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Decrease in total hardness and amount of chlorides present in well water: influence of the aquatic plants of *Phragmites australis* and *Lemna minor*[Disminución de dureza total y cantidad de cloruros presentes en las aguas de pozos: influencia de las plantas acuáticas de *Phragmites australis* y *Lemna minor*]

Lourdes E.Saavedra^a ,Hans R. Portilla^b, Aldo R. Castillo^b, Cesar P. Arevalo^b, Luis W. Aquilar^b

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Resumen

El objetivo del presente trabajo fue evaluar la influencia de las plantas acuáticas *Phragmites australis* (carrizo) y *Lemna minor* (lenteja de agua) en la reducción de la dureza total y cloruros presentes en las aguas de los pozos de Huanchaquito- Trujillo, utilizados por los habitantes para regar cultivos y autoconsumo, afectando su salud y teniendo baja producción en sus campos. Las plantas acuáticas utilizadas para el tratamiento de agua de pozo, según antecedentes, tienen un alto rendimiento en absorción de sal lo que ha permitido disminuir la cantidad de Cloruros y dureza presentes en las aguas del pozo de Huanchaquito cada 15 días durante 8 meses. Los datos obtenidos en los análisis de las muestras iniciales fueron: Con respecto a la dureza 542,7 ppm; Cantidad de Cl 300,7 ppm. Luego de que los datos promedio obtenidos para la dureza fueron de 502,4 ppm con *Lemna minor* solo 537,6ppm, con *Phragmites australis* solo y 489,8 ppm con *Lemna minor* y *Phragmites australis*, En cuanto a los resultados de cloruros tenemos: 296, 9 ppm solo con *Lemna minor*, 248,8 ppm solo con *Phragmites australis* y 233,8 ppm con *Lemna minor* y *Phragmites australis*

Palabras clave: Phragmites australis, Lemna minor, dureza total, Cloruros.

Abstract

The objective of present work was evaluating the influence *Phragmites australis* (common reed) and *Lemna minor* (duckweed) aquatic plants in the reduction of total hardness and chlorides present in the waters of wells of Huanchaquito-Trujillo. They are used by the inhabitants to irrigate crops and own consumption, affecting their health and having low production in their fields. The aquatic plants used for the treatment of well water, according to background, have a high yield in salt absorption which has allowed to decrease the amount of Chlorides and hardness present at the well's waters of Huanchaquito every 15 days for 8 months. The data obtained in the analyses of the initial samples were: With respect to hardness 542,7 ppm; CI- amount 300,7 ppm. After the average data obtained for the hardness were of 502,4 ppm with *Lemna minor* only 537,6ppm, with *Phragmites australis* only and 489,8 ppm with *Lemna minor* and *Phragmites australis*, In terms of the results of chlorides we have: 296,9 ppm with *Lemna minor* only, 248,8 ppm with *Phragmites australis* only and 233,8ppm with *Lemna minor* and *Phragmites australis*.

Keywords: Phragmites australis, Lemna minor, Total hardness, Chlorides

^a Escuela de Ingenieria de Materiales, Universidad Nacional de Trujillo - Av Juan Pablo s/n - Trujillo, Peru

^b Escuela de Ingenieria de Metalurgica, Universidad Nacional de Trujillo - Av Juan Pablo s/n - Trujillo, Peru



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1. Introduction

Water treatment systems with aquatic plants are an efficient and economical alternative for the treatment of wastewater, wells, water with pollutants, etc. Among these types of plants are the *Lemna minor* abundant in the district of Huanchaco and *Phragmites australis* which presents characteristics of growth adaptability in any area around 25 °C (Arroyave, 2004).

One of the main problems nowadays is the corrosion that occurs in the pipes due to the hardness of the water, but it is not the same electrical appliances or water pipes with the human body, due to the consumption of the population of this type of water is harmful to health. According to the WHO (2020), some 785 million people around the world do not have access to clean sources of drinking water. The climate crisis is making this situation worse. Salt water, which makes up about 97% of our planet's water, is a huge untapped resource. Solutions are urgently needed to make it fit and safe. Therefore, in this work the chloride ion is detailed, it is one of the inorganic ions found in greater quantity in natural, waste and treated wastewater, its presence is necessary in drinking water. In drinking water, the chalky taste produced by the concentration of chlorides is variable, in some waters containing 25 mg Cl- / L the bitter taste of chlorine can be detected. On the other hand, it may be absent in waters containing up to 1g Cl- / L when the predominant cations are calcium and magnesium (Ordoñez, 2011). A high content of chlorides can damage metallic structures and even prevent the growth of flora. High concentrations of chloride in water for irrigation in agricultural fields deteriorate crops, importantly the quality of the soil.

This investigation was conducted based on the following background:

The concentrations of tetracycline (TC) and degradation products were determined in the roots, stems and leaves of the plants, resulting in the plants of *P. australis* uptake TC and degradation products. The decreasing order of *P. australis* uptake was determined as ETC> TC> EATC> ATC. (Topal, 2015). Both road drainage rainwater and duckweed (*Lemna minor* L.) were sampled and metals Cr, Mn, Cu and Zn were analyzed. This approach at the micrometric level allows a better understanding of the elemental tissue partition in this biomonitoring organism (Brito et al, 2013). The study was divided into two phases, with the following treatments: phase I with a) tap water, b) tap water + *P. australis*, c) ARS; phase II with a) ARS + CLT (0.29 mg/L), b) ARS + CLT (2.18 mg/L), c) CLT (0.29 mg/L), d) CLT (2.18 mg/L). Each experiment was done in duplicate. The influence of the variables relative humidity (RH), solar radiation (Rs), ambient temperature (T), barometric pressure (PB), evaporation and potential evapotranspiration (ETo) on the respiration frequency of *P. australis* was analyzed. No significant differences were found in the respiratory rate of P. australis (p <0.05) with tap water and ARS during the phase I experiments; The same was found for all the experiments of the phase, concluding that the CLT pesticide affects the respiratory rate of *P. australis* (Serna and Casas, 2012).

Water treatment is carried out using artificial wetlands built with floating macrophytes, floating leaf macrophytes, submerged macrophytes and emergent macrophytes (Arias et al., 2003). Wetlands physically fix pollutants from the contact surface with roots, stones, soil, among others, using the aquatic plant *Lemna minor L*, where through biological and chemical processes they transform them into nutrients for microphites with a low elimination of pollutants (Mogollón, 2005). The efficiency of aquatic plants was evaluated, resulting in the most effective *Lemna minor> Pistia Stratoides> Eichhorna Crassipes* (Cupe and Portocarrero, 2009). Applications of wastewater treatment with aquatic plants to treat effluents from industrial, mining, agricultural and domestic activities (Montano, J.J; Sandoval, M., 2005).

Floating microphytes have proven to be efficient in the remediation of waters with nutrient content, organic matter and toxic substances such as arsenic, zinc, cadmium, copper, lead, chromium, and mercury (Martelo, 2012). It is proposed to institutionalize instruments that incorporate the environmental variable (Rodríguez, 2010). The most important sources of pollution are made



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known, it constitutes industrial and domestic discharges causing a strong impact on the receiving environment (the sea) (Guillen et al. 1978).

2. Materials and Methods

The procedure was carried out, as described below:

2.1 Procedure to create Artificial Wetland:

- The best *Lemna minor* seeds and *Phragmites australis* buds were selected, transferring them into 35cm deep jars for 1 day.
- Lemna minor plants and Phragmites australis buds were prepared.
- Make glass fish tanks, a small layer of soil of approximately 2cm was placed as a base.
- The layer was covered with Tecnopor (the Tecnopor must have as many holes as there
 are *Phragmites* plants to be transplanted) (Menéndez, 2005).
- The technopor was covered with sand and small gravel at a height of approximately 3cm, be careful to leave the holes for transplanting the Phragmites.
- Phragmites were transplanted into the holes from the aforementioned procedure.
- The fish tank was filled with well water (slowly on one side of the glass walls), let it rest for 1 hour (Bushmann, 2001).
- Lemna minor was placed on the surface of the well water of the fish tank.
- Finally, the same procedure was done for the *Phragmites* alone and for the *Lemna minor* alone, both with well water samples.

2.2 Procedure to calculate the total Hardness of Well water:

- According to Rodríguez, S. (2010), 25 mL of water sample is taken in the Erlenmeyer flask.
- Then 10 mL of buffer solution were added.
- A pinch of eriochrome black T (ENT) was added, showing a purple color.
- Titrated with 0.01 M EDTA solution (disodium salt), until a blue color was appreciated.
- Reactions:

$$Ca^{2+} + Mg^{2+} + Buffer pH10-----> Ca^{2+} + Mg^{2+} + ENT-----> [Ca-Mg--ENT]$$

Purple complex

Calculus:

$$DT (ppm) = \frac{M_{EDTA} X V_{EDTA} X 1000}{V_{SAMPLE}}$$

Where:

 $M_{EDTA} = 0.01M$

 V_{EDTA} = Volume of EDTA expense.

V_{MUESTRA} = 25 mL (volume of water for analysis)





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2.3. Procedure to calculate the amount of CI- by Mohr's method:

- 10mL of well water sample was measured with a pipette and transferred to a 250mL Erlenmeyer flask.
- Dilute it in 50 mL of distilled water and observe the turn.
- 3 to 4 drops of 5% K2CrO4 were added (Escutia, 2012).
- Adjust the pH to a range of 6.3 10.5, that is, if the sample is less than 6.3, make it alkaline with sodium carbonate (NaHCO3), but if it is greater than 10.5, add acetic acid (CH3COOH).
- Titrate the flask sample with 0.1N silver nitrate (AgNO3) until it turns red or pink (Skoog et al., 1995).
- The expenditure volume of AgNO3 0.1N was recorded.
- Reactions:

CI
$$^-$$
 + Ag $^+$ \rightarrow AgCI \downarrow (White Precipitate)
CrO₄= + 2Ag $^+$ \rightarrow Ag $_2$ CrO₄ \downarrow (Brick red precipitate)
Calculus:

$$Cl^{-1}(ppm) = \frac{V_{AgNO3} \, x \, V_{NAgNO3} x \, P_{equi} Cl \, x \, 1000}{V_{sample}}$$

Where:

 $NAgNO_3 = 0.1M$ solution of $AgNO_3$

VAgNO₃ = expenditure volume of solution AgNO₃

P_{equi}Cl = Equivalent weight of Cl = 35.5/1

V_{sample} = water volume for analysis

2.4 Procedure for calculating the removal percentage

 To calculate the removal percentage, the initial and final results are replaced in the following formula:

$$\% Removal = \frac{(Initial \ value \ - Final \ value)}{Initial \ value}$$

3. Results

Table 1 shows the initial values of the characterization of the well water of the Huanchaquito Alto district with CI- and Hardness presence above the MPL (Maximum Permissible Limits), with which the research work began; treated with the *Lemna minor* aquatic plant, monitored every 15 days of treatment.



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Table 1. Chlorine concentrations and Hardness as a function of *Lemna minor* plant.

Sample	Aquatic plant	Time (days)	Total hardness (ppm)	Cl ⁻ (ppm)
Initial	Lemna minor	0	542,7	300,7
Sample 1	Lemna minor	15	541,3	300,1
			542,5	299,8
			540,8	300,0
Sample 2	Lemna minor	30	532,6	298,2
			533,1	298,1
			533,6	299,1
Sample 3	Lemna minor		510,6	298,0
		45	510,9	297,1
			509,0	297,6
Sample 4	Lemna minor	60	502,7	297,2
			502,5	296,4
			502,1	297,1

Table 1 shows a initial sample (0 days of exposure with *Lemna minor*) of water obtained from the wells of Huanchaco to which analyzes were carried out obtaining a result of 542.7 ppm of total hardness and 300.7 ppm of quantity of Chlorides present in these waters, a fact that shows us high levels of contamination, that same standard sample is subjected to 15 days under the influence of the *Lemna* plant.

Minor (sample 1), which shows 541.3ppm; 542.5ppm; 540.8ppm of total hardness and 300.1ppm; 299.8ppm; 300ppm of amount of chlorides, likewise after 30 days of this same sample under the influence of *Lemna min*or, a significant decrease in these concentrations of total hardness and amount of chlorides is observed, with results of 532.6ppm; 533.1ppm and 533.6 ppm of total hardness and 298.2ppm 298.1ppm 299.1ppm of amount of chlorides, in the following samples the results obtained for 45 and 60 days the decrease in total hardness and amount of chlorides is much lower than the initial one, such that the percentage of removal of total hardness and amount of chlorides is evidenced as follows:

Removal to hardness: % Removal = $(542,7 - 502,1) / 542,7 \times 100 = 7,5\%$

Removal to CI-: % Removal = $(300,7 - 297,1) / 300,7 \times 100 = 1,2\%$

Table 2. Chlorine concentrations and Hardness as a function of Phragmites australis plant.

Sample	Aquatic plant	Time (days)	Total hardness (ppm)	Cl ⁻ (ppm)
Initial	Phragmites australis	0	542,7	300,7
Sample 1	Phragmites australis	15	542,4 542,1	289,0 288,7



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			542,3	287,5
Sample 2	Phragmites australis		541,6	267,3
		30	541,9	268,5
			541,5	266,9
Sample 3	Phragmites australis		540,3	253,2
		45	540,0	255,3
			541,4	254,3
Sample 4	Phragmites australis	60	538,5	249,5
			537,0	249,1
			537,2	247,9

In table 2, the values corresponding to the analyzes performed to the water treatment with the *Phragmites australis* aquatic plant are recorded, where the standard sample is observed in a zero treatment time. For which, there is 542.7 ppm of total hardness and 300.7 ppm of Chlorides, likewise in the lower part a second sample is observed (sample 1) where these contaminated waters have been treated for a period of 15 days, which showed a decrease in hardness between 542.4ppm; 542.1ppm and 54.3ppm, while the amount of chlorides decreased by 289.0 ppm; 288.7ppm and 287.5, the following samples are sample 2 analyzed after 30 days of treatment, sample 3 analyzed after 45 days and finally sample 4 of the contaminated samples in a 60-day treatment, these samples as observed have had a significant decrease in both the amount of total hardness and the amount of chlorides.

Removal to hardness: % Removal = $(542,7 - 537,2) / 542,7 \times 100 = 1,01\%$ Removal to CI-: % Removal = $(300,7 - 247,9) / 300,7 \times 100 = 17,6\%$

Table 3. Chlorine concentrations and Hardness as a function of *Lemna minor* and *Phragmites australis* plants.

Sample	Aquatic plant	Time (days)	Total hardness (ppm)	Cl ⁻ (ppm)
Initial	Phragmites australis y Lemna minor	0	542,7	300,7
Sample 1	Phragmites australis y Lemna minor	15	540,0	287,5
			540,5	288,1
			538,4	287,7
Sample 2	Phragmites australis y Lemna minor	30	531,1	268,3
			530,3	266,7
			525,0	269,2
Sample 3	Phragmites australis y Lemna minor	45	529,0	254,7
			528,1	254,5
			519,0	253,8
Sample 4	Phragmites australis y Lemna minor	60	490,4	232,2
			489,7	240,4
			489,5	228,9



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Table 3 shows the values of the analysis carried out on polluted well waters subjected to treatments with aquatic plants such as *Lemna minor* and *Phragmites australis*, where it is observed that the contamination is above the MPL in hardness and Cl-, starting by the analysis performed on the initial sample showing 542.7 ppm of total hardness above the maximum allowable and 300.7 ppm of Cl-. After 15 days of subjecting the contaminated water to the two aforementioned aquatic plants, the hardness decreased in the following concentrations 540.0ppm; 540.5 ppm and 538.4 ppm, likewise, chloride concentrations decreased, obtaining figures of 287.5; 288.1; 287.7 respectively, after 30 days from the initial process, the hardness concentrations decrease having the following values: 531.1 ppm; ; 530.3ppm and 525.0ppm and chloride concentrations also decrease to 268.3ppm; 266.7ppm and 269.2ppm, in this way the decrease is observed as we increase the number of treatment days such as sample 03 of 45 days and sample 4 of 60 days of exposure to water contaminated with aquatic plants.

Removal to hardness: % Removal = $(542,7 - 489,5) / 542,7 \times 100 = 9,8\%$ Removal to CI-: % Removal = $(300,7 - 228,9) / 300,7 \times 100 = 3,9\%$

Table 4. Comparison of the results obtained after treating the well water with the water MPL.

Evaluated parameters	End results	MPL water
Hardness(ppm)	489,5	500
Chlorides(ppm)	228,9	250

Table 4 shows the final influence obtained from the *Lemna minor* and *Phragmites australis* aquatic plants in the contaminated water from the Huanchaco wells, obtaining 489.5 ppm of decrease in hardness in 60 days and 228.9 ppm of decrease in amount of chlorides which are already below the MPL.



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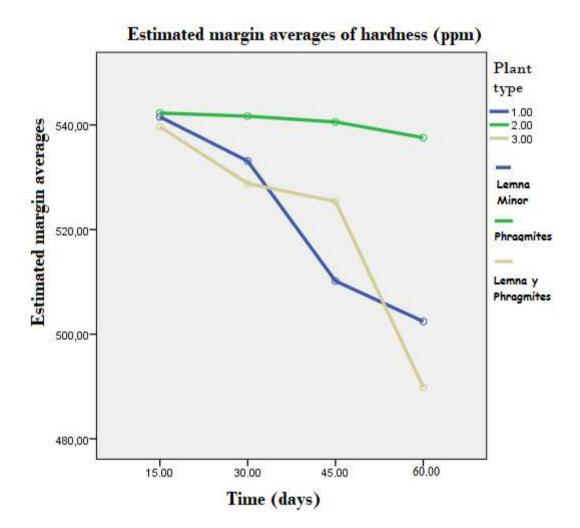


Figure 1. Behavior of the decrease in hardness of the Huanchaquito well water with the aquatic plants *Lemna minor* and *Phragmites australis*

In figure 1, the three trends of decrease in total hardness in contaminated waters are observed and as can be seen, the beige line marks the best decrease represents the influence of the two aquatic plants together and the green line (*Phragmites australis*) represents the smallest decrease in hardness in polluted waters.



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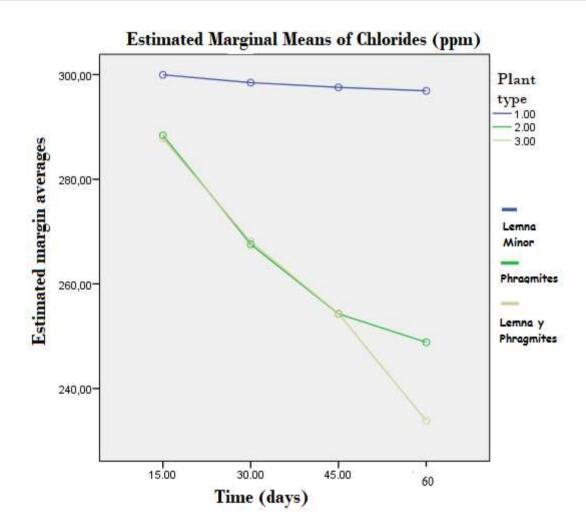


Figure 2. Decrease in the amount of chlorides in the waters of Huanchaquito wells with the *Lemna minor* and *Phragmites australis* plants

Figure 2 shows that the beige line that corresponds to the two aquatic plants *Phragmites australis* and *Lemna minor* has better performance in reducing chlorine concentrations, unlike the Lemna represented by the blue color, which decreases less chloride concentration.

With these results obtained in table 3 it is observed that the presence of these two plants decreases the amount of chlorides and hardness with greater intensity, decreasing the total hardness in 50 days until reaching 489.5ppm and 228.9ppm amount of chlorides reaching the MPL that establishes Supreme Decree No. 015-2015-mINAm.

If we compare these three experiments in Figure 1 with only the *Lemna minor*, it decreases until almost reaching the maximum permissible limits, unlike when the two aquatic plants act together, the decrease in total hardness decreases until it reaches the range of MPL below 500ppm contemplated in Peruvian law.

If figure 2 is analyzed, the decrease is equal between the well water exposed only to the aquatic plants *Phragmites* vs *Lemna minor* plus *Phragmites* up to 45 days with a range of 253ppm, this



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is where it is observed that the two plants together reach decrease the hardness to approximately 230ppm in 50 days, reaching the MPL range.

4. Conclusions

According to the results obtained by authors, it can be concluded that:

- It was possible to reduce the hardness and quantity of chlorides present in the well waters
 of the Huanchaquito-Trujillo district using Lemna minor (Lentil water) and Phragmites
 australis (Common reed) in artificial media at laboratory level to improve the quality of these
 waters.
- The Total Hardness of 542.7ppm and 300.7ppm Amount of chlorides present in the well waters of the Huanchaquito-Trujillo district was determined.
- The aquatic plants *Phragmites australis* and Lena Minor were conditioned in artificial wetlands at the laboratory level.
- The removal percentage was determined for the parameters of hardness and amount of chlorides, the highest percentages in hardness being 9.8% and 17.6% of chlorides present in the waters of the wells of Huanchaquito-Alto, Trujillo-La Libertad.
- The decrease in hardness is much faster with the two plants together than with only Lemna minor and that the decrease in Chlorides is much more accelerated with the presence of these two plants than with only Phragmites australis. Likewise, it is stated that Lemna minor alone does not have much effect in reducing Chlorides, as well as Phragmites australis in reducing hardness.

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