

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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**DRINKING WATER QUALITY
RESEARCH AND IMPROVEMENT
MEASURES**

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Introduction

Topicality of the problem

According to the data of the State Food and Veterinary Service, the concentration of iron compounds exceeds permissible hygienic standards in 718 wellfields in Lithuania, concentration of ammonium ions – in 462 wellfields, concentration of manganese compounds – in 165 wellfields, while concentration of organic compounds together with colour intensity exceed the standards in 30 wellfields (2009 data). Increased concentrations of organic compounds in groundwater are usually found in the III group (open) wellfields. These wellfields are of increased risk. The aquifers exploited in the wellfields have a contact with surface water and receive recharge from open water bodies or atmospheric precipitation (HN 44:2006). In these wellfields it is necessary to design water treatment plant that would remove organic compounds, iron and manganese compounds and ammonium ions. In open wellfields usually more than one water parameter exceeds the limits of drinking water quality: colour, ammonium ions, iron, manganese and organic compounds. Such water also contains other compounds, for example, carbon dioxide, hydrogen sulphide, etc., that are not regulated by hygienic standards but interfere with the operation of water treatment plant. When iron and manganese exceed permissible hygienic standards in groundwater, the standard water treatment technologies may be applied. However, when all above mentioned compounds must be removed from groundwater, there is not sufficient scientific and practical knowledge about integrated drinking water treatment technologies.

At high concentrations of organic compounds, a hydrophobic film is formed in water on the surface of filter media grains. The formation of the film disturbs the removal of ammonium ions and iron and manganese compounds from water. Organic compounds firstly assimilate the oxygen needed for oxidation of iron compounds, ammonium ions and manganese compounds. Most metals can form complex organic compounds. Organic compounds condition water taste and odour which are unacceptable for consumption. During disinfection, dissolved organic compounds form secondary compounds such as haloacetic acid and trihalomethanes.

Organic compounds are usually efficiently removed using chemical methods of water treatment. Still, ammonium ions and manganese compounds can rarely be removed by reagent methods. The best option to remove these materials is biological methods. Surface water treatment is usually performed with reagent water treatment technologies, while for groundwater treatment biological technologies are applied. The wellfields of open type is an intermedium between surface bodies and groundwater bodies. For groundwater

taken from open wellfields combined methods must be applied. These methods have received little consideration in scientific literature by now.

Object of the work – groundwater with ammonium ions and concentrations of iron, manganese and organic compounds that exceed permissible drinking water hygienic standards.

Aim and tasks of the work

The aim of the work is to examine drinking water treatment technologies that remove ammonium ions as well as iron, manganese and organic compounds from groundwater using a minimal amount of reagents.

To achieve the aim, the following objectives must be fulfilled:

1. To analyse existing water treatment technologies for removal of ammonium ions, iron, manganese and organic compounds.
2. To compare by experiment the conventional quantitative organic compounds determination methods to the water colour determination method and the ultraviolet spectrum absorbance of organic compounds at 254 nm wavelength method. To analyse the applicability of these methods for quantitative determination of organic compounds concentration in groundwater.
3. To determine the fractions of organic compounds found in groundwater.
4. To explore the efficiency of coagulants – aluminium sulphate, polyaluminium chloride and ferric chloride – in removal of ammonium ions, iron, manganese and organic compounds from groundwater.
5. To investigate possible applications of filter media (quartz sand, quartz sand with oxidizing bacteria, Birm and zeolite) in removal of ammonium ions, iron, manganese and organic compounds from groundwater when coagulant is dosed.
6. Under field conditions, to examine drinking water treatment technology that would integrally remove ammonium ions, iron, manganese and organic compounds from groundwater.

Methodology of research

The standard and specific methodologies for water quality parameter determination are applied in the work. There are used a laboratory setup for filter media tests and a setup of drinking water treatment technologies in which the research was done under field conditions.

Scientific novelty of the work

Three-stage filtration drinking water treatment technologies with aeration and coagulant insertion were studied and proposed. The technologies permit to integrally remove ammonium ions as well as iron, manganese and organic compounds from groundwater.

Practical value

On the basis of the research results, a fast and simple methodology for organic compounds determination in groundwater was proposed. The work also proposed the three-stage filtration drinking water treatment technologies with aeration and coagulant insertion that integrally remove ammonium ions as well as iron, manganese and organic compounds from groundwater. These technologies may be applied in the III group (open) wellfields in Lithuania and abroad where ammonium ions and concentrations of iron, manganese and organic compounds in groundwater exceed permissible drinking water hygienic standards.

Defended propositions

1. The method of ultraviolet spectrum absorption of organic compounds at 254 nm wavelength and water colour determination method could be applied for quantitative measurement of organic compounds in groundwater.
2. In the groundwater from the wellfields of the III group (open) and the II group (semi-closed), the major part of organic compounds consist of the fraction of very hydrophobic acids which is efficiently removed by coagulation method.
3. Polyaluminium chloride is the coagulant that removes iron and organic compounds most efficiently.
4. Drinking water treatment technology that consists of three-stage filtration, open and closed aeration and coagulation, integrally removes ammonium ions as well as iron, manganese and organic compounds from groundwater to meet the requirements of the hygienic standards.

The scope of the scientific work

The dissertation is comprised of an introduction, three chapters, general conclusions and recommendations.

The volume of the work is 112 pages; 16 numbered formulas, 52 figures and 19 tables are used. 113 literature resources were used in the dissertation work.

1. Analysis of water quality improvement measures

This chapter provides the literature review, reviewing physical, chemical, catalytic and biological methods and technologies used for removal of ammonium ions as well as iron and manganese compounds from groundwater. It is analysed, which compounds in groundwater contain iron and manganese. It is also examined, which organic compounds influence the removal of ammonium ions as well as iron and manganese compounds, and how these compounds are determined. The literature review provides a review of fractions of organic compounds, possible methods for organic compounds determination and options for removal. The removal of organic compounds from surface water by coagulation is precisely described, as well as the factors that influence the efficiency of coagulation process. There are also analyzed the filter media commonly used in water treatment plants and presented their characteristics. A review of drinking water treatment technologies existing in practice in different countries and in Lithuania is provided. Limitations of the existing water treatment plants and problems in work with groundwater that has properties corresponding to the water quality in open wellfields are described in this chapter.

2. Drinking water quality and treatment plants research methodologies

This chapter describes standard and specific methodologies of organic compounds determination (permanganate index (PI), chemical oxygen demand (COD), total organic carbon (TOC), water ultraviolet wave absorbance at 254 nm wavelength (UV_{254}) and determination of water colour). A methodology of determination of organic compounds fractions is described in this chapter. Using three different resins, 4 fractions of organic compounds can be separated: very hydrophobic acids, slightly hydrophobic acids, hydrophilic charged and hydrophilic neutral. To identify the most efficient coagulant and its dose, three coagulants were used: aluminium sulphate ($Al_2(SO_4)_3 \cdot 17H_2O$), polyaluminium chloride (PAC18, Al – 9 %) and ferric chloride ($FeCl_3 \cdot 6H_2O$) at five different coagulant doses: 3 mgAl/l; 5 mgAl/l; 7 mgAl/l; 10 mgAl/l; 15 mgAl/l. Laboratory tests methodology used to evaluate possible applications of filter media (zeolite, Birm, quartz sand and quartz sand with oxidizing bacteria) in removal of ammonium ions, iron, manganese and organic compounds from groundwater is described. The tests in laboratory were carried out with groundwater from open and semi-closed wellfields. The chapter also describes the work of the drinking water treatment plant setup under field conditions.

Figure 1 presents the examined scheme of drinking water treatment plant technological setup.

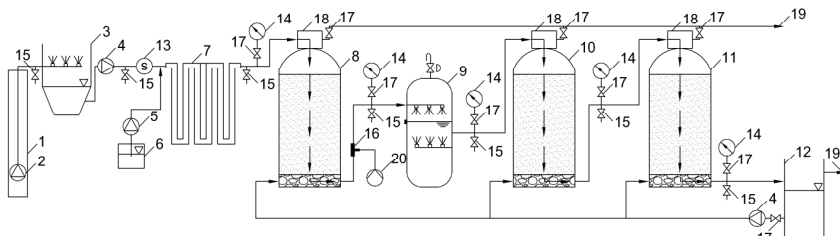


Fig. 1. Drinking water treatment technology setup

- (1 – well; 2 – pump; 3 – open aerator; 4 – pump; 5 – coagulant dosing pump; 6 – coagulant tank; 7 – reaction chamber; 8 – first filter; 9 – closed aerator; 10 – second filter; 11 – third filter; 12 – clean water tank; 13 – water meter; 14 – manometer; 15 – sample taking place; 16 – injector; 17 – valve; 18 – filter control valve; 19 – discharge into wastewater network; 20 – compressor)

The drinking water treatment setup in the wellfield of Nida operated from April 2012 till December 2012 (8 months). The water quality parameters from the examined wellfield are provided. Two technologies were used for drinking water treatment. Basically, these technologies only differ in principle of ammonium ions removal. In the first technology, a sorption method by using zeolite filling in the second filter was applied. In the second technology, a biological method of ammonium ions removal was used, and the second filter was filled with quartz sand with oxidizing bacteria. The water was pumped from the well to the open aerator. After the open aerator the pump delivered the water to the first filter. The water filtering rate fluctuated from 2 to 3 m³/m²/h. Before the filter, 5 mg Al/l of coagulant polyaluminium chloride were dosed to the water by pump. The coagulant got into a 50 meters length and DN25 diameter plastic pipe. Afterwards, the water reached the first pressure filter. This filter was filled with quartz sand with the fraction of 1–2 mm. From the first filter the water flowed into the closed aerator which was supplied with air by compressor. From the aerator the water got into the second pressure filter filled with natural zeolite (0,3–0,6 mm fraction) or quartz sand with oxidizing bacteria (1–2 mm fraction). After the second filter, the water flowed into the third pressure filter filled with quartz sand with oxidizing bacteria (1–2 mm fraction). Clean water after treatment was collected in the tank from which it was supplied for filter backwashing. Water samples were taken after each

technological treatment stage. The tests of determination of iron, ammonium, manganese, organic compounds, colour, water pH and dissolved oxygen were carried out in water samples.

3. Drinking water quality and treatment plants studies results

This chapter provides the comparative analysis of quantitative methods for organic compounds determination, the results of identification tests of organic compounds fractions that prevail in the groundwater of Lithuanian wellfields, the test results of determination of coagulants efficiency, the test results of the efficiency of different filter media and the test results of the application of drinking water treatment technologies that integrally remove ammonium ions, iron and manganese compounds as well as organic compounds.

After quantitative organic compounds tests in different drinking water resources, the relations between total organic carbon and UV_{254} absorbance, between permanganate index and UV_{254} absorbance, between water colour and total organic carbon concentration, between water colour and permanganate index, between water colour and chemical oxygen demand were studied. In the comparison of quantitative organic compounds determination methods, strong relations were found between all indirect compound matter quantitative parameters. Figure 2 shows dependence of total organic carbon concentration on UV_{254} absorption.

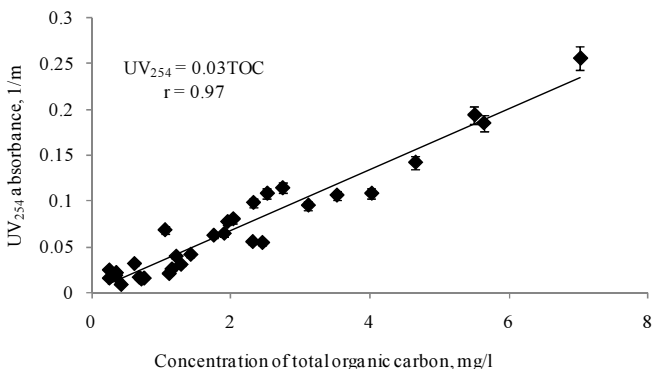


Fig. 2. Dependence of total organic carbon concentration on UV_{254} absorbance

The intensity of relations between the quantitative parameters of organic compounds was determined: total organic carbon concentration and UV₂₅₄ absorbance ($r = 0.97$), permanganate index and UV₂₅₄ absorbance ($r = 0.94$), water colour and permanganate index ($r = 0.92$), water colour and chemical oxygen demand ($r = 0.88$), water colour and total organic carbon ($r = 0.87$).

It was found from the fractionation tests that in the groundwater from the wells of Lithuanian wellfields very hydrophobic acids fraction forms the major part of organic compounds (75 % in Taujėnai, 69 % in Nida, 70 % in Petronys and 69 % in Preila) (Fig. 3).

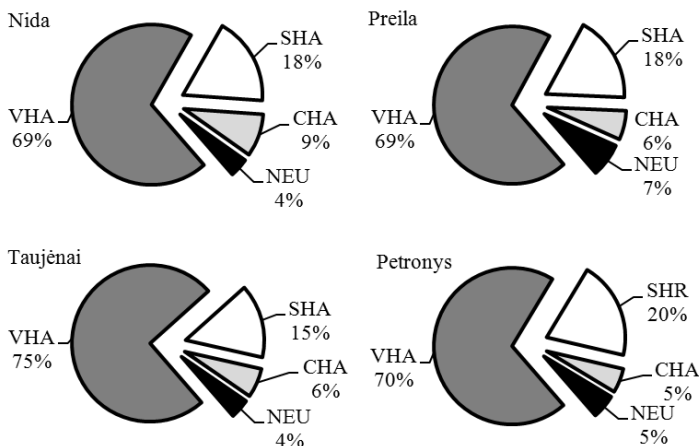


Fig. 3. Fractions of organic compounds in groundwater

A coagulation process of different quality groundwater from four wellfields was carried out in laboratory using three coagulants. In this process, the efficiency of removal of organic compounds and iron from groundwater was evaluated. When all coagulant doses are used, the polyaluminium chloride is more efficient in organic compounds removal than aluminium sulphate at an average of 13 % and more efficient than ferric chloride by 4 %. Iron compounds are removed most efficiently by the polyaluminium chloride (it is more efficient than aluminium sulphate by 11 % and more efficient than ferric chloride by 6 %). Ammonium ions and manganese compounds cannot be removed from water by coagulation. The determined optimal coagulant (polyaluminium chloride) dose is 5 mgAl/l (Fig. 4), and it will be used in further studies. In the optimization of coagulation process, in addition to the above mentioned tests,

the studies of UV_{254} absorbance and residual aluminium concentration were carried out. These studies show that the organic compounds concentration (74 %) decreases most efficiently when water pH value is equal to 5.5. If pH values increase, the efficiency of organic compounds removal decreases. However, the concentration of residual aluminium varies inversely: the higher pH value, the lower residual aluminium concentration in water. Residual aluminium concentrations do not exceed permissible hygienic standards when water pH is 7.0–7.5

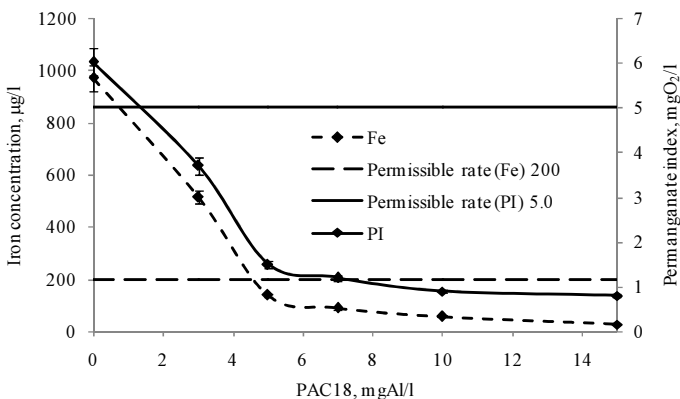


Fig. 4. Iron and organic compounds dependence on coagulant doses

According to the requirements of HN 24:2003, the drinking water pH value must be above 6.5. Although the efficiency of the reduction of organic compounds concentration is lower when water pH is above 6.5, the residual aluminium concentration and water pH value meet the requirements of hygienic standard. Therefore, the value of water pH for the removal of organic compounds and iron will have to be above 7.0. In this case the efficiency of the reduction of organic compounds concentration reaches 50–60 %.

In the following work stage, possible applications of different filter media in water treatment plants are analyzed. The media used in the studies are: zeolite, Birm, quartz sand and quartz sand with oxidizing bacteria. Before filtration, the water was coagulated. The test showed that all examined filter media in coagulation process efficiently (up to 99 %) remove iron compounds from groundwater.

When removing ammonium ions from groundwater, it was found that the zeolite media removes ammonium ions most efficiently (up to 98 %).

Ammonium ions can also be efficiently removed (95 %) by the media of quartz sand with oxidizing bacteria. Manganese compounds are most efficiently (85 %) removed by quartz sand with oxidizing bacteria. All examined filter media remove organic compounds similarly as the efficiency is more influenced by coagulation process than by filtration itself. In almost all examined cases, the effective working time of zeolite and Birm media due to faster colmatation is 40 % shorter compared to the working time of quartz sand. According to the obtained results, quartz sand and zeolite fillings will be used in further studies.

Evaluating the results of the studies and the quality of groundwater, water treatment technology described in the second chapter was proposed. The studies were carried out under field conditions in Nida wellfield in which water quality is one of the worst and most complicated in the country. The main function of examined water treatment technology is to integrally remove ammonium ions, iron, manganese and organic compounds from groundwater using the least possible amount of reagents. The figures 5, 6, 7 and 8 present the changes of removable compounds concentrations at different stages of water treatment plant (I technology – in second filter used zeolite, II technology – in second filtre used quartz sand with oxidizing bacteria).

Permanganate index in groundwater exceeds permissible hygienic standards (5.0 mgO₂/l). After the first filter, the permanganate index of water decreases and does not exceed permissible hygienic standard anymore. Afterwards, permanganate index in treatment plant almost does not alter.

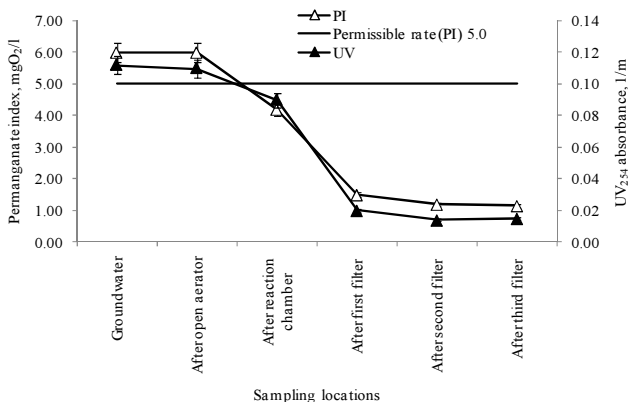


Fig. 5. Permanganate index and UV₂₅₄ absorbance at different sampling locations

The removal of iron compounds in laboratory suggested an assumption that the major part of the contaminant could be removed in the first filter together with organic substances. However, working under real conditions, it was set that iron concentration decreases evenly during all process steps. The principal efficiency of iron compound removal is only reached in the second and in the third filters. After the third filter, the total iron concentration does not exceed permissible hygienic standards anymore.

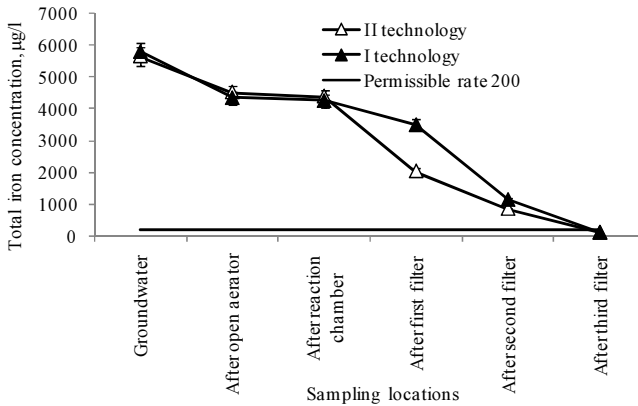


Fig. 6. Total iron concentration at different sampling locations

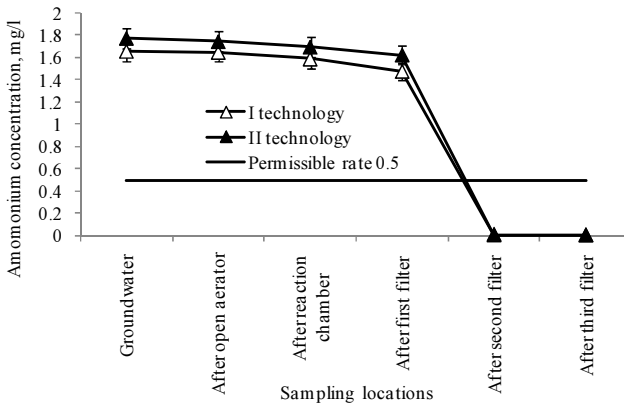


Fig. 7. Ammonium concentration at different sampling locations

The second filter was designed exclusively for the removal of ammonium ions. In the first stage of test, this filter was filled with zeolite. In the second filter ammonium ions were removed in an efficient way, around 99 %, and it did not exceed permissible hygienic standards. However, the zeolite media removes ammonium by sorption. When the zeolite sorption capacity is used up, the zeolite media must be recovered by sodium chloride solution. In order to avoid additional reagent, in the second stage of test the filter media of the second filter was changed into quartz sand from another water treatment plant. It was found by tests that quartz sand media efficiency is the same as zeolite efficiency. Therefore, the use of zeolite can only be justified in cases when ammonium ions concentration in treated water exceeds 2 mg/l. If ammonium ions concentration is higher, one more aeration step is necessary as the biological process requires high amount of oxygen; moreover, biological oxidation rate is limited.

The third quartz sand with oxidizing bacteria filter was designed for manganese compounds removal. As expected manganese removal is not possible until iron and organic compounds and ammonium ions are removed. After the removal of these compounds, manganese is removed in the last filter.

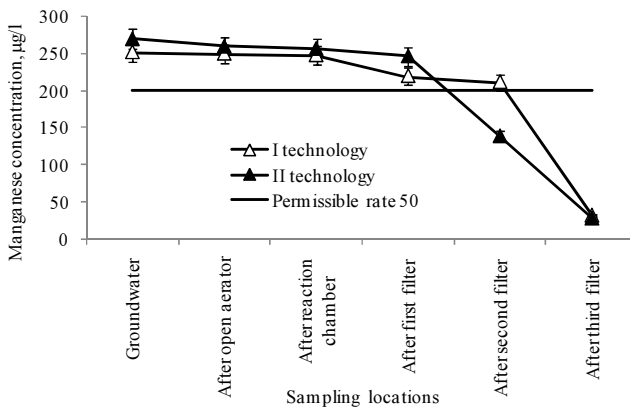


Fig. 8. Manganese concentration at different sampling locations

After the analysis of drinking water preparation technology that removes ammonium ions as well as iron, manganese and organic compounds from groundwater, it was set that this technology efficiently removes ammonium ions, organic, iron and manganese compounds.

In Nida drinking water treatment plant four types of chemical reagents are used: hydrochloric acid, caustic soda, hydrogen peroxide and coagulant. According to the plant managing company data, 44 m³ of chemical substances are inserted into water annually. The whole amount of treated water is repumped four times. For additional water treatment the membranes are used, and the electric energy costs are correspondingly high. Still, ammonium is not removed in the present water treatment plant.

Assessing the tests carried out, a new drinking water treatment technology for Nida and Pervalka wellfields was proposed (Fig. 9).

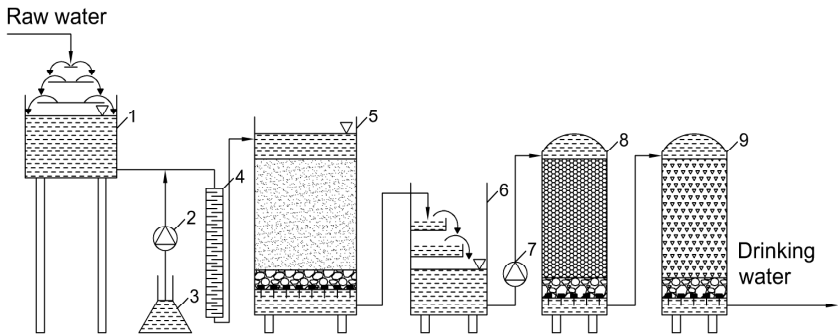


Fig. 9. Water treatment technology

- (1 – open aerator; 2 – coagulant dosing pump; 3 – coagulant tank; 4 – reaction chamber; 5 – first open filter; 6 – open aerator and water tank; 7 – pump; 8 – second closed pressure filter; 9 – third closed pressure filter)

In the proposed technology only one reagent will be used, that is coagulant. Total annual reagent amount would be 8 times smaller. In the proposed technology water would be aerated in the open weir aerator and then supplied to the first open filter by gravity flow, but coagulant would be dosed before the filter. After the first stage, the water would be aerated once more and provided via pump to the second and to the third pressure filters. From the filters it could flow into existing clean water tanks. The proposed water treatment technology is based on the studies carried out. It treats groundwater efficiently, only one reagent is used and electric energy input is low. The plant operates steadily and do not require intense maintenance.

General conclusions and recommendation

General conclusion

1. By applying indirect quantitative organic substances determination methods, the strongest relations were found between total organic carbon concentration and UV₂₅₄ absorbance (correlation coefficient is 0.97), between permanganate index and UV₂₅₄ absorbance (correlation coefficient is 0.94) and between water colour and permanganate index (correlation coefficient is 0.92). It was found that UV₂₅₄ absorbance and colour determination methodologies may be used for quantitative organic compounds determination in groundwater as an alternative for standard quantitative determination methods.
2. The fractionation of groundwater taken from open and semi-closed Lithuanian wellfields showed that the fraction of very hydrophobic acids forms a major part (around 70 %) of organic compounds in water.
3. Polyaluminium chloride is the coagulant that removes iron and organic compounds most efficiently. This coagulant is more efficient in organic compounds removal than aluminium sulphate by 13 % and more efficient than ferric chloride by 4 %. Accordingly, the polyaluminium chloride in organic compounds removal is more efficient than aluminium sulphate by 11 % and more efficient than ferric chloride by 6 %.
4. It was determined that quartz sand is the most efficient media to remove iron compounds and coagulation products from water. Ammonium ions are most efficiently removed by zeolite (when ammonium ions concentration is > 2 mg/l) and quartz sand (when ammonium ions concentration is < 2 mg/l). Manganese is most efficiently removed by quartz sand. Quartz sand efficiently removes ammonium and manganese only when there is a necessary quantity of oxidising microorganisms.
5. Drinking water treatment technology that consists of three-stage filtration, open and closed aeration and coagulation, and integrally removes ammonium ions as well as iron, manganese and organic compounds from groundwater to meet the requirements of Lithuanian hygienic standards is analysed. Applying the tested technology, the annual quantity of reagents would decrease by 7 times compared to the quantity of reagents that is used in the water treatment plant currently.

Recommendations

1. In order to simplify and accelerate quantitative organic compounds determination in groundwater, it is proposed to use UV₂₅₄ absorption and

- water colour determination methods for drinking water treatment plant start-up and evaluation of operation process efficiency.
2. It is recommended to perform fractionation of water organic compounds when designing new plants for organic compounds removal. When organic compounds fractions in water are determined, it is possible to choose the most efficient method for removal of organic.
 3. If ammonium concentration in water is below 2 mg/l, quartz sand media is recommended for the removal of ammonium. Whereas, if the concentration is above 2 mg/l, zeolite media is more appropriate for this purpose.
 4. Usually in open and sometimes in semi-closed wellfields, there are some different compounds that must be removed from the groundwater. The water treatment technologies studied in this work are recommended when iron, manganese and organic compounds as well as ammonium ions concentrations exceed permissible hygienic standards in groundwater.

List of published works on the topic of the dissertation In the reviewed scientific journals

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Albrektienė R.; Rimeika M. 2011. Organinių junginių ir spalvos šalinimo iš požeminio vandens efektyvumas naudojant koaguliantus. *Mokslas – Lietuvos ateitis. Aplinkos apsaugos inžinerija*. 3 (5): 5–8. ISSN 2029-2341 (Index Copernicus)

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In the other editions

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Ramunė Albrektienė was born in Klaipėda on 12 February 1981. In 2003, she acquired bachelor's degree in chemistry engineering from the Faculty of Marine Engineering at Klaipėda University. In 2005, she received a master's degree in Chemistry from the Faculty of Chemistry at Vilnius University. Since 2009 she is a graduate student at Vilnius Gediminas Technical University. Since 2003 she is working in UAB "Vilniaus vandenys" Drinking Water Laboratory, and since 2005 she is also working as a lector at the Department of Chemistry and Bioengineering at Vilnius Gediminas Technical University.

GERIAMOJO VANDENS KOKYBĖS TYRIMAI IR GERINIMO PRIEMONĖS

Mokslu problemos aktualumas

Valstybinės maisto ir veterinarijos tarnybos duomenimis 718 Lietuvos vandenviečių leistinas higienos normas viršija geležies junginių koncentracijos, 462 vandenvietėse – amonio jonų koncentracijos, 165 vandenvietėse – mangano junginių koncentracijos ir 30 vandenviečių organinių junginių koncentracijos ir spalvos intensyvumas (2009 m.). Padidėjusios organinių junginių koncentracijos požeminiame vandenyje dažniausiai pasitaiko III grupės (atvirose) vandenvietėse. Tai padidintos rizikos vandenvietės, jose eksploatuojami vandeningieji sluoksniai turi ryšį su paviršinio vandens šaltiniais, pasipildo atvirų telkinių vandeniu arba atmosferos krituliais (HN 44:2006). Atvirose vandenvietėse dažniausiai geriamojo vandens kokybės parametrus viršija ne vienas, o keletas rodiklių: spalva, amonio jonai, geležies, mangano ir organinių junginiai. Kai požeminiame vandenyje leistinas higienos normas viršija tik geležies ar mangano junginiai, tai galima taikyti standartines vandens ruošimo technologijas. Kai iš požeminio vandens reikia pašalinti visus minėtus junginius, tokiu atveju trūksta tiek mokslinių, tiek praktinių žinių apie kompleksines geriamojo vandens ruošimo technologijas.

Esant didelėms organinių junginių koncentracijoms vandenyje ant filtravimo užpildų grūdelių paviršiaus susidaro hidrofobinė plėvelė. Dėl šios plėvelės susidarymo sutrinka amonio jonų, geležies ir mangano junginių šalinimas iš vandens. Organiniai junginiai pirmiausiai įsisavina deguonį, kuris reikalingas geležies junginių, amonio jonų ir mangano junginių oksidavimui. Dauguma metalų gali sudaryti kompleksinius organinius junginius. Organiniai junginiai sąlygoja nepriimtina vartojimui vandens skonį ir kvapą. Ištirpę organiniai junginiai, dezinfekavimo metu sudaro šalutinius junginius, tokius kaip haloacetatinė rūgštis ir trihalometanai.

Organiniai junginiai paprastai efektyviai šalinami naudojant cheminius vandens ruošimo metodus. Tačiau amonio jonus ir mangano junginius retai kada pavyksta pašalinti reagentiniais metodais. Šių medžiagų pašalinimui geriausiai tinka biologiniai metodai. Paviršiniam vandeniui valyti paprastai taikomos reagentinės, o požeminiam vandeniui biologinės vandens ruošimo technologijos. Atvirojo tipo vandenvietės yra tarpinė grandis, tarp paviršinio ir požeminio vandens telkinių. Požeminiam vandeniui, kuris imamas iš atvirų vandenviečių reikia taikyti kombinuotus metodus, kurie iki šiol mažai nagrinėti mokslinėje literatūroje.

Tyrimų objektas

Požeminis vanduo, kuriame leistinas geriamojo vandens higienos normas viršija amonio jonai, geležies, mangano ir organinių junginių koncentracijos.

Darbo tikslas ir uždaviniai

Darbo tikslas – ištirti geriamojo vandens ruošimo technologijas, iš požeminio vandens šalinančias amonio jonus, geležies, mangano ir organinius junginius, naudojant minimalų reagentų kiekį

Darbo tikslui pasiekti reikia išspręsti šiuos uždavinius:

1. Išnagrinėti pasaulyje naudojamas vandens ruošimo technologijas, kuriose šalinami amonio jonai, geležies, mangano ir organiniai junginiai.
2. Eksperimentiškai palyginti įprastinius kiekybinius organinių junginių nustatymo metodus su vandens spalvos nustatymo metodu bei organinių junginių ultravioletinės šviesos spektro 254 nm bangos ilgyje sugerties metodu ir ištirti šių metodų taikomumą kiekybiniam organinių junginių koncentracijos nustatymui požeminiame vandenyje.
3. Nustatyti požeminiame vandenyje esančių organinių junginių frakcijas.
4. Ištirti koagulantų: aliuminio sulfato, polialiuminio chlorido ir geležies chlorido naudojimo efektyvumą šalinant amonio jonus, geležies, mangano ir organinius junginius iš požeminio vandens.
5. Ištirti filtravimo užpildų (kvarcinio smėlio, kvarcinio smėlio su oksiduojančiomis bakterijomis, Birm ir ceolito) dozuojant koagulantą panaudojimo galimybes šalinant amonio jonus, geležies, mangano ir organinių junginius iš požeminio vandens.
6. Gamybinėmis sąlygomis ištirti geriamojo vandens ruošimo technologiją, kuri iš požeminio vandens kompleksiskai šalintų amonio jonus, geležies, mangano ir organinius junginius.

Tyrimų metodika

Darbe naudojamos standartinės ir specifinės vandens kokybės rodiklių nustatymo metodikos. Naudojami filtravimo užpildų tyrimų laboratorinis stendas bei geriamojo vandens ruošimo technologijos stendas, kuriame atlikti tyrimai gamybinėmis sąlygomis.

Darbo mokslinis naujumas

Ištirtos ir pasiūlytos trijų filtravimo pakopų su aeravimu bei koagulianto įterpimu geriamojo vandens ruošimo technologijos, kompleksiskai šalinančios amonio jonus, geležies, mangano ir organinius junginius iš požeminio vandens.

Darbo rezultatų praktinė reikšmė

Remiantis atliktų tyrimų rezultatais pasiūlyta greita ir paprasta organinių junginių nustatymo metodika, tinkanti požeminiam vandeniui. Pasiūlytos trijų filtravimo pakopų su aeracija bei koagulianto įterpimu geriamojo vandens ruošimo technologijos, kompleksiška šalinančios amonio jonus, geležies, mangano ir organinius junginius iš požeminio vandens. Šios technologijos gali būti taikomos III grupės (atvirose) Lietuvos ir užsienio valstybių vandenvietėse, kurių požeminiame vandenyje leistinas geriamojo vandens higienos normas viršija amonio jonai, geležies, mangano ir organinių junginių koncentracijos.

Ginamieji teiginiai

1. Organinių junginių ultravioletinės šviesos spektro 254 nm bangos ilgyje sugerties ir vandens spalvos nustatymo metodai yra taikytini kiekybiniam organinių junginių nustatymui požeminiame vandenyje.
2. III grupės (atvirųjų) ir II grupės (pusiau uždarytųjų) vandenviečių požeminiame vandenyje didžiausią organinių junginių dalį sudaro stipriai hidrofobinių rūgščių frakcija, kuri efektyviai pašalinama koaguliacijos metodu.
3. Geležies ir organinius junginius efektyviausiai šalina koaguliantas – polialiuminio chloridas.
4. Geriamojo vandens ruošimo technologija, susidedanti iš trijų laipsnių filtravimo, atviros ir uždaros aeracijos, bei koaguliacijos, kompleksiška pašalina amonio jonus, geležies, mangano ir organinius junginius iš požeminio vandens iki leistinų higienos normų reikalavimų.

Darbo apimtis

Disertaciją sudaro įvadas, trys skyriai, bendrosios išvados ir rekomendacijos.

Darbo apimtis 112 puslapių, panaudota 16 numeruotų formulių, 52 paveikslai ir 19 lentelių. Rašant disertaciją buvo panaudota 113 literatūros šaltinių.

Pirmasis skyrius skirtas mokslinės literatūros analizei. Pateikiami vandens kokybės parametrai ir gerinimo priemonės. Skyriaus pabaigoje formuluojamos išvados ir tikslinami disertacijos uždaviniai.

Antrame skyriuje pateiktos naudojamos standartinės ir individualios vandens kokybės rodiklių nustatymo metodikos. Aprašoma filtravimo užpildo laboratorinio stendo tyrimų metodika bei pateiktas geriamojo vandens ruošimo įrenginių stendo darbo gamybinėmis sąlygomis principas.

Trečiajame skyriuje pateikta kiekybinių organinių junginių nustatymo metodų palyginamoji analizė, Lietuvos vandenviečių požeminiame vandenyje vyraujančių organinių junginių frakcijų nustatymo tyrimų rezultatai, koaguliantų efektyvumo tyrimų rezultatai, filtravimo užpildų panaudojimo galimybių tyrimų rezultatai bei geriamojo vandens ruošimo įrenginių stendo darbo gamybinėmis sąlygomis tyrimų rezultatai.

Bendrosios išvados

1. Taikant netiesioginius kiekybinius organinių junginių nustatymo metodus stipriausi ryšiai gauti tarp bendrosios organinės anglies koncentracijos ir UV_{254} sugerties (koreliacijos koeficientas lygus 0,97), tarp permanganato indekso ir UV_{254} sugerties (koreliacijos koeficientas lygus 0,94), bei tarp vandens spalvos ir permanganato indekso (koreliacijos koeficientas lygus 0,92). Nustatyta, kad UV_{254} sugerties ir spalvos nustatymo metodikas galima naudoti kaip alternatyvą kiekybiniam organinių junginių nustatymui požeminiame vandenyje vietoj standartinių kiekybinių nustatymo metodų.
2. Atlikus atvirų ir pusiau uždarų Lietuvos vandenviečių požeminio vandens frakcionavimą nustatyta, kad didžiausią (~ 70 %) organinių junginių dalį vandenyje sudaro stipriai hidrofobinių rūgščių frakcija.
3. Geležies ir organinius junginius efektyviausiai šalina koaguliantas – polialiuminio chloridas. Šis koaguliantas iki 13 % efektyvesnis už aliuminio sulfatą ir iki 4 % efektyvesnis už geležies chloridą šalinant organinius junginius. Analogiškai polialiuminio chloridas yra iki 11 % efektyvesnis už aliuminio sulfatą ir iki 6 % efektyvesnis už geležies chloridą šalinant geležies junginius.
4. Nustatyta, kad geležies junginių ir koaguliacijos produktų šalinimui iš vandens efektyviausiai tinka kvarcinis smėlis, amonio jonų šalinimui – ceolitas (kai amonio jonų koncentracija > 2 mg/l) ir kvarcinis smėlis (kai amonio jonų koncentracija < 2 mg/l), mangano šalinimui – kvarcinis smėlis. Kvarcinis smėlis amonį ir manganą šalina efektyviai tik tada, kai susiformuoja reikalingas oksiduojančių mikroorganizmų kiekis.
5. Ištirta geriamojo vandens ruošimo technologija susidedanti iš trijų laipsnių filtravimo, atviros ir uždaros aeracijos, bei koaguliacijos, kompleksiškai pašalina amonio jonus, geležies, mangano ir organinius junginius iš požeminio vandens iki Lietuvos higienos normų reikalavimų. Naudojant išbandytą technologiją sunaudojamų reagentų kiekis per metus sumažėtų 7

kartus lyginant su šiuo metu ruošimo įrenginiuose sunaudojamu reagentų kiekiu.

Rekomendacijos

1. Siekiant supaprastinti ir pagreitinti kiekybinį organinių junginių nustatymą požeminiame vandenyje, atliekant geriamojo vandens ruošimo įrenginių paleidimo-derinimo darbus ir eksploatacijos proceso efektyvumą vertinimą, siūloma naudoti UV₂₅₄ sugerties ir spalvos nustatymo metodus.
2. Projektuojant naujus organinių junginių šalinimo įrenginius, rekomenduojama atlikti vandens organinių junginių frakcionavimą. Nustačius organinių junginių frakcijas vandenyje, galima parinkti efektyviausią organinių junginių šalinimo metodą.
3. Kai amonio koncentracija vandenyje yra iki 2 mg/l, jo šalinimui rekomenduojama naudoti kvarcinio smėlio užpildą, kai amonio koncentracija yra virš 2 mg/l, tikslingiau būtų naudoti ceolito užpildą.
4. Paprastai atvirose ir kiek rečiau pusiau uždaroje vandenvietėse iš požeminio vandens reikia pašalinti keletą junginių. Jei požeminiame vandenyje leistinas higienos normas viršija geležies, mangano, organinių junginių ir amonio jonų koncentracijos, rekomenduojama naudoti darbe aprašytas vandens ruošimo technologijas.

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**DRINKING WATER QUALITY RESEARCH
AND IMPROVEMENT MEASURES**

Summary of Doctoral Dissertation
Technological Sciences, Environmental Engineering (04T)

Ramunė Albrektienė

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IR GERINIMO PRIEMONĖS**

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