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Water quality in swamps by evaluating the presence of physical-chemical and biological parameters

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ABSTRACT
The objective of this study was to evaluate the water quality of the San Benito de Abad-Sucre-Colombia, swamp by analyzing the physicochemical and microbiological parameters present in the water. Initially, a search for scientific information on the current state of contamination was carried out, then a visit and pre-diagnosis of the current state of the water were carried out, and finally, sampling, storage, processing, packaging and chain of custody were carried out for water quality analysis and analysis of the current state compared to the national regulations for surface waters established in Colombia. According to the principal component analysis (PCA), the chemical parameters with the highest values analyzed corresponded to orthophosphate, total phosphorus and total solids, followed by the presence of turbidity, salinity and chlorophyll b. These variables are of great importance for aquatic ecosystems because they are indicative of the composition and dynamics of the polluting agents and contribute to the evaluation of the water quality of lotic bodies.

Keywords: Water, ecosystem, indicator, quality

1. INTRODUCTION

According to Guadrón (2016), water is a fundamental resource, representing nearly 70% of living beings, acting as a fundamental element in physical, chemical and biological processes that allow life on the planet. Since the industrial revolution, water resources have undergone significant changes due to multiple factors contributing to the physical, chemical and biological contamination of water.

According to the Ministry of Housing, Development of Sectoral Mitigation Action Plans (PASm) for Wastewater and Solid Waste. 2010, the department of Sucre is located in the Colombian Caribbean plain, north of the central and western mountain ranges, with an area of 10,917 km2. It is bordered to the north and east by the department of Bolívar, to the south by the departments of Antioquia and Córdoba and to the northeast by the Caribbean (Colombia) Sea, covering an area of 102 km of coastline33. Nearly a third of its territory is part of the floodable depressions of the Bajo Magdalena, Cauca and San Jorge rivers, characterized by numerous swamps (the main ones being Malambo, la Hormiga, Punta de Blanco and San Benito-Colombia), especially along the San Jorge River.

According to the observation carried out by the Government of the Department of Sucre-Colombia (2011), it indicates that 31% do not have a wastewater treatment system or oxidation ponds, which implies the disposal of discharges directly into the soil or surface water sources with negative impacts on the ecosystem and effects on public health due to the proliferation of diseases and insects; it also indicates that many municipalities, despite having oxidation pond systems, are managed inadequately without adequate periodic maintenance, which causes the system to not function correctly.

According to the report presented by the Municipal Council for Disaster Risk Management (CMGRD) (2012), the municipality of San Benito Abad and its hydrological ecosystem are exposed to risks of contamination by the transport of agrochemical inputs without the necessary prevention measures through the San Jorge River, in addition, the different channels and swamps of the municipality by the dumping of toxic waste used in the agroindustry, by inadequate practices of the irrational use of agrochemicals; there are also other risks from the spill of chemicals, such as mercury, cyanide and lead hydrochloride used by mining activity on the banks of the Cauca and San Jorge rivers, it is the factor of greatest impact of chemical risk suffered by the population of the municipality of San Benito and the region of La Mojana, when the Cauca and San Jorge rivers overflow they pour their contaminated waters into La Mojana and the Municipality of San Benito-Colombia.

The scarcity of quality water is a critical global challenge that arises from the systemic interaction between humans and the environment, where conditioning factors such as: productive and/or extractive activities, population density, human settlements adjacent to water bodies; together, they generate serious effects on the space-time availability of water supply, deteriorating the physicochemical and biological conditions of water.

Despite the high water supply in Colombia, there are serious problems with the availability of quality water in many regions; especially, those most populated areas.
The current problem of water quality is mainly derived from the discharge of waste resulting from human activities that interfere with the desirable use of water.
Among the physicochemical variables, temperature, color, turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), presence of nitrates, sulfates and phosphates, heavy metals, dissolved oxygen, pH and conductivity are identified.
Raw water can contain a wide variety of microorganisms, some of which are pathogenic and others non-pathogenic. Pathogenic organisms are those with the ability to cause diseases in living beings, while non-pathogenic organisms do not have any effects on human or animal health. The most important microorganisms found in water and which have pathogenic potential are bacteria, viruses, algae, fungi and some protozoa.
Total coliforms are used to identify possible changes in the biological locality of water, indicating that the water body has been contaminated with organic matter of fecal origin, both animal and human, accelerating the primary productivity of the lotic bodies. Fecal coliforms are a group of bacteria represented by the Enterobacteriaceae families that have been used as an ideal indicator for drinking water. Within this group, aerobic and facultative anaerobic bacteria stand out; although the largest representative is the *Escherichia bacteria. coli*, distinguished by its ability to grow at high temperatures and its capacity to produce the enzyme glucuronidase.
Based on the information available on the quality of pollution of water bodies in Colombia caused by anthropogenic activities, the main objective of this study was to evaluate the water quality of the San Benito de Abad swamp by analyzing the physicochemical and microbiological parameters present in the water and comparing the results with existing regulations for water bodies in Colombia.

2. MATERIALS AND METHODS

The methodology to determine the water quality of the swamp was carried out with the activities that will be described below in Figure 1, with which it is intended to objectively establish the current state of chemical, physical and microbiological contamination of the water body, in addition to the knowledge of the ecosystemic integrity and the anthropogenic deterioration factors, and also, to have a baseline to observe how the contamination rates.

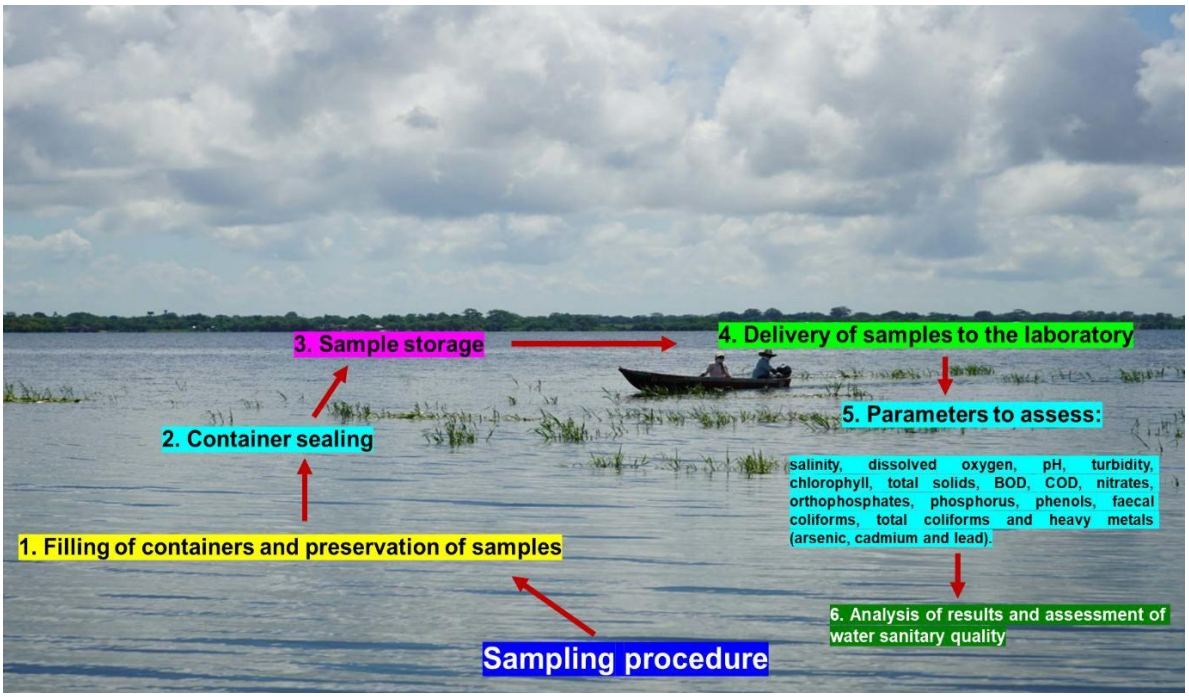

Figure 1. Sampling, storage, processing, packaging and chain of custody for water quality analysis in a swamp ecosystem in the department of Sucre, Colombia. Image source: https://mapaculturaldesucre.com/municipios/san-benito-abad/

3. RESULT AND DISCUSSION

Figure 2 describes the main physicochemical and microbiological parameters found in the water body in the municipality of San Benito de Abad, department of Sucre, Colombia. According to the principal component analysis (PCA), the chemical parameters with the highest values analyzed corresponded to orthophosphate, total

phosphorus and total solids, followed by the presence of turbidity, salinity and chlorophyll b, the latter indicating a sufficient estimate of the concentration of phytoplankton (microscopic algae) and indirectly of biological activity. The parameters that presented intermediate values corresponded to chlorophyll c, phenols, BOD. Finally, the lowest values were shown by the parameters Total coliforms, arsenic and *Clostridium. Perfringens* (Figure 2).

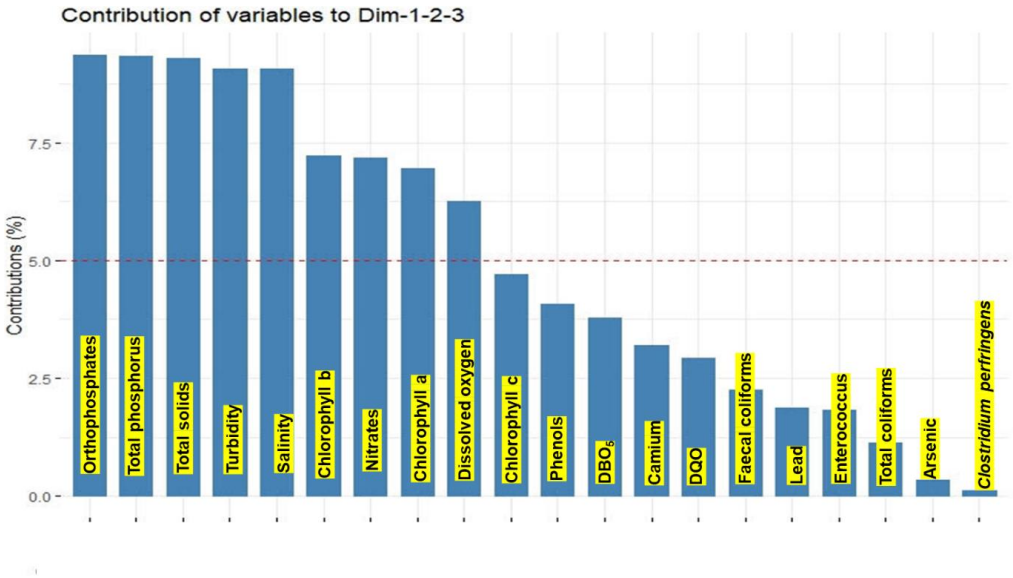

Figure 2. Distribution of physicochemical and microbiological parameters present in water body in the municipality of San Benito de Abad, department of Sucre, Colombia.

The parameter orthophosphate is more evident in the swamp, leading to eutrophication in surface water bodies, which implies the explosive growth of algae and the subsequent reduction of dissolved oxygen. Next, the presence of total phosphorus is observed to a large extent in the swamp water body. This element, when found in excess in combination with high temperatures and sunlight, stimulates the growth of excessive algae and these in turn, when they die, consume a lot of oxygen, leaving little for the fish and preventing their life.

The presence of turbidity is one of the most important parameters in water quality. Turbidity not only has a negative aesthetic impact for the consumer, but is also indicative of a higher probability of microbiological contamination and toxic compounds, which adhere to the dispersed matter in the water. And, consequently, it also indicates a greater difficulty in effective water disinfection. Dispersed solids and suspended particles in turbid water can act as carriers of microbiological contamination and also promote the adhesion of heavy metals, toxic organic compounds and pesticides.

Nitrates are observed in high levels in water bodies. The presence of this compound due to agricultural activities in the area leads to the impact on water bodies and therefore on the life of higher organisms.

As shown in Figure 2, phenolic compounds are present in greater abundance. The presence of these compounds is due to the agricultural activity carried out in the area, which by leaching reach the water bodies.

Regarding the analysis of the presence of heavy metals (mercury, lead, cadmium and arsenic) in the water bodies, the presence of the metal cadmium was determined with the highest concentration in the swamp, with respect to lead and arsenic (Figure 1).

According to the results of the microbiological analysis, the presence of water contamination bacteria with *Clostridium is observed perfringens*, *Enterococcus faecalis*and total coliforms are more prevalent. These types of bacteria can cause diarrhea and more serious intestinal conditions, such as colitis. They also cause endocarditis, urinary and intra-abdominal infections, prostatitis, cellulitis and wound infections. These bacteria are found in these bodies of water because the areas where they are found are filled with waste from the farms surrounding the swamps and because of the presence of animals in these swamps that defecate in them.

The presence of photosynthetic pigments (Chlorophyll a, b and c), the greatest presence corresponded to chlorophyll a and b. According to Eckhardt et al., (2004) and Scheer, (2006), although both chlorophyll *a*and chlorophyll *b* absorb light, chlorophyll *a* has a unique and crucial function in converting light energy into chemical energy. All photosynthetic plants, algae and cyanobacteria contain chlorophyll *a*, while only green plants and algae contain chlorophyll *b*, along with some types of cyanobacteria.

As Gil (2014) points out, the chemical composition of water is related to its capacity to maintain elements and substances in solution, which are important for the development of the microbiota. In addition to all of the above, the physicochemical parameters of water determined by environmental factors directly influence the diversity of macroinvertebrate communities. Some factors such as depth, pH, alkalinity, hardness, calcium ions, organic matter, industrial and domestic pollutants determine the relative abundance of the communities. Turbidity, color and suspended solids affect organisms that directly require plants for their food because they reduce the entry of sunlight, suppressing primary production.

The Chemical Oxygen Demand (COD) parameter is the value that indicates the amount of oxygen required for the oxidation of all organic substances in the water. The results show a higher consumption of oxygen. This shows low levels of oxygen in the swamps leading to future eutrophication of these bodies of water. Regarding the Biological Oxygen Demand (BOD), which is the amount of oxygen that microorganisms, especially bacteria (aerobic or anaerobic), fungi and plankton, consume during the degradation of the organic substances contained in the sample. It is used to measure the degree of contamination. Regarding the parameter Dissolved Oxygen, the highest concentration of this element is evident, demonstrating that this body of water is less disturbed.

According to the results of research carried out by Gualdrón (2016), high levels of turbidity in water bodies are not only indicative of the geomorphological conditions of our Colombia caused by drag processes, but also point to industrial and/or urban discharges as a source of pollution, altering the aquatic biota. Likewise, total dissolved solids when presenting values higher than permissible, indicating that the water quality of the water body is critical and does not present optimal conditions for the growth and reproduction of many aquatic organisms.

On the other hand, dissolved oxygen is a value associated with the values of nitrate (within permissible limits) and phosphate (slightly higher than the established limits), as well as the temperature that increases or reduces the potential of certain chemical substances, reducing the oxygen concentration of the water.

High BOD implies a decrease in dissolved oxygen in the water, which can cause anaerobiosis and death of organisms. Therefore, its elimination is a main objective of water treatment (Abdel- Raouf et al. 2012). The use of microalgae has proven to be efficient in reducing BOD and COD (Li et al. 2011, Abdel- Raouf et al. 2012) and also provides oxygen to aerobic bacteria that help in biotransformation (Abdel- Raouf et al. 2012). It is also reported that intense photosynthesis during the day in culture systems can increase dissolved oxygen levels to saturation > 200%. It is believed that high saturation could affect algae productivity.

Biochemical oxygen demand (BOD_5) is an indicator of the pollution load that can be generated by domestic and industrial waste of an organic nature when discharged into water streams in which aerobic conditions exist. Meanwhile, the chemical oxygen demand (COD)determines the amount of oxygen required to oxidize the organic matter present in a water sample, under specific conditions of an oxidizing agent, temperature and time. The high levels of fecal coliforms indicate the deplorable state of some rivers in Colombia related to the existence of wastewater discharges. In addition, this indicates that much of the water in Colombia's rivers is not suitable for human consumption.

4. CONCLUSION

According to the principal component analysis (PCA), the chemical parameters with the highest values analyzed corresponded to orthophosphate, total phosphorus and total solids, followed by the presence of turbidity, salinity and chlorophyll b, the latter indicating a sufficient estimate of the concentration of phytoplankton (microscopic algae) and indirectly of biological activity. Municipal wastewater comes from domestic human activity. Specifically, the current Technical Regulations for the Drinking Water and Basic Sanitation Sector establish requirements to be met for the management of domestic and industrial wastewater, which must comply with the parameters defined in Decree 1594 of 1984 and Resolution 0631 of 2015, prior to its final discharge.

Current scientific research has turned its attention to bio-absorbents such as microalgae, due to their great variety, abundance, availability of different species, good capacity to absorb metal ions (Yin et al., 2019; Gutiérrez-Benítez et al., 2014), high efficiency, low cost and respect for the environment (Yin et al., 2019; Vitola et al., 2018). In addition, they have different biochemical mechanisms for capturing heavy metals (Lee and Fisher, 2017) and neutralizing toxicity (Yin et al., 2019; Bilal et al., 2018). However, the growth of microalgae is limited by factors such as pollutant

5. Acknowledgements

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6. Author contribution.

Alexander Perez Cordero: experiment execution, data analysis. Donicer Montes V and Yelitza Aguas M, conceptualization, writing - revision and editing. All authors have read and approved the manuscript.

7. Conflict of interest

All the authors of the manuscript declare that they have no conflict of interest.

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