Removal of Nitrate from Drinking Water by Sodium Thiosulfate and its Impact on Health

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Abstract

Nitrate is a stable and highly soluble ion with a low potential for precipitation or adsorption; nitrate is seldom present in geological formations; therefore, contamination due to nitrate is mainly attributed to anthropogenic sources.

Water resource pollution by nitrate occurs for many reasons and has effects on human health and the environment; therefore, nitrate removal from drinking water is necessary.

In this study, nitrate removal was attempted by the addition of sodium thiosulfate, and a 72% reduction in nitrate level was detected when 1 ml of a 1.09% solution of sodium thiosulfate was added to 100 ml of polluted water after 30 minutes of contact. The literature was reviewed to determine the effect of sodium thiosulfate on human health.

Keywords: Nitrate removal • Sodium thiosulfate • Health effect

Introduction

Nitrate is seldom present in geological formations; therefore, contamination by nitrate is mainly attributed to anthropogenic sources such as sewage and fertilizers. Microbial nitrification is the natural origin of nitrate. Through this process, ammonia is converted into nitrite and then nitrite to nitrate by the *Nitrosomonas* genus and *Nitrobacter* genus bacteria, respectively. Nitrate has a more stable oxidation state, so it is less readily absorbed by the aquifer matrix. Nitrate can travel long distances and pollute groundwater easily.

Pollution of water resources by nitrate occurs due to industrial wastewater containing nitrate, agricultural fertilizers, discharge from animal operations, domestic wastewater, wastewater treatment facilities, septic systems and commercial activities. Other sources include seepage from landfills, the spread of sewage sludge to land, and atmospheric deposition [1-3].

Groundwater contamination by nitrate is affected by soil type, well depth, and land use practices. Nitrate concentrations in groundwater can change over months and years due to changes in land use, such as the installation of septic systems, increased agricultural activities, and deforestation. A groundwater nitrate concentration greater than 3 mg/l may indicate contamination due to human activities.

The nitrate concentration in water can be determined by techniques such as voltammetry, spectroscopy, and ion-selective electrodes.

Both nitrate and nitrite can cause methemoglobinemia or "blue-baby syndrome". In this disease, nitrite binds to hemoglobin instead of oxygen, and these conditions may lead to brain damage and death if not treated. High levels of nitrate in blood have effects on health conditions, such as hypertension; thyroid disability; other diseases, including gastric cancer; meningitis; and Parkinson's disease. Studies on animals in the laboratory have not indicated that nitrate or nitrite are directly carcinogenic, but they may also react in the stomach with food containing secondary amines to produce N-Nitroso Compounds (NOC), which are known to be carcinogenic in animals.

High concentrations of nitrate in surface water can affect the environment by causing eutrophication, which has adverse effects on mammals, birds, and fish populations by producing toxins and reducing oxygen levels and can cause poisoning in animals and emission of greenhouse gases due to the production of N_2O [4,5].

Nitrate is a stable and highly soluble ion with a low potential for precipitation or adsorption. These properties make it difficult to remove nitrate from water using conventional processes such as filtration or activated carbon and adsorption, so more complex treatment processes must be considered, such as reverse osmosis, electrodialysis, ion exchange, biological denitrification, catalytic denitrification, membrane filtration, hybrid systems based on fly ash adsorption, and electrocoagulation [6].

Chemical denitrification can be accomplished by the reduction of nitrate by metals, including aluminum and iron (both Feo and Fe^{2+}). The advantage of chemical denitrification over removal technologies is that nitrate is converted to other nitrogen species rather than simply displaced to a concentrated waste stream that requires disposal. Problems with chemical denitrification of potable water include the reduction of nitrate beyond nitrogen gas to ammonia, partial denitrification, and insufficient nitrate removal. No full-scale chemical denitrification systems have been installed in the United States for the removal of nitrate in potable water treatment.

Other metals used in chemical denitrification include Zero-Valent Iron (ZVI), Sulfur-Modified Iron (SMI-III), MicroNos Technology, and Cleanit-LC.

The removal of nitrate from water via hydrogenation is a good technique that requires low temperature and highly active catalysts, in which nitrate is reduced to NO_2-, NO-, N_2O- and N_2-. The undesired byproduct NH4 is also formed by a side reaction due to over hydrogenation.

Sodium thiosulfate ($Na_2S_2O_3$, STS) is an industrial compound that is typically available as a pentahydrate, $Na_2S_2O3 \cdot 5H_2O$. It has medical uses in the treatment of some rare medical conditions. These include calciphylaxis in hemodialysis patients with end-stage kidney disease as well as cyanide poisoning. It also functions as a preservative in table salt (less than 0.1%) and alcoholic beverages (less than 0.0005%).

The aim of this research was to investigate the potential of removing nitrate from drinking water using sodium thiosulfate and to study its effect on the concentrations of other water quality parameters.

Materials and Methods

1.09% solution of sodium thiosulfate was prepared by dissolving the pills (taken from Hach vials) in 100 ml of deionized water. Different doses of sodium thiosulfate solution (0.1, 0.3, 0.5, 1, 2, 3, and 5 ml) were added to 100 ml of water to determine the lowest dose that provided a high percentage of nitrate removal. The lowest contact time was determined by adding the lowest dose that resulted in a high percentage of nitrate removal. The nitrate level was determined by the cadmium reduction method (Hach method no. 8039) using the NitraVer 5 high-range powder pillow nitrate reagent. The effect of adding sodium thiosulfate on the TDS content, alkalinity, sulfate content and total hardness was studied after one hour of contact. The TDS was determined by a Hach CO 150 conductivity meter. Alkalinity was determined by Hach method no. 8203 (phenolphthalein and total method). The sulfate concentration was determined by Hach method no. 8051. Total hardness was determined by a Hach test kit (20-400 mg/l; Model 5-EPMG-L Cat. No. 1454-01). The literature was reviewed to determine the effect of sodium thiosulfate on human health. SPSS version 15 was used for statistical analysis [7].

Results and Discussion

Table 1 shows the effect of adding different doses of sodium thiosulfate on the different parameters of the raw water. The electrical conductivity and total dissolved substances increased with increasing dose of the 1.09%solution of sodium thiosulfate [8].

Table 1. Effect of adding different doses of sodium thiosulfate on different parameters of raw water.

Sodium thiosulfate dose	**0**	**0.1**	**0.3**	**0.5**	**1**	**2**	**3**	**5**
Nitrate	41.5	41	31	20.5	11.5	10	2.2	1.5
pH	7.18	8.04	8	7.99	7.94	8.08	7.76	7.85
Turbidity	0.33	0.17	0.21	0.26	0.27	0.23	0.17	0.34
EC	925	931	954	989	1056	1209	1346	1611
TDS	427	437	448	465	497	572	639	767

There was a gradual decrease in the level of nitrate with increasing dose of a 1.09% solution of sodium thiosulfate. There was no effect on the pH or turbidity.

Table 2 shows the percentage of reduction in nitrate level and percentage increase in EC and TDS level at different doses of 1.09% sodium thiosulfate solution. A 72% reduction in nitrate level was observed when 1 ml of a 1.09% solution of sodium thiosulfate was used, while the levels of EC and TDS were still at acceptable levels in drinking water (EPA standards). The lowest dose of sodium thiosulfate that results in a high percentage of nitrate removal (72%) and a lower increase in TDS (16%, the level of TDS still below 500 mg/l) was 1 ml of 1.09% solution (Table 2).

Table 2. The percentage of reduction in nitrate level and percentage increase in EC and TDS levels at different doses of 1.09% sodium thiosulfate solution.

Sodium thiosulfate dose	**0.1**	**0.3**	**0.5**	**1**	**2**	**3**	**5**
% Reduction in nitrate concentration	1%	25%	51%	72%	76%	95%	96%
% increase in EC	0.60%	3%	7%	14%	31%	45%	74%
% increase in TDS	2%	9%	9%	16%	34%	50%	80%

Table 3 shows the effect of contact time on the percentage of removal of nitrate by adding the lowest dose of sodium thiosulfate. More than two-thirds of the nitrate was removed after 30 minutes of contact between the sodium thiosulfate and the raw water. Table 3 shows that the best contact time was 30 minutes.

Table 3. Effect of contact time on the percentage of removal of nitrate by sodium thiosulfate.

Time	**% of nitrate removal**
10 minutes	56%
30 minutes	69%
60 minutes	94%

Table 4 shows the effect of the addition of 1 ml of a 1.09% solution of sodium thiosulfate to raw water on the total hardness, alkalinity, and sulfate content after one hour of contact.

Table 4. Effect of 1 ml of a 1.09% solution of sodium thiosulfate on different parameters of raw water.

Test	Before addition	After addition
Total Hardness	490	500
Sulfate	53	56
Alkalinity	259	235
Turbidity	0.33	0.27
TDS	427	497
EC	925	1056
pH	7.18	7.94
Nitrate	41.5	11.5

All the results after the addition of 1 ml of a 1.09% solution of sodium thiosulfate to the water were within the acceptable limits of Palestinian standards.

The P values (all <0.05) of the T tests revealed that the differences in total hardness, sulfate content, alkalinity, TDS, EC, and pH before and after the addition of 1 ml of a 1.09% solution of sodium thiosulfate were not statistically significant (Table 5).

A total of 10 liters of 1.09% sodium thiosulfate solution was needed to treat one cubic meter of raw water. The cost of treating one cubic meter of water using high -grade anhydrous sodium thiosulfate is 8 US dollars.

Table 5. T test for different parameters before and after the addition of 1.09% sodium biosulfate to 100 ml of water.

One-sample test						
Test value=0						
	t	**df**	**Sig. (2-tailed)**	**Mean difference**	**95% Confidence interval of the difference**	
	Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Alkalinity	20.583	1	0.031	247	94.5255	399.4745
Hardness	99	1	0.006	495	431.469	558.531
Sulfate	36.333	1	0.018	54.5	35.4407	73.5593
TDS	13.2	1	0.048	462	17.2828	906.7172
EC	15.122	1	0.042	990.5	158.2436	1822.756
pH	19.895	1	0.032	7.56	2.7316	12.3884
Turbidity	10	1	0.063	0.3	-0.0812	0.6812

Sodium thiosulfate health effect

Sodium thiosulfate was used as a therapeutic drug for the treatment of cyanide poisoning at a dose of 1 ml/hr/kg in a 10% solution at a total dose of 12 g and for the treatment of nephrogenic systemic fibrosis at a dose of 12.5 g three times a week for three months.

Concurrent injections of sodium thiosulfate intraperitoneally or intravenously at a dose of 400 mg/kg once weekly for 3 consecutive weeks prevented hypomagnesemia and the nephrotoxic effects of cisplatin and could be of clinical significance. Compared with saline, sodium thiosulfate alone also significantly inhibited tumor growth (p<.005).

The development of embryos exposed to 0.1~1 mol/L sodium thiosulfate was severely retarded, and this change was accompanied by the malformation of multiple organs; embryos exposed to 10 μmol/L~10 mmol/L sodium thiosulfate had circulatory, nervous and maxillofacial malformations. Pioneering studies suggest that chemicals can have very similar toxicological and teratological effects in many cases on zebrafish embryos and humans.

Conclusion

The removal of nitrate from drinking water by the addition of 1.09% sodium thiosulfate is easy and removes a high percentage of nitrate.

However, further research is needed to confirm that the addition of sodium thiosulfate to drinking water is a safe process.

However, further studies are needed to determine the chemical compounds produced from the reaction between sodium thiosulfate and nitrate.

Declaration

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors”.

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