

Physicochemical, Heavy Metal, and Microbiological Water Quality Assessment of the AgSur Shipyard Construction and Repair Facility, Butuan City

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ABSTRACT

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Shipyard construction and repair operations are a recognized source of industrial water contamination worldwide, yet no published assessment has evaluated water quality at the AgSur Shipyard Construction and Repair facility in Butuan City, Philippines, across a full physicochemical, heavy metal, and microbiological parameter set. This study determined the physicochemical parameters (color, turbidity, pH, total suspended solids, total dissolved solids, and dissolved oxygen), heavy metal concentrations (lead, nickel, copper, cadmium, and chromium), and microbiological parameters (total coliform and fecal coliform) of water sampled at the AgSur Shipyard relative to Department of Environment and Natural Resources (DENR) water quality standards. The study employed a quantitative, non-experimental descriptive-evaluative design. One water sample was collected closest to the shipyard dockyard, within its perimeter fence, in Barangay Bading, Butuan City, Agusan del Norte, and analyzed at the Department of Science and Technology laboratory in Ampayon, Butuan City. pH (7.66), total dissolved solids (241 mg/L), dissolved oxygen (8.48 mg/L), lead, chromium, and nickel (0.0080

mg/L) all fell within DENR limits. Color (876 color units), turbidity (16.7 NTU), and total suspended solids (159 mg/L) exceeded their physical standards; copper (0.0945 mg/L) and cadmium (0.0413 mg/L) exceeded their chemical standards; and fecal coliform (5,400 MPN/100 mL) exceeded its standard nearly sevenfold, while total coliform remained compliant. These results reveal two distinct, plausibly overlapping contamination pathways, an industrial pathway consistent with elevated copper, cadmium, color, and turbidity, and a sanitation pathway consistent with severe fecal coliform contamination, indicating that corrective action must address both shipyard industrial discharge and surrounding community sanitation infrastructure.

INTRODUCTION

Shipyards, like other industrial sites, can release organic waste, heavy metals, and lubricants that significantly affect the aquatic ecosystems surrounding them, and shipbuilding operations near rivers or shorelines often affect water health through the ongoing construction, repair, and maintenance activities that introduce harmful substances into nearby waterways (Budiyanto, 2016; Ashari, Soesilo, & Herdiansyah, 2021). Heavy metal pollution from shipyard and comparable industrial operations, particularly cadmium, lead, and mercury released through waste products, poses a well-documented global concern: because heavy metals cannot be broken down chemically or biologically, they accumulate in sediment and can be deposited in marine organisms, entering the food chain and posing risk to human health (Briffa, Sinagra, & Blundell, 2020; Miranda, Wijesiri, Ayoko, Egodawatta, & Goonetilleke, 2021). Once released, heavy metals also settle and accumulate in bottom sediment, functioning as long-term secondary sources of contamination for the surrounding water column (El-Sharkawy, Abdel-Aziz, & Salem, 2025), and such bioaccumulative contaminants have been shown to persist and biomagnify in aquatic organisms over time (Savoca & Pace, 2021).

Water quality evaluation requires examining physical, chemical, and biological factors that vary significantly over time and between sites, and industrial operations near rivers can degrade water quality in ways that threaten ecology, aquatic life, and human health (Chapman & Sullivan, 2022; Boyd, 2019). Physical parameters, including total suspended solids, total dissolved solids, temperature, color, and turbidity, work alongside chemical parameters, such as dissolved oxygen and pH, and biological parameters, such as coliform bacteria, to provide a complete picture of water body condition (O'Donnell, 2022; Verma, Verma, Ramakant, Pandey, & Verma, 2025). Sahin and Bilgili (2024) distinguished construction shipyards, which build vessels from the ground up, from dismantling shipyards, which disassemble retired vessels for parts recycling, and noted that both processes cause significant environmental damage, prompting international bodies such as the European Union and the International Maritime Organization to commission studies aimed at reducing shipyard waste without further environmental harm.

Within the Association of Southeast Asian Nations (ASEAN) region, water quality indices have become a standard tool for evaluating industrial contamination. Indonesia, Malaysia, Thailand, and Vietnam have each applied water quality indices to characterize different aspects of their surface water conditions (Wong, Shimizu, He, & Nik Sulaiman, 2020), and Tevapitak and Helmsing (2019) documented that small and medium-sized industrial enterprises in Thailand contribute significantly to local water pollution, illustrating the stakeholder-coordination challenges local governments across the region face in enforcing water quality regulations. Beyond ASEAN, comparable pressures are documented elsewhere in South Asia: Bangladesh, facing severe water contamination from increasing industrialization and urbanization, has documented widespread organic and heavy metal contamination from agricultural and industrial activities alongside fecal coliform contamination linked to flash floods and inadequate sanitation infrastructure (Islam, Ruponti, Rakib, Nguyen, & Mourshed, 2023), a dual industrial-and-sanitation contamination pattern that closely foreshadows the profile examined in this study.

In the Philippines, comparable local water quality assessments applying standard physicochemical and statistical methods have been conducted in rivers such as the Surigao River in Surigao City (Escatron, Villamor, Eviota, & Escatron, 2022) and the Mananga River in Metro Cebu, where industrial and commercial effluent from urban expansion has been linked to measurable water quality degradation (Mercado, Cai, Futralan, Ligaray, & Sy Choi, 2024).

The AgSur Shipyard is a small harbor located in Barangay Bading, Butuan City, Agusan del Norte, along the Mahay River, a 9.3-kilometer waterway that flows into Barangay Masao. Established in 2017, the shipyard is a key contributor to the local economy through employment and support for maritime activities, but its construction, repair, and maintenance operations threaten adjacent water quality through industrial effluent, oil spills, and other contaminants, consistent with the broader pattern of shipyard-related waste management challenges documented in comparable ship repair facilities (Ashari et al., 2021). The shipbuilding industry is broadly recognized as one of the more demanding sectors within the metalworking field, involving exposure to hazardous chemicals and materials and contributing to significant pollution and energy consumption (Rahman & Karim, 2015). Despite this established link between shipyard operations and water contamination risk, no published assessment has evaluated water quality specifically near the AgSur Shipyard against DENR and comparable regulatory standards across a full physicochemical, heavy metal, and microbiological parameter set. This gap justifies the present study, which the researchers undertook to determine the extent and nature of pollution near the AgSur Shipyard and to identify which specific physical, chemical, and microbiological parameters indicate 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 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, two distinct Drivers are anchored in the design: the continued construction, repair, and maintenance operations of the AgSur Shipyard, and the domestic activity of the surrounding residential community along the Mahay River. These two Drivers generate two corresponding Pressures, industrial effluent and metal-containing waste from shipyard operations, and untreated or inadequately treated domestic wastewater from nearby households. The State is represented by the study's measured variables: the physicochemical parameters (color, turbidity, pH, total suspended solids, total dissolved solids, and dissolved oxygen), heavy metal concentrations (lead, nickel, copper, cadmium, and chromium), and microbiological parameters (total coliform and fecal coliform) of the water sampled at the shipyard dockyard. The potential Impact is the risk that parameters found outside acceptable limits pose to aquatic ecosystem health and to the human communities, including shipyard workers and residents, that depend on the Mahay River. The Response is embodied in the applicable DENR water quality standards against which the measured State is benchmarked, and in the corrective action recommended once a parameter is found non-compliant.

This dual-driver structure directly informed the study's variables and analytic structure: it justifies measuring State indicators across three domains, physicochemical, heavy metal, and microbiological, as the empirical link needed to distinguish an industrial Pressure from a sanitation Pressure, rather than requiring the study to isolate a single causal source in advance. 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 water quality at the AgSur Shipyard Construction and Repair facility in Butuan City relative to Department of Environment and Natural Resources (DENR) standards through the following specific objectives: (1) determined the physicochemical parameters of the water sample in terms of color, turbidity, pH, total suspended solids (TSS), total dissolved solids (TDS), and dissolved oxygen (DO); (2) determined the heavy metal concentrations of the water

sample in terms of lead (Pb), nickel (Ni), copper (Cu), cadmium (Cd), and chromium (Cr); and (3) assessed the microbiological parameters of the water sample in terms of total coliform and fecal coliform counts.

METHODOLOGY

Research Design

This study employed a quantitative, non-experimental descriptive-evaluative research design to assess the physicochemical, heavy metal, and microbiological water quality at the AgSur Shipyard Construction and Repair facility. The design combined targeted field sampling within the shipyard perimeter with standardized laboratory analyses, comparing empirical findings against DENR water quality standards.

Research Site

The study was conducted at the AgSur Shipyard Construction and Repair facility in Purok 4, Barangay Bading, Butuan City, Agusan del Norte, within the Caraga Region (Region XIII), Philippines. The shipyard, established in 2017, draws water flow from the Mahay River, a 9.3-kilometer waterway extending to Barangay Masao. The sampling point was located closest to the shipyard dockyard, within its perimeter fence, to capture direct shipyard influence.

Participants

This study did not involve human participants. The unit of analysis was a single water sample collected at the designated sampling point 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 Global Positioning System (GPS) device or smartphone for recording sampling coordinates, personal protective equipment (lab coat, gloves, and safety goggles), distilled water for equipment rinsing, and a field notebook. Laboratory instrumentation included standard environmental testing equipment for color, turbidity, pH, total suspended solids, total dissolved solids, and dissolved oxygen; a Flame Atomic Absorption Spectrophotometer (Flame AAS) for heavy metal quantification, with method-specific detection limits of 0.013 mg/L for lead, 0.008 mg/L for nickel, 0.0045 mg/L for copper, 0.0028 mg/L for cadmium, and 0.0054 mg/L for chromium; and the Most Probable Number (MPN) method for total coliform and fecal coliform quantification. 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 informed, voluntary permission from AgSur Shipyard management before sampling, disclosing the study's purpose, methodology, and potential outcomes without coercion. 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, using scientifically established methods to ensure reliability and validity. Sensitive information related to individuals or proprietary shipyard operations was treated with strict confidentiality, and anonymity was maintained wherever feasible. The researchers adhered to relevant local regulations governing environmental research and water quality sampling.

Data Collection

The sample collection process followed a systematic and standardized procedure. Formal permits and clearances were first secured to conduct sampling at the AgSur Shipyard, which included confirming site coordinates and obtaining permission from shipyard authorities. Subsequently, the researchers prepared sterile sample containers and necessary materials—including markers, glass containers, tape, and specialized sampling equipment for cadmium, chromium, copper, lead, and nickel analysis—while coordinating with on-site shipyard personnel. Samples were collected at the location closest to the dockyard to accurately represent direct shipyard influence. Immediately following collection, the containers were labeled, sealed, and stored under parameter-specific conditions to maintain sample integrity. The samples were then transported within the required holding time to the DOST laboratory in Ampayon, Butuan City, using designated containers and proper preservation protocols. Upon arrival, the DOST laboratory performed standardized analyses for heavy metals and other parameters using established procedures and apparatus. Finally, the researchers retrieved the official laboratory results and analyzed them against regulatory standards, supported by relevant literature.

Data Analysis

Physicochemical parameters (color, turbidity, pH, total suspended solids, total dissolved solids, and dissolved oxygen) were measured following standard environmental testing protocols. Heavy metal concentrations, specifically lead, nickel, copper, cadmium, and chromium, were quantified using Flame Atomic Absorption Spectroscopy against method-specific detection limits. Microbiological quality was evaluated by quantifying total coliform and fecal coliform bacteria using the Most Probable Number method. All analytical results were compared directly against applicable DENR water quality guidelines to determine regulatory compliance. No inferential statistical formulas were applied, consistent with the single-sample descriptive-evaluative design.

RESULTS AND DISCUSSION

Physicochemical Parameters

Table 1

Physicochemical Analysis of Water Samples at the AgSur Shipyard Facility Relative to DENR Standards

Physicochemical parameter	Standard	Result	Interpretation
Color	150 color units (maximum)	876 color units	Above the standard (unclear color)
Turbidity	5 NTU (maximum)	16.7 NTU	Above the standard (very high turbidity)
pH	6.0–9.0	7.66	Within the standard
Total suspended solids	110 mg/L (maximum)	159 mg/L	Above the standard (highly polluted)
Total dissolved solids	500 mg/L (maximum)	241 mg/L	Within the standard
Dissolved oxygen	2 mg/L (minimum)	8.48 mg/L	Exceptionally high oxygen content

Note. DENR standards per Department of Environment and Natural Resources (2016) Administrative Order No. 2016-08 applicable freshwater quality criteria.

Color measured 876 color units, nearly six times the 150-unit standard, indicating pronounced water discoloration likely attributable to suspended sediment, organic debris, or industrial effluent (Gordon, 2018). Turbidity followed the same pattern, measuring 16.7 NTU against a 5-unit standard; the U.S. Environmental Protection Agency identifies suspended matter such as clay, silt, organic content, and bacteria as the primary drivers of turbidity, and elevated turbidity can both reduce light penetration necessary for aquatic organisms and interfere with disinfection processes, allowing pathogens to persist (U.S. Environmental Protection Agency, 2023; U.S. Geological Survey, 2019). Total suspended solids similarly exceeded the standard, measuring 159 mg/L against a 110 mg/L limit; elevated suspended solids reduce water clarity, can carry adsorbed contaminants, and may clog the gills of fish and other aquatic organisms, with cumulative long-term exposure raising the risk of broader ecological harm (Adjovu, Stephen, James, & Ahmad, 2023).

By contrast, pH measured 7.66, comfortably within the 6.0 to 9.0 standard range typically applied to support diverse aquatic life, and total dissolved solids measured 241 mg/L, below the 500 mg/L standard; a total dissolved solids reading in this range is generally considered a mild mineral presence rather than a pollution signal, though continued monitoring of its specific composition remains advisable even when the aggregate value falls within acceptable limits (Dewangan, Toppo, & Kujur, 2023). Dissolved oxygen measured 8.48 mg/L, more than four times the 2 mg/L minimum standard, indicating an oxygen-rich environment generally

favorable to aquatic life; however, unusually high dissolved oxygen can, under certain conditions, mobilize sediment-bound compounds such as phosphate, iron, and manganese into the water column, with potential harm to aquatic biota (Hermans, Astudillo Pascual, Behrends, Lenstra, Conley, & Slomp, 2021). Taken together, the physical parameter results present a mixed picture: while the site's chemical buffering capacity (pH), overall mineral load (total dissolved solids), and oxygenation (dissolved oxygen) remain sound, the pronounced elevation in color, turbidity, and suspended solids together indicate substantial particulate and possibly organic contamination consistent with ongoing shipyard and surrounding community discharge.

Heavy Metal Concentrations

Table 2

Heavy Metal Analysis of Water Samples at the AgSur Shipyard Facility Relative to DENR Standards

Heavy Metal Concentrations	Standard	Result	Interpretation
Lead	0.01 mg/L (maximum)	Not detected	Not detected
Nickel	1 mg/L (maximum)	0.0080 mg/L	Low concentration, within standard
Copper	0.04 mg/L (maximum)	0.0945 mg/L	Above the standard (highly polluted)
Cadmium	0.01 mg/L (maximum)	0.0413 mg/L	Above the standard (highly polluted)
Chromium	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 applicable freshwater quality criteria. Non-detection reflects concentrations below the Flame Atomic Absorption Spectroscopy method detection limit.

Lead and chromium were not detected, and nickel measured 0.0080 mg/L, far below its regulatory threshold and well within levels the World Health Organization associates with negligible health risk from drinking-water exposure (World Health Organization, 2021), indicating that these three metals do not currently pose a contamination concern at this site. Copper and cadmium, by contrast, both exceeded their respective standards. Copper measured 0.0945 mg/L against a 0.04 mg/L limit, more than double the permissible concentration; copper exposure has been shown to cause histological alterations in fish, including gill epithelial damage and liver necrosis, that can impair survival and reproduction even at comparatively low concentrations (Padrilah, Shukor, Yasid, Ahmad, Sabullah, & Shamaan, 2018; Cui et al., 2024). Cadmium measured 0.0413 mg/L against a 0.01 mg/L limit, more than four times the permissible concentration; cadmium is a well-documented toxic heavy metal that accumulates in living organisms, with long-term exposure

associated with kidney impairment, bone demineralization, and elevated cancer risk in humans (Charkiewicz, Åkesson, Bielawska, & Cywinski, 2023). Because both metals are strongly associated with industrial waste discharge, including shipyard operations that generate metal-containing waste during repair activities, these findings point toward shipyard-related industrial discharge as a plausible, though not exclusively confirmed, contributing source (Briffa et al., 2020).

Microbiological Parameters

Table 3

Microbiological Analysis of Water Samples at the AgSur Shipyard Facility Relative to DENR Standards

Microbiological parameter	Standard (MPN/100 mL)	Result (MPN/100 mL)	Interpretation
Total coliform	15,000 (maximum)	Greater than 1,600	Within the standard
Fecal coliform	800 (maximum)	5,400	Highly contaminated

Total coliform, at greater than 1,600 most probable number (MPN) per 100 milliliters, remained within the 15,000 MPN per 100 milliliters standard, but fecal coliform measured 5,400 MPN per 100 milliliters, nearly seven times the 800 MPN per 100 milliliters standard. Because fecal coliform indicates recent contamination by human or animal waste and correlates with elevated pathogen risk (Holcomb & Stewart, 2020; Xu, Wang, Wei, Zhang, & Chen, 2022), this result signals a serious public health concern independent of the shipyard's industrial contribution, since fecal contamination of this magnitude more commonly originates from inadequate sanitation infrastructure, such as failing septic systems, among nearby residential communities than from shipyard industrial processes themselves. Consistent with Philippine Department of Health guidance, water carrying fecal and total coliform concentrations at this level poses elevated risk of gastrointestinal illness and other waterborne diseases, including cholera, hepatitis A, and typhoid fever, for anyone exposed to or consuming it (Department of Health, 2017).

CONCLUSIONS

Water quality near the AgSur Shipyard in Barangay Bading, Butuan City, shows a genuinely mixed compliance profile: pH (7.66) and total dissolved solids (241 mg/L) fall within acceptable standards, and dissolved oxygen (8.48 mg/L), lead, chromium, and nickel all indicate no cause for immediate concern, while color, turbidity, and total suspended solids substantially exceed their physical standards, and copper (0.0945 mg/L) and cadmium (0.0413 mg/L) substantially exceed their chemical standards. Most strikingly, fecal coliform at 5,400 MPN per 100 milliliters, nearly seven times the regulatory limit, indicates severe microbiological contamination posing a direct public health risk. This study's principal contribution

beyond existing literature is its demonstration that shipyard-adjacent water contamination, when assessed comprehensively across physical, chemical, and microbiological domains rather than any single domain alone, can reveal two analytically distinct contamination sources, industrial metal discharge and community-level sanitation failure, that together produce a pollution profile broader and more urgent than either source considered separately would suggest. Read against the DPSIR framework, the findings support the model's core premise that a single measured environmental State can simultaneously encode multiple, independently operating Driver-Pressure chains; as a descriptive-evaluative assessment, this study does not test or generate new formal theory beyond this confirmatory application. These findings indicate that corrective action at this site must proceed on two parallel tracks: industrial waste management reform at the shipyard itself, and sanitation infrastructure improvement in the surrounding community, since addressing only one track would leave the other contamination pathway unresolved.

TRANSLATIONAL RESEARCH

Corrective action at the AgSur Shipyard site would likely need to proceed on two parallel tracks to be effective: industrial waste management reform at the shipyard itself, targeting the copper, cadmium, color, and turbidity exceedances through improved effluent handling and repair-area containment practices, and sanitation infrastructure improvement in the surrounding Barangay Bading community, targeting the severe fecal coliform contamination through septic system upgrades and wastewater management support coordinated with the Butuan City local government unit. Since addressing only one track could leave the other contamination pathway unresolved, it is suggested that findings from this assessment be translated into a plain-language, color-coded advisory brief, in Filipino and English, that separately flags the industrial-source parameters and the sanitation-source parameters, so that shipyard management, barangay officials, and residents can each identify and consider the specific findings relevant to their respective responsibility.

This advisory brief, together with a simple social media infographic summarizing the DENR-benchmarked compliance status of each parameter, could help make the dual-pathway nature of the contamination understandable to non-technical stakeholders and support more coordinated, rather than duplicated or misdirected, corrective investment by both the shipyard and the local government unit.

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