

Evaluation of Drinking Water Quality in the Mining Municipality of Moa

Evaluación de la calidad del agua potable en el municipio minero de Moa

Amanda Fernández-Rodríguez^{1*}, Moraima Fernández-Rodríguez¹, Rafael M. Guardado Lacaba¹

¹University of Moa, Holguín, Cuba

*Corresponding author: afernandez@ismm.edu.cu

Abstract

The quality of drinking water supplied to the city of Moa, Cuba, was evaluated over the course of one year using the Water Quality Index of the United States National Sanitation Foundation (WQI-NSF), with the aim of verifying the efficiency of the treatment process for the water consumed by the population. The water entering the purification process comes from the Moa River, which is surrounded by a mining environment and a high percentage of deforested areas with slopes that favor runoff into the stream during rainy periods. These factors can affect water quality, requiring greater consumption of chemical reagents for treatment. Based on the analysis of 1,460 samples, nine physicochemical and microbiological parameters were integrated. The results showed that all parameters were within the permissible limits established by Cuban standards NC 1021:2014 and NC 827:2017. The WQI-NSF value ranged between 79,8 % and 84,6 %, with an average of 81,8 %, classifying the water in the "good quality" category according to the index scale. It is concluded that the purification process at the Treatment Plant is efficient and delivers good-quality water suitable for human consumption.

Keywords: water treatment, water quality, WQI-NSF

Resumen

Se evaluó la calidad del agua potable abastecida a la ciudad de Moa, Cuba, aplicando el Índice de Calidad de Agua de la Fundación Nacional de Saneamiento de Estados Unidos (ICA-NSF) durante el año 2024, con el fin de verificar la eficiencia del proceso de tratamiento del agua que consume la población. Las aguas que entran al proceso de potabilización provienen del río Moa, el cual está rodeado por un entorno minero, y con un alto porcentaje de áreas deforestadas, con pendientes, que favorecen las escorrentías hacia

la quebrada en tiempos de lluvia. Estos factores pueden afectar la calidad de las aguas, lo que exige un mayor consumo de reactivos químicos para su tratamiento. A partir del análisis de 1 460 muestras, se integraron nueve parámetros físico-químicos y microbiológicos. Los resultados mostraron que todos los parámetros se encuentran dentro de los límites permisibles establecidos por las normas cubanas NC 1021:2014 y NC 827:2017. El valor del ICA-NSF osciló entre 79,8 % y 84,6 %, con una media de 81,8 %, lo que clasifica al agua en la categoría de "buena calidad" según la escala del índice empleado. Se concluye que el proceso de potabilización en la Planta de Tratamiento es eficiente y entrega agua de buena calidad, apta para el consumo humano.

Palabras clave: tratamiento de agua, calidad del agua, ICA-NSF

1. INTRODUCTION

Surface water sources are central to human development as they enable supply for various socioeconomic activities, although some of these activities cause alteration and deterioration of water quality. In general, surface waters are subject to natural contamination (entrainment of particulate and dissolved matter and presence of natural organic matter) and anthropogenic contamination (effluents from industrial processes, domestic wastewater discharges, agricultural runoff, among others).

The greatest impact on health occurs through water supply systems; the alteration of the organoleptic, physical, chemical, and microbiological characteristics of the water source directly affects the level of sanitary risk present in the water, which is defined as the risk of transporting contaminating agents that may cause waterborne diseases to humans and animals.

Drinking water is that which complies with a set of standards established by national and international institutions and is considered not to cause harm to consumer health.

Water quality is defined as a complex concept involving a subjective judgment that is a function of use, and also includes a set of physical, chemical, and biological parameters describing its composition, degree of alteration, and the utility of the water body (Larrea-Murrell et al., 2022).

In every community, drinking water quality is a fundamental determinant of public health and socioeconomic well-being. In industrial cities where mining activity may affect water resources, systematic monitoring of water quality becomes an essential priority.

Moa, a region known for its mining-metallurgical activity in northeastern Cuba, is not immune to this reality, generating a constant need to evaluate the efficiency of water treatment processes. Despite the existence of rigorous national regulations, such as NC 1021:2014 and NC 827:2017, the application of integrative quality indices, such as the Water Quality Index of the National Sanitation Foundation (NSF-WQI) of the United States, offers a holistic and synthetic perspective that facilitates communication and decision-making. Water quality indices allow for the general assessment of the water body, showing spatial and temporal variation through easily interpretable categories.

This study aimed to comprehensively evaluate, through the application of the NSF-WQI, the quality of drinking water supplied to the city of Moa during the year 2024, using a broad set of physicochemical and microbiological data, in order to validate the efficiency of the treatment system and provide an objective tool for local water management.

2. MATERIALS AND METHODS

The research was conducted at the water treatment plant responsible for supplying drinking water to the inhabitants of the city of Moa. Physicochemical and bacteriological analyses of the treated water were performed, and a total of 1,460 samples were analyzed during the period January–December 2024.

2.1. Analysis of Quality Indicators

The analysis of physicochemical and bacteriological indicators was carried out following the methodologies established in the standard method for the analysis of water and wastewater (Gilcreas, 1966). It was processed using classifications according to De Miguel-Fernández (2012).

2.2. Water Quality Analysis

Water quality analysis was carried out using the NSF-WQI methodology (Brown et al., 1970) based on the following criteria: a) widespread international use, b) classification considering the resource's destination for public supply purposes, and c) feasibility of the parameters to be evaluated.

2.3. Design Methodology

The water quality index (WQI) is a tool that allows identifying the water quality of a surface or groundwater body at a given time. In general, the WQI incorporates data from multiple physical, chemical, and biological parameters

into a mathematical equation, through which the state of the resource is evaluated.

To determine the WQI, arithmetic averages of the ratings for all variables were calculated; the temporary weights were calculated by dividing the importance of each parameter by the weight rating of the most important variable (dissolved oxygen). Thus, the temporary weights were individually divided by the sum of the temporary weights, which produced the final weights (Osorio-Ortega et al., 2021), as established by the methodology.

The NSF-WQI uses a weighted linear sum of the effect of the response variables, and the results are expressed as integer numbers on a scale from 0 to 100, where values between 0 and 25 represent very poor quality; 26 to 50 poor; 51 to 70 fair; 71 to 90 good; and 91 to 100 very good.

The methodology uses nine parameters and their corresponding weighting factors (Table 1), taking into account the formula described below (Equation 1):

$$WQI(ICA) = \sum_{i=1}^n Q_i W_i \quad (1)$$

Where:

Q_i = Sub-index of parameter i

W_i = Weight or weighting factor for sub-index i






Table 1. Weighting factors for calculating the NSF-WQI

Parameter	Units	Weighting Factor (Wi)
Dissolved Oxygen	%	0.17
Thermotolerant Coliforms	MPN/100ml	0.16
Biochemical Oxygen Demand	mg/L	0.10
pH	pH units	0.12
Nitrates	mg/L	0.10
Water Temperature	°C	0.10
Total Phosphate	mg/L	0.10
Turbidity	NTU	0.08

Total Dissolved Solids	mg/L	0.08
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The final result is interpreted according to the following classification scale and color corresponding to each range (Table 2).

Table 2. General water criterion according to the NSF-WQI value

NSF-WQI	Value Range	Color
Excellent	91 - 100	
Good	71 - 90	
Medium	51 - 70	
Poor	26 - 50	
Very Poor	0 - 25	

Among all existing water quality indices for environmental studies, the NSF-WQI has the particularity of being widely used due to a combination of characteristics that make it practical, adaptable, and internationally recognized. It is a de facto standard in environmental assessment because it combines scientific rigor, communicative practicality, and applicative flexibility. Its design allows adaptations without losing global comparability, which explains its superiority over more local or specialized indices.

2.4. Components for WQI Evaluation

The following were determined: pH, dissolved oxygen, turbidity, biochemical oxygen demand, nitrates, thermotolerant coliforms, water temperature, total phosphate, total dissolved solids (Quispe-Capcha & Villa-Cayetano, 2022; Sandoval de Avalar & Acosta-Martínez, 2025).

3. RESULTS AND DISCUSSION

3.1. Water Classification by pH according to Pasoxov and BOD₅

pH values ranged between 7.4 and 8.3 (Figure 1). In general, the waters are classified as weakly basic, with values between 7.5 and 8.5. BOD₅ values ranged from 0.3 mg/L to 1.9 mg/L during the study period, complying with the limit of 4 mg/L established by Cuban Standard 1021 (2014a). A direct correlation was observed between BOD₅ and pH values, where a decrease in pH (increased acidity) coincided with lower BOD₅ values. This relationship is explained by the fact that acidity inhibits microbial development, thus reducing the degradation of organic matter that determines BOD₅ (Cuban Standard 1021, 2014).

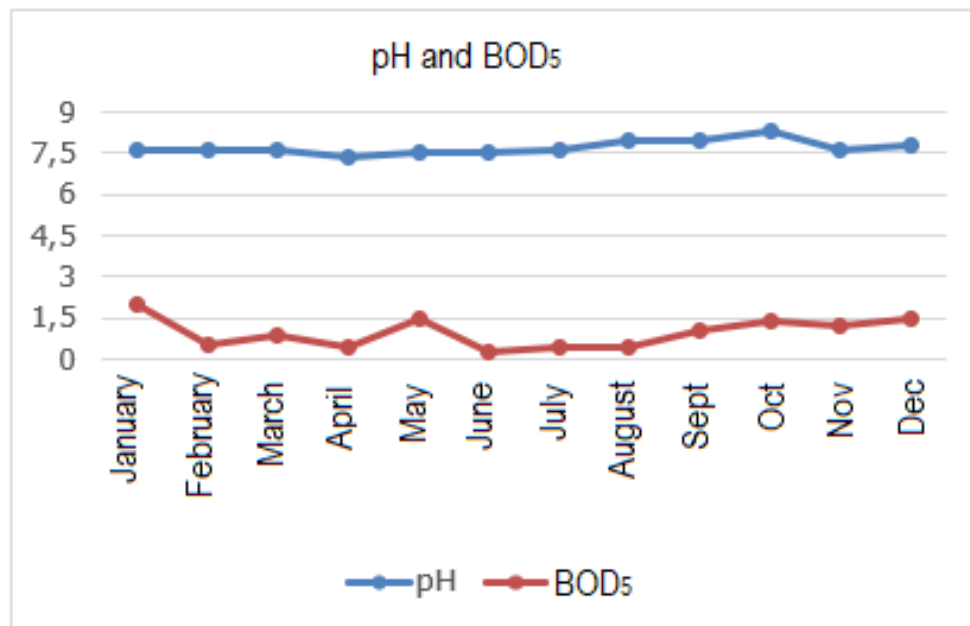


Figure 1. Behavior of pH and BOD₅.

3.2. Temperature and Mineralization

Water temperature during the analyzed period ranged between 23.5°C and 26°C (mean 25°C), showing a direct relationship with environmental temperature depending on factors such as time of day and season. These values, which classify the water as tepid (20°C–37°C) according to De Miguel Fernández (2012), reflect normal fluctuations within the expected range for the environmental conditions of the study area (Figure 2).

Meanwhile, water mineralization, which reflects its total content of dissolved solids (in mg/L), is key to determining its use. Although more than 60 elements may be found in natural waters, only a few, such as Ca²⁺, Mg²⁺, Na⁺, and Cl⁻, are present in significant quantities. According to the results, the studied waters have mineralization below 1 g/L, classifying them as fresh. The months with the highest mineralization (January, March, and April) coincided with those of highest rainfall.

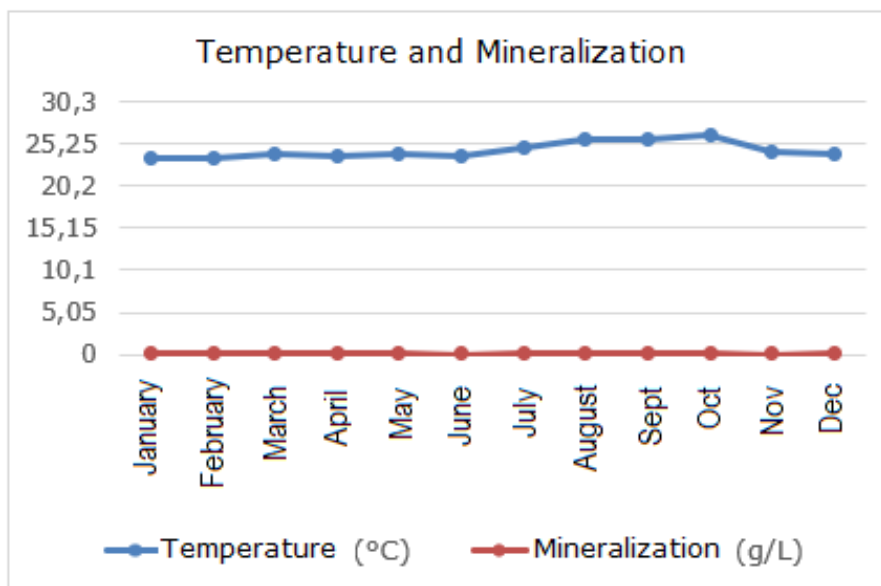


Figure 2. Behavior of Temperature and Mineralization

Water hardness depends on calcium and magnesium salts (measured in $\text{mg}\cdot\text{eq/L}$). According to the water classification used, they are soft, with values between $1.5 \text{ mg}\cdot\text{eq/L}$ and $3.0 \text{ mg}\cdot\text{eq/L}$ (Figure 3). This low hardness is mainly due to low calcium levels, influenced by the geological environment of the river, dominated by serpentinized ultrabasic rocks. This pattern was maintained in both raw and treated waters.

3.3. Turbidity (NTU)

During rainfall, runoff carries mineral sediments that increase river turbidity, raising reagent consumption to meet quality standards. In treated waters, turbidity remained between 0.4 NTU and 1.00 NTU , well below the maximum limit of 5 NTU recommended by WHO (2006) for drinking water.

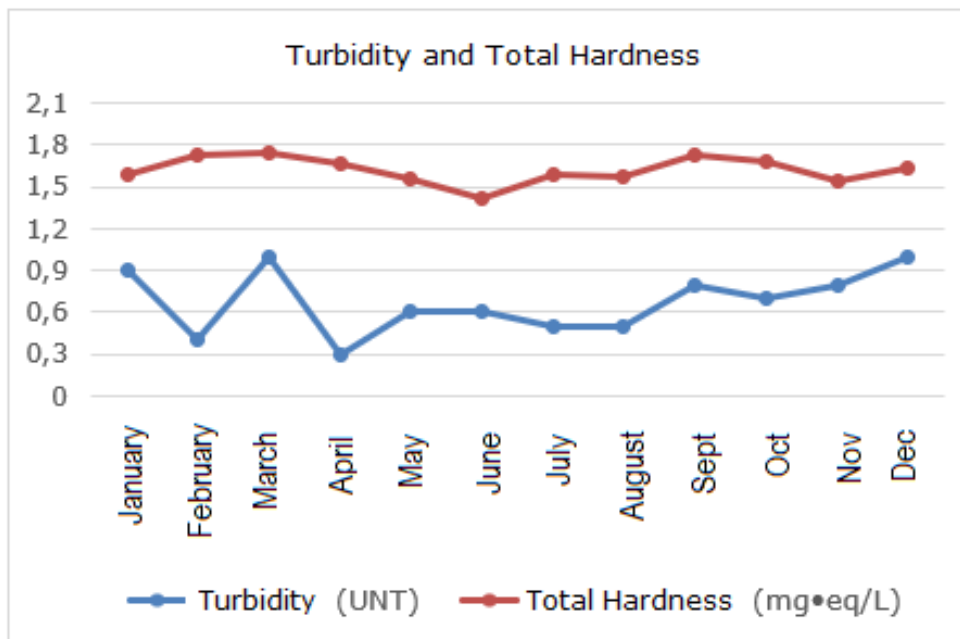


Figure 3. Behavior of turbidity and total hardness.

3.4. Classification of waters by electrical conductivity and total dissolved solids

The electrical conductivity of water ($165.3 \mu\text{S}/\text{cm}$ – $201.0 \mu\text{S}/\text{cm}$) reflects its content of dissolved solids (TDS: $74.4 \text{ mg}/\text{L}$ – $90.0 \text{ mg}/\text{L}$), showing a direct relationship between both parameters. Maximum values occur in December due to increased ions from runoff during rainfall, approaching the upper conductivity limit ($200 \mu\text{S}/\text{cm}$) according to Cuban Standard 827 (2017). However, both conductivity and TDS ($1,000 \text{ mg}/\text{L}$) remained within potable ranges (Figure 4), confirming water quality for consumption according to WHO (2006), Cuban Standard 1021 (2014), and Cuban Standard 827 (2017).

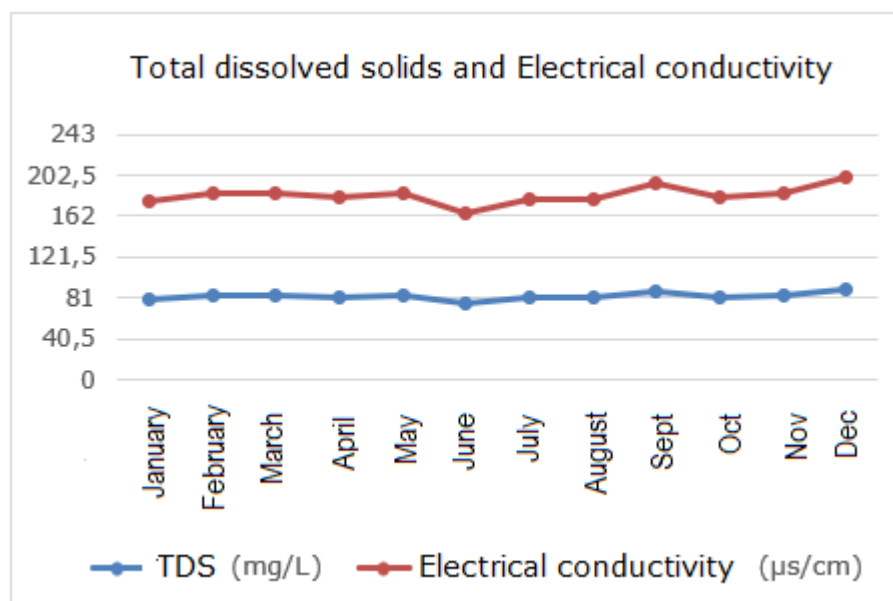


Figure 4. Behavior of total dissolved solids and electrical conductivity.

3.5. Microbiological Parameters

The determination of microorganisms in drinking water and their concentration provides control tools indispensable for decision-making. The values in the samples regarding fecal coliforms were absent (NMP/100 mL).

Total coliform values were reported for each month at -2.2 NMP/100 mL, below the permitted ranges according to Cuban Standard 827-2017. It can be concluded that, bacteriologically, this water is suitable for human consumption.

3.6. Quality of Treated Waters According to the NSF-WQI

The NSF-WQI ranges from 71% to 90%. The values of this index for the waters of Moa that receive treatment for human consumption were between 79.8% and 84.6% over the 12 months evaluated. The minimum value corresponded to the month of October (79.71%), while the maximum was reached in January (84.58%), the mean was 81.84%, the variance 29.69%, reflecting good water quality for consumption (Table 5).

Table 5. Monthly results of NSF-WQI values

Year 2024	Monthly values of the Total WQI									
	OD	Col. Fec.	pH	DBO ₅	T °C	PO ₄ ³⁻	NO ₃ ⁻	Turb	STD	WQI total
January	15,1	15,2	10,7	8,8	23,5	9,7	9,3	7,8	5,9	84,6
February	15,9	15,38	10,7	10,3	23,6	6,7	9,3	6,9	5,9	83,2
March	16,5	15,4	10,7	10,3	24	6,7	9,4	6,8	5,8	80,4
April	15,9	15,41	10,2	10,5	23,7	6,9	9,2	6,9	5,8	82,9
May	16,5	15,4	10,2	9,5	24,1	6,8	9,3	6,9	5,8	82,9
June	16,7	15,38	10,2	10,5	23,9	6,8	9,2	6,9	5,9	81,8
July	15,9	15,4	10,0	10,5	24,8	6,8	9,2	6,9	5,8	82,0
Agust	14,8	15,4	9,4	10,5	25,8	6,4	9,3	6,9	5,8	82,4
September	15,9	15,4	9,4	10,2	25,8	6,4	9,2	6,8	5,9	81,2
October	16,5	15,4	9,0	9,6	26,2	6,7	9,2	6,8	5,7	79,8
November	15,9	15,4	10,0	9,8	24,2	6,7	9,3	6,8	5,8	80,8
December	16,5	15,4	9,7	9,5	24	6,8	9,2	6,8	5,8	80,3

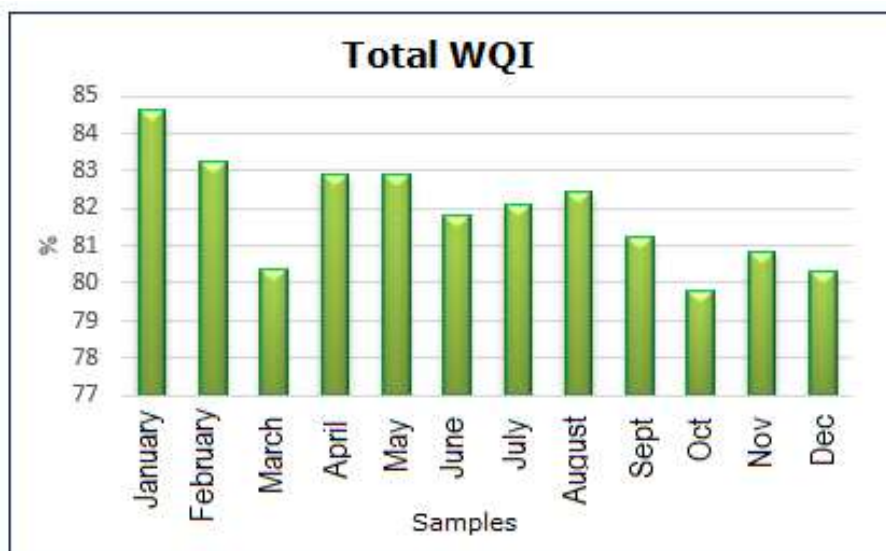


Figure 5. Graphical representation of the NSF-WQI behavior in the samples analyzed during the 12 months of the year 2024.

4. CONCLUSIONS

- The physical and chemical properties determined in the treated waters of the Moa municipality present values below the admissible limits,

according to NC:1021:2014, NC:827:2017, and the World Health Organization standard (WHO, 2006). They are classified as hydrocarbonate-magnesium-chloride-calcium waters; by hardness, as very soft waters; and by pH, as neutral and weakly basic.

- The Water Quality Index established by the United States National Sanitation Foundation methodology (NSF-WQI) for the 12 months evaluated lies in the range of 71%–90%. The quality values for the analyzed waters ranged between 79.8% and 84.6%, with a mean value of 81.8%, which indicates effective water treatment for human consumption in the Moa municipality.

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Additional Information

Conflict of Interest

The authors declare that there are no conflicts of interest.

Author Contributions

All authors contributed equally.

ORCID

AFR, <https://orcid.org/0009-0007-1239-814X>

MFR, <https://orcid.org/0000-0003-1211-3865>

RMGL, <https://orcid.org/0000-0003-1075-8176>

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