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Article

Analysis of Chemical Parameters in Water Pollution Using the Winkler Titration

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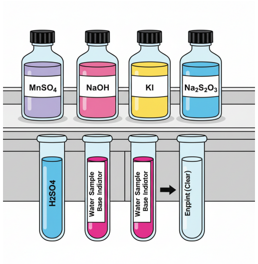

Abstract: An experiment titled *"Water Pollution"* was conducted to identify indicators of water pollution, determine the chemical parameters contributing to water contamination, and calculate the pollution index. The methods used in this experiment were both qualitative and quantitative, involving the Winkler Titration technique and the calculation of Biochemical Oxygen Demand (BOD) values. A seawater sample was treated with $MnSO_4$, NaOH, and KI, forming a white precipitate. After standing, H_2SO_4 and a basic indicator were added, producing a pinkish-red color. The solution was then titrated with $Na_2S_2O_3$ until it became clear (at 15 ml), and the BOD value was calculated. The results obtained were DOi = 1.73 mg/L, DO_5 = 0.14 mg/L, and BOD = 1.59 mg/l. This experiment provides insight into the causes and chemical parameters responsible for water pollution

Keywords: Water Pollution, winkler titration, seawater

1. Introduction

Water pollution is a significant global concern, primarily stemming from human activities such as industrial discharge, agricultural runoff, and domestic waste. The intricate role water bodies play in ecosystems and human livelihoods makes combating this pollution imperative. The hydrological cycle, which integrates various phases of water movement, is adversely affected as contaminants infiltrate lakes, rivers, oceans, and groundwater [1]. Notably, the relationship between water quality and land use practices is critical in understanding how pollutants enter aquatic systems [2]. The quality of natural water bodies is often compromised due to the presence of various pollutants, making pure water increasingly rare. Even seemingly pristine rainwater carries dissolved gases such as CO_2, O_2, and N_2, along with particulates from the atmosphere [3]. Consequently, measuring water quality hinges on various parameters that indicate levels of contamination. Two ubiquitous indicators are Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which are critical for assessing organic and inorganic pollution, respectively. BOD reflects the oxygen required by microorganisms to decompose organic matter, while COD measures the total oxygen demand needed to oxidize all organic and inorganic matter [4]. A high BOD level signifies high organic pollution, which has direct implications for aquatic life, contributing to decreased oxygen levels and unfavorable living conditions for aquatic organisms [5].

Nitrogen and phosphorus are essential nutrients in aquatic ecosystems. Nitrate (NO_3^-), produced through the nitrification process, can lead to eutrophication when present in excess. This excessive algal growth depletes oxygen levels in the water, harming marine life [6]. Aquatic environments are categorized based on their nutrient status: low nutrient levels create oligotrophic conditions, while high nutrient levels lead to eutrophic conditions, characterized by oxygen depletion and potential dead zones in various water bodies [4,6]. To accurately monitor and analyze water quality, techniques such

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as Winkler titration play an important role. This method is used for determining dissolved oxygen (DO) levels in water, an essential factor in calculating BOD. Although electronic methods exist, Winkler titration remains valuable for its cost-effectiveness and ease of use in various settings [1]. Such assessments are crucial for understanding the extent of pollution, guiding water management practices, and developing strategies to mitigate contamination effects on ecosystems [7]. Through rigorous testing and analysis of water quality indicators, including BOD, COD, dissolved oxygen, and nutrient concentrations, researchers can formulate effective strategies for managing aquatic ecosystems. Addressing the multifaceted nature of water pollution and its sources is essential for ensuring the sustainability of water resources for future generations [4]. Furthermore, continuous monitoring and proper sanitation management are vital to safeguard water bodies from anthropogenic impacts [6–8]. In conclusion, the detrimental effects of water pollution on the environment underscore the need for comprehensive monitoring approaches, such as the Winkler titration method, to assess water quality. The insights gained from these investigations inform wastewater management practices, enabling the development of strategies aimed at preserving and restoring water quality in a methodical manner.

2. Results

2.1.1. *Purpose of the Experiment*

The purpose of this experiment is to identify the indicators of water pollution, to determine the chemical parameters that contribute to water contamination, and to understand the pollution index used to assess water quality. The results of the observations from this experiment are presented in the table below :

Table 1. results of the observations

No.	Treatment	Observation Result	DO_1 (mg/L)	DO_5 (mg/L)	BOD (mg/L)
1	Seawater + 2 mL $MnSO_4$ + 2 mL NaOH + 2 mL KI	Brownish-white precipitate			
2	Brownish-white precipitate + $Na_2S_2O_3$	Solution turned pale pink	1.92	0.14	1.78

3. Discussion

The results of the experiment clearly demonstrate evidence of organic pollution in the tested seawater sample, indicated by a Biochemical Oxygen Demand (BOD) value of 1.78 mg/L. This value was calculated based on the difference between the initial dissolved oxygen concentration (DO_1 = 1.92 mg/L) and the dissolved oxygen concentration after five days of incubation (DO_5 = 0.14 mg/L). The significant reduction in dissolved oxygen over this incubation period strongly suggests active microbial degradation of organic matter under aerobic conditions, a well-established indicator of organic pollution in aquatic systems [9], [10]. Generally, a BOD value below 2 mg/L is indicative of moderate levels of organic pollution, suggesting that while the water may still support aquatic life, it reflects underlying environmental stress [10]. The observed BOD level in this study aligns with findings that even lower BOD values can precipitate oxygen depletion, especially in poorly circulated or warmer waters, conditions that naturally reduce oxygen solubility [11], [12]. Such environments may pose risks to oxygen-sensitive aquatic organisms, potentially disrupting the ecosystem.

The measured DO_1 of 1.92 mg/L is also notably low, as healthy aquatic ecosystems typically maintain dissolved oxygen levels above 5 mg/L [13]. This already low oxygen concentration suggests pre-existing oxygen stress, likely due to the presence of biodegradable organic matter. Potential sources include domestic wastewater, agricultural runoff, and decomposing organic debris, all of which are common contributors to coastal pollution [13]. This experiment underscores the critical role of both BOD and Chemical Oxygen Demand (COD) as complementary indicators of water quality. Although COD was not measured in this experiment, its inclusion in future assessments would provide a more comprehensive picture of the total oxidizable load, particularly from pollutants not biodegradable by microorganisms [14]. The BOD-COD relationship is essential, as BOD values can never exceed COD. The ratio between the two can reveal the proportion of easily degradable versus persistent organic substances [14]. The Winkler titration method, applied in this study, is a reliable, cost-effective, and accurate technique for determining dissolved oxygen concentrations. Its minimal equipment requirements make it especially useful in low-resource settings or field studies [14]. However, the method requires careful reagent handling and precise technique, as introducing atmospheric oxygen during titration may lead to artificially elevated DO readings [14]. Moreover, for continuous or real-time water quality monitoring, automated sensor-based methods may offer greater efficiency, though at a higher cost. In conclusion, the BOD result of 1.78 mg/L indicates moderate organic pollution, with enough biodegradable matter to significantly deplete oxygen levels. While the findings do not point to severe contamination, they highlight the importance of regular monitoring and preventive measures in managing coastal water quality. The Winkler titration remains a valuable analytical tool in environmental research and can serve as a foundational method for both academic and practical water quality assessment efforts.

4. Research Methods

4.1. General

This experiment was conducted at the Marine Chemistry Laboratory, Faculty of Marine and Fisheries, Syiah Kuala University, located in Banda Aceh. The chemical materials used in this experiments were 25 mL of seawater as the test sample; 4 drops of manganese(II) sulfate ($MnSO_4$) and 4 drops of sodium hydroxide (NaOH) to bind dissolved oxygen and form a precipitate; 4 drops of potassium iodide (KI) to release iodine in the presence of oxidizing agents; 4 drops of sulfuric acid (H_2SO_4) as a catalyst to acidify the solution; 4 drops of methyl red as a pH indicator; and 15 mL of sodium thiosulfate ($Na_2S_2O_3$) as the titrant to reduce free iodine during the titration step.

4.2. Experimental Procedure

A 25 mL seawater sample was placed into an Erlenmeyer flask. To this sample, 4 drops of $MnSO_4$ and 4 drops of NaOH were added to precipitate manganese hydroxide, which reacts with the dissolved oxygen present in the water. This was followed by the addition of 4 drops of KI, which released iodine through redox reactions involving oxidized manganese compounds. The solution was then left undisturbed until a white precipitate formed, indicating the reaction had proceeded.

5. Conclusions

Based on the results of this experiment, it can be concluded that the Winkler titration method is an effective technique for determining the concentration of dissolved oxygen (DO) in water samples. The Biochemical Oxygen Demand (BOD) value represents the amount of oxygen required by microorganisms to decompose biodegradable organic matter present in the water. From the analysis, the initial dissolved oxygen (DO_1) of the seawater sample was found to be 1.92 mg/L, while the fifth-day dissolved oxygen (DO_5) value decreased to 0.14 mg/L. Using these values, the calculated BOD of the sample was 1.78 mg/L, indicating the level of organic pollution in the water. Furthermore, it was observed that excessive concentrations of phosphorus and nitrate in aquatic environments can stimulate algal blooms, which consume large amounts of dissolved oxygen. This leads to a decline in oxygen availability and overall water quality, demonstrating the interconnected relationship between nutrient enrichment and aquatic pollution.

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Conflicts of Interest: The authors declare no conflicts of interest.

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