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RESEARCH ARTICLE

Analysis of Chemical Parameters in Water Pollution Using the Winkler Titration

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Abstract

The study has carried out to identify key indicators of water contamination, evaluate the chemical parameters influencing water quality, and determine the pollution index. The study employed both qualitative and quantitative approaches, including the Winkler titration method and the calculation of Biochemical Oxygen Demand (BOD). Seawater samples were treated sequentially with $MnSO_4$, NaOH, and KI, resulting in the formation of a white precipitate. After settling, H_2SO_4 and an appropriate indicator were added, producing a pinkish-red coloration. The solution was subsequently titrated with NaSO until it turned colorless at a volume of 15 mL. The measured values were DOi = 1.73 mg/L, DO_5 = 0.14 mg/L, and BOD = 1.59 mg/L. These findings provide an understanding of the chemical parameters contributing to water pollution.

Keywords: Water Pollution, Winkler Titration, Seawater.

1 Introduction

Water pollution represents a major global environmental challenge, largely driven by anthropogenic activities including industrial effluents, agricultural runoff, and domestic waste disposal. Given the essential role of aquatic systems in sustaining ecosystems and human livelihoods, mitigating water contamination has become increasingly critical. Pollutants entering lakes, rivers, oceans, and groundwater disrupt the hydrological cycle, thereby affecting water availability and ecosystem balance [1]. Land-use practices are closely linked to water quality degradation, as they influence the pathways through which contaminants reach aquatic environments [2]. Natural waters rarely remain chemically pure, as even rainwater contains dissolved gases such as CO_2, O_2, and N_2, in addition to atmospheric particulates [3]. Consequently, water quality assessment relies on specific physicochemical indicators that reflect contamination levels. Among the most widely applied parameters are Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). BOD quantifies the oxygen required by microorganisms to decompose organic matter, whereas COD measures the total oxygen necessary to oxidize both organic and inorganic substances [4].

Elevated BOD values indicate substantial organic pollution, which can reduce dissolved oxygen concentrations and threaten aquatic organisms by creating hypoxic conditions [5]. Nutrients such as nitrogen and phosphorus play dual roles in aquatic ecosystems. While essential for primary productivity, excessive concentrations, particularly nitrate (NO_3^-) generated through nitrification, can trigger eutrophication. This process stimulates algal blooms that ultimately deplete dissolved oxygen and impair aquatic life [6]. Based on nutrient concentrations, water bodies are classified

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as oligotrophic (low nutrient levels) or eutrophic (high nutrient levels), the latter often associated with oxygen depletion and the formation of ecological dead zones [4,6].

Accurate monitoring of water quality parameters is therefore essential. The Winkler titration method remains a widely used and reliable technique for determining dissolved oxygen (DO), which is fundamental for BOD calculation. Despite the availability of electronic sensors, Winkler titration continues to be valued for its simplicity, cost-effectiveness, and applicability in various field and laboratory settings [1]. Comprehensive assessment of indicators such as BOD, COD, DO, and nutrient concentrations enables researchers and policymakers to evaluate pollution severity and design appropriate management strategies [7]. In summary, the complex and multifactorial nature of water pollution necessitates systematic monitoring and integrated management approaches. Continuous evaluation of key water quality parameters, coupled with improved sanitation and pollution control measures, is essential to protect aquatic ecosystems and ensure the long-term sustainability of water resources [4,6–8].

2 Methodology

2.1 General

This experiment was carried out at the Marine Chemistry Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh. The materials used in this study consisted of 25 mL of seawater as the sample. The reagents included four drops of manganese(II) sulfate ($MnSO_4$) and four drops of sodium hydroxide (NaOH) to bind dissolved oxygen and produce a precipitate. Four drops of potassium iodide (KI) were added to liberate iodine in the presence of oxidizing agents. Additionally, four drops of sulfuric acid (H_2SO_4) were used to acidify the solution and facilitate the reaction, while four drops of methyl red served as a pH indicator. Sodium thiosulfate ($Na_2S_2O_3$), approximately 15 mL, was used as the titrant to reduce free iodine during the titration process.

2.2 Experimental Procedure

A 25 mL seawater sample was transferred into an Erlenmeyer flask. Subsequently, four drops of manganese(II) sulfate ($MnSO_4$) and four drops of NaOH were added to form manganese hydroxide precipitate, which reacts with dissolved oxygen in the sample. Afterward, four drops of KI were introduced to release iodine through redox reactions involving oxidized manganese species. The mixture was allowed to stand undisturbed until the appearance of a white precipitate, indicating that the reaction had occurred successfully.

3 Results

The objective of this experiment is to examine and identify key indicators associated with water pollution. Specifically, this study aims to analyze the physical and chemical parameters that contribute to the degradation of water quality, including factors that may indicate the presence of contaminants. In addition, the experiment seeks to provide an understanding of the pollution index as a quantitative tool used to evaluate and classify water quality status based on established environmental standards. Through systematic observation and analysis, the collected data are used to assess the level of contamination and determine whether the water sample meets acceptable quality criteria. The results obtained from these observations and measurements are summarized and presented in the table below for further interpretation and discussion.

Table 1. Determination of Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) in Seawater Sample

No.	Treatment	Observation Result	DO_1 (mg/L)	DO_5 (mg/L)	BOD_5 (mg/L)
1	Seawater + $MnSO_4$ + NaOH + KI	Brownish-white precipitate formed	–	–	–
2	Precipitate + H_2SO_4 + titration with $Na_2S_2O_3$	Solution turned pale pink at endpoint	1.92	0.14	1.78

4 Discussion

The Biochemical Oxygen Demand (BOD) obtained in this study was 1.78 mg/L. This value was derived from the difference between the initial dissolved oxygen concentration ($DO_1 = 1.92$ mg/L) and the dissolved oxygen concentration measured after five days of incubation ($DO_5 = 0.14$ mg/L). The marked decline in dissolved oxygen during the incubation period indicates substantial microbial activity, reflecting the aerobic decomposition of organic matter. Such oxygen consumption is widely recognized as a primary indicator of organic contamination in aquatic environments. In general, BOD values below 2 mg/L are classified as indicative of moderate organic pollution. Although such levels may still allow aquatic organisms to survive, they suggest the presence of environmental stress within the ecosystem. The BOD value recorded in this investigation supports previous findings that even relatively low BOD concentrations can contribute to oxygen depletion, particularly in stagnant or warm waters where

oxygen solubility is naturally reduced. Under these conditions, oxygen-sensitive organisms may experience physiological stress, potentially leading to ecological imbalance.

The initial dissolved oxygen concentration (DO_1) of 1.92 mg/L was also considerably lower than the typical threshold for healthy aquatic systems, which generally maintain DO levels above 5 mg/L. This low baseline oxygen level suggests that the water body was already under oxygen stress prior to incubation, likely due to the presence of biodegradable organic pollutants. Common sources of such contaminants include domestic sewage discharge, agricultural runoff, and the decomposition of organic debris, all of which frequently contribute to coastal water pollution. This experiment highlights the importance of using both Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) as complementary parameters in water quality assessment. Although COD was not analyzed in this study, incorporating it in future investigations would provide a more comprehensive evaluation of the total oxidizable material, including substances that are not readily biodegradable. Importantly, BOD values are inherently lower than or equal to COD values, and the ratio between these two parameters offers insight into the proportion of biodegradable versus persistent organic compounds present in the water.

The Winkler titration method employed in this study remains a dependable, economical, and accurate technique for determining dissolved oxygen concentrations. Its relatively simple equipment requirements make it particularly suitable for field applications and laboratories with limited resources. Nevertheless, careful reagent handling and precise procedural control are essential, as inadvertent exposure to atmospheric oxygen during titration can artificially increase measured DO values. For continuous or real-time monitoring purposes, automated sensor-based technologies may provide greater operational efficiency, albeit at higher financial cost. Overall, the BOD value of 1.78 mg/L suggests moderate organic pollution, characterized by sufficient biodegradable material to significantly reduce dissolved oxygen levels. Although the results do not indicate severe contamination, they emphasize the necessity of routine monitoring and proactive management strategies to maintain coastal water quality. The Winkler titration method continues to serve as a fundamental analytical approach in environmental research and practical water quality monitoring programs.

5 Conclusion

The results of this study demonstrate that the Winkler titration method is a reliable and effective approach for measuring dissolved oxygen (DO) concentrations in water samples. The method provided accurate determination of the initial dissolved oxygen (DO_1 = 1.92 mg/L) and the dissolved oxygen after five days of incubation (DO_5 = 0.14 mg/L). Based on the difference between these values, the Biochemical Oxygen Demand (BOD_5) was calculated to be 1.78 mg/L. This BOD value indicates the presence of biodegradable organic matter in the seawater sample and reflects a moderate level of organic pollution. The substantial decrease in dissolved oxygen during the incubation period confirms active microbial decomposition under aerobic conditions, which contributes to oxygen depletion in aquatic systems.

Moreover, the study highlights the broader environmental implication that elevated nutrient concentrations, particularly phosphorus and nitrate, can promote algal blooms. Such blooms increase oxygen consumption during respiration and decomposition processes, further reducing dissolved oxygen availability and deteriorating water quality. Therefore, the findings emphasize the importance of routine monitoring of DO and BOD parameters, along with nutrient control strategies, to maintain ecological balance and protect aquatic environments.

Data Availability Statement

Data will be made available on request.

Author Contributions

F.L. conceived and designed the study. F.L. performed the methodology, formal analysis, investigation, data curation, and data visualization, and prepared the original draft of the manuscript. Validation of the results was also conducted by F.L. The author has read and approved the final published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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