Research paper

Influence of ammonium nitrogen on the treatment efficiency of underground water at iron removal stations

Viktor Yushchenko, Elena Velyugo, Valentin Romanovski

https://doi.org/10.1016/j.gsd.2023.100943

Abstract

Providing the population with high-quality drinking water is one of the main tasks, which has become particularly relevant in connection with the observed deterioration of the general environmental situation and excessive pollution of water supply sources. This challenge is especially relevant for small towns. Underground water is widely used as a source of water supply for settlements, a significant part of which has an excess concentration in several indicators, including iron and ammonium compounds. Such water has a complex composition in terms of its processing when classical methods and schemes do not work. The growth of populated areas, the development of industry and the increasing requirements for water quality from various water users lead to the need to find rational methods of water treatment. It has been established that ammonium nitrogen significantly makes it difficult the decrease the concentration of total iron to a normalizing value of 0.3 mg/L, and it is required to apply high air intensity (210 L/min). Practically only a small part of air oxygen is spent on the oxidation of iron, while even at a ratio of 5:1 in filters with sand loading, the problem of reducing the concentration of ammonium nitrogen to the standard values is not solved. The use of the proposed technological scheme with an aeration column will increase the degree of purification of underground water from iron and total ammonium nitrogen to values of 0.15 and 1.5 mg/L, respectively, as well as reduce the cost of manufacturing the installation and the purification process due to the absence of expensive materials (reagents) and equipment in the scheme.

Introduction

In most underground drinking water sources, an increased iron concentration is observed. However, in addition to elevated concentrations of iron in underground water, there are often excesses of nitrogen-containing substances. It is known that the combined presence of several pollutants can hinder the process of purification of natural waters (Gouzinis et al., 1998). Some of these components are iron, manganese, and ammonium nitrogen (Pradhan et al., 2022). The water treatment process is usually solved quite effectively for large drinking water supply sources, but this problem is relevant for small settlements. Despite the rather simple removal of iron and manganese, the presence of ammonium nitrogen can significantly complicate their oxidation process (Zeng et al., 2020).

The most common technologies for underground water treatment and removing contaminants such as iron and similar elements are presented in Table 1.

Organic nitrogen accounts for 50–75% of the total nitrogen dissolved in water (Poste et al., 2014). Nitrogen leaching from agricultural lands leads to the development of eutrophication processes in water bodies. Thus, from 1 ha of irrigated land, about 8–10 kg of nitrogen is washed away into water systems (Fox and Rockström, 2003). The main sources of ammonium nitrogen in natural waters include (Poste et al., 2014): i) decarboxylation during the breakdown of protein substances under the influence of bacterial and fungal decarboxylases, and amination; ii) open water bodies, including swampy areas; iii) seaweed; iv) atmospheric precipitation, in which their concentration is close to that observed in surface waters; v) wastewater from various municipal, agricultural and industrial enterprises. It should be noted that all forms of nitrogen, including gaseous, are capable of mutual transformations (Myrold 2021). However, most of the ammonium ions enter the water with runoff from livestock farms, agricultural fields, and industrial enterprises (Xin et al., 2020; Manu et al., 2022). High values of ammonium content can be found in reservoirs or underground water located near municipal treatment facilities, and sewerage (Fox and Rockström, 2003). Ammonium nitrogen binds to other elements in water and can create highly toxic compounds.
Excess levels of ammonium nitrogen and ammonia can give water a very unpleasant odor and taste. Moreover, long-term use of such water leads to a violation of the acid-base balance in the body. Ammonium ions alkalize the blood plasma, which can lead to cell hypoxia. All this is not a complete list of problems caused by excess ammonium and ammonia in water. According to WHO and EU standards, the concentration of ammonium nitrogen should not exceed 2 mg/L. In accordance with the requirements of the global environmental monitoring system (GEMS), ammonium nitrogen, nitrite and nitrate ions are included in the programs of mandatory observations of the composition of drinking water and are important indicators of the degree of pollution and the trophic status of surface and underground natural water resources.

Simultaneous removal of several contaminants in natural water is a very complex process, mainly due to the different values of the redox potential required for their oxidation. This parameter affects the sequence of removal of these contaminants in the aquatic environment and thus affects the possibility of developing the sequence and number of necessary elements of the technological scheme for the purification of natural water of complex composition.

Removal of iron and manganese is achieved quite easily due to simplified aeration and subsequent water filtering through a granular load. The oxidation process occurs through two mechanisms (Romanovskii and Khort, 2017). To increase the efficiency of iron removal, the use of modified granulated filter materials is most effective, for example, fireclay (Romanovski et al., 2021), modified anthracites (**Romanovski 2020**), activated carbons (Propolsky et al., 2020). Some well-known approaches include defferisation in aquifers (Hurynovich and Ramanouski, 2018). At present, a number of approaches have been proposed to increase the efficiency of ammonium nitrogen removal from underground water. For ammonia nitrogen removal, both simple sorbents, for example, zeolites (Rožić et al., 2000), some minerals (Schoeman 1986), coals (Le Leuch and Bandosz, 2007), and more complex systems, including, in most cases, biological treatment (Ribári and Kollár, 1991), have been proposed. In some cases, a simple reorganization of water and air flows in the filter can help to increase both iron and ammonium nitrogen removal (Yushchenko et al., 2023). For example, some options for complex biological purification from iron, manganese, ammonium, and arsenic (Fu et al., 2011; Li et al., 2013; Algieri et al., 2022), the use of membrane methods (Du et al., 2017), trickling filters (Tekerlekopoulou and Vayenas, 2007; Tekerlekopoulou et al., 2010), and the use of granular materials with a biofilm (Homagai and Poudel, 2018) have been proposed. It is also proposed to use strong oxidants such as hypochlorites (Yang et al., 2021), and ozonation (Khuntia et al., 2013). In some articles, authors suggest using nanomaterials, for example, FeCu nanocomposite (Chan et al., 2021) or nanosized titanium dioxide (El Shafey et al., 2021). From the point of view of rationality, the next approaches can be considered as promising: i) the use of new granular materials, since they are already used in existing iron removal filters (**Romanovski, 2020**; Propolsky et al., 2020); ii) and the use of hypochlorites, since sodium hypochlorite, is also used for disinfection water supply facilities (Ramanouski et al., 2013; Romanovski et al., 2020; Kumar et al., 2020). First, the assessment of the operation of existing technological schemes of water supply facilities with the possibility of their reconstruction and modernization should be analyzed. Recent publications on this topic in high-ranking journals, like the removal of ammonia using biofiltration processes (Said et al., 2022; Koike et al., 2022; Nie et al., 2023), ultrafiltration (Ye et al., 2022), using granulated loads (Novembre et al., 2022), by prechlorination (Choo et al., 2005), and some others (Al-Ajeel et al., 2022; Zhai et al., 2022) confirm the relevance of these studies and their significance for providing a population with quality water.

This work aims to study the features of the treatment of underground water containing iron and ammonia compounds and to develop a technology for treating underground water of complex composition, reducing the cost of manufacturing the installation, and the water treatment process. To achieve this goal, the following tasks were identified and solved: i) study the efficiency of removing ammonium compounds from natural water and its individual effect on the removal of iron present in water; ii) exploring possible alternative solutions for the removal of iron and ammonium nitrogen; iii) carrying out research on pressurized filters with the development of a water purification process flowsheet that provides the required amount of oxygen in the water to oxidize all pollutants.

Section snippets

Underground water characteristics

The object of research was underground water in the western part of the Vitebsk region (Belarus), the composition of which is given in Table 2, Table 3.

Sampling

According to the monitoring results, in the North-Western part of the Vitebsk region (Belarus), about 60% of underground water supply sources have a complex composition. In this case, not only iron exceed the standard values, but also manganese and ammonia nitrogen, which can influence the choice of water treatment technology. Specific oxygen

Influence of ammonium nitrogen on the composition and treatment of underground water

The initial water in the settlements (site 1) had an excess content of iron (3.5 mg/L) and manganese (0.14 mg/L). The existing plants operated in the original mode with an installed capacity of 2.5 m^3/h (August–September). During this time (at a ratio of air and water 1:1 (42 L/min)), the concentration of iron in the filtrate decreased from 3.5 to 1.95 mg/L, manganese remained equal to the original 0.14 mg/L, which is much higher than the required standard values (Fig. 3). The presence of

Conclusions

The scientific novelty consists in i) establishing the regularity of iron extraction in the presence of other pollutants in water and ii) determining and developing the most efficient water treatment technology in relation to low-capacity water supply systems under industrial conditions. Based on the obtained results, next conclusions were drawn.

- –

The article analyzes the efficiency of processing underground water from ammonium nitrogen and conducts an experiment to establish the individual

Author contributions

Viktor Yushchenko: supervision, Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – review & editing. Elena Velyugo: validation, Formal analysis, Data curation, Investigation, Writing – original draft. Valentin Romanovski: Validation, Formal analysis, Visualization, Data curation, Writing – original draft, Writing – review & editing.

Funding

The authors received no funding from any source.

Declaration of competing interest

References (40)

- Y. Zhai *et al.*

  Interactions between anthropogenic pollutants (biodegradable organic nitrogen and ammonia) and the primary hydrogeochemical component Mn in groundwater: evidence from three polluted sites
  Sci. Total Environ.
  (2022)
- X. Ye *et al.*

  Simultaneous removal of iron, manganese, and ammonia enhanced by preloaded MnO2 on low-pressure ultrafiltration membrane
  J. Membr. Sci.
  (2022)
- H. Yang *et al.*

  Oxidants-assisted sand filter to enhance the simultaneous removals of manganese, iron and ammonia from groundwater: formation of active MnOx and involved mechanisms
  J. Hazard Mater.
  (2021)
- T.J. Xin *et al.*

  Monthly physicochemical variation of tropical island groundwater of Pulau Bidong, South China Sea
  Groundwater for sustainable development
  (2020)
- A.G. Tekerlekopoulou *et al.*

  Ammonia, iron and manganese removal from potable water using trickling filters
  Desalination
  (2007)
- M. Rožić *et al.*

Ammoniacal nitrogen removal from water by treatment with clays and zeolites
Water Res.
(2000)

- V. Romanovski *et al.*

  Recycling of iron-rich sediment for surface modification of filters for underground water deironing
  J. Environ. Chem. Eng.
  (2021)
- D. Propolsky *et al.*

  Modified activated carbon for deironing of underground water
  Environ. Res.
  (2020)
- A.E. Poste *et al.*

  Amines and amine-related compounds in surface waters: a review of sources, concentrations and aquatic toxicity
  Sci. Total Environ.
  (2014)
- J. Nie *et al.*

  Composite functional particle enhanced gravity driven ceramic membrane bioreactor for simultaneous removal of nitrogen and phosphorus from groundwater
  Chem. Eng. J.
  (2023)
- D.D. Myrold

  Transformations of Nitrogen. InPrinciples and Applications of Soil Microbiology
  (2021)
- E. Manu *et al.*

  Estimation of natural background and source identification of nitrate-nitrogen in groundwater in parts of the Bono, Ahafo and Bono East regions of Ghana
  Groundwater for Sustainable Development
  (2022)
- X.K. Li *et al.*

  Molecular characterization of microbial populations in full-scale biofilters treating iron, manganese and ammonia containing groundwater in Harbin, China
  Bioresour. Technol.
  (2013)
- L.M. Le Leuch *et al.*

The role of water and surface acidity on the reactive adsorption of ammonia on modified activated carbons
Carbon
(2007)

- M. Kumar *et al.*

  Frontier review on the propensity and repercussion of SARS-CoV-2 migration to aquatic environment
  Journal of Hazardous Materials Letters
  (2020)
- K. Koike *et al.*

  Distinct comammox Nitrospira catalyze ammonia oxidation in a full-scale groundwater treatment bioreactor under copper limited conditions
  Water Res.
  (2022)
- A. Gouzinis *et al.*

  Removal of Mn and simultaneous removal of NH3, Fe and Mn from potable water using a trickling filter
  Water Res.
  (1998)
- P. Fox *et al.*

  Supplemental irrigation for dry-spell mitigation of rainfed agriculture in the Sahel
  Agric. Water Manag.
  (2003)
- X. Du *et al.*

  Removal of iron, manganese and ammonia from groundwater using a PAC-MBR system: the anti-pollution ability, microbial population and membrane fouling
  Desalination
  (2017)
- K.H. Choo *et al.*

  Iron and manganese removal and membrane fouling during UF in conjunction with prechlorination for drinking water treatment
  J. Membr. Sci.
  (2005)

There are more references available in the full text version of this article.