RESEARCH ARTICLE

Correlation Between CO, Temperature and Salinity

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Abstract

The study on investigation of the relationship among carbon dioxide (CO_2) concentration, temperature, and salinity in seawater. The laboratory equipment utilized in this study included an Erlenmeyer flask, volumetric flask, dropper pipette, funnel, and sample bottle. The materials consisted of seawater samples, phenolphthalein (PP) indicator, sodium hydroxide (NaOH), and sodium carbonate (Na_2CO_3). The experimental procedure employed an acid–base titration method using standardized NaOH solution. The findings indicated that the seawater sample initially contained dissolved CO_2, as evidenced by the absence of a pink coloration upon the addition of phenolphthalein indicator. During titration, the solution gradually developed a pink color after the addition of NaOH, signifying the neutralization and removal of dissolved CO_2. This color change confirmed the successful completion of the titration process and the presence of carbon dioxide in the sample.

Keywords: Seawater, Carbon Dioxide (CO_2), Temperature, Salinity.

Academic Editor:
Aprizon Putra

Submitted: September 28, 2025
Accepted: October 21, 2025
Published: October 31, 2025

Vol. 1, **No.** 2, 2025.
xx.xxxx/xxxxx

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1 Introduction

Water functions as a fundamental solvent for life, constituting up to 90% of the biomass in organisms such as plants and microorganisms. The nature and concentration of dissolved substances in water play a critical role in regulating biological and ecological processes within aquatic systems. Among these substances, dissolved oxygen (O_2) is particularly essential, as it supports cellular respiration in a wide range of aquatic organisms [1]. The concentration of dissolved oxygen (DO) serves as a key indicator of water quality and is influenced by several environmental variables, including temperature, atmospheric pressure, salinity, hydrodynamic conditions, and climatic factors [2]. When DO levels decline below the minimum requirements for survival, aquatic organisms experience physiological stress, potentially leading to ecosystem imbalance. Prolonged oxygen depletion can act as a limiting factor for biodiversity, highlighting the importance of continuous DO monitoring to preserve ecological stability [1].

Salinity is another critical parameter in aquatic environments, representing the total concentration of dissolved salts in water. Its distribution is largely controlled by evaporation and precipitation patterns; regions characterized by intense evaporation generally exhibit higher salinity, whereas areas with substantial rainfall tend to have lower salinity levels [3]. In addition, freshwater inflows, ocean circulation patterns, and climate variability further influence salinity dynamics. The interaction among temperature, salinity, and dissolved gases such as CO_2 and O_2 is fundamental to understanding water quality, as these

Citation
Idawati, I., & Supini, S. (2025). Correlation Between CO, Temperature and Salinity. *Scientia Naturalis*, 1(2), 55–59.

factors directly affect gas solubility and bioavailability [4].

Therefore, this study will help us to understanding on how temperature, salinity, and dissolved gases interact within both marine and freshwater ecosystems. Continuous water quality evaluation is essential for clarifying the physical and chemical mechanisms governing aquatic environments. Monitoring parameters such as DO and salinity, in conjunction with biochemical indicators like Biochemical Oxygen Demand (BOD), allows researchers to assess the organic load of pollutants and the extent of ecological degradation [5], [6]. Furthermore, these measurements provide valuable information for pollution control and environmental management. For example, BOD quantification reflects the level of biodegradable organic matter, while salinity variations help explain the ecological consequences of freshwater inputs and hydrological changes [6], [7].

By integrating these physical and chemical parameters, a more comprehensive assessment of water quality can be achieved, enabling informed decision-making for environmental protection. In conclusion, dissolved oxygen and salinity play indispensable roles in determining the condition and sustainability of aquatic ecosystems. Sustained research and systematic monitoring are therefore crucial to maintaining water quality standards, safeguarding biodiversity, and ensuring long-term environmental and public health.

2 Methodology

2.1 General

This experiment was carried out in the coastal waters of Lhok Mata Ie, Aceh Besar, to represent natural marine environmental conditions. The study was designed to examine the relationship between the solubility, temperature, and salinity of carbon dioxide (CO_2) in seawater. These parameters were selected because they significantly influence the chemical equilibrium and gas exchange processes in aquatic ecosystems. By analyzing their interaction, the experiment aimed to provide a clearer understanding of how environmental factors regulate dissolved CO_2 levels in marine environments.

2.2 Experimental Procedure

Three clean 50 mL Erlenmeyer flasks were prepared for sample analysis. A measured volume of 25 mL of seawater was transferred into each flask to ensure consistency across replicates. Prior to chemical treatment, the salinity and temperature of the seawater sample in the first flask were recorded using appropriate measuring instruments to establish baseline physical parameters. Subsequently, 3–4 drops of phenolphthalein indicator were added to each sample to qualitatively assess the presence of dissolved CO. The indicator functions based on pH changes: a pink coloration indicates alkaline conditions, while a colorless solution suggests the presence of dissolved carbon dioxide forming carbonic acid in water.

If the solution turned pink immediately after the addition of the indicator, the sample was considered to have negligible free CO_2, and no further titration was required. However, if the solution remained colorless, the sample was titrated with a standardized sodium hydroxide (NaOH) solution. NaOH was gradually added while the flask was continuously swirled until a faint but persistent pink endpoint was observed. This color change indicated the neutralization of dissolved CO. The volume of NaOH used during titration was recorded for subsequent quantitative calculation of CO_2 concentration.

2.3 Data Analysis

The concentration of dissolved carbon dioxide (CO) in the seawater sample was determined using the titration data obtained from the reaction with NaOH. The calculation was based on the stoichiometric relationship between CO and NaOH under acid–base neutralization principles. The general formula used for determining CO_2 concentration is expressed as follows:

$$\mathrm{CO_2} = \frac{V_{\mathrm{titrant}} \times N_{\mathrm{titrant}} \times 22}{V_{\mathrm{sample}}} \tag{1}$$

where V_{NaOH} is the volume of NaOH used in the titration (mL), N_{NaOH} is the normality of the NaOH solution, 44,000 represents the equivalent weight of CO_2 expressed in mg, and V_{sample} is the volume of the seawater sample (mL).

This calculation allows for the quantitative determination of dissolved CO_2 concentration and facilitates comparison with the measured temperature and salinity values to assess their correlation.

3 Results

In the first treatment, 25 mL of seawater was combined with four drops of phenolphthalein indicator. The solution remained clear and colorless, indicating that the pH of the sample was below the transition range of phenolphthalein (approximately pH 8.2–10). This observation suggests the presence of dissolved carbon dioxide (CO_2), $whichformscarbonicacid$(H_2CO_3) in water and lowers the pH. Based on the titration calculation, the concentration of dissolved CO in the sample was determined to be 0.44 ppm. This value indicates that free carbon dioxide was present in measurable quantities under the natural environmental conditions of the sampling site.

In the second treatment, 5 mL of sodium hydroxide (NaOH) solution was added to the same sample. Upon gradual addition and mixing, the solution changed from colorless to a faint but persistent pink color. This color change confirmed that the NaOH had neutralized the dissolved carbonic acid, shifting the solution from acidic to slightly alkaline conditions. The pink endpoint signified that all free CO_2 had reacted according to the neutralization reaction (Table 1).

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$$

Table 1. Determination of Dissolved CO_2 Concentration in Seawater Sample

No.	Treatment	Observation (Colour)	CO_2 Concentration (ppm)
1	25 mL seawater + 4 drops of phenolphthalein	Clear	0.44
2	+ 5 mL NaOH	Pink	–

Although the CO_2 concentration was not recalculated after NaOH addition, the qualitative observation of the color change demonstrated the effectiveness of the titration process in removing dissolved CO_2 from the seawater sample. Overall, the experimental results confirm the presence of dissolved carbon dioxide in the sampled seawater and demonstrate the applicability of the acid-base titration method for detecting and neutralizing CO_2. These findings also suggest that variations in pH, influenced by dissolved gases, may be closely associated with environmental factors such as temperature and salinity, which regulate gas solubility in aquatic systems.

4 Discussion

Carbon dioxide (CO_2) is a fundamental component of aquatic ecosystems, exerting both biological and chemical influences. Structurally, CO_2 is composed of one carbon atom bonded to two oxygen atoms through covalent interactions. In natural water bodies, CO_2 primarily originates from biological respiration, the decomposition of organic matter, and diffusion from the atmosphere. In addition to these natural sources, human activities, including industrial emissions, agricultural runoff, biomass burning, and fossil fuel combustion, substantially elevate CO_2 concentrations in aquatic environments [8]. Within aquatic systems, phytoplankton and submerged vegetation utilize CO_2 during photosynthesis, converting inorganic carbon into organic matter that sustains higher trophic levels [9]. The aquatic carbon cycle is closely integrated with biological processes, involving continuous CO_2 release through respiration and decomposition, followed by its assimilation by photosynthetic organisms and subsequent chemical transformations. One important transformation is the hydration of CO_2 to form carbonic acid (H_2CO_3), which further dissociates into bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions. These inorganic carbon species serve as alternative carbon sources for autotrophic organisms, such as algae, thereby enhancing primary productivity [10], [11].

In the present experiment, a 25 mL seawater sample was evaluated for CO_2 concentration using phenolphthalein as an acid–base indicator. The absence of a pink coloration after indicator addition indicated the presence of free dissolved CO_2. Subsequent titration with sodium hydroxide (NaOH) resulted in a distinct pink color, confirming the neutralization of carbonic acid and validating the presence of dissolved CO_2. The calculated concentration of CO_2 was 0.44 ppm. This value is lower than the generally recommended concentration of approximately 2 ppm required to support optimal photosynthetic activity and growth in aquatic organisms [12]. Such a reduced concentration suggests potential carbon limitation in the water body, which may suppress primary productivity and indirectly affect oxygen generation and nutrient cycling processes essential for ecosystem stability. The interaction between CO_2, temperature, and salinity further influences aquatic chemistry. Elevated temperature and salinity conditions can alter gas solubility dynamics, often reducing dissolved oxygen (DO) levels because oxygen solubility decreases as temperature and salinity increase.

This inverse relationship may intensify competition among aquatic organisms for available oxygen and increase the likelihood of hypoxic conditions [12]. Moreover, excessive CO_2 concentrations can lower water pH, potentially impairing metabolic and enzymatic functions in sensitive marine species. Conversely, moderate concentrations of CO_2 contribute positively to ecosystem functioning by supporting microbial decomposition of organic matter and facilitating nutrient recycling. Therefore, maintaining balanced CO_2 levels is critical to sustaining both biological productivity and ecological resilience in aquatic systems [12]. In summary, the experimentally determined CO_2 concentration of 0.44 ppm indicates a relatively carbon-limited condition in the analyzed water sample. Although not immediately harmful, such levels may constrain biological productivity and influence overall ecosystem dynamics. Continuous monitoring of CO_2, alongside dissolved oxygen, temperature, and salinity measurements, remains essential for comprehensive water quality assessment and early detection of environmental stressors affecting aquatic habitats [9], [8].

5 Conclusion

The findings of this study reveal that the concentration of carbon dioxide (CO_2) in the Alue Naga seawater sample was 0.44 ppm, a value considered relatively low for sustaining optimal biological activity. In aquatic ecosystems, a minimum CO_2 concentration of approximately 2 ppm is generally required to support essential biological processes, particularly photosynthesis in aquatic plants and phytoplankton. Concentrations exceeding 15 ppm, however, may become harmful, as elevated CO_2 levels can induce physiological stress, intensify respiratory competition among organisms, and potentially lead to mortality.

The observed relationship among CO_2, temperature, salinity, and dissolved oxygen (DO) highlights the interconnected nature of physical and chemical parameters in aquatic systems. Increased CO_2 concentrations are often associated with higher temperature and salinity conditions, which in turn reduce the solubility of oxygen and lower DO levels. Such conditions may elevate the risk of hypoxia and ecological imbalance. Conversely, insufficient CO_2 availability can limit photosynthetic efficiency, thereby suppressing primary productivity and affecting nutrient cycling within the ecosystem.

Overall, maintaining balanced CO_2 concentrations is essential for supporting biological productivity and preserving aquatic ecosystem stability. Continuous monitoring of CO_2, alongside temperature, salinity, and DO, is therefore critical for effective water quality management and long-term environmental sustainability.

Data Availability Statement

Data will be made available on request.

Author Contributions

I.I. and S.S. contributed to the conceptualization of the study. I.I. performed the methodology, formal analysis, investigation, data curation, visualization, and prepared the original draft of the manuscript. Validation of the results was carried out by I.I. and S.S. All authors have read and approved the final version of the manuscript.

Acknowledgement

This research was conducted in strict accordance with the ethical guidelines, academic standards, and research regulations established by the Department of Aquaculture, Faculty of Marine and Fisheries, Universitas Syiah Kuala. All experimental procedures and data collection processes were carried out responsibly, ensuring compliance with institutional policies governing scientific integrity and environmental research.

The authors gratefully acknowledge the academic supervision, technical support, and laboratory facilities provided by the Department of Aquaculture, which significantly contributed to the successful completion of this study. Appreciation is also extended to the faculty members and laboratory staff for their valuable guidance, assistance, and constructive input throughout the research process. Their support played an essential role in ensuring the accuracy, reliability, and scientific rigor of the experimental work.

Funding

This work was supported without any funding.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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