Colegio de Postgraduados

Physicochemical quality of underground water from agricultural influence

Vinay-Soto, I.[1]; **Amaro-Espejo, I.**[1*]; **Zúñiga-Ruíz, P.**[1]; **Galaviz-Villa, I.**[1]; **Navarrete-Rodríguez, G.**[1]

[1] Tecnológico Nacional de México/Instituto Tecnológico de Boca del Río. Boca del Río, Veracruz, Veracruz, México. 94290 (C. P.).

* Correspondence: isabelamaro@bdelrio.tecnm.mx

ABSTRACT

Groundwater in rural areas is the only source of supply for consumption and various activities. It is exposed to various pollutants that arrive through the subsoil layers. The objective of this study was to evaluate the quality of water from 15 wells in the municipality of Cotaxtla, through physicochemical variables such as pH, conductivity (EC), salinity and total dissolved solids (TDS), where the results were compared with the regulations according to its use. The samples were collected according to NOM-230-SSA1-2002. The physicochemical variables were determined with the multiparametric Consort C6010. Results ranged from pH 6.71-8.04, EC 228-4500 mS/cm, salinity 0.13-2.42 mg/L, and TDS 132-2250 mg/L. In every case, water is destined for agricultural use, where 52% is used for livestock and 80% for consumption, 60% of the wells are community and supply 612 inhabitants. According to Mexican regulations, the results obtained from EC, 13% of the wells were not suitable for consumption, in relation to the TDS results, 33% were not suitable for consumption and 13% were not suitable for agricultural irrigation. The pH showed values within the norm, however, one showed a pH of 6.71±0.043, while the rest were found between 7.4±0.03-8.1±0.19. In all values, significant differences were shown between the sites analyzed.

Keywords: Infiltration, groundwater table, water use.

Citation: Vinay-Soto, I., Amaro -Espejo, I., Zúñiga-Ruíz, P., Galaviz-Villa, I. & Navarrete-Rodríguez, G. (2024). Physicochemical quality of underground water from agricultural influence. *Agro Productividad*. https://doi.org/10.32854/agrop.v17i2.2759

Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas

Received: November 28, 2023.
Accepted: January 16, 2024.
Published on-line: April 04, 2024.

Agro Productividad, 17(2). February. 2024. pp: 129-134.

INTRODUCTION

During recent years, the increase in anthropogenic activities has caused deterioration in water quality. Globally, 20% of the population does not have access to drinking water and close to 50% does not have adequate sanitation [1]. However, more than 50% of the population depends on underground water; in rural zones, underground water is the sole source of supply destined to primary activities, domestic use and consumption [2]. However, it is also exposed to incoming contaminant compounds that reach the water table, thus affecting the water quality [3]. The impact that they cause happens through the subsoil layers, where contaminants manage to dissolve substances as they infiltrate, forming undesirable compounds [4]. The main sources of underground water pollution can come primarily from industrial activities, agriculture and livestock production, although the intensive use of fertilizers and agrichemicals in agricultural zones can be a diffuse source of pollution.

Cotaxtla, located in the Sotavento plains, in the central coastal zone of the state of Veracruz, is a municipality devoted primarily to agriculture and its only source of drinking water supply comes mainly from underground water supplied by the Cotaxtla aquifer [5]. The aquifer is reloaded moslty from infiltration of rainwater that falls in the valley and along the main rivers (Jampa River and Cotaxtla River), and induced from infiltration of the agricultural irrigation excess produced along the irrigation canals [6]. Therefore, this study had the objective of evaluating the physicochemical quality of underground water and its relationship with the maximum permissible limits specified in the national and international regulations according to its use.

MATERIALS AND METHODS

The study zone is the municipality of Cotaxtla, located in coordinates 18° 50' latitude North and 96° 24' longitude West (Figure 1). It has a territorial extension of 537.8 km^2, of which 203 km^2 are used for agriculture [7]. A total of 15 sampling points were selected from 9 localities: Paso Faisán (PF), Las Lomitas (LL), Paso Anona (PA), Bajo Tlachiconal (BT), Mundo Nuevo (MN), Loma Angosta (LA), Mata Tejón (MT), Mata Tambor (MTB), and La Aurora (LAU). A survey was carried out with the aim of understanding the characteristics of the wells, such as total depth, time when it was built, type of material with which it was built, and uses to which underground water is destined.

Sampling of underground water was done in the months of September to November 2022. The samples were collected according to the NOM-230-SSA1-2002 [8]; they were obtained after letting the water run for 3 minutes, rinsing the container before collecting the sample. Polyethylene containers with 500 mL capacity were used, which were identified by sampling point and locality, and then were conserved in a refrigerator at 4 °C and

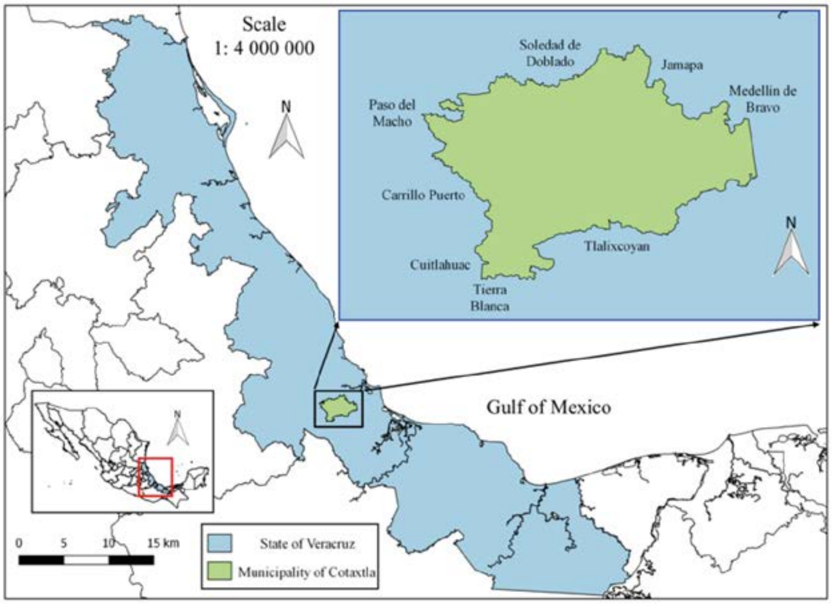

Figure 1. Location of the study area.

transported to the Aquatic Resources Research Laboratory (*Laboratorio de Investigación en Recursos Acuáticos*, LIRA) of Instituto Tecnológico de Boca del Río.

The physicochemical variables analyzed were pH, electric conductivity (EC), total dissolved solids (TDS), and salinity (S), measured using a multiparametric catheter Consort C6010, through three successive independent readings. Descriptive statistics were applied for data analysis through the PAST program, to summarize the data obtained in this study. The minimal values, maximum values and mean ± SD of the physicochemical variables (pH, salinity, EC and TDS) of underground water were obtained. In addition, a normality test was applied, to understand the distribution of the data obtained. The Shapiro-Wilk test and the Kruskal-Wallis test were applied to determine if there are significant differences, for which the PAST program was used [9, 10]. The results were compared with the established permissible limits from the national and international normativity according to its use (Table 1).

RESULTS AND DISCUSSION

The depth of the wells analyzed ranged between 20 and 100 m, where water is extracted through a pumping system. The survey results indicated that 100% of the wells analyzed are destined primarily to agricultural activity, 52% are used for livestock production, and 80% are used for domestic activities and consumption (Figure 2); 60% correspond to community wells that supply 612 inhabitants.

According to the Shapiro-Wilk test, it was seen that the physicochemical data did not show a normal distribution ($p<0.05$); however, significant differences were observed in all the parameters evaluated and regarding all the sampling points according to the Kruskal-Wallis test.

The pH results ranged between 6.71±0.043 and 8.04±0.19, with a mean of 7.68 (Figure 3a). Of the wells, 93% had a pH above neutrality. The results are like those reported

Table 1. Maximum permissible limits for water quality of the national and international normativity according to its use.

Normativity	Use	pH	SDT (mg/L)	CE (mS/cm)
NOM-127-SSA1-2021 [11]	Human consumption	6.5-8.5	1000	-
CE-CCA-001 [12]	Agricultural irrigation	4.5-9	500	-
WHO [13]	Human consumption	6.5-8.5	200	720

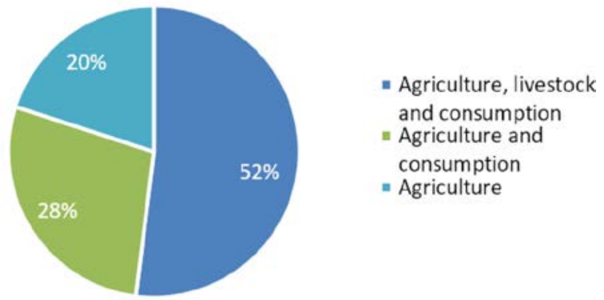

Figure 2. Main uses of underground water in the sampling sites.

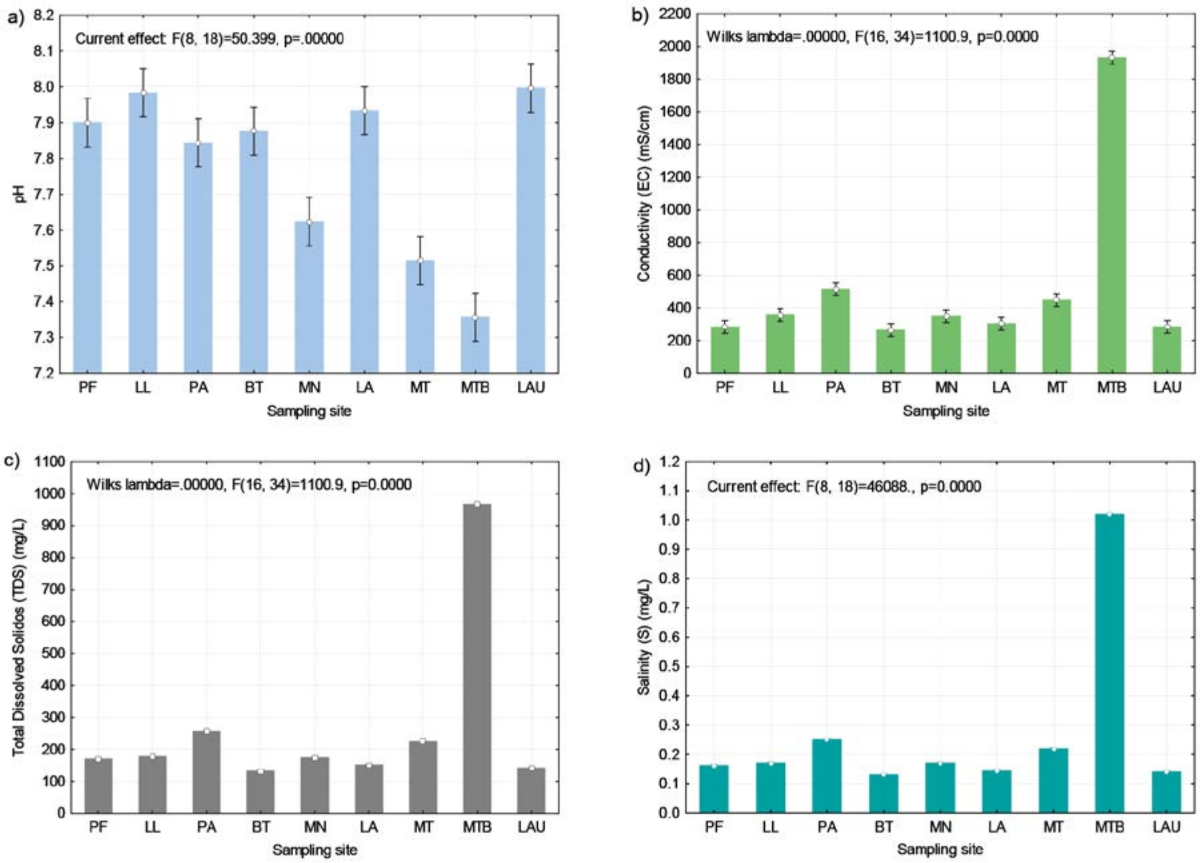

Figure 3. Variation of physicochemical variables in underground water of the municipality of Cotaxtla, Veracruz, Mexico. a) pH, b) conductivity (EC) in mS/cm, d) Total Dissolved Solids (TDS) in mg/L, d) salinity (S) in mg/L.

by Sánchez *et al.* (2016) [14], who found values of 7.15-7.63 in underground water from Quintana Roo, Mexico; it was the same case with Rauf *et al.* (2021) [15] who reported pH values of 6.5-8.8 with a mean of 7.65. However, the pH values of this study were found within the maximum permissible limits for agricultural consumption and irrigation according to those established by the national and international normativity (Table 1).

Regarding the EC results, values between 228.15±2.08 and 4500±5.033 mS/cm with a mean of 681 mS/cm (Figura 3b) were detected; they were lower than those reported by Vijayakumar *et al.* (2022) [16] who found a mean of 1067.65 mS/cm. The EC of the samples depends on the concentrations of various species of ions and their capacity to transport energy in a solution, which is affected by the presence of metal ions in the water [17].

The high concentrations of EC in underground water are due primarily to soluble salts that reach through the infiltration of soil layers [18]. According to WHO (2006) [13], the values should not exceed the 750 μS/cm for the water to be optimal for human consumption, which is why 13% of the wells were not apt for consumption.

According to the water quality guidelines of the consulting committee for agricultural irrigation from the University of California, the water has a mean risk of 750-1500 mS/cm, while a higher risk is 1500-3000 mS/cm [19]. The results of total dissolved solids (TDS) are between 132 and 2247 mg/L, with a mean of 344 mg/L (Figure 3c), where the highest concentrations were observed in the MTB2 and MTB3 wells of the locality of Mata Tambor. The results agree with those reported by Vijayakumar *et al.* (2022) [16], who found values between 212 and 1905 mg/L, with a mean of 751.3 mg/L; likewise, Lanjwani *et al.* (2020) [18] found higher concentrations, of 318 to 7411 mg/L. The presence of TDS is due to the elements, minerals, salts, anions, and cations dissolved in the water sample. The high concentration of total dissolved solids can cause stomach irritation and its prolonged use can cause cardiac disease and kidney stones in humans [18]. However, the normativity by the WHO [13] establishes values with a maximum permissible limit of 200 mg/L for drinking water; therefore, 33% of the samples were not apt for consumption and 13% were not apt for agricultural irrigation. The TDS can also be affected by the geological nature of the soil present in underground water (Lanjwani *et al.*, 2020) [18].

The salinity results observed in this study varied between 0.13 and 2.42±0.005 mg/L, with a mean of 0.35 mg/L (Figure 3d). The salinity in underground water is associated with the intrusion of marine water and various anthropogenic activities; however, in irrigation water it can cause serious problems in certain crops and affect the growth of the plants [15]. The results from this study were similar to those reported by CONAGUA (2020) [6], who analyzed the underground water of the Cotaxtla aquifer, with pH values of 6.76-7.32, EC values of 220-930 mS/cm, and TDS values of 110-460 mg/L; they reported that these values are within the Mexican normativity for human consumption NOM-127-SSA1-2021 [11].

CONCLUSIONS

The variation of the parameters analyzed in this study indicated that underground water from the municipality of Cotaxtla has great influence from the strong agricultural activity in the zone, where variation of these parameters is due to intensive agricultural practices from the use of fertilizers and agrichemicals that are infiltrated through the subsoil layers.

In addition to this, the 80% destined to consumption in the zone, and which supplies more than 612 inhabitants, indicated that according to the normativity for EC values, 13% of the wells were not apt for consumption, while according to the TDS values, 33% were not apt for consumption.

Likewise, the increase in salts present in the underground water can have effects on the crops, and they indicated that 13% were not apt for agricultural irrigation according to the levels of TDS and of EC.

It is recommended to take precautions for the management of underground water consumption, to opt for preliminary water treatments before consumption, as well as to manage the control of the excessive use of organic fertilizers and agrichemicals that alter the chemical quality of the underground water.

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