

Title: Smart Water Quality Monitoring in Oil, Gas and Petrochemical Industries ‹Case Study of Bidboland Gas Refinery

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ABSTRACT

Water, as one of the most critical process fluids in the oil, gas, and petrochemical industries, plays a significant role in the optimal performance of equipment, operational stability, and product quality (19, 16). Any undesirable change in water quality parameters can lead to disorders such as severe equipment corrosion, formation of deposits in heat exchangers, reduced efficiency of cooling systems, and increased operating costs (12, 13, 4). Therefore, accurate and continuous monitoring of water parameters is of utmost importance (19, 4). The aim of this research is to investigate, analyze, and compare modern methods for measuring water parameters in the oil, gas, and petrochemical industries with a smart approach, compared to traditional measurement methods. This research is applied in terms of purpose and descriptive-analytical in nature. The data were collected through library studies, reliable scientific sources, industrial standards, and technical reports (5). Research results indicate that traditional measurement methods face significant limitations due to their discontinuous nature, dependence on human resources, and delays in providing results (4, 20). In contrast, new technologies, including electrochemical sensors, optical sensors, online analyzers, Internet of Things (IoT)-based systems, and advanced data analysis algorithms, enable real-time monitoring, reduce human error, and significantly improve operational decision-making (10, 14, 11). In addition, results indicate that the use of these technologies can improve operational efficiency and reduce long-term costs in the oil, gas, and petrochemical industries by reducing corrosion rates (13), controlling deposits more effectively (6), optimizing chemical consumption (6), and extending equipment life (12).

Keywords: *Industrial water quality; Online measurement of water parameters; Smart monitoring; Electrochemical sensors*

1. *INTRODUCTION*

1.1. Importance of Water in Oil, Gas, and Petrochemical Industries

Water, as one of the fundamental fluids in the value chain of oil, gas, and petrochemical industries, plays a vital role in a wide range of applications including steam production systems (boilers), heat transfer (cooling towers), process units, water injection systems for reservoirs, and wastewater treatment units (19, 6). The quality of water used in these industries has a direct impact on overall operational efficiency, equipment lifespan, and operational costs (4, 16).

1.2. Challenges Caused by Poor Water Quality

Neglecting water quality control can lead to a wide range of operational problems. These include:

a) Extensive corrosion in pipelines and metal equipment (12, 13).
b) Formation of mineral and organic deposits on heat exchange surfaces, which reduces heat transfer efficiency and increases energy consumption (6, 4).
c) Microbial growth and biofilm formation in cooling systems, which causes microbial corrosion and reduces fluid flow.

1.3. Evolution in Water Quality Monitoring Approaches

In the past, water quality monitoring relied primarily on manual sampling and laboratory analysis (4, 20). Although these methods have acceptable accuracy and are recognized as reference methods (1, 2), they are unable to provide a real-time picture of the system's status due to their intermittent and time-consuming nature (4). With significant advancements in instrumentation, information technology, and communications, new approaches based on smart and online water quality monitoring have emerged (10, 20).

1.4. Research Objectives

The main objective of this research is to comprehensively investigate modern methods of measuring water quality parameters in oil, gas, and petrochemical industries, evaluate their advantages and limitations compared to traditional methods, and examine the role of smart monitoring in improving operational

Chapter 2: Theoretical Foundations and Background

2.1. Role of Water in Process Units of Oil and Gas Industries

The role of water in oil and petrochemical industries is not limited to utility purposes. In many key processes, water is directly involved. For example, in sulfur recovery units, hydrogen production, as well as refining and separation processes, the quality of consumed water affects the efficiency and quality of the final product (19).

2.2. Key Industrial Water Quality Parameters

Identifying and controlling water quality parameters forms the basis of proper water system management. These parameters are typically categorized into:
a) Physical parameters:
Including temperature, turbidity, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS).
b) Chemical parameters:
Including pH, electrical conductivity (EC), hardness, alkalinity, dissolved oxygen (DO), chloride (Cl^-), sulfate (SO_4^{2-}), silica (SiO_2), and heavy metals.
c) Biological parameters:
Including total bacteria count, and presence of pathogens if necessary.
Credible standards such as APHA (1) and ASTM (2) provide standard and precise methods for measuring these parameters.
2.3. Traditional Approaches to Water Quality Measurement
Traditional water quality measurement methods, which have a long history in industry, rely mainly on manual sampling and laboratory analysis. These methods include:
a) Colorimetry and Photometry methods: For measuring parameters such as chlorine and certain
b) ions.
b) Titration: The classic method for measuring hardness, alkalinity, and some other elements.
c) Electrical conductivity and TDS measurement: Using portable or laboratory devices.
While accurate and considered reference methods (1, 2), these methods have fundamental limitations in providing real-time information and require skilled operators and significant time (4, 20).

2.4. Modern Technologies in Smart Water Monitoring
Technological advancements, particularly in sensors, communication systems, and data processing,

have led to the emergence of modern technologies in water quality monitoring:

a) Electrochemical sensors: Based on changes in electrical potential or current, these sensors allow

b) continuous measurement of parameters like pH, EC, DO, and redox potential (ORP) (8, 14).

b) Optical sensors: Used for measuring turbidity, color, and certain specific chemical parameters.

c) Online analyzers: Specialized devices capable of continuously measuring parameters such as silica, sodium, phosphate, and residual chlorine.

c) Internet of Things (IoT) and Cloud Systems: These technologies enable collecting data from

d) numerous sensors, transmitting them to a central platform, and analyzing and storing data in the cloud (11, 17).

e) Artificial Intelligence (AI) and Machine Learning (ML): These tools are capable of analyzing

f) complex patterns in monitored data, predicting trends, detecting anomalies, and optimizing control parameters (11).

Chapter 3: Methodology

3.1. Research Approach:

This research is classified as applied research, as it aims to provide solutions for improving industrial processes. In terms of method, a descriptive-analytical approach was adopted. In this method, the current status and technical knowledge related to the topic (traditional and modern water monitoring methods) are first described, and then by analyzing data and comparing the methods, an evaluation and conclusion are drawn (5).

3.2. Data Collection :

The data required for this research were gathered from credible scientific and technical sources, including:

a) Books and: Such as reference books in the field of industrial water quality (4, 6) and corrosion topics (12, 16).

industrial references b) Scientific and research articles: From credible domestic and international journals in the fields of

water engineering, chemistry, and oil and petrochemical industries (10, 13, 14, 15, 17, 20).

c) Industrial standards: International standards such as ASTM (2) and APHA Standard Methods (1), as well as internal guidelines of major companies (18, 19).

d) Technical reports and specialized websites.

3.3. Analysis and Comparison of Methods:

During the analysis phase, the key water quality parameters that have the greatest impact on industrial processes were identified first. Then, traditional and modern water measurement methods were compared considering the following criteria:

a) Accuracy and precision of measurement.

b) Response speed and capability of real-time monitoring.

c) Initial investment cost and Operational and Maintenance (O&M) costs.

d) Reliability and durability of equipment in industrial conditions.

e) Ease of use and requirement for skilled personnel.

f) Capability of integration with existing control systems (such as DCS and SCADA).

Chapter 4: Findings and Analysis

4.1. Comprehensive Analysis of Key Water Quality Parameters

Literature review shows that controlling parameters such as pH, electrical conductivity, hardness, silica, chloride, sulfate, and dissolved oxygen is vital for preventing corrosion (12, 13) and scaling (6) in industrial oil, gas, and petrochemical systems. Deviation from the permissible ranges of these parameters, as mentioned in (4) and (19), can lead to reduced efficiency and increased maintenance costs.

4.2. Evaluation of Traditional Measurement Methods:

Traditional methods, despite their high accuracy (1, 2), remain intermittent in nature. The time-

consuming sampling and analysis process (sometimes up to several hours or days) (4), lack of real-time monitoring of sudden changes, and high dependence on human error (20) are the most important limitations of this approach.

4.3. Capabilities of Modern Smart Monitoring Technologies :
Modern technologies, especially online sensors and IoT systems, enable continuous and real-time monitoring of various water parameters (10, 11). This allows operators to perform preventive actions in a timely manner by observing trends in water quality changes. Electrochemical sensors (8, 14), online silica analyzers (1), and IoT-based data collection systems (11, 17) are examples of these technologies.

4.4. Comparative Analysis of Traditional and Modern Methods

Comparsrison Criteria	***Traditional Method***	***Modern(Smart) Method***
Monitoring Speed	*Intermittent*	*Continuous(online)*
Response Speed	*Slow(Hours/Days)*	*Fast (seconds/Minutes)*
Human Error	*High*	*Low*
Initial Cost	*Low*	*High*
Operating Cost	*Dependent on Labor*	*Lower(via optimization)*
Advanced Analytics	*Limited*	*High(with Al/ML)*
Integration	*Difficult*	*Easy(DCS/SCADA)*

This comparison shows that despite higher initial costs, modern smart monitoring methods offer significant advantages in the long term in terms of operational optimization, cost reduction, and system safety (10, 11).

Chapter 5: Discussion

5.1. Transition to Smart Water Quality Management
The current research confirms that leveraging modern smart monitoring technologies facilitates the transition from traditional approaches to active and preventive water quality management (4, 10).
Continuous monitoring and analysis of data from online sensors enable early identification of deviations from desired conditions and timely decision-making. This is of particular importance in industries such as Bidboland Gas Refinery, which have high operational sensitivity.

5.2. Developing Predictive Maintenance
Intelligence and Machine Learning algorithms (11). By analyzing this data, patterns affecting phenomena like corrosion (13) and scaling (6) can be identified. This provides the basis for

developing predictive maintenance capabilities; an approach where, instead of reactive repairs or scheduled periodic maintenance, repairs are based on the predicted future condition of equipment. This strategy leads to reduced unplanned downtime and optimized maintenance costs.

5.3. Improving Operational Efficiency and Reducing Costs
Precise control of water quality parameters plays a direct role in increasing industrial system efficiency. For example, preventing scaling in heat exchangers (6) keeps heat transfer efficiency at the desired level and reduces energy consumption. Furthermore, controlling corrosion (12, 13) extends the useful life of expensive equipment and minimizes replacement or major repair costs. Optimizing chemical consumption (such as corrosion and scale inhibitors) (6) is another positive achievement of smart monitoring.

Chapter 6: Conclusion

6.1. Summary of Findings
This research showed that modern smart water quality monitoring technologies, with capabilities such as online measurement, reduced human error, comprehensive data collection and analysis, and integration with advanced control systems, have created a fundamental evolution in water quality management in oil, gas, and petrochemical industries (10, 11). Comparison with traditional methods revealed the significant superiority of these technologies in terms of speed, accuracy, continuity, and predictability (4, 20).

6.2. Implications for the Oil and Gas Industry
The use of smart water quality monitoring systems directly helps with the following in related industries, including Bidboland Gas Refinery:
a) Significant reduction in corrosion and scaling rates in sensitive systems (13, 6).
b) Extending equipment lifespan and reducing maintenance costs (12).
c) Optimization of energy and chemical consumption (6).
d) Improvement of operational safety and stability.

6.3. Implementation Requirements
Successful implementation of these technologies requires attention to technical infrastructure (such as stable communication networks and data processing capacity), development of specialized human skills in instrumentation, data science, and smart system management, and careful selection of equipment tailored to the operational needs and environmental conditions of each industrial unit (11, 19).

Chapter 7: Recommendations

7.1. Hybrid Monitoring Approach
It is recommended that oil, gas, and petrochemical industries, especially Bidboland Gas Refinery, adopt a hybrid approach to water quality monitoring. In this approach, smart and online monitoring systems should be used as the primary tool for identifying trends and early warnings, while traditional and standard methods (1, 2) are used alongside them as tools for periodic sensor calibration and validation of results.

7.2. Future Research
To expand knowledge in this field, it is suggested that future research focus on the following:

a) *Case Studies: Conducting detailed case studies in similar operational units to comprehensively*
b) *evaluate the economic and operational costs and benefits of implementing smart monitoring systems.*
c) *Developing Prediction Algorithms: Research and development of advanced AI and ML algorithms*
d) *to more accurately predict types of corrosion and scaling, and to offer optimal control solutions.*
c) *Impact on Equipment Lifespan: Conducting more comprehensive studies to determine the*
d) *quantitative relationship between water quality parameters and the useful life of key equipment in oil and gas industries.*
e) *Economic Analysis of Technologies: Comparative and economic assessment of various online monitoring*
f) *technologies based on diverse operational scenarios.*

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