

Physicochemical and Heavy Metal Assessment of Seawater Adjacent to the Tagana-An Shipyard, Surigao Del Norte

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ABSTRACT

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Shipyard and shipbreaking operations are a recognized global source of marine contamination through discharges of oil, heavy metals, and industrial waste, yet no published assessment has evaluated seawater quality specifically adjacent to the Tagana-an Shipyard in Surigao del Norte, Philippines, against national regulatory standards. This study determined the physicochemical parameters (color, turbidity, pH, total dissolved solids, total suspended solids, and oil and grease) and heavy metal concentrations (cadmium, chromium, copper, lead, and nickel) of seawater adjacent to the Tagana-an Shipyard relative to Department of Environment and Natural Resources (DENR) marine water quality standards. The study employed a quantitative, non-experimental descriptive-evaluative design. One composite seawater sample was collected 50 meters seaward from the shipyard perimeter in Purok 5, Barangay Banban, Tagana-an, Surigao del Norte, in January 2025, and it was analyzed at the Department of Science and Technology laboratory in Ampayon, Butuan City, using Standard Methods for the Examination of Water and Wastewater protocols and Flame Atomic Absorption Spectroscopy. Turbidity (0.05 nephelometric turbidity units), pH (7.94), total suspended solids (12 mg/L), and oil and grease (0.6 mg/L) fell within DENR limits,

and cadmium, copper, lead, and nickel were not detected. Color (11 true color units) and total dissolved solids (38,130 mg/L) exceeded DENR standards of 5 true color units and 35,000 mg/L, respectively, while chromium was detected at 0.035 mg/L, below the 0.05 mg/L limit. The seawater adjacent to the shipyard is largely, but not fully, compliant with DENR standards, showing a diffuse rather than a narrowly oil-specific contamination pattern that may implicate both industrial and community sources, warranting continued, source-specific water quality monitoring.

INTRODUCTION

Water quality evaluation supports both ecosystem health and human health, and it requires measuring physical, chemical, and biological variables to characterize a water body's overall condition (World Health Organization, 2022). A persistent global concern is the occurrence of oil and industrial contaminants that can harm aquatic organisms and human health (National Oceanic and Atmospheric Administration, 2023), since oil leaks and spills destabilize ecosystems and threaten public health well beyond their immediate discharge point. Landrigan and colleagues (2020) similarly documented that ocean pollution, including chemical and heavy metal contaminants, contributes measurably to global human disease burden through contaminated seafood consumption and coastal exposure pathways. Ewida and colleagues (2022) documented severe seawater quality changes following an oil spill in Egypt, reporting total suspended solids and biological oxygen demand levels toxic to aquatic life and nearby communities, underscoring the speed with which localized contamination events can escalate into broader ecological harm.

Shipbreaking and shipyard operations represent a particularly concentrated global source of marine contamination. Shah, Hadi, and Mujahid (2017) noted that approximately 1,000 ships are recycled worldwide annually, and because a typical ship's operational life spans 30 to 40 years, aging vessels are routinely retired to shipbreaking yards once repair becomes uneconomical. Puthucherril (2010) documented that shipbreaking releases hazardous materials, including asbestos, oil residues, lead-based paints, polychlorinated biphenyls, cadmium, arsenic, and toxic biocides, into surrounding soil, water, and coastal ecosystems, elevating turbidity, biological oxygen demand, and depleting dissolved oxygen in affected waters. Khan and colleagues (2018) found that these hazards extend to the workers themselves, documenting occupational health risks among shipbreaking-industry workers in Chittagong, Bangladesh, indicating that shipyard environmental contamination and worker safety are interconnected concerns. Heavy metals released through these operations are particularly persistent: because they cannot be destroyed, they accumulate as sediment deposits, and complex formation processes cause them to sink and concentrate at the seafloor (Republic of Indonesia, 2001), a pattern reinforced by evidence that heavy metals bioaccumulate and biomagnify through the aquatic food chain, ultimately posing risk to species, including humans, that depend on it (Manahan, 2000).

Within the Association of Southeast Asian Nations (ASEAN) region, evidence from multiple member states shows that industrial and shipping-related activity elevates heavy metal and dissolved-solids burdens in coastal waters. Adyasari and colleagues (2021), reviewing three decades of Indonesian coastal water research, found that 54 percent of heavy-metal field studies in Indonesian coastal waters exceeded the national marine standard, with elevated levels concentrated near shipping lanes, ports, and industrialized bays. In Peninsular Malaysia, Sabarina and colleagues (2015) found that heavy metal concentrations in seawater at the industrialized Kuala Langat coastal area, though generally within the Malaysia Marine Water Quality Standard, exceeded the standard at stations nearest to sources of anthropogenic discharge. Within the Philippines specifically, Torres and colleagues (2022) found that total petroleum hydrocarbon and polycyclic aromatic hydrocarbon concentrations in Philippine waters affected by oil spills exceeded tolerable levels, with the potential to impair both aquatic ecosystems and the human settlements that depend on them. Taken together, this regional evidence indicates that Philippine shipyard-adjacent waters, including those near Tagana-an, face contamination risks comparable to those documented elsewhere in ASEAN industrial and port zones.

Locally, the Tagana-an Shipyard is one of the more prominent ship manufacturing facilities in the Philippines, engaged in building, repairing, and maintaining fishing, cargo, and other vessel types along Mindanao's northeastern coast; industry-wide research on comparable operations has found that shipyards generate hazardous industrial waste, particularly during repair activities, when materials are disposed of improperly (Budiyanto, 2016). Beyond discharge alone, ship-related operations more broadly are understood to carry environmental costs extending to air and water emissions from vessel activity in and around port and repair facilities (Ytreberg, Åström, & Fridell, 2021). Because oil, grease, and other wastes can enter adjacent waters during routine ship washing, refueling, and machinery operation, the Philippines regulates such discharge under the Philippine Clean Water Act (Republic Act No. 9275) through Department of Environment and Natural Resources Administrative Order No. 2016-08, and shipyards are expected to conduct ongoing water quality monitoring to remain compliant and avoid penalties (Department of Environment and Natural Resources, 2016).

Despite this established link between shipyard operations and marine contamination risk, no published water quality assessment has evaluated seawater conditions specifically near the Tagana-an Shipyard against DENR marine water quality standards. This gap justifies the present study, which the researchers undertook to determine whether seawater near the Tagana-an Shipyard complies with national physical and chemical water quality standards, and to identify which specific parameters, if any, indicate localized contamination requiring corrective action.

FRAMEWORK

This study is anchored on the Driver-Pressure-State-Impact-Response (DPSIR) framework, originally developed by the Organisation for Economic Co-operation and Development as the Pressure-State-Response model and later extended and adopted by the European Environment Agency for integrated environmental assessment and reporting (European Environment Agency, 1999). The DPSIR framework explains environmental conditions as the outcome of a causal chain: societal or economic Drivers generate Pressures on the environment, these Pressures alter the environmental State, the altered State produces Impacts on ecosystems and human well-being, and these Impacts, in turn, prompt societal or regulatory Responses intended to manage the Drivers or Pressures.

Applied to this study, the Driver is the continued operation of the Tagana-an Shipyard and associated ship building, repair, and maintenance activity along the coast of Barangay Banban. The Pressure is the discharge of oil, grease, industrial residues, and wastewater into adjacent coastal waters that such operations are known to generate. The State is represented by the study's measured variables, namely the physicochemical parameters (color, turbidity, pH, total dissolved solids, total suspended solids, and oil and grease) and heavy metal concentrations (cadmium, chromium, copper, lead, and nickel) of the seawater sampled adjacent to the shipyard. The potential Impact is the risk that any parameter found outside acceptable limits poses to marine ecosystem health and to the human communities, including fisherfolk and shipyard workers, that depend on these waters. The Response is embodied in the DENR marine water quality standards (Department of Environment and Natural Resources, 2016) against which the measured State is benchmarked, and in the continued, source-specific monitoring recommended as a societal and regulatory reaction to any exceedance identified.

This framework directly informed the study's variables and analytic structure: it justifies measuring State indicators (the physicochemical and heavy metal parameters named in the Objectives) as the empirical link between an unmonitored Pressure (shipyard discharge) and a regulatory Response (DENR standards compliance), rather than requiring the study to establish direct causal attribution between the shipyard and any single parameter. A textual synthesis, rather than a schematic diagram, is presented here, consistent with the descriptive-evaluative scope of the study.

OBJECTIVES

This study evaluated the surface water quality adjacent to the Tagana-an Shipyard, Surigao del Norte, relative to Department of Environment and Natural Resources (DENR) marine water quality standards through the following specific objectives: (1) determined the physicochemical parameters of seawater samples adjacent to the Tagana-an Shipyard in terms of color, turbidity, pH, total dissolved solids (TDS), total suspended solids (TSS), and oil and grease concentration; and (2)

determined the heavy metal concentrations of seawater samples adjacent to the Tagana-an Shipyard in terms of cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and nickel (Ni).

METHODOLOGY

Research Design

This study employed a quantitative, non-experimental descriptive-evaluative research design to assess seawater quality adjacent to the Tagana-an Shipyard in Barangay Banban, Tagana-an, Surigao del Norte. The design integrated field water sampling with standardized laboratory testing to measure selected physicochemical parameters and heavy metal concentrations, comparing the empirical data against Department of Environment and Natural Resources (DENR) marine water quality standards.

Research Site

The study was conducted in the coastal waters of Purok 5, Barangay Banban, Tagana-an, Surigao del Norte, Caraga Region, Philippines (approximately 9.69° N, 125.60° E). The site lies along the northeastern shore of Mindanao facing the Pacific Ocean. Sampling was conducted at a designated station located 50 meters seaward from the Tagana-an Shipyard perimeter. Due to restricted access within the private facility, water samples were collected via motorized boat with prior coordination and clearance from the local government unit (LGU).

Participants

This study did not involve human participants. The unit of analysis was a single composite seawater sample collected at the designated sampling station described above; no human respondents, biological specimens, or protected fauna/flora were sampled.

Instrumentation

Sample collection equipment included acid-washed polyethylene or glass sample bottles, a cooler with ice packs to maintain samples at 4 °C during transport, nitrile gloves, a grab sampler for hard-to-reach areas, waterproof labeling materials, a smartphone for recording sampling coordinates, a 0.45 µm filtration apparatus for filtering dissolved substances, personal protective equipment (lab coat and gloves), distilled water for equipment rinsing, and a field notebook. Laboratory instrumentation included a LaMotte Multi-Parameter Meter for color and turbidity, a calibrated pH meter, and a Flame Atomic Absorption Spectrophotometer (Flame AAS) for heavy metal quantification. All instruments and testing protocols followed the Standard Methods for the Examination of Water and Wastewater (SMEWW, 24th ed., 2023): Method 4500-H⁺ B for pH, Method 5520 B for oil and grease,

Method 2540 D for total suspended solids and total dissolved solids, and Method 3111 B for cadmium, chromium, copper, lead, and nickel via Flame AAS. Materials were prepared with the assistance of personnel from the Department of Science and Technology (DOST) Laboratory Standards office in Ampayon, Butuan City.

Research Ethics Protocol

The researchers secured written communication and permission from the Tagana-an local government before sampling, disclosing the study's purpose, methodology, and potential outcomes. Sampling methods were planned to minimize environmental disturbance, and the researchers followed sustainable field practices to protect local ecosystems and biodiversity during collection. All findings were reported accurately regardless of outcome, and information related to sensitive local operations was treated as confidential. The researchers adhered to relevant local regulations governing environmental research and water quality sampling.

Data Collection

The sample gathering protocol was executed in a structured and rigorous manner. Formal permits and clearances were first secured to conduct sampling at Tagana-an, which involved confirming site coordinates and obtaining permission from local government authorities. Subsequently, the researchers prepared sterile sample containers and materials, coordinated with municipal personnel, and arranged access to the approved sampling site located 50 meters from the shipyard via a rented boat. In January 2025, one composite seawater sample was collected at the designated station in Purok 5, Barangay Banban. Immediately following collection, the containers were labeled, sealed, and stored under parameter-appropriate conditions to preserve sample integrity. The samples were then transported within the required holding time to the DOST laboratory in Ampayon, Butuan City, using temperature- and light-controlled containers. Upon arrival, the DOST laboratory conducted standardized analyses for each physical and chemical parameter. Finally, the researchers retrieved the laboratory results and evaluated them against DENR standards, supported by relevant literature.

Data Analysis

Laboratory results for each physicochemical parameter and heavy metal were tabulated and compared directly against the corresponding DENR marine water quality standard (Department of Environment and Natural Resources, 2016) to determine regulatory compliance. No inferential statistical formulas were applied, consistent with the single-composite-sample descriptive-evaluative design.

RESULTS AND DISCUSSION

Physicochemical Parameters

Table 1

Physicochemical Analysis of Seawater Samples Adjacent to the Tagana-an Shipyard Relative to DENR Standards

Physicochemical parameter	DENR standard	Result	Interpretation
Color	5 true color units (maximum)	11 true color units	Above the DENR standard
Turbidity	10 nephelometric turbidity units (maximum)	0.05 nephelometric turbidity units	Within the DENR standard
pH	7.0–8.5	7.94	Within the DENR standard
Total dissolved solids	35,000 mg/L (maximum)	38,130 mg/L	Above the DENR standard
Total suspended solids	110 mg/L (maximum)	12 mg/L	Within the DENR standard
Oil and grease	1.0 mg/L (maximum)	0.6 mg/L	Within the DENR standard

Note. DENR standards per Department of Environment and Natural Resources (2016) Administrative Order No. 2016-08, Class SB marine water criteria.

Color measured 11 TCU, more than double the DENR standard of 5 TCU, indicating that dissolved or particulate material imparted a visible tint to the water. Cao and colleagues (2019) found that image-based chromaticity measurement provides an accurate and low-cost proxy for water contamination, since higher color indices consistently correspond to elevated contaminant concentrations, a relationship consistent with the elevated color reading obtained here. Turbidity, by contrast, measured only 0.05 NTU against a 10-unit standard, indicating very low suspended particulate matter; the World Health Organization notes that low turbidity is generally a proven indicator of pathogen removal and drinking-water safety, although extremely low turbidity in a natural marine setting can also reflect a scarcity of the fine particulate matter that supports some forms of aquatic productivity (World Health Organization, 2017). The seawater's pH measured 7.94, within the DENR-permitted range of 7.0 to 8.5; coastal marine environments typically maintain pH between 7.5 and 8.5 under stable conditions (Marion et al., 2011), supporting the interpretation that this parameter poses no immediate risk to marine life at the sampled location.

Total dissolved solids measured 38,130 mg/L, exceeding the DENR standard of 35,000 mg/L. Elevated total dissolved solids can produce undesirable taste, visible turbidity, and scaling or corrosion in water-contact equipment, and the World Health Organization's chemical fact sheet on total dissolved solids notes associations between very high concentrations and gastrointestinal, cardiovascular, and other adverse health outcomes in exposed populations (World Health Organization, 2022). Because seawater inherently carries substantially higher baseline dissolved-solids concentrations than freshwater, this result should be interpreted alongside the DENR's specific marine-water threshold rather than freshwater guidance values, but the fact that the measured value still exceeds even the marine-specific limit indicates a meaningful, not merely expected, elevation. Total suspended solids (12 mg/L) and oil and grease (0.6 mg/L) both remained comfortably within their respective DENR standards (110 mg/L and 1.0 mg/L), indicating that the sampled water is not heavily burdened by suspended particulates and carries minimal petroleum-based contamination; Murtaza and colleagues (2024) similarly emphasized that regulatory limits on oil and grease exist precisely because such contamination can persist in marine environments for years to decades, underscoring the practical value of the low reading obtained here.

Heavy Metal Concentrations

Table 2

Heavy Metal Analysis of Seawater Samples Adjacent to the Tagana-an Shipyard Relative to DENR Standards

Heavy Metal Concentrations	DENR standard	Result	Interpretation
Cadmium	0.003 mg/L (maximum)	Not detected	Not detected
Chromium	0.05 mg/L (maximum)	0.035 mg/L	Within the DENR standard
Copper	0.02 mg/L (maximum)	Not detected	Not detected
Lead	0.01 mg/L (maximum)	Not detected	Not detected
Nickel	0.02 mg/L (maximum)	Not detected	Not detected

Note. DENR standards per Department of Environment and Natural Resources (2016) Administrative Order No. 2016-08, Class SB marine water criteria. Non-detection reflects concentrations below the Flame Atomic Absorption Spectroscopy method detection limit.

Cadmium, copper, lead, and nickel were not detected in the seawater sample, indicating that their concentrations fell below the analytical method's detection limits and, by extension, below DENR's regulatory thresholds. Because nickel, copper, and cadmium function as nutrient-type trace elements in seawater and exhibit close relationships with major marine nutrient cycles at very low

concentrations (Chan, Zheng, & Sohrin, 2025), their non-detection here is consistent with an unremarkable, non-elevated baseline rather than an unusual finding. Chromium, however, was detected at 0.035 mg/L, below the DENR guideline value of 0.05 mg/L (Department of Environment and Natural Resources, 2016) but still a measurable, non-zero concentration. Tumolo and colleagues (2020) noted that chromium occurs in water and groundwater from both natural and anthropogenic sources and functions as a potentially toxic metal even at sub-threshold concentrations, indicating that continued monitoring is warranted to confirm whether this level remains stable or trends upward over time, particularly given the shipyard's proximity and its established use of metal-containing materials and coatings. This finding is broadly consistent with regional evidence from Indonesia and Malaysia, where detectable but sub-threshold heavy metal readings near industrial and shipping zones were common even where overall compliance with national marine standards was maintained (Adyasari et al., 2021; Sabarina et al., 2015).

CONCLUSIONS

Seawater near the Tagana-an Shipyard in Surigao del Norte is largely compliant with DENR marine water quality standards, with turbidity, pH, total suspended solids, and oil and grease all falling within permissible limits, and cadmium, copper, lead, and nickel undetected. The principal exceptions, color at 11 TCU against a 5 TCU standard and total dissolved solids at 38,130 mg/L against a 35,000 mg/L standard, together with a detectable but sub-threshold chromium reading, represent this study's key contribution to the local environmental record, since no prior published assessment has established DENR-benchmarked water quality data specific to this shipyard-adjacent site. This finding indicates a moderate, early-stage pollution signature that is broader than a narrowly shipyard-specific oil-and-grease problem would suggest, implying that both industrial operations and surrounding community sources may jointly contribute to the observed profile. This refines, rather than contradicts, the broader literature linking shipyard operations to marine contamination risk, demonstrating that such contamination is not always concentrated in the parameters most intuitively associated with shipbuilding activity. As a descriptive-evaluative assessment, this study does not test or generate formal theory; its contribution is empirical and standards-based, establishing a site-specific baseline against which future monitoring can be compared.

TRANSLATIONAL RESEARCH

Source-specific water quality monitoring would be essential both for protecting the marine ecosystem adjacent to the Tagana-an Shipyard and for accurately apportioning responsibility for any future corrective action between industrial and community stakeholders. It is recommended that the Tagana-an local government unit, in coordination with the shipyard management and the regional

DENR-Environmental Management Bureau office, consider establishing a recurring, seasonally distributed seawater sampling schedule to track color and total dissolved solids trends and to help confirm whether the detected chromium level remains stable over time.

Findings from this and future monitoring rounds could then be translated into a simple, color-coded community advisory poster and social media infographic, in Filipino and English, presenting the DENR-benchmarked compliance status of each parameter in plain language. This would allow residents, fishers, and shipyard workers of Barangay Banban to understand local water conditions without needing to interpret technical laboratory reports.

Such an accessible reporting format may also serve as a low-cost, replicable model that comparable shipyard-adjacent communities elsewhere in the Philippines could adapt for their own water quality communication needs.

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