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The Trend of Water Quality in the Heavy Industrial Area of Batangas Bay East, Verde Island Passage, Philippines and its Surrounding Areas

June 2022

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Executive Summary

Rising pollutants in aquatic ecosystems can have major implications on ecological balance. Impacts vary from a decrease in biodiversity, ecosystem function changes by habitat and food chain alterations, and loss of productivity. One of the coastal ecosystems of the country, the Verde Island Passage (VIP), is currently facing various threats due to ever-increasing population, over-harvesting of resources, overdevelopment, overexploitation, climate change and pollution. The VIP is a biodiversity hotspot, the epicenter of marine shore fish biodiversity in the world. However, it has also become a hotspot of point and nonpoint pollutants coming from industrial activities and concentrated human activity in recent times.

VIP houses five out of the six fossil gas power plants in the country with eight more fossil gas power plants [1] and seven liquified natural gas (LNG) terminals [2] being proposed in Province of Batangas. Pollution and disturbance from the further expansion and operation of LNG and fossil gas projects in Batangas is seen to exacerbate the existing pressures in the area. It is imperative that further developments around VIP's coastal area is well regulated. And a regular water monitoring system in the heavy industrial zones along the coast of VIP are needed.

The aim of this study is to collate data on the water quality values within the VIP, focusing on one of the heavy industrial areas of Batangas Bay to identify possible trends occurring in the water quality of the said site over a temporal scale.

Secondary data on water quality studies conducted along the coast of the heavy industrial zone of Batangas Bay east and nearby areas were gathered. To supplement this data set, water was also collected for analysis from the coast fronting Barangays Ilijan and Dela Paz in Batangas City. Water quality will then be assessed using the water quality and general effluent standards established by the DENR Administrative Order No. 2021-19.

Based on the DENR Water Quality Standards (WQS), the sampled waters cannot be categorized as Marine Water Class SC. At the least, Class SC must be attained for it to be conducive for propagation of fish and other aquatic resources, commercial and sustenance fishing, wildlife sanctuaries, and recreational activities. Among all parameters tested, excessive concentrations of phosphate, chromium, total copper, lead, and zinc exhibits the area's noncompliance to Class SC.

Results of water quality analysis of primary parameters show that phosphates, detected at 0.533 mg/L on average across the sampling sites, exceeded Class SC standards (0.2 mg/L). High concentration of phosphates could result to eutrophication or overfertilization. A parallel marine ecology assessment conducted in the same area provides evidence already of algal growth on coral assemblages. Although it did not exceed the DENR WQS in the sampled waters, sulfate is another primary parameter that is of concern. Sulfate ions are involved in reactions which affect solubility of metals and other substances. This is significant as the study found that there are several heavy metals that exceeded the standards.

For secondary parameters, the study reveals several heavy metals of concern exceeded Class SC standards, including chromium, copper, and lead. These elements are potentially toxic metals found in water due to both natural and anthropogenic processes. These can be detrimental to ecological health, and human health due to bio accumulation in commercially important fish. In the case of chromium, it could cause liver damage in high concentrations. Algae and fish can naturally regulate heavy metals such as copper. High concentration of copper in the study area could be attributed to the low fish abundance. Lead, detected at high concentrations across all sampling sites can also be one of the most toxic metals for aquatic life and coastal residents.

While several heavy metals were detected and exceeded Class SC standards, concentrations of these metals are on the rise still. Secondary data gathering dating back to 2015 reveals that chromium, copper, lead, and mercury all show a rising trend in terms of concentration in Barangays Ilijan and Dela Paz. Mercury concentrations in particular, did not exceed Class SC standards. However, mercury remains one of the most serious contaminants in aquatic resources. Much like other detected heavy metals, mercury has been linked to coal combustion, electrical power generation and industrial waste disposal through point source discharges. Current trends project continued exposure to serious contaminants and potentially, additional and compounding risks in the future.

Despite being declared as one of the most biodiverse marine ecosystems in the world, the VIP Marine Corridor is still being eyed for development of various industries that will introduce additional pressures. With 15 more new fossil gas facilities proposed to be built in the Province of Batangas, it is very important for stakeholders to create a regular and year-round water quality monitoring system along the coast, not only to know the present conditions of its waters but also to determine the possible effects should more fossil gas and other heavy industry facilities be constructed and be allowed to operate in the area.

Community-led initiatives are especially important to ensure transparency and availability of the data to the public. The lack of data or the difficulty to access available data to properly monitor the water quality along the coast of the heavy industrial area within the VIP is seen as a gap that needs to be addressed by concerned agencies and organizations. Further monitoring will be able to confirm the rising trend of key parameters as observed in this study so that appropriate measures can be taken to address this potential problem.

Contents

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I. Introduction

The decline of water quality in coastal waters is a huge concern for many nations as this is closely intertwined with human health, food production, ecosystem function, and economic growth. Water pollution is said to be one of the major challenges that many nations will be facing in the 21st Century. [3] Pollutants can have various effects on biological life ranging from metabolic malfunction, genetic and phenological damage to death. If not lethal, exposure to water pollutants can lead to fitness changes, a decrease in biodiversity, ecosystem function changes by habitat and food chain alterations, and loss of productivity. [4] The United Nations Sustainable Development Goals brings this concern to the forefront of international action, as it highlights the importance of preserving all of the world's aquatic ecosystems through the elimination of potential hazards from the disposal of effluents and the protection of water-related ecosystems, including rivers, lakes, and aquifers from the introduction of any type of pollution to water bodies. [5] Coastal waters, in particular, bear the brunt of this problem as they are the endmembers of point and nonpoint pollutants coming from land. Coastal areas are also subject to concentrated human activity and activity that add on to this pressure.

Such is the case for the Philippine archipelago where the coastal waters house roughly 9% of the world's coral reefs and where more than 1 million fishers are dependent on for livelihood. Philippine reefs bear global significance as they are located within the coral triangle, the region which houses some of the most biodiverse coral ecosystems in the world. A study by Carpenter and Springer (2005) identified the Verde Island Passage, a body of water found in the northwestern side of the Philippine archipelago, bounded by the provinces of Batangas, Oriental and Occidental Mindoro, Romblon, and Marinduque (Fig. 1) as the epicenter of marine shore fish biodiversity and is said to house 60% of the world's known shore fish species. [6]

However, the country is also considered to be a biodiversity hotspot where natural resources face various threats. As of 2012, it was reported that nearly 60% of the coral reefs in the country are threatened by coastal development and associated sewage. [7] The country's coastal water and marine ecosystems are under high and constant threat from the ever-increasing population, over-harvesting of resources, overdevelopment, overexploitation, climate change and pollution. [8]

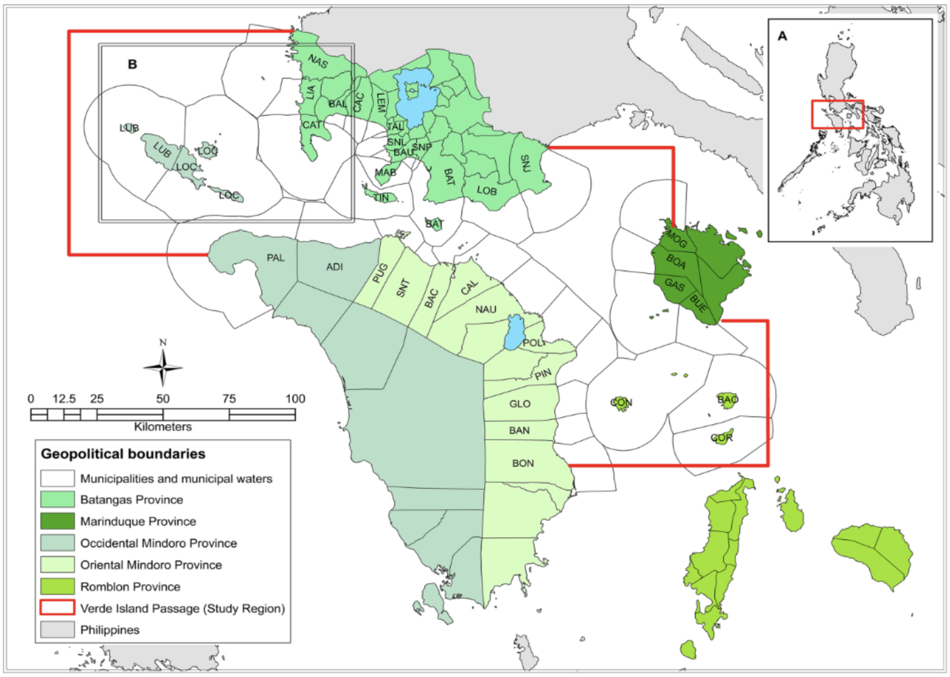

Figure 1. *Map of the Verde Island Passage showing the different provinces bordering the marine corridor. Image Source: Horigue et al., 2015*

Ironically, various threats to the biodiversity in the Verde Island Passage have been identified. Anthropogenic activities such as overfishing, shipping, and pollution from upland agriculture and shoreline development and industries are some of the biggest threats to VIP. [9] At present, the VIP houses five out of the six fossil gas power plants in the country. It is also a busy shipping route servicing marine vessels that enter and exit Manila, the country's capital.

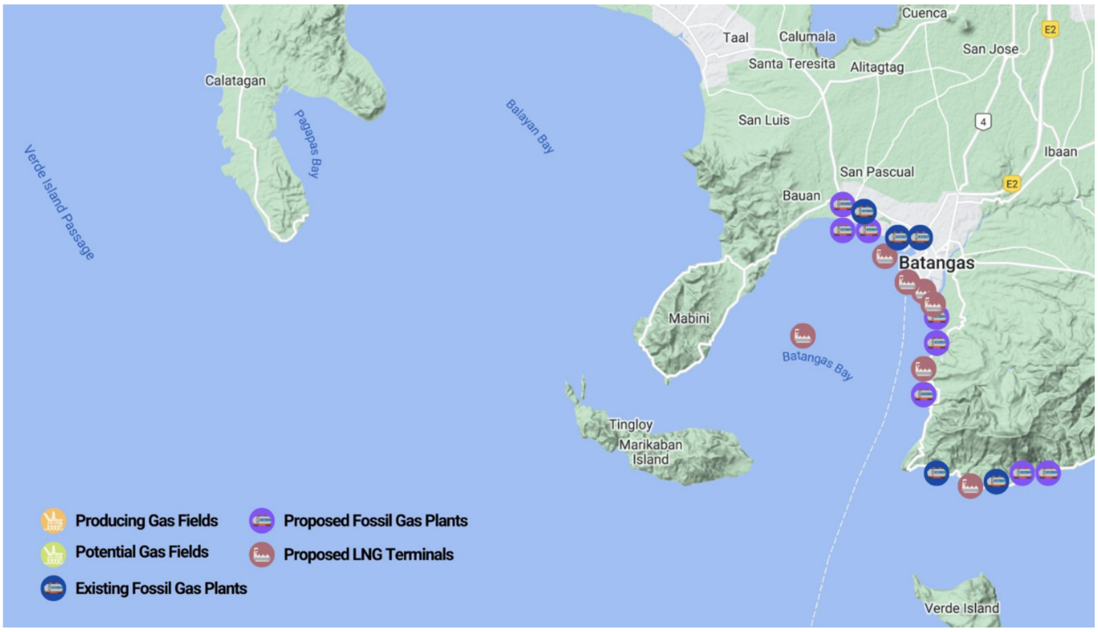

Figure 2. *Location of existing and proposed fossil gas plans and LNG Terminals along the coast and in the waters of Batangas Bay*
Image Source: CEED, 2022.

Aside from the present facilities already operating within the VIP, eight more fossil gas power plants [10] and seven liquified natural gas (LNG) terminals [11] are being proposed to be built in the Province of Batangas (Fig. 2). [12] The expectation of having these facilities in communities is usually high with the hopes of locals gaining jobs brought about by the said industry, revenues, and compensation payments. However, much of the existing research suggests that coastal communities remain on the fringes of these developmental prospects, bearing many costs without receiving the due benefits. [13] Pollution and disturbance from the further expansion and operation of LNG and fossil gas projects in Batangas is seen to exacerbate the existing pressures that are already challenging the survival of marine life in VIPMC as well as the health, food security, and livelihood of coastal communities and businesses around it. [14]

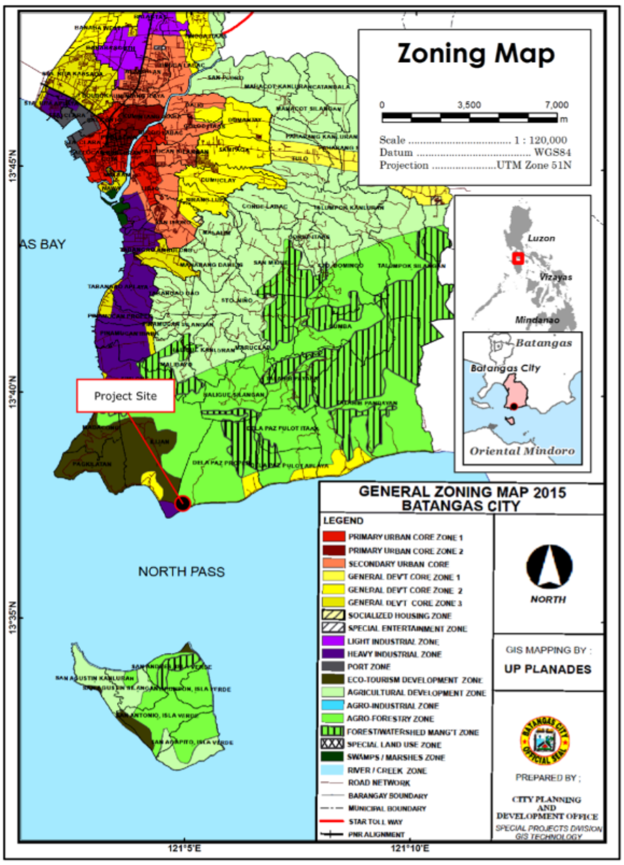

Figure 3. *Zoning map of the eastern part of Batangas Bay showing the heavy industrial zone covering Barangays Ilijan and Dela Paz.*
Image source: EIA report of the Proposed 1,700 MW Batangas Combined Cycle Power Plant Project, 2021.

Several areas along the coast of Batangas Bay have been identified as light to heavy industrial areas for the operation of various industries, including four fossil gas power plants. Barangays Ilijan and Dela Paz are two of the barangays that fall within the heavy industrial zone and where two more fossil fuel facilities are set to start commissioning this year (Fig. 3). This is an area of concern as pollutants such as heavy metals released from coal-fired plants and their subsequent deposition to the environment are well known to significantly alter the environmental quality of surrounding areas. [15] Coal-fired power plants are considered to be one of the largest sources of mercury pollution in America as reported in its National Emissions Inventory in 2005. [16]

Considering the global significance of the Verde Island Passage as the epicenter of marine shore fish biodiversity and the present and looming threats to its coastal waters, it is imperative that further developments around VIP's coastal area should be well regulated. Issues pertaining to water quality are primarily regional and site-specific. It is very important therefore to establish a regular water monitoring system in the heavy industrial zones along the coast of VIP, such as the area identified in this study.

The aim of this study is to collate data on the water quality values within the Verde Island Passage, focusing on one of the heavy industrial areas of Batangas Bay to identify possible trends occurring in the water quality of the said site over a temporal scale. The data will make use of previously reported values that have been published from past reports. Actual water quality analysis will also be done to represent present values for comparison.

II. Methods

Data from water quality studies conducted along the coast of the heavy industrial zone of Batangas Bay east and nearby areas were collected from previous studies and available publications. Values taken from these studies, conducted in different years will be used to get a glimpse of the quality of the water in the said site over a temporal scale. To supplement this data set, water was also collected for analysis from the coast fronting two barangays in Batangas City, which are nearest to an industrial area and where two more fossil fuel facilities are set to be constructed within the year.

Water was collected along the coast of Barangays Ilijan and Dela Paz (Fig. 4). Three stations were established in Barangay Ilijan while another three stations were established in Barangay Dela Paz. Parameters that were collected are shown in Table 1. The water samples were delivered to a DENR accredited laboratory for analysis, less than 24 hours after collection to preserve the integrity of the samples. Water quality will be assessed using the water quality and general effluent standards established by the DENR Administrative Order No. 2021-19. [17] Primary parameters are the parameters that are taken for water classification by the Department of Environment and Natural Resources. The secondary parameters on the other hand are the parameters used in conducting environmental impact assessments.

Figure 4. The study sites showing the points where water samples were collected for Barangay Ilijan (yellow dots) and Barangay Dela Paz (green dots)

PRIMARY PARAMETERS	METHOD
pH	Electrometric
Biological Oxygen Demand	Azide Modification (Dilution Technique)
Dissolved Oxygen	Azide Modification
Chloride	Argentometric
Boron	Carmine
Fluoride	Ion-selective Electrode
Total Suspended Solids	Gravimetric
Coliform	Multiple Tube Fermentation Technique
SECONDARY PARAMETERS - INORGANICS	
Ammonia	Phenate
Nitrate	Brucine-Sulfanilic
Phosphate	Stannous Chloride
Sulfate	Turbidimetric
SECONDARY PARAMETERS - HEAVY METALS	
Arsenic	Hydride Generation - AAS
Cadmium	Flame AAS
Chromium	Flame AAS
Total copper	Flame AAS
Iron	Flame AAS
Lead	Flame AAS
Manganese	Flame AAS
Mercury	Cold Vapor Technique - AAS
Nickel	Flame AAS
Selenium	Hydride Generation - AAS
Zinc	Flame AAS

Table 1. *Water parameters used for the analysis of water samples collected from the coast of Barangays Ilijan and Dela Paz.*

It is noteworthy to mention that the data collected from other studies were not taken in the same exact location but should be able to provide a picture of the water quality trends of the heavy industrial area of the eastern part of Batangas Bay. Regular water quality monitoring is very important in this area as the construction and operation of fossil fuel facilities are known to pose certain risks that have been reported by many studies to compromise the water quality and the associated ecosystems of coastal areas.

III. Results and Discussions

Tables 2 and 3 show the mean results for the primary and secondary parameters that were taken in Barangay Ilijan (n=3) and Barangay Dela Paz (n=3). To maintain vital conditions where the marine water quality is protected and conducive for propagation of fish and other aquatic resources, commercial and sustenance fishing, wildlife sanctuaries, and recreational activities, water quality parameters must comply to the DENR 2021 Water Quality Standards (WQS): Marine Water Class SC.

At the least, Class SC must be attained to secure beneficial environmental services for local residents and marine life. Among all parameters tested, excessive concentrations of phosphate, chromium, total copper, lead, and zinc exhibits the area’s noncompliance to Class SC. In addition, if the prior 2016 WQS, which had stricter limitations, was used, sulfate will also not comply with Class SC.

PRIMARY PARAMETERS	Barangay Ilijan	Barangay Dela Paz	DENR Classification			
			SA	SB	SC	SD
pH	8.31	8.32	7.0-8.5	7.0-8.5	6.5-8.5	6.0-9.0
Color	<5	<5	5	50	75	150
BOD (mg/L)	7	7	n/a	n/a	n/a	n/a
DO (mg/L)	6.9	7	6	6	5	2
Nitrate (mg/L)	0.03	0.03	10	10	10	15

Phosphate (mg/L)	0.532	0.534	0.1	0.2	0.2	0.4
Total Suspended Solids (mg/L)	11.6	4	25	50	80	110
Coliform (MPN/100 ml)	< 1.8	< 1.8	<20	100	200	400
SECONDARY PARAMETERS - Inorganics						
Ammonia as NH3-N	0.01	<0.004	0.04	0.06	0.06	0.3
Boron	3.9	3.1	0.75	0.75	5	20
Fluoride	0.533	0.534	1.5	1.5	1.5	3
Sulfate	2500	2,653	n/a	n/a	n/a	n/a
Selenium	<0.001	<0.001	0.01	0.01	0.1	0.2

Table 2. *Water analysis results for the primary parameters, compared to the standards set by DENR to classify marine waters in the Philippines (DAO 2021-19)*

SECONDARY PARAMETERS - Heavy Metals	Barangay Ilijan	Barangay Dela Paz	DENR Classification			
			SA	SB	SC	SD
Arsenic	< 0.001	< 0.001	0.01	0.01	0.02	0.04
Cadmium	<0.003	<0.003	0.003	0.003	0.005	0.01
Chromium	0.06	0.07	0.05	0.05	0.05	0.1
Total Copper	0.095	0.101	0.02	0.02	0.02	0.04
Iron	0.19	0.19	1.5	1.5	1.5	7.5
Lead	0.12	0.13	0.01	0.01	0.05	0.1
Manganese	<0.01	<0.01	0.4	0.4	0.4	4
Mercury	<0.0006	<0.0006	0.001	0.001	0.002	0.004
Nickel	<0.01	<0.01	0.02	0.04	0.06	0.3
Zinc	0.096	0.086	0.04	0.05	0.08	1.5

Table 3. *Water analysis results for the secondary parameters, compared to the standards set by DENR to classify marine waters in the Philippines (DAO 2021-19)*

3.1 Sulfate

Sulfate is a naturally occurring compound that is produced from the breakdown of organic matter, such as leaves that fall into bodies of water, of water passing through rock or soil containing gypsum and other common minerals, or of atmospheric deposition. Although the DENR 2021 WQS no longer provides a reference standard for sulfate, the substantial presence in the area can be a result of municipal or industrial discharges such as coal mines, power plants, phosphate refineries, and metallurgical refineries. [18] On the other hand, the prior DENR 2016 WQS provided a reference standard for sulfate. In the 2016 WQS, Class SC marine waters has a limit of 275 mg/L. Detected sulfate in the study sites range from 2500 to 2653 mg/L, almost 10 times above the limit. Even for Class SD of the 2016 WQS, the class of marine waters with the highest allowable concentrations of harmful pollutants, the limit for sulfate is 500 mg/L. Very limited studies have been published on the effect of high concentrations of sulfates in coastal waters, but this compound has been known to form strong acids which changes the pH of a system. Sulfate ions also are involved in complexing and precipitation reactions which affect solubility of metals and other substances. [19]

3.2 Phosphates

Phosphates on the other hand are essential nutrients for the growth of plankton and plants that serve as food for other aquatic organisms. However, in the case of Barangays Ilijan and Dela Paz, high concentration of phosphates could result to eutrophication or overfertilization. Detected concentration of phosphate in the study sites range from 0.532 to 0.534 mg/L, more than twice the limit for Class SC. This range does not fall under Class SD either, the class for marine waters with the highest limits. Detected concentration of phosphate is not suitable for propagation of fish and other aquatic resources.

Phosphate is one of the two drivers of marine eutrophication and excessive amounts of which can lead to algal blooms, anoxic conditions and ocean acidification. [20] Once nutrients are depleted by the excessive growth algae and plants, they will soon die and decompose thus depleting the dissolved oxygen next. Without both essential parameters, aquatic life will perish.

Eutrophication may already be underway in the area. Based on findings of a parallel marine ecology assessment in the same area, algal growth on coral assemblages is already present. [21] Phosphates can be toxic to humans and other aquatic organisms, but only in very high concentrations and could result to digestive problems. Phosphates are commonly found in sewage, detergents, and organic pesticides. Another use for phosphates is for treating boiler waters. [22] Occurrence of eutrophication becomes more likely as phosphate availability rises in the water body.

Data collected in the past years were also collated to serve as a rough comparison of the water quality of the heavy industrial zone of Batangas Bay. Table 4 shows the collation of water quality data taken during 2015 in the Municipality of Lobo; [23] 2019 in Barangay Dela Paz, [24] 2020 in Barangay Ilijan, [25] and the recent samples collected by this study in 2021, together with the trends of the values over the said years. Lobo, although not part of the heavy industrial zone, is the municipality next to Barangay Dela Paz and is situated roughly 15 kilometers away from the heavy industrial area.

3.3 Chromium

Among the many contaminants reaching the coastal area, heavy metals have been identified as among the most significant due to their persistence and potential implications to the health of the environment. [26]

Chromium is a potentially toxic metal that occurs in the water due to both natural and anthropogenic processes. It exists mainly in three oxidation states which are Cr (0), Cr (III), and Cr (VI). Cr (0) is the metallic form of chromium that, once introduced into the water, forms Cr (III) and Cr (IV) which are the most predominant forms in both land and water bodies. [27] Chromium (IV) pollution is largely produced in industries related to energy production, manufacturing of metals and chemicals and wastewater treatment. [28]

Under DENR's water quality standards, the maximum concentration of chromium for Class SC marine waters is 0.5 mg/L. Detected concentration of chromium in the study sites range from 0.06 and 0.07 mg/L. This range falls under Class SD, which is considered for purpose as navigable waters only. Higher concentrations can be considered as a risk to human health, the degrees of which can vary depending on concentration and exposure. Cr (IV) which is the most toxic form of the metal has been reported to cause liver damage, internal hemorrhage, respiratory disorders, and have been labeled as carcinogenic to humans under the International Agency for Research on Cancer. [29]

The concentrations recorded in the present sampling activity compared to the data reported in the past investigations have gone past the recommended range. It is noteworthy to mention that if the same increasing trend were to be observed in the following years, concentrations of this metal in the heavy industrial area of Batangas Bay could increase further and result into an even wider gap from the ideal values.

3.4 Total Copper

Copper on the other hand is a naturally occurring metal that is present in coastal ecosystems in low concentrations. It is an essential trace element that is required by many aquatic organisms. However, copper is also easily accumulated in plant and animal tissue, and toxic effects are usually seen when the rate of copper accumulation exceeds the organism's capacity to remove it from its system. [30]

Toxic effects of copper can vary from one organism to another. Copper is acutely toxic to mullet at a concentration of 5.8 ug/L and to crabs as 600 ug/L. [31] Gastropods were reported to be more resilient with tolerance at 0.8 to 1.2 mg/L. Certain species of marine and freshwater algae have also been reported to be particularly sensitive to copper which can lead to decreases in algal growth. [32]

he partitioning and bioaccumulation of copper is controlled not only by chemical equilibria but also very much by biological processes. Aquatic organisms such as algae and fish release organic ligands which bind to copper and regulate its update and bioavailability. [33] Thus, the more organisms are present in an ecosystem to produce organic ligands, the better is the system's buffering capacity to counter the absorption of copper by other aquatic organisms.

Findings of CEED's Marine Ecology Assessment in the area reveals low abundance of fish, fish that could potentially aid in regulating copper. [34] Under the DENR WQS, the maximum copper concentration for Class SC of marine water bodies is 0.02 mg/L. Detected concentrations in the study sites range from 0.095 to 0.101 mg/L, which is about 10 time larger than the 0.02 mg/L limit established for Class SC marine waters.

This is an area of concern because (1) such values are considered toxic for marine organisms and (2) even though this portion of the coast has been declared as a heavy industrial area, this is flanked by communities that live along the coast of Barangays Ilijan and Dela Paz. However, the values should be taken with caution as sampling was only done once for this particular area of the coast and past data has reported no detectable limits of copper. A regular monitoring system should be established in the future to confirm or refute this observed trend so that appropriate measures can be taken if such values are confirmed by repetitive samplings.

3.5 Lead

Lead is a toxic metal that is naturally found in the earth's crust and is ubiquitous in the aquatic environment. Anthropogenic activities can also introduce this metal into waterways and coastal waters through the manufacture of batteries, paint, cement as well as mining and smelting. [35] Different sources of lead are present in the study sites as indicated by the high concentration of lead detected. It ranges from 0.12 to 0.13 mg/L, which is more that double the limit set for Class SC marine waters. As it stands, water quality is not conducive for the growth of aquatic resources.

High concentration of lead can be harmful as it can become accumulated into the tissues of marine organisms as it is capable of forming a flexible bond with oxygen and sulfur atoms in proteins. Lead exposure therefore can be fatal to aquatic animals, even in small concentrations because of bioaccumulation. The toxic effects of lead can range from disruptions to an organism's physiological and biochemical functions to neurotoxicity. [36] Toxic concentrations also vary among aquatic organisms and can range from 20 ul/L (algae) to 27,000 ug/L (for soft-shelled clams). [37]

3.6 Mercury

Mercury is a naturally occurring metal that is found in a mineral called cinnabar. However, one of the main conduits for mercury to enter aquatic ecosystems are human activities that involve coal combustion, electrical power generation and industrial waste disposal. [38] Mercury is one of the most serious contaminants in many coastal waters around the globe. It is readily absorbed into the food chain and is a potent neurological poison to fish and many other different types of wildlife. [39] It is commonly introduced into aquatic ecosystems by atmospheric deposition which eventually settles into nearby water bodies or through point source discharges.

The study indicates that concentration of mercury in the study sites do not exceed limits set for marine waters. However, as the next section elaborates, previous studies indicate alarming concentrations in the future, not only for mercury but also for several other parameters.

3.7 Trends in the concentration of certain parameters

The items highlighted in green show increasing trends in the concentration of certain parameters in the water samples collected in 2015, 2019, 2020, and 2021. Among the primary parameters, pH, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), phosphates and total suspended solids

(TSS) showed an increasing trend over the said years. Two of the parameters of concern are the increasing values for phosphates and total suspended solids. For the secondary parameters, selected heavy metals showed an increasing trend from 2015-2021, specifically chromium, copper, lead, and mercury. The trend for other parameters cannot be determined due to insufficient data.

Comparing the present data to past data sets taken along the coast of the heavy industrial area of Batangas Bay and the nearby municipality of Lobo, it is chromium, copper, lead and mercury that show an upward trend from the years 2015, 2019, 2020 and at present.

YEAR OF SAMPLING	2015	2019	2020	2021		TREND
Location	Lobo	Dela Paz	Ilijan	Dela Paz	Ilijan	
pH	7.9	nd	nd	8.31	8.32	↑
Color	<5.0	<5.0	nd	<5.0	<5.0	no change
BOD (mg/L)	2.8	nd	nd	7	7	↑
DO (mg/L)	6.48	nd	6	6.9	7	↑
Nitrate (mg/L)	0.01	0.289	0.01-0.04	0.03	0.03	↓
Phosphate (mg/L)	0	<0.008	0.02-0.05	0.532	0.534	↑
Total Suspended Solids (mg/L)	7.8	<2.5	1	11.6	4	↑
Coliform (MPN/100 ml)	106	< 1.8	>200	< 1.8	< 1.8	↓
SECONDARY PARAMETERS - Inorganics						
Ammonia as NH3-N	nd	0.17	nd	0.01	0.05	↓
Boron	nd	nd	nd	3.9	5	insufficient data
Fluoride	nd	nd	nd	0.533	1.5	insufficient data
Sulfate	nd	nd	nd	2500	275	insufficient data
Selenium	nd	nd	nd	<0.001	<0.001	insufficient data
SECONDARY PARAMETERS - Heavy Metals						
Arsenic	nd	0.006	<0.007-0.0042	< 0.001	< 0.001	↓

Cadmium	nd	0.123	bdl	<0.003	<0.003	↓
Chromium	nd	<0.03	bdl	0.06	0.07	↑
Total Copper	<0.01	nd	ndl	0.095	0.101	↑
Iron	nd	nd	nd	0.19	0.19	insufficient data
Lead	0.34	<0.06	bdl	0.12	0.13	↑
Manganese	nd	nd	nd	<0.01	<0.01	insufficient data
Mercury	<1	<0.0001	bdl	<0.0006	<0.0006	↑
Nickel	nd	nd	nd	<0.01	<0.01	insufficient data
Zinc	nd	0.118	bdl	0.096	0.086	↓

nd - no data; bdl - beyond detectable limits

Table 4. *Water quality parameters in the coastal area fronting the heavy industrial zone of Batangas Bay and its surrounding areas from 2015 to 2021*

Several primary parameters have exhibited a growth trend in recent years. Detected pH showed growth over the years but still fell within standards for stable marine waters. Growth of BOD and DO are not bad indicators for water quality as abundance of these parameters are beneficial to aquatic life. However, excessive growth of phosphates and TSS can be problematic as mentioned in the previous section. Detected concentration of phosphate in 2021 is 66 times larger than what was detected just two years prior. In addition, presence of TSS affects light penetration and consequently the vital processes of aquatic organisms such as aquatic photosynthesis.

Some heavy metal parameters have shown strong growth trends. Chromium concentrations have increased significantly since 2019. In 2021, detected concentrations have increased to more than twice that of 2019, and beyond standards fit for marine resources. The trend in total copper concentrations shows one of the largest margins of growth since 2015. In just six years, total copper has increased up to 10 times that of 2015 values.

Another heavy metal that was observed to have an increasing trend was lead. Values taken in the adjacent municipality of Lobo in 2015 reported high values that exceed the DENR 2021 WQS. [40] Under the agency's Water Quality Standards, the maximum concentration set by the DENR water Class SC standards for marine water is 0.05 mg/L. In 2015, lead concentration in Barangay Lobo, a town adjacent to Barangay Dela Paz was reported to be at 0.34 mg/L and present data taken were reported to be at 0.12 and 0.13 mg/L for Barangay Dela Paz and Ilijan, respectively. Though the present values collected are not as high as previously reported in 2015, these values still exceed the range set by DENR's water quality standards and are several magnitudes higher compared to the toxicity levels for some marine organisms reported in the US Environmental Protection Agency Water Quality Standards. [41]

The last metal of interest that showed the same increasing trend is mercury. Although the values reported in all of the studies have not exceeded the limits set by DENR 2021 WQS, an increasing trend was observed from data collected in 2019 and 2021 with concentrations at <0.0001 and <0.0006, respectively. In the US, coal fired plants are known to be the major sources of mercury pollutants, responsible for approximately 50% of the known human-caused mercury emissions in the country. [42]With this said, mercury levels in coastal waters that are near such facilities should be properly and regularly monitored for the presence and toxic concentrations of this heavy metal.

IV. Conclusions and Recommendations

The water quality along the coast is one of the biophysical factors that have been identified to influence the vulnerability of coastal communities to climate change. [43] Water quality directly affects the health of coastal ecosystems and fisheries and should therefore be a primary concern to creating climate-resilient communities.

Concern over the area's degrading water quality is substantiated by the result of the water quality assessment. Based on the DENR 2021 WQS, the sampled waters cannot be categorized as Marine Water Class SC. Among all parameters tested, excessive concentrations of phosphate, chromium, total copper, lead, and zinc exhibits the area's noncompliance to Class SC.

Secondary data gathering dating back to 2015 reveals that phosphate, TSS, chromium, copper, lead, and mercury all show a rising trend in terms of concentration in Barangays Ilijan and Dela Paz. Phosphate in 2021 is 66 times larger than what was detected just two years prior, while total copper has increased up to 10 times compared to 2015 values. These trends indicate the threat of worsening water quality in the near future.

Despite being declared as one of the most biodiverse marine ecosystems in the world, the whole expanse of the Verde Island Passage Marine Corridor has not yet been declared as a protected area. Currently there are a total of 144 locally managed marine protected areas along the coast of the different provinces bordering the Verde Island Passage and a VIP MPA Network has been established in 2009. [44]

However, as with most of the marine protected areas in the Philippines, the size of these marine sanctuaries are fairly small (>1km2) and coastal areas outside of these protected "pockets" of the coast are still subject to a variety of stress such as the five fossil gas plants found along the coast of Batangas. With 15 more new fossil fuel facilities being planned to be built in the Province of Batangas, [45] it is very important for stakeholders to create a regular water quality monitoring system along the coast, not only to know the present conditions of its waters but also to determine the possible effects should more fossil fuel facilities be constructed and be allowed to operate in the area. Community-led initiatives are especially important to ensure transparency and availability of the data to the public.

It is difficult to identify all the sources of pollutants that are introduced into the coastal waters as these pollutants come from a combination of point and nonpoint sources. However, it is still very important to regularly monitor the quality of the water in coastal areas as they are the endmember of all types and forms of pollutants that are introduced into the land and waterways. In the heavy industrial area of Batangas Bay, there is currently no monitoring system set in place that is aimed to specifically monitor the presence and the concentrations of pollutants known to come from the operation of fuel facilities, apart from those that are established by the plants presently operating in the area.

Data from such activities are also not very accessible and thus, are hard to utilize for community-led monitoring initiatives. Known monitoring stations established by the DENR that are located in the Verde Island Passage are Nasugbu Bay, Muelle Bay, and Sabang Bay which classified these waters as Class SA for Muelle Bay and Class SB for Nusgbu and Sabang Bay. [46] These monitoring stations are located very far from the heavy industrial zones and therefore, will not reflect the water conditions in these areas which need to be regularly monitored.

The lack of data or the difficulty to access available data to properly monitor the water quality along the coast of the heavy industrial area within the Verde Island Passage is seen as a gap that needs to be addressed by concerned agencies and organizations. Concerned agencies should establish monitoring stations closer to the heavy industrial zones of Batangas bay, Nasugbu Bay, Muelle Bay, and Sabang Bay, as well as in the coastal zones of Oriental and Occidental Mindoro, Romblon, and Marinduque, provinces bordering the Verde Island Passage. Regular and year-round monitoring in these areas should augment lack of data on a biodiversity hotspot, such as the Verde Island passage.

Further monitoring will be able to confirm the rising trend of certain heavy metals as observed in this study so that appropriate measures can be taken to address this potential problem. Other factors that could possibly influence the movement of water within Batangas Bay such as seasonality and current flow should be taken into account in future investigations as well. In aid of establishing a wider monitoring network across Verde Island Passage, concerned agencies should begin to set-up a network of stakeholders with one of its primary focuses being capacity building of coastal communities, in pursuit of integrating community-led initiatives in resource management.

End Notes

1 This includes projects that have been removed from DOE's list of Private Sector-initiated Projects but have not been officially announced as cancelled.

2 This includes the project that has been declared on hold.

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This report is produced by CEED and Caritas Philippines, as part of the effort to Protect Verde Island Passage (Protect VIP).

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