Case study of groundwater treatment contaminated with total ammoniacal nitrogen: challenges for drinking water production

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Highlights:

- Groundwater in two wells showed high total ammoniacal nitrogen, iron, and manganese levels
- Due to the presence of these compounds, an average dose of 12.7 mg/L of active chlorine was necessary for treatment
- Chlorination with 60% sodium dichloroisocyanurate followed by filtration ensured drinking water quality without disinfection byproducts

Keywords: Groundwater; disinfection by-products; ammoniacal nitrogen

INTRODUCTION

Groundwater is a fundamental source of water supply for many Brazilian municipalities. It is common for districts located far from central urban areas to rely on wells for their water supply. In this context, groundwater contamination poses a significant concern due to its potential effects on water treatment processes. Groundwater contamination with total ammoniacal nitrogen (including both free ammonia (NH_3) and ammonium (NH_4) in water) is worrisome because the maximum permissible concentration in drinking water, as per Brazilian legislation (Brazil, 2021), is 1.2 mg/L. In Brazil, groundwater treatment is often limited to chlorination, and more comprehensive treatment systems are typically designed to address only the presence of iron and manganese, common contaminants in groundwater. Consequently, the presence of nitrogen in groundwater can pose serious challenges to treatment processes.

This work aims to present the case study of two wells contaminated by total ammoniacal nitrogen, exploring its causes, impacts, and the operational measures implemented to ensure the quality of drinking water. The study highlights the importance of knowing and addressing groundwater contamination to ensure water treatment is adapted to meet quality standards and minimize the formation of potential disinfection by-products.

METHODOLOGY

The methodological approach adopted for this case study relies on quantitative and qualitative data gathered from a real-world operation, thus constituting primary data, which are organized and analyzed. Initially, the findings pertaining to the raw groundwater will be presented, accompanied by a discussion of potential causes and impacts on treatment processes. Subsequently, the operational measures undertaken by the facility operator to ensure water quality will be outlined, followed by an examination of the quality of treated (drinking) water.

Groundwater originates from two wells, each equipped with a pump located at a depth of 30 meters, which sends the water for a direct filtration treatment process. The treatment unit, which receives water from both wells, comprises a filter filled with zeolite material, a metering pump for pre-chlorination and a 30m³ reservoir for drinking water storage. The production capacity can reach up to 950m³ per day.

A total of 7 samplings and analyses were conducted on the water sourced from the two wells before treatment. The analyses included measurements of total and dissolved iron, total and dissolved manganese, color, turbidity and total ammoniacal nitrogen. Furthermore, additional analyses were conducted on the treated water collected from the reservoir outlet for the entire scope of Brazilian public drinking water standard, regulation number 888/21 (Brasil, 2021). These analyzes included disinfection by-products such as chlorates, bromate, chlorite, haloacetic acids, trihalomethanes (THM), volatile organic compounds, pesticides, to name a few. All analyses were carried out by a third-party accredited laboratory following standard methodologies (APHA, 2012).

RESULTS AND CONCLUSIONS

Analyzes of the raw groundwater (Table 1) revealed the presence of total ammoniacal nitrogen, iron, and manganese. The total ammoniacal nitrogen is primarily attributed to sewage contamination, given the shallow depth of the wells (30m) and their urban location. There are no landfills or other known pollution point sources nearby, but the wells are situated within a district with 600 residential water connections and no sewage sanitation services.

Iron and manganese are oxidized by chlorine, forming solid precipitates that are removed in subsequent filtration stage. Stoichiometrically, 1 mg of Fe requires 0.62 mg of Cl_2, and 1 mg of Mn requires 1.29 mg of Cl_2 (Ferreira Filho, 2017). Total ammoniacal nitrogen also reacts with chlorine, forming chloramines. Due to the presence of these compounds, an average dose of 12.7 mg/L of active chlorine, in the form of 12% sodium hypochlorite, liquid, was required to achieve drinking water quality. This high dosage increases operational expenditures and the risk of disinfection by-product formation, particularly chlorates. Chlorates are formed during the production and storage of all chlorine-based disinfectants, and so increased disinfectant addition correlates with higher chlorate levels in drinking water (Lakhian and Dickson-Anderson, 2020).

To address these challenges, initial efforts focused on reducing chlorine usage by enhancing chlorination processes and trying to improve groundwater quality. A 10 m³ contact tank was installed before the filter to allow longer contact time and better mixing of groundwater with added chlorine. Additionally, well pumps were placed at greater depths within the wells. Despite these measures, chlorine demand remained high and variable due to persistently high total ammoniacal nitrogen levels (Table 1).

		Turbidity (uT)	Color (uH)	Ammoniacal Nitrogen (mg/L)	Total Iron (mg/L)	Dissolved Iron (mg/L)	Total Manganese (mg/L)	Dissolved Manganese (mg/L)
Analysis 1	Well 1	6.7	25	1.37	2.10	0,035	0.356	0.321
	Well 2	4.3	25	0.62	1.65	0,052	0.36	0.334

Analysis 2	Well 1	< 0.1	5	2.2	1.98	1,812	0.368	0.315
	Well 2	< 0.1	5	1.28	1.60	1,595	0.333	0.331
Analysis 3	Well 1	18.7	25	2.8	1.54	N.A.	0.32	N.A.
	Well 2	8.38	10	1.4	1.18	N.A.	0.34	N.A.
Analysis 4	Well 1	23.4	26	0.1	1.86	N.A.	0.02	N.A.
	Well 2	3.87	5	0	0.23	N.A.	0.02	N.A.
Analysis 5	Well 1	11.7	25	2.8	1.66	N.A.	0.33	N.A.
	Well 2	13.8	21	1.4	1.3	N.A.	0.34	N.A.
Analysis 6	Well 1	11.55	43	1.8	1.52	N.A.	0.32	N.A.
	Well 2	5.78	49	1.4	1.32	N.A.	0.33	N.A.
Analysis 7	Well 1	16.3	25	3.2	1.62	N.A.	0.32	N.A.
	Well 2	19.6	33	0	1.4	N.A.	0.33	N.A.

Table 1 – Analyzes of raw groundwater.

To mitigate chlorate formation in drinking water, then, liquid sodium hypochlorite 12% was replaced with granular sodium dichloroisocyanurate 60%. This substitution is based on the slower decomposition rate of solid chlorine-based disinfectants compared to liquid sodium hypochlorite (WHO, 2005), thereby reducing chlorate formation during storage. Drinking water analyses have consistently shown all parameters below limit values given by Brazilian public drinking water standard number 888/21 (Brasil, 2021). Table 2 summarizes some of these analyses, focusing on disinfection by-products.

	Analysis 1	Analysis 2	Analysis 3	Limit values
Bromate (mg/L)	N.D.	N.D.	N.D.	0.01
Chlorate (mg/L)	N.D.	0.516	0.07	0.7
Ammoniacal Nitrogen (mg/L)	0.2	N.D.	N.D.	1.2
Trihalomethanes (THMs) (mg/L)	0.0283	N.A.	0.0644	0.1

Table 2 – Drinking water analyzes and limit values according to Brazilian public drinking water standard (Brazil, 2021).

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