly likely to never been educated on the fact on there are many current recovery projects targeting plastic pollution in Taiwan and it is in fact ocean chemical pollution that is not getting enough recognition as a serious marine problem. As proven in the literature analysis, the prolonged harms of ocean chemical pollution will continue if students aren’t educated on the distressing reality of ocean chemical pollution and will continue to acknowledge plastic pollution as the most serious problem simply due to the fact that the term is heard much more frequently in media broadcasting stations and news articles. As a part of the marine pollution

education that needs to be integrated into school curriculums, students must be taught a clearer system of defining the seriousness of an ecological problem, where both the level of environmental harm and the number of current targeted recovery projects and organizational efforts to prevent the harms are taken into consideration to evaluate the urgent nature of a problem.

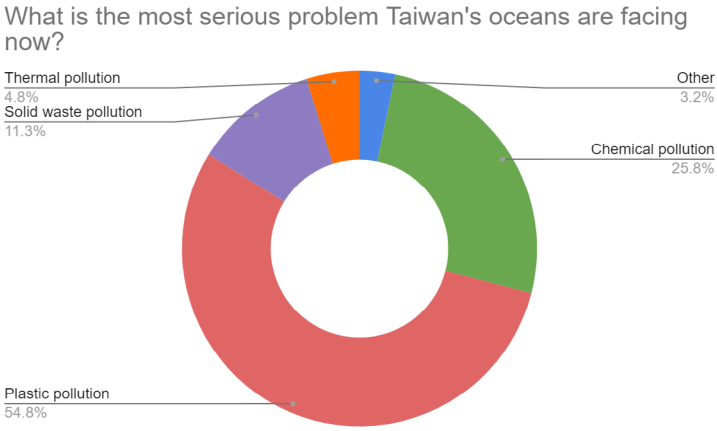

Figure 3. Results on what the students personally thought was the most serious problem that Taiwan's oceans are facing in the status quo

The students were later asked questions about their confidence in Taiwan's marine ecosystem safety and health, Figure 4 shows the results being a variety of answers in this case.

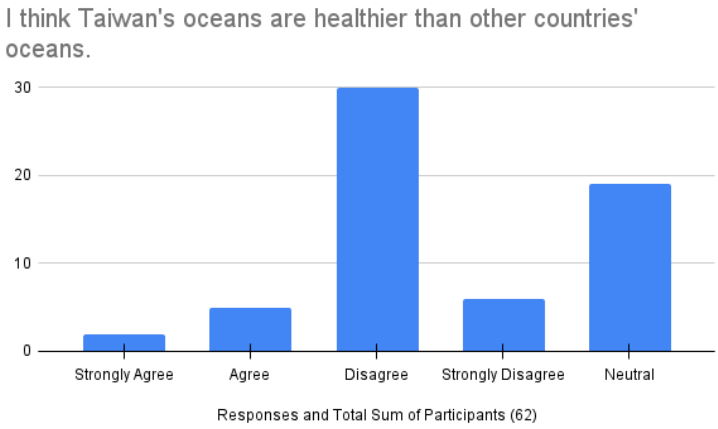

Figure 4. Results on the students' opinions on whether Taiwan's oceans safer and cleaner when compared to other countries' oceans

In response to the statement "I think Taiwan's oceans are healthier than other countries' oceans: 3.2% (2 people) strongly agreed, 8.1% (5 people) agreed, 30.6% (19 people) remained neutral, 48.4% (30 people) disagreed, and 9.7% (6 people) strongly disagreed. These statistics prove how there is a considerable variation in the students' answers and this in turn will affect the ability for these university students to later collaborate to work towards marine pollution recovery projects and prevention policies. This proves the need for a more effective integration of marine pollution education in school curriculums to enable the growth of a more consistent mindset towards protection of Taiwan's oceans amongst young minds. A clearer, more unified viewpoint established amongst students will aid the effective development of successful preventive measures of marine pollution issues.

The slight majority of students, however, did disagree to the fact that Taiwan's oceans are healthier and safer than other countries'. This piece of data also shows that there is a certain urge in the youth population of Taiwan to take better care of Taiwan's oceans. If they are provided with proper education on these topics and a healthy development of ocean literacy from a young age, these students and future young workers will be more capable of launching legitimate recovery projects and ultimately better practice sustainable decision making via successfully passing and monitoring marine protection policies. Another data point to support this assertion was gathered from the students' responses to the question on whether they believed that ocean chemical pollution would have a direct negative impact on human health and lifestyle.

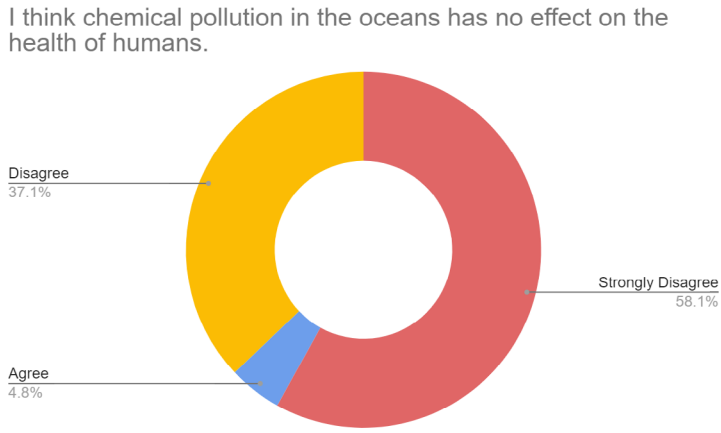

Figure 5. Students' responses to whether they thought ocean chemical pollution affected human health

Responses had an overwhelming majority of students who disagreed with the statement "I think chemical pollution in the oceans has no effect on the health of humans" with: 58.1% (36 people) who strongly disagreed, 37.1% (23 people) who disagreed, and 4.8% (3 people) who agreed with the statement. These results are shown in Figure 5, demonstrating that there is a general concern for the prevalence of ocean chemical pollution due to the threat it poses to human health. Furthermore, this shows how students do have an urge to help due to the fear brought about by the possible risk it poses to humans, however, proper marine pollution education is necessary for the effective use of the widespread concern in the youth population of Taiwan to better solve these marine issues.

This statistic proves how only a minority of the survey population have had actual marine pollution education in their school curriculums, which when applied to the wider population of university students in Taiwan is very concerning due to the fact that the majority of Taiwanese society's future workers and young minds have not had the proper schooling on the dire topics of ocean chemical pollution and marine pollution issues.

Conclusion

According to the conducted research study, results clearly demonstrate the need for the adequate integration of ocean chemical pollution and other marine issues education into the school curriculum. Even though it was a limited survey, the gathered statistics still prove the claim made in this paper. This paper has conducted an analysis and thorough investigation of ocean chemical pollution both on how certain toxic chemicals affect marine biodiversity and how each case of ocean chemical pollution applies to Taiwan. Through the literature analysis, this paper has proven the seriousness of the problem that ocean chemical pollution is in Taiwan's oceans and have also proposed the best way to lessen the environmental harms. To better solve problems such as ocean chemical pollution that do not get much attention from public or governmental sectors, proper marine education and development of students' ocean literacy must be enforced. The introduction of marine education into school curriculums can be brought upon, for example, by the development of a Taiwan Marine Education Act, which sets proper guidelines for schools to develop their curriculum to allow students to be educated on topics such as ocean chemical pollution and other marine issues. This will allow for more consistent social awareness on the topic of ocean chemical pollution and also the enhancement of a basic understanding of such topics in students.

A basic understanding of ocean chemical pollution and other marine issues are crucial in the next generation of young minds in Taiwan due to the potential for

1) increased public support when the government or other private organizations take charge to implement solutions

2) development of life styles that reduce the risk of man-made ocean chemical pollution in youth populations
3) the growth of a common willingness to contribute to preventive measures.

In future research, investigations on university students can be done on a larger sample population of students and from a greater variety of universities in Taiwan. These future studies will allow for the gathering of legitimate data to back up the development of marine education in school curriculums. Ocean chemical pollution is a real threat to Taiwan's oceans and educating the youth of Taiwan is the best way to combat the prolonged destruction it has on the marine ecosystems of Taiwan.

REFERENCES

Bacey, J. (2000). *Environmental Fate of Hydramethylnon*. Environmental Monitoring & Pest Management Branch, Department of Pesticide Regulation. http://piat.org.nz/uploads/PIAT_content/pdfs/Environmental%20fate%20of%20Hrdramethylnon.pdf

Bardach, J. E., Fujiya, M., & Holl, A. (1965). Detergents: Effects on the Chemical Senses of the Fish *Ictalurus natalis* (le Sueur). *Science*. *148*(3677), 1605–1607. https://science.sciencemag.org/content/148/3677/1605.abstract

Charlier, P. (2016). *Grounded Ship Presents Serious Environmental Threats*. Taiwan English News. https://taiwanenglishnews.com/grounded-ship-presents-serious-environmental-threats/

Chen, M.-H., Lin, Y.-T., Lai, C.-C., Chou, L.-S., & Chen, C.-Y. (2020). Tissue concentrations of Fe, Zn, Cu and Mn of four Taiwanese toothed cetaceans. *Marine Pollution Bulletin*, *158*, 111094. https://doi.org/10.1016/j.marpolbul.2020.111094

Chiau, W. Y. (2005). Changes in the marine pollution manage system in response to the *Amorgos* oil spill in Taiwan. *Marine Pollution Bulletin*. *51*(8–12), 1041–1047. https://doi.org/10.1016/j.marpolbul.2005.02.048

Chou, R. J. (2013). Addressing watercourse sanitation in dense, water pollution-affected urban areas in Taiwan. *Environmental and Urbanization*. *25*(2), 523–540. https://doi.org/10.1177/0956247813501140

Cox, C. (1994). Insecticide Fact Sheet – Cyfluthrin. *Journal of Pesticide Reform*. *14*(2), 28–34. shorturl.at/fqBGJ

Everington, K. (2018). *Surfers stuck in sewage sludge at southern Taiwan beach*. Taiwan News. https://www.taiwannews.com.tw/en/news/3420075

Fang, T.-H., Hwang, J.-S., Hsiao, S.-H., & Chen, H.-Y. (2006). Trace metals in seawater and copepods in the ocean outfall area off the Northern Taiwan Coast. *Marine Environmental Research*, *61*(2), 224–243. https://doi.org/10.1016/j.marenvres.2005.10.002

Fauville, G., Strang, C., Cannady, M. A., & Chen, Y.-F. (2018). Development of the International Ocean Literacy Survey: Measuring Knowledge Across the world. *Environmental Education Research*, *25*(2), 238–263. https://doi.org/10.1080/13504622.2018.1440381

Howard, J. (2019). *Marine pollution, explained*. National Geographic. https://www.nationalgeographic.com/environment/article/critical-issues-marine-pollution

Hu, Y. C., & Chen, S. C. (2012). *Taiwan's Chemical Industry: Looking Back and Looking Ahead*. American Institute of Chemical Engineers. http://fscarbonmanagement.org/sites/default/files/cep/20120441.pdf

Kunz, A., Walther, B. A., Löwemark, L., & Lee, Y.-C. (2016). Distribution and quantity of microplastic on sandy beaches along the northern coast of Taiwan. *Marine Pollution Bulletin*, *111*(1–2), 126–135. https://doi.org/10.1016/j.marpolbul.2016.07.022

Liu, S. C., Lin, H. S., & Tsai, C. Y. (2019). Ninth grade students' mental models of the marine environment and their implications for environmental science education in Taiwan. *The Journal of Environmental Education*. *51*(1), 72–82. https://doi.org/10.1080/00958964.2019.1633990

Made Safe. (2016). *How to Avoid Toxic Chemicals in Plastics*. Made Safe. https://www.madesafe.org/avoid-toxic-chemicals-plastics/

Micronics Engineered Filtration Group. (2021). *Industrial Wastewater: What is it & Where does it come from?* Micronics. https://www.micronicsinc.com/filtration-news/what-is-industrial-wastewater/

Monosson, E. (2000). Reproductive and developmental effects of PCBs in fish: a synthesis of laboratory and field studies. *Reviews in Toxicology*, *3*, 25–75. https://semspub.epa.gov/work/02/68517.pdf

Moore, J. T., Hren, C., & Mikulecky, P. J. (2021). *The Top 10 Industrial Chemicals*. Dummies. https://www.dummies.com/education/science/chemistry/the-top-10-industrial-chemicals/

National Oceanic and Atmospheric Administration. (2021). *How much oxygen comes from the Ocean?* National Ocean Service. https://oceanservice.noaa.gov/facts/ocean-oxygen.html

Novelli, A., Vieira, B. H., Braun, A. S., Mendes, L. B., Daam, M. A., & Espíndola, E. L. (2016). Impact of runoff water from an experimental agricultural field applied with Vertimec® 18EC (abamectin) on the survival, growth and Gill morphology of zebrafish juveniles. *Chemosphere*, *144*, 1408–1414. https://doi.org/10.1016/j.chemosphere.2015.10.004

Srivastava, N., Kumari, U., Rai, A. K., Mittal, S., & Mittal, A. K. (2014). Alterations in the gill filaments and secondary lamellae of *cirrhinus mrigala* exposed to "Nuvan," an organophosphorus insecticide. *Journal of Histology*, *2014*, 1–11. https://doi.org/10.1155/2014/190139

Taiwan Environmental Protection Administration. (2018). *Plastic-Free Ocean Promoted in Response to International Trend*. Environmental Protection Administration Executive Yuan, R.O.C. (Taiwan). https://www.epa.gov.tw/eng/F7AB26007B8FE8DF/fea08fd0-3afe-4ba9-a9c2-d5f6efd337d8

Tsai, L. T., & Chang, C. C. (2018). Measuring ocean literacy of high school students: psychometric properties of a Chinese version of the ocean literacy scale. *Environmental Education Research*. *25*(2), 264–279. https://doi.org/10.1080/13504622.2018.1542487

Tsai, W. T. (2019). Promoting the Circular Economy via Waste-to-Power (WTP) in Taiwan. *Resources*, *8*(2), 95. https://doi.org/10.3390/resources8020095

US Environmental Protection Agency. (2000). *Public Health Concerns About Chemical Constituents in Treated Wastewater and Sludge*. Environmental Protection Agency (EPA). https://www3.epa.gov/npdes/pubs/mstr-ch6.pdf

Villarrubia-Gomez, P., Cornell, S.E., & Fabres, J. (2018). Marine plastic pollution as a planetary boundary threat – The drifting piece in the sustainability puzzle. *Marine Policy*, *96*, 213–220. https://doi.org/10.1016/j.marpol.2017.11.035

Walther, B. A., Yen, N., & Hu, C. S. (2021). Strategies, actions, and policies by Taiwan's ENGOs, media, and government to reduce plastic use and marine plastic pollution. *Marine Policy*, *126*, 104391. https://doi.org/10.1016/j.marpol.2021.104391

Wong, S. (2021). *Domestic consumption of agricultural pesticides in Taiwan 2010-2020*. Statistica. https://www.statista.com/statistics/816857/taiwan-agricultural-pesticides-domestic-consumption/

Worm, B., Elliff, C., Fonseca, J. G., Gell, F. R., Serra-Gonçalves, C., Helder, N. K., Murray, K., Peckham, H., Prelovec, L., & Sink, K. (2021). Making ocean literacy inclusive and accessible. *Ethics in Science and Environmental Politics*, *21*, 1–9. https://doi.org/10.3354/esep00196

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