JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(2), 183–189
https://doi.org/10.12911/22998993/197044
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.11.12
Accepted: 2024.12.15
Published: 2025.01.01

Aluminum contamination in the Carrizal River sub-basin and its impact on the water purification process and public health

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ABSTRACT

The objective of the research was to analyze aluminum contamination in the water purification process of the Carrizal River sub-basin and the Municipal Joint Drinking Water Company (EMMAP-EP) of the Tosagua canton, with an exploratory-descriptive approach and eight sampling points were established, aluminum was analyzed in sediments, sludge, and water at different stages of the purification process. the ICP-OES method was used to determine the concentrations of aluminum. Then the mass balance of this element was carried out. The results showed aluminum concentrations at different stages of the process, with the highest concentration in the settling of sludge for both sediments (10902.93 mg/kg) and water (0.896 mg/L). In comparison, the reservoir and the river presented similar concentrations for sediments (9329.75 mg/kg and 9344.46 mg/kg) and water (0.736 mg/L and 0.662 mg/L). While in the distribution networks, a concentration of less than 0.17 mg/L was evidenced, which is below the limits proposed by the WHO and the EPA, while the mass balance revealed a net accumulation of 42.16 g/day of aluminum, indicating that the system retains this element.

Keywords: aluminum, water, sediments, sludge, coagulation process.

INTRODUCTION

Aluminum, an element of natural origin and the third most abundant in the earth's crust is found in rocks, minerals, soils, sediments, and colloidal systems [Ospina and Cardona, 2021]. The erosion of these materials releases aluminum, which is considered toxic to the growth of living organisms, causes diseases in populations, and its accumulation is harmful to the environment [Torrellas, 2012].

The incorporation of aluminum into the environment can occur naturally through contact with deposits, or as the emergence of anthropogenic activities [Leal and Granados, 2018], the population increase has caused an increase in food production, which in turn increases the use of chemical fertilizers [Díaz et al., 2019], humans apply it in the soil mostly indirectly as a result of the emission of acidifying substances such as tetcosilicates, phyllosilicates, hydroxides, aluminosilicates [Rivera et al., 2015], while in drinking water it is incorporated into the clarification process in which aluminum salts are used as coagulants due to their efficiency. However, remnants that arise from this process can be found [Silva et al., 2012].

In Ecuador, water treatment plants face challenges due to the lack of adequate process sludge management and chemical characterization. Currently, they use coagulants such as aluminum sulfate and aluminum polychloride, among others. This situation highlights the urgent need to improve sludge management and optimize the use of coagulants to guarantee water quality and minimize environmental impacts.

The research seeks to analyze the behavior of aluminum in the process of purifying water from the Carrizal River and the Municipal Joint Drinking Water Company (EMMAP-EP). Considering strategic points such as the Catchment Phase, The Reservoir, The River, The Process Sludge for the sampling of sediments, sludge, and water, as well as points in the distribution networks that allowed determining the concentration of aluminum.

MATERIALS AND METHODS

Study area

The research was carried out in the La Estancilla Parish where the EMMAP-EP is located and the banks of the Carrizal River, located in the province of Manabí, Tosagua canton (Figure 1), the sub-basin is born in the mountainous area of the Bolívar Canton, extends from the southeast to the northeast, it is also influenced by the waters of the Canuto and Chone rivers. Being considered the largest hydrographic basin in the province and flows into the Canton Sucre.

Type of research

The research was carried out with an exploratory and descriptive methodological design, evaluating the concentrations of aluminum in raw and treated water, according to the collection of sampling data.

Establishing sampling points

Eight strategic sampling points were established for the sampling of sediments, sludge, and water, for sediments it was carried out in the catchment phase (before), Reservoir (during), and in the riverbed (after), in relation to the sludge in the discharge area, On the other hand, the water was considered raw water and treated water [Rosado and Peralta, 2022], the points were established according to the activities as shown in Figure 2.

Sediment and water sampling

For the collection of samples in water and sediment, the criteria NTE INEN - ISO 5667-1 and NTE INEN 2176:2013 were considered, and the samples were packaged and previously identified [Valdés and Alexis, 2014].

Sample rate

Sampling is punctual and subsamples were taken from each station for each week for a month, since the point sample allows the identification of possible pollution or to determine its extent, which will allow greater representativeness to be obtained for the results as indicated [Martínez et al., 2021].

Aluminum concentration

The aluminum concentration was determined using the Coupled Induced Plasma (ICP-OES) method [Jaimes, 2020] and UV-visible spectrophotometry which determines the concentration of substances by measuring light absorbance [Ramos, 2021] (Table 1).

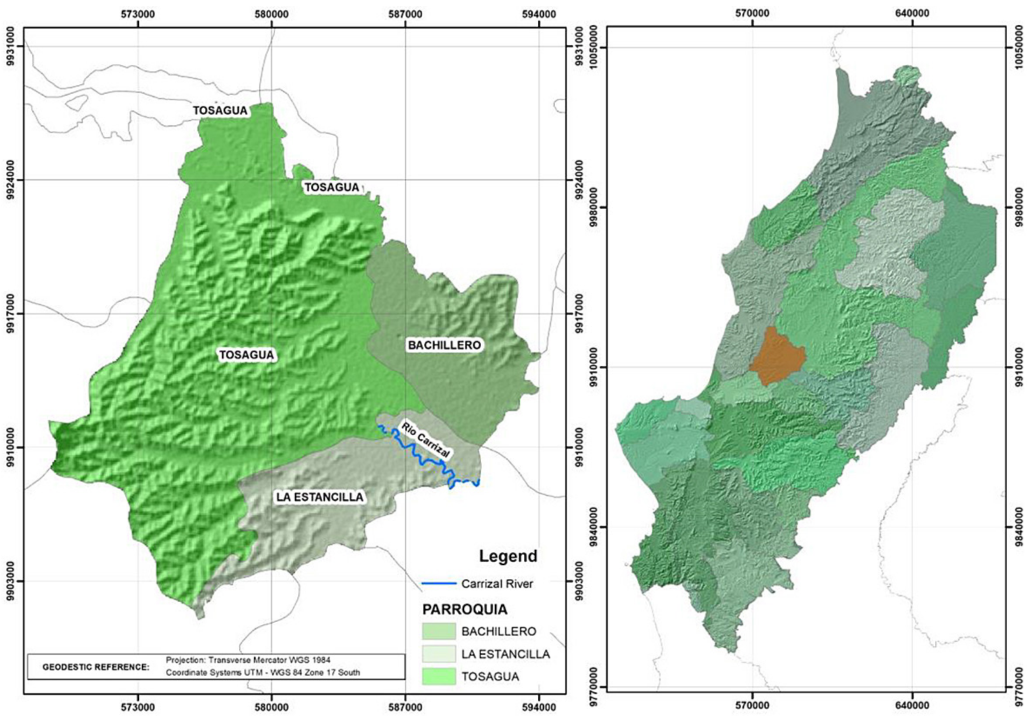


Figure 1. Location of research

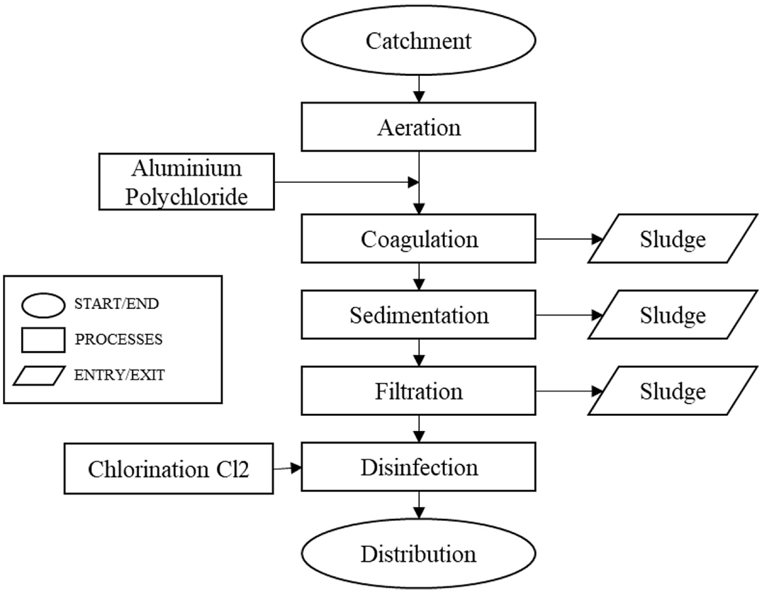


Figure 2. Flowchart of EMMAP-EP processes

Table 1. Parameters to be sampled

Parameters	Sample	Units	Methods
Aluminium	Sediments	mg/kg	ICP-OES (coupled induced plasma)
	Sludge	mg/kg	
	Water	mg/L	

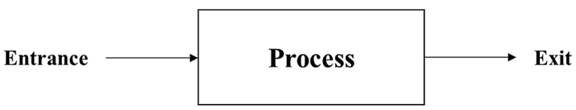
Mass balance or mass flow

The mass balance or flow will identify the monitoring of the mass of the substances from the flow or mass that enters a process until when it leaves either as a product or waste in this study the balance made was of the aluminum of the drinking water treatment system [Valencia et al., 2024] (Figure 3).

RESULTS

Establishing sampling points

The EMMAP-EP has two water treatment plants that follow the same water treatment system, which includes raw water collection (Rio Carrizal), aeration, coagulation, flocculation, sedimentation, filtration, and disinfection. Three of these processes generate a large amount of daily waste. During coagulation, particles are destabilized by the addition of polyaluminum chloride. In sedimentation, the suspended solids are grouped and decanted by the action of slow agitation and filtration removes remaining particles using sand and gravel filters, considering the process and this scenario in Figure 4 illustrates the points established for the investigation.



Definition of the Balance
Accumulation = Inputs - Outputs

Figure 3. Mass balance

Aluminum concentration

The concentrations of aluminum in Sediments, Sludge, and Water are detailed below. Figure 5 presents the concentrations of aluminum at different points of the water purification process of the Carrizal River sub-basin, the results obtained offer a detailed vision of the behavior of this metal.

Figure 5 presents an analysis of the concentrations of aluminum (mg/kg) in the different stages of the water treatment process, it is shown that the catchment, reservoir, and river maintain a considerable trend with an average of 9300 mg/kg, however, in the stage of settling of generated

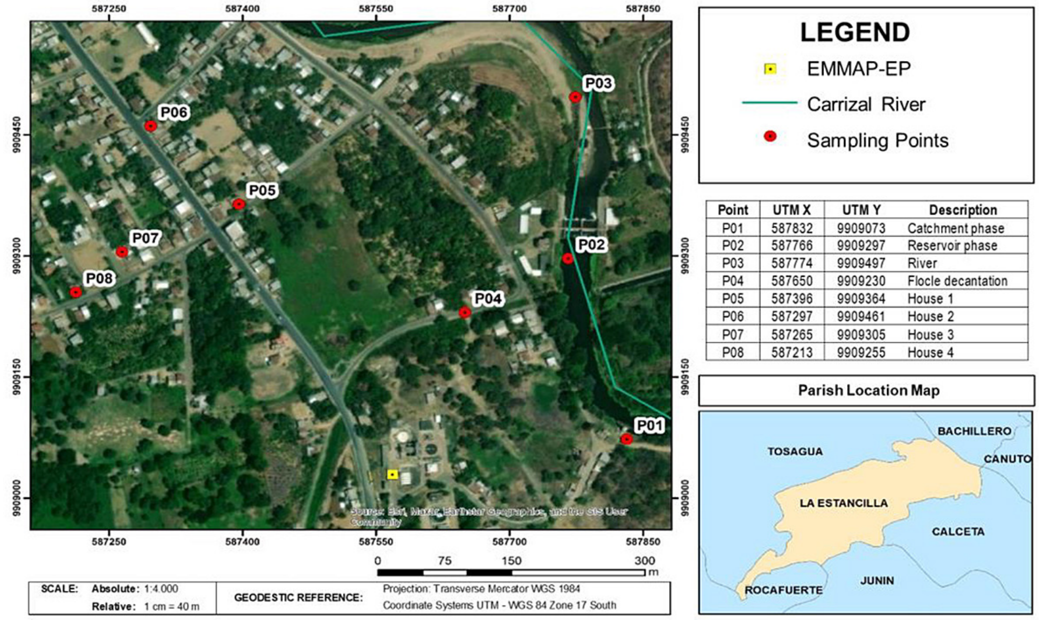


Figure 4. Sampling points

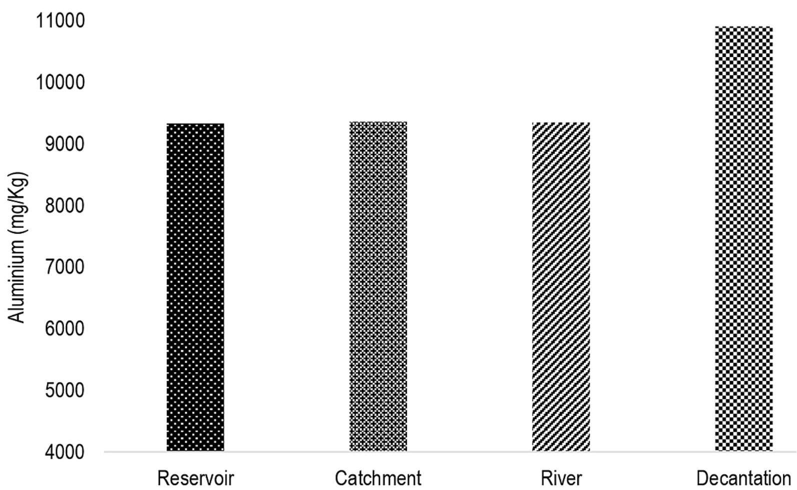


Figure 5. Concentration of aluminum in sediments and sludge.

sludge an increase is registered, reaching a maximum value of 10900 mg/kg.

Figure 6 presents a comparative analysis of aluminum concentrations (expressed in mg/L) at different stages of the water treatment process, Raw water (catchment) and river water (200 m downstream of the reservoir) have relatively low concentrations of reservoir water (0.763 mg/L), on the other hand it is shown that the settling water has considerably high concentrations compared to all established sampling points (0.896 mg/ L) and finally treated water that has values below the points (0.471 mg/L) and a more relevant case is the concentration in the distribution phase (0.141, 0.156, 0.167 and 0.168 mg/L).

Mass balance or mass flow

Considering the data obtained from the EMMAP-EP such as the concentration of aluminum in the raw water, water flow (1333.3 m^3/d), sludge flow (47.81 kg/day), flow rate of the flocculous decantation (207.35 m3/d) and dose of Polyaluminum Chloride (37.5 ppm), the mass flow was established and the behavior of aluminum was inferred.

The total input of aluminum to the system is 1377.47 g/day, from three main sources: raw water (850.45 g/day), coagulant (80.0 g/day), and sediments (447.02 g/day), as for the output of aluminum is considered 1335.35 g/day, of which the sludge purge generates 521.72 g/day and

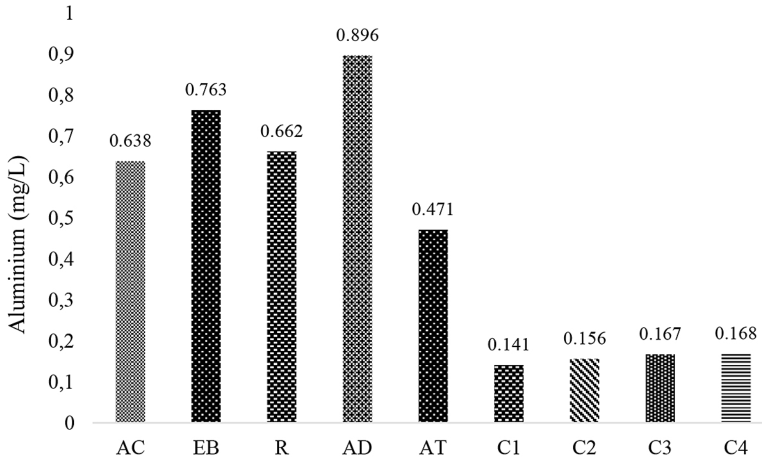


Figure 6. The concentration of aluminum in water. AC (raw water), EB (reservoir), R (river), AD (decantation water), AT (treated water), C (houses)

aluminum from the treated water 672.84 g/day. The mass balance shows a net accumulation of 42.16 g/day of aluminum, which represents 3% of the total input. This buildup indicates that the system is holding a small portion of the incoming aluminum (Figure 7).

DISCUSSIONS

Treatments for the purification of surface water are of utmost importance for society, since the quality of water for human and domestic consumption and uses of different kinds depends on them. If the treatments are applied correctly, each community could satisfy an essential requirement for the environment. From the environmental point of view, it has been reported that in analyses carried out on samples of drinking water, traces of aluminum sulfate have been found, which indicates that the control regarding the addition of this substance is not appropriate. Thus, representing a potential risk to human health [Martínez, 2003]. Bratby [2006] and Colbert [2007] mention that there is a growing concern about the relationship between residual aluminum and adverse neurological effects, mainly manifested in Alzheimer's disease.

Hernández [2017] and Vasquez [2018], in their research evaluated the concentration of heavy metals in the surface sediments of river water, the values ranged between 4700.00 and 9988.00 mg/kg respectively, Flauzino [2017] in his study entitled analysis of the concentration of aluminum in water and sediment in a section of the Docampo River presents aluminum concentrations of 11083.00 mg/kg emphasizing that the

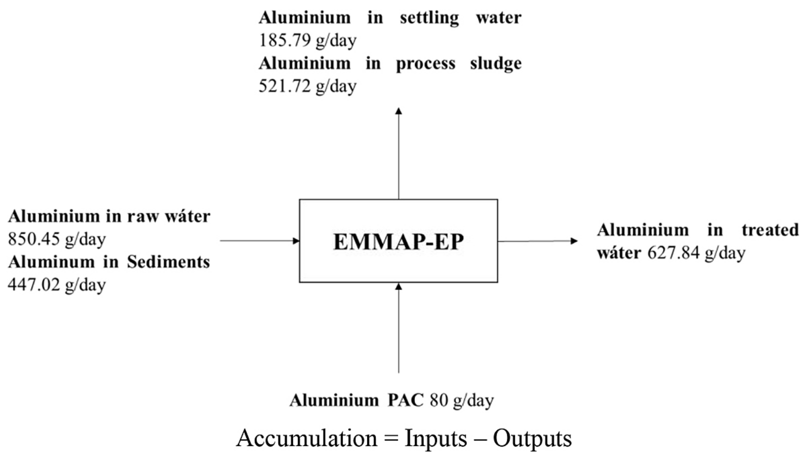


Figure 7. EMMAP-EP: acumulation = inputs – outputs; inlets = raw water aluminum + sediment aluminum + pac aluminum; outputs = aluminum settling water + aluminum sludge + aluminum treated water; accumulation = 1377.47 – 1335.35 = 42.16 g/day

factors that Concentrations of heavy metals in sediments can increase are non-point sources of natural or anthropogenic origin.

In the study by Alfaro [2021] on the average concentration of Al in surface waters for rainy and dry seasons they were 0.06050 and 0.03057 mg/L, while a study by Capacoila [2017] found average concentrations of 1.043 and 0.718 mg/L corresponding to poor management by farmers that allows sediments, together with pesticides and garbage flowing into the river, the study by Ospina and Cardona, [2021] which consisted of the evaluation of aluminum contamination of water for human consumption, central region of Colombia, determined a concentration of 0.118 mg/L in the water distribution network, according to the maximum concentration of aluminum for drinking water established is 2 mg/L and the EPA of 0.05 to 2 mg/L.

Taking into account the concentration of aluminum present in the sludge pool that was obtained from the physicochemical characterization, where there is a value of 25543 mg/kg of dry soil and the concentration of aluminum resulting from the material balance, where the value of 22.05 mg/s was obtained, these high aluminum contents are due to the addition of the type A aluminum sulfate coagulant that accumulates in the sedimentation generally.

CONCLUSIONS

The concentrations of aluminum in the sediment of the river, the reservoir, and the catchment have values less than 9400 mg/kg, which does not exceed the levels established by the environmental quality guide for sediments in freshwater bodies of Canada (10000 mg/kg).

There is an accumulation of aluminum according to the mass balance carried out, typical of conventional purification processes, so these processes require an analysis of the properties of the aluminum, such as solubility, sedimentation rate, and dosage of the coagulant/flocculant used.

Acknowledgments

A cordial acknowledgment to Anthony Jahir Santana Vera and Joffre Alberto Andrade Candell (Environmental Engineers) for their proactive and constant participation in the determination of the monitoring points, sampling, and contribution to scientific production, during the execution of the research work.

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