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Review Article

Safeguarding Water Resources: Protocols And Practices For Quality Analysis And Management

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ABSTRACT

Water, often regarded as the second most vital natural resource following air, plays a pivotal role in sustaining life on Earth. Despite covering a significant portion of the planet's surface, only a fraction of this water is readily usable, rendering it a scarce and invaluable asset. Given its importance, judicious management and utilization of this limited resource are imperative. The multifaceted utility of water underscores the necessity of evaluating its suitability for various purposes. Moreover, continuous monitoring of water sources is indispensable to assess their health and integrity. The degradation of water bodies not only serves as a barometer of environmental decline but also poses a grave threat to ecosystems. In industrial settings, substandard water quality can precipitate hazards and substantial economic losses. Consequently, ensuring the quality of water assumes paramount significance from both environmental and economic standpoints. To this end, comprehensive water quality analysis emerges as an indispensable prerequisite for its utilization across diverse sectors. Years of dedicated research have yielded standardized protocols for water quality analysis, encompassing guidelines for sampling, preservation, and analysis procedures. This paper provides a succinct overview of the established chain of actions in water quality analysis, offering valuable insights to analysts and researchers alike. By adhering to these protocols, stakeholders can effectively assess and manage water resources, thereby safeguarding both human well-being and environmental sustainability.

INTRODUCTION

Water Quality encompasses the intricate interplay of its chemical, physical, and biological attributes, crucially defining its suitability for various

designated purposes. The versatility of water usage spans across recreation, drinking, fisheries, agriculture, and industry, each demanding specific standards tailored to its intended use. Consider, for

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instance, the rigorous benchmarks requisite for water earmarked for drinking or recreational activities, where stringent criteria ensure safety and purity. In contrast, water employed in agricultural or industrial domains may adhere to different parameters, prioritizing factors such as nutrient content or pH levels over absolute purity. Thus, understanding and adhering to these diverse standards tailored to specific applications are paramount in safeguarding water quality and ensuring its optimal utilization across different sectors. After extensive research efforts, water quality standards have been established to guarantee the suitability and efficient utilization of water for specific purposes. Water quality analysis involves measuring essential parameters of water using standardized methods to assess their compliance with these established standards.

1. Water quality analysis serves as a critical tool primarily for monitoring purposes, encompassing several vital objectives:

(i) Ensuring Compliance:

The analysis verifies whether water quality adheres to established standards, thereby determining its suitability for designated purposes.

(ii) Assessing System Efficiency:

Monitoring water quality provides insights into the effectiveness of systems dedicated to maintaining water quality standards.

(iii) Informing System Upgrades:

By evaluating analysis results, decision-makers can discern the need for system upgrades or modifications, guiding strategic improvements.

(iv) Regulatory Compliance:

Regular analysis ensures adherence to applicable rules and regulations governing water quality, fostering legal compliance and environmental stewardship.

The significance of water quality analysis is particularly pronounced in key sectors such as:

Public Health:

Especially critical for ensuring the safety of drinking water, safeguarding human health against waterborne contaminants.

Industrial Use:

Essential for maintaining the integrity of water utilized in industrial processes, preventing adverse environmental impacts and ensuring operational efficiency.

2. Procedures for Water Quality Analysis

The process for conducting water quality analysis is outlined in Figure-1.

A. Selection of Parameters

The choice of parameters for assessing water quality is dictated by the intended purpose of its use. Examples include:

Drinking Water:

Compliant with WHO/CPCB Standards

Irrigation:

Including pH, conductivity, sodium & potassium levels, nutrients, and specific compounds

Industrial Use:

Tailored to specific industry requirements

Domestic Consumption:

Adhering to BIS Standards

Water Bodies:

In accordance with CPCB guidelines

However, for evaluating potability and industrial suitability in India, some of the most commonly assessed parameters are depicted in Figure-2.



Figure 1: steps for water quality analysis

Steps for Water Quality Analysis

1. Sample Collection

- Identify Sampling Sites
- Use Proper Sampling Equipment
- Collect Representative Samples

| 2. Sample Preservation |

- | - Maintain Proper Storage Conditions |
- | - Use Suitable Preservation Methods |

| 3. Laboratory Analysis |

- | - Conduct Physical Analysis |
- | - Perform Chemical Analysis |
- | - Conduct Biological Analysis |

| |

| 4. Data Interpretation |

- | - Compare Results to Standards |
- | - Analyze Trends Over Time |
- | - Assess Implications for Use |

This diagram outlines each step of water quality analysis along with detailed sub-steps for clarity. It covers everything from sample collection to data interpretation, providing a comprehensive overview of the process. Feel free to adjust the design or content to better suit your needs.

B. Selection of Methods

Choosing the appropriate methods for water quality analysis is contingent upon several factors, including:

(i) Sample Volume and Quantity:

Determining the volume and number of samples to be analyzed guides the selection process, ensuring efficiency and accuracy.

(ii) Cost Considerations:

Evaluating the cost of analysis helps strike a balance between accuracy and affordability, optimizing resource allocation.

(iii) Precision Requirements:

Assessing the level of precision needed ensures that the selected methods meet the desired standards of accuracy, tailored to specific analytical needs.

(iv) Timeliness:

Considering the urgency of analysis informs the selection of methods that offer timely results, facilitating prompt decision-making and action.

C. Precision and Accuracy According to Requirements

Determining the precision and accuracy levels for a chosen method is contingent upon the objectives

of monitoring. This decision is influenced by several factors, including:

Budgetary Constraints:

The financial resources allocated to the monitoring system play a pivotal role in determining the acceptable levels of precision and accuracy.

Scope of Parameters:

The specific parameters being monitored dictate the required precision and accuracy levels, ensuring comprehensive data collection aligned with monitoring objectives.

Intended Use of Water:

Considering the ultimate purpose of the water being monitored helps calibrate precision and

accuracy to meet the standards necessary for its designated use.

D. Chain-of-Custody Protocols

Effective chain-of-custody procedures, when meticulously designed and implemented, safeguard sample integrity throughout the entire analysis process, from collection to data reporting. This entails establishing a transparent system to track the possession and handling of samples from collection through analysis to final disposition. The meticulous documentation of this process, known as "chain-of-custody," is essential to demonstrate sample control and ensure the reliability and credibility of analytical results.

Figure -2: Parameters for Water Quality Analysis.

Parameters for Water Quality Analysis	
Drinking Water Standards:	
1. pH	
2. Total Dissolved Solids (TDS)	
3. Turbidity	
4. Chlorine Residual	
5. Bacterial Contamination	
Industrial Use Criteria:	
1. pH	
2. Suspended Solids	
3. Heavy Metal Concentrations	
4. Organic Compounds	
5. Oil and Grease	
Surface Water Quality Parameters:	
1. Dissolved Oxygen	
2. Biochemical Oxygen Demand (BOD)	
3. Nitrate and Phosphate Levels	
4. Temperature	
5. Conductivity	



This diagram provides a comprehensive overview of the parameters commonly analyzed for different water quality standards, including drinking water, industrial use, and surface water quality. Each category is clearly listed with the specific parameters relevant to its intended use. When data are intended for regulatory or legal purposes, meticulous chain-of-custody procedures become indispensable. Even in routine situations where litigation is not a concern, implementing these procedures ensures the integrity and reliability of sample analysis. A sample is deemed under an individual's custody if it remains within their physical possession, stays within their line of sight, is secured and tamper-proofed by them, or is stored in an area restricted to authorized personnel. The following procedures encapsulate the critical aspects of chain-of-custody:

1. Sample Labels:

Labels serve to prevent sample misidentification and attribute responsibility to the collector. These labels also aid in identifying the collector when necessary.

2. Sample Seals

Seals are utilized to detect unauthorized tampering with samples until the time of analysis. Proper sealing is essential before the sample leaves the collector's custody, and breaking the seal is necessary to access the sample.

3. Field Log Book:

A comprehensive log book records all pertinent information related to field surveys or sampling. This includes the purpose of sampling, location details, contact information, sample type, and preservation methods.

4. Sample Analysis Request Sheet:

This accompanies samples to the laboratory, providing essential details for analysis. It includes information completed by both the collector and laboratory personnel, ensuring comprehensive documentation of the sample journey.

5. Sample Delivery to the Laboratory:

Timely delivery of samples to the laboratory is crucial, typically within two days of collection. Special arrangements are made for shorter holding times, and commercial shipments include the waybill number in custody documentation.

6. Receipt and Logging of Sample:

Upon arrival at the laboratory, the sample undergoes thorough inspection by the custodian to verify its condition and seal against the chain-of-custody record. After acceptance, it receives a laboratory number, is logged into the system, and stored securely until analysis.

7. Assignment of Sample for Analysis:

The laboratory supervisor assigns samples for analysis, with subsequent responsibility falling on the supervisor or analyst for their care and custody within the laboratory.

8. Disposal:

Samples are held for the prescribed duration or until data review and acceptance. Disposal occurs after proper documentation, adhering to approved methods and regulations.

E. Ensuring Proper Sampling

Proper sampling stands as a cornerstone in accurately measuring water quality parameters. Despite the employment of advanced techniques and sophisticated tools, inaccurate results may arise from improper sampling practices. To ensure robust sampling, the following criteria must be met:

(i) Representative:

Sampling must accurately reflect the characteristics of the water body or wastewater being assessed. Critical factors to consider during planning include the sampling process, size/volume of samples, number of sampling locations, number of samples taken, types of samples, and time intervals. During sampling, attention should be paid to selecting appropriate containers, preventing contamination, and ensuring the personal safety of the collector.

(ii) Reproducible:



The data collected should be reproducible by others who follow the same sampling and analytical protocols. Consistency in methodology enhances confidence in the reliability of results.

(iii) Defensible:

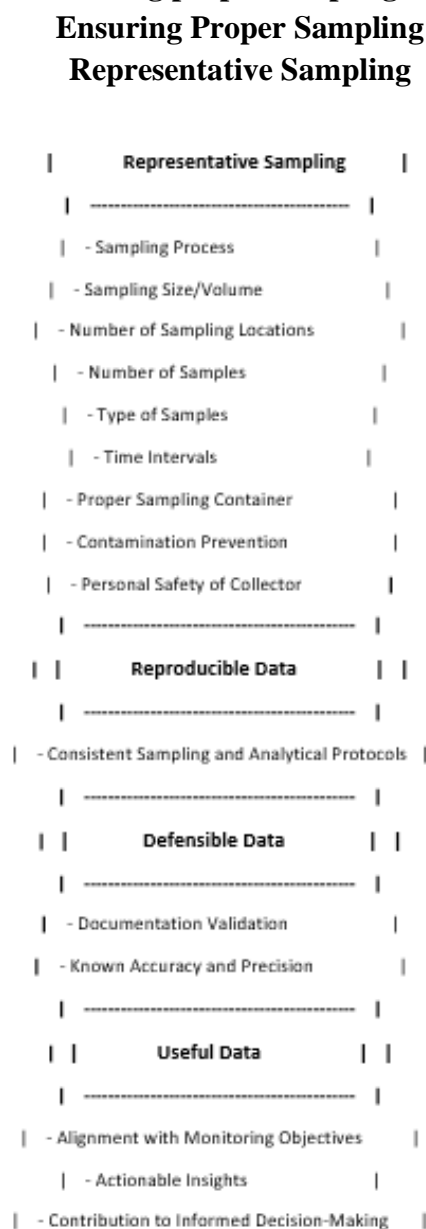
Documentation validating sampling procedures is essential. Data should possess a known degree of

accuracy and precision, bolstering its credibility and reliability.

(iv) Useful:

The collected data should align with the objectives of the monitoring plan. It should provide actionable insights and contribute meaningfully to informed decision-making processes regarding water quality management.

Figure 3: key aspects of ensuring proper sampling for water quality analysis:



This diagram outlines the critical components of proper sampling for water quality analysis, emphasizing the need for representative,

reproducible, defensible, and useful data. Each section includes key considerations and practices to ensure robust sampling procedures.



F. Ensuring Proper Labeling

Proper labeling serves as a critical safeguard against sample misidentification, ensuring the integrity of data and upholding the accountability of the collector. Adequate labeling of sample containers is paramount, achieved by affixing appropriately inscribed tags or labels directly onto the containers. Alternatively, waterproof markers or barcode labels can be utilized for this purpose. Key information to be included on the sample container or tag comprises:

(i) Sample Code Number:

A unique identifier specifying the sampling location.

(ii) Date and Time of Sampling:

Providing a timestamp for reference and chronological organization of samples.

(iii) Source and Type of Sample:

Describing the origin and nature of the sample, facilitating accurate identification and classification.

(iv) Pre-treatment or Preservation:

Indicating any treatments or preservation methods applied to the sample before analysis, ensuring data reliability.

(v) Special Notes for Analyst:

Noting any specific considerations or observations relevant to the analysis process.

(vi) Sampler's Name

Identifying the individual responsible for sample collection, enhancing traceability and accountability throughout the sampling process. By adhering to proper labeling protocols, stakeholders can mitigate the risk of errors or discrepancies in sample identification, thereby bolstering the credibility and reliability of analytical results.

G. Sample Preservation: Ensuring Data Integrity

In the interval between sample collection and analysis, a temporal gap often arises, during which alterations to the sample's characteristics may

occur. To mitigate these changes, proper preservation measures are imperative both during transit to the laboratory and within the laboratory premises until analysis commences. Achieving complete and unequivocal preservation of samples, whether they are derived from domestic wastewater, industrial effluents, or natural water sources, presents a practical challenge. While it's unrealistic to maintain absolute stability for every constituent, preservation techniques can effectively retard chemical processes, particularly the hydrolysis of constituents, and minimize biological changes that persist after sample collection. It's important to note that no single method of preservation is universally satisfactory. The choice of preservative depends on the specific determinations to be made. Preservation methods encompass a range of techniques, including pH control, chemical additives, utilization of amber and opaque bottles to minimize light exposure, refrigeration to inhibit microbial growth, filtration to remove particulate matter, and freezing to preserve sample integrity. Each method is tailored to address the unique preservation requirements of the constituents under investigation. By meticulously implementing appropriate preservation measures, analysts can maintain the integrity of samples, ensuring that subsequent analyses yield reliable and accurate results. These preservation practices are essential for safeguarding the integrity of environmental monitoring data and facilitating informed decision-making processes regarding water quality management.

H. Laboratory Analysis: Ensuring Methodical Assessment

Upon arrival at the laboratory, the samples undergo analysis, meticulously scrutinizing the requisite parameters in accordance with established methods and protocols.

This process entails:

Parameter Specification:



Identifying and prioritizing the parameters relevant to the analysis based on the intended purpose and regulatory requirements.

Method Selection:

Choosing appropriate analytical methods and protocols tailored to each parameter, ensuring accuracy, precision, and adherence to industry standards.

Sample Preparation:

Preparing the samples for analysis by following standardized procedures, which may include filtration, dilution, or extraction, to ensure optimal sample integrity and suitability for analysis.

Instrumental Analysis:

Employing state-of-the-art instrumentation and equipment to quantitatively and qualitatively measure the target parameters with precision and reliability.

Quality Assurance:

Implementing rigorous quality assurance and quality control measures throughout the analytical process to validate results, detect any anomalies, and ensure data integrity.

Data Interpretation:

Analyzing the obtained results in context, comparing them against established benchmarks, and drawing meaningful conclusions to inform decision-making processes. By adhering to these systematic and meticulous procedures, laboratories can consistently deliver accurate and reliable analytical results, thereby supporting informed decision-making and effective management of water resources.

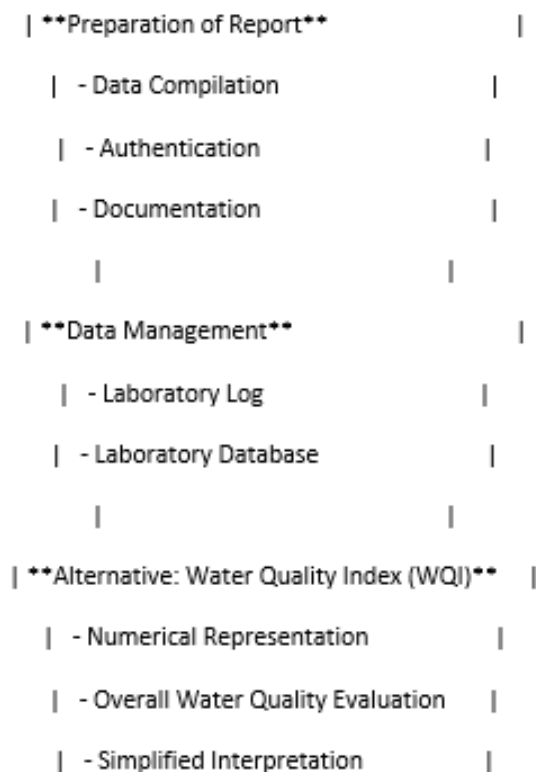
I. Reporting: Ensuring Transparency and Accessibility

The culmination of water analysis entails the preparation of a comprehensive report in response to the submitted requisition. Prior to dissemination, the report undergoes authentication to ensure its accuracy and reliability. All data generated during the analysis process are meticulously documented in the laboratory log and

preferably stored in a laboratory database for easy access and future reference. An alternative method for presenting the overall quality of water is through the use of a Water Quality Index (WQI). The WQI serves as a concise numerical representation of the overall water quality of a water body, facilitating easy interpretation and widespread use. Unlike reporting individual water quality parameters (WQP), the WQI condenses complex data into a single digit, making it readily comprehensible for a broad audience, including the general public. By adopting transparent reporting practices and utilizing tools such as the WQI, laboratories can effectively communicate water quality information to stakeholders, empowering them to make informed decisions regarding water resource management and environmental stewardship. This diagram illustrates the process of reporting water analysis results, including the preparation of the report, data management practices, and the alternative approach of using a Water Quality Index (WQI) for conveying overall water quality information. Each section outlines key components and considerations involved in reporting water quality data effectively.



Figure 4: the process of reporting water analysis Results.
Reporting



CONCLUSION: ENSURING WATER QUALITY FOR INTENDED USE

The evaluation of water quality stands as a crucial step in verifying the suitability of a water source for its intended purpose. Through the assessment of various water quality parameters and comparison with established standards, the acceptability of water for use is determined. Over time, extensive research has led to the standardization of procedures for water assessment.

This article serves as a concise resource, consolidating guidelines for water quality assessment into one accessible source. By providing a comprehensive overview of standards and procedures, it aims to support researchers and analysts in navigating the complexities of water quality assessment. Ultimately, the aim is to

facilitate informed decision-making and ensure the provision of safe and suitable water resources for various applications.

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