TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING

Department of Civil Engineering and Architecture

IMPACT OF WATER POLICIES ON GROUNDWATER QUALITY IN NITRATE VULNERABLE ZONE IN ESTONIA

VEEPOLIITIKATE MÕJU PÕHJAVEE KVALITEEDILE NITRAADITUNDLIKUL ALAL EESTIS

MASTER THESIS

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AUTHOR’S DECLARATION

Hereby I declare, that I have written this thesis independently.
No academic degree has been applied for based on this material.
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TASK FOR THE FINAL PAPER

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Raw monitoring data on ground water quality (nitrate content) in NVZ

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Data on pressures to water quality in NVZ

Explanatory letter:

Summary in English:

The aim of the study is an assessment of the impact of implemented agro-environmental policies on nitrate content in groundwater within Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone. Results about dynamic changes of nitrate concentrations will be compared to existing policies, regulations and action plans towards NVZ, also to fertilizer inputs and nitrate concentrations in surface water bodies.

Resümee Eesti keeles:

Töö eesmärgiks on hinnata põllumajandus-keskkonna poliitikate mõju põhjavee nitraadisisaldusele Pandivere ning Adavere-Põltsamaa nitraaditundlikul alal. Nitraadisisalduse dünaamikat võrreldakse rakendatud poliitikate, regulatsioonide ja tegevuskavadega nitraaditundlikul alal aga ka väetisekasutusega ja nitraadisisaldusega pinnaveekogudes.

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1. Introduction

Water protection is one of the most important parts of the current environmental policy. Water and groundwater reserves are a vital part of our civilization: farming and agricultural activities, manufacturing, everyday life support, etc., everything highly depends on water availability and in most cases on the high quality of it.

Water and groundwater protection policies and legislations are provided in order to: avoid pollution or prevent further deterioration of state; and create conditions for improving existing quality.

Usually, policies are based on combinations of theoretical know-how and real life examples and scenarios, providing proper legislations for each country and region specifically, based on existing natural, environmental and socio-economic conditions of each target area.

The current study concentrates on the Estonian nitrate vulnerable area - Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone. This area is heavily used for agriculture and thus prone to pollution with nitrates more than other areas. The situation is worsened by the fact that significant part of the target area is geologically represented with karst, through which pollution is very easy to infiltrate into groundwater.

Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone (NVZ) covers 7.19% of Estonia, including around 160000 ha of arable land and involves 3 counties (Figure 1). NVZ consists of [1]:

- Pandivere upland – groundwater accumulation, karsts;
- Adavere-Põltsamaa limestone plateau - relatively thin soil cover on limestone bedrock.

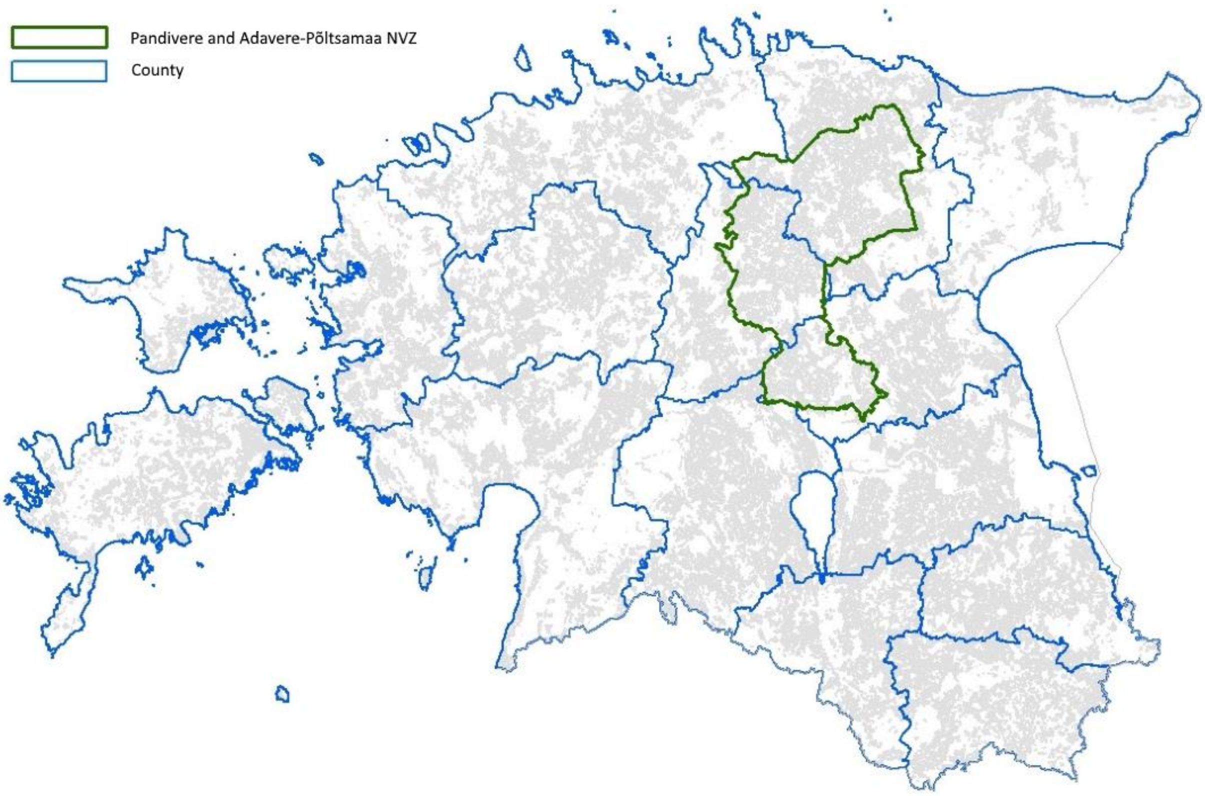


Figure 1. Location scheme of Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone (Source: Nitraaditundliku ala (NTA) laiendamisvajaduse analüüs, 2011)

Currently, NVZ area is under constant monitoring, which includes both surface and groundwater monitoring points. Surface water samples are taken from streams, rivers, and lakes; and groundwater samples – from karst springs and wells with various depth (Figure 2).

Figure 2. Pandivere and Adavere-Põltsamaa NVZ with monitoring points by 2010
(Source: Nitraaditundliku ala põhjavee seire 2010. MAVES)

The aim of the study is an assessment of the impact of implemented agro-environmental policies on groundwater quality (specifically - nitrate content) within Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone.

In order to reach this goal, 20 groundwater monitoring points were selected and nitrate content data obtained for past 15 years period (2001-2016). Results were analyzed and conclusions made about dynamic changes of concentrations.

Monitoring points include 2 karst springs and 18 wells with various depths located within whole NVZ area, with >10 mg/l nitrate content and continuous monitoring period (for most of them). A detailed description of selection criteria is provided in Chapter 4.

Monitoring results were compared to existing policies, regulations and action plans towards nitrate vulnerable areas, to reveal their impact on groundwater quality.

And finally, subsequent conclusions and recommendations were made (Chapter 5).

2. General overview of water policies and targets towards nitrate vulnerable areas

During past 27 years, two major reforms of Estonian water management have taken place. First one occurred soon after regaining of independence and the second - prior to and after becoming an EU member state. Reforms of both phases were politically driven as a part of broader political and economic reforms. Both have affected (directly and indirectly) three key areas of water management - elaboration and enforcement of legislation, water infrastructure management, and the cost of water services. [4]

One of the main directions of water-related legislation is to control agricultural pollution caused by anthropogenic sources and in the current case study - by agriculture activities within the target area.

2.1. Legislative framework

Water protection is regulated in Estonia by different laws and acts, of which the most important for limiting agricultural pollution are: [6]

- Water Act (from 1994);
- Integrated Pollution Prevention and Control Act (from 2001);
- Government regulation of 28 August 2001 “Water protection requirements for fertilizers, manure and silage storage facilities and requirements for usage and storage of manure, silage, and other fertilizers”;
- Government regulation of 21 January 2003 “Protection rules of Pandivere and Adavere-Põltsamaa nitrate vulnerable area”;
- Regulation of Ministry of Social Affairs of 2 January 2003 “The quality and control requirements of surface and groundwater used for producing drinking water”;
- Regulation of Ministry of Social Affairs of 31 July 2001 “The quality and control requirements and analysis methods of drinking water”;
- Regulation of Ministry of the Environment of 10 May 2004 “Water classes of groundwater bodies, according to quality indicators values and procedure for defining water classes”;

- Regulation of Ministry of Agriculture of 21 August 2004 “Requirements for manure ingredients”.

Based on the Water Act, water protection and use measures are planned for river and sub-basin management plans (Estonia has 3 river basins and 9 sub-river basins). The planning process, which started in 2003 now is completed for all the sub-river basin management plans. [6]

Issued environmental permits in Estonia are [6]:

- Integrated environmental permits - these are issued for releasing substances simultaneously to air, water, soil or groundwater and for management of waste;
- Simple permits (permits for the special use of water, ambient air pollution permits and waste permits) to use the natural resource or to release pollutants from one source or for waste management to one person.

The Estonian Integrated Pollution Prevention and Control Act is stricter than the EU directive 96/61/EC, which demands integrated permit only in the cases of poultry and pig farming. In Estonia, cattle farming is also subject to integrated permit.

2.2. Water sector reforms in Estonia

In general, water sector reforms are divided into two phases. The first phase of reforms is related to the regaining of independence and the establishment of a market economy (1990-1999). The second phase was mainly driven by accession process in EU (2000-2016). Both phases are clearly distinct and interrelated since they have taken place in a very short period of time. Reforms of both phases mainly addressed the same water problems, with the difference in their magnitude. [4]

During the first phase of reforms, the main focus was on the establishment of the basic legal acts. In the second phase, attention directed at upgrading and enforcing existing legislation to meet the requirements of the EU water-related Directives. [4]

The most of the Estonian water problems are related to the water infrastructure and the excessive pollution loads (from point and diffuse sources): [4]

- Point source pollution originates mainly from the industrial sector or small wastewater treatment plants.
- Diffuse source pollution originates mostly from agricultural areas, forestry or fish farms.

To deal with above mentioned problems, reforms have focused on legislation, infrastructure management, and water services.

Regardless rather well-developed water sector in the 1990s, complying with existing drinking water and water pollution standards was difficult due to insufficient financial resources. It was also clear that improvement of the ecological status of water bodies was not guaranteed by the standardization of water quality parameters, using only chemical parameters. Therefore, reforms in water legislation were expected to include improvements in water quality assessment systems for more target-oriented water management. [4]

The main results of first phase reforms were: The Water Act in 1994, the Public Water Supply and Sewerage Act in 1999 and the Pollution Charge Act in 1999. [4]

At the end of the 1990s, reforms took a new direction, towards the EU, focused on legislation, infrastructure, and water services, to harmonize entire water legislation with the existing EU legislation. Most of these changes made to improve and make stricter existing Estonian legislation. As a result, it became more expensive to implement. In order to ensure drinking water safety, proper treatment of wastewater and achievement of good environmental status of waters, infrastructure had to conform to stricter standards. [4]

The main results of the second phase of reforms were amendments to the Water Act (made from 2001 to 2010), to the Public Water Supply and Sewerage Act (in 2008 and 2010) and the new Environmental Charges Act (in 2009). [4]

2.3. National water legislation enactment and modification

The main components of the national water legislation were introduced during the first phase of elaboration of the Water Act and supporting water legislation. With the second phase, they were modified based on the EU requirements. Specifically - Water Act, Public Water Supply and Sewerage Act and the Environment Charges Act. [4]

Water Act and related water legislation

The Water Act was adopted in 1994 and reflected the level of knowledge and needs in the mid-90s. Water protection measures were based on HELCOM recommendations. Limits for municipal discharges were set as emission standards, considering technical and economic possibilities, focusing primarily on phosphorus and nitrogen compounds. Water Act and limit values for discharges of pollutants into water and soil (Decree of the Government nr. 269, 31.07.2001) were developed. [4]

The adoption of the EU WFD (Water Framework Directive, 2000/60/EC) changed the water protection principles and obliged the EU member states to review the existing legislation accordingly. The aim of WFD was establishing a framework for the protection of inland surface waters, transitional waters, coastal waters, and groundwater. Consequently, several new chapters and paragraphs were added to the Water Act, including a new chapter about environment objectives, water use and protection planning and a paragraph concerning the combined approach for point and diffuse pollution sources. Decree of limit values for pollutant discharges into water and soil was revised following WFD main objectives, adding emission standards strengthening possibility. [4]

The revision of the Water Act increased the overall "strictness" over the control of discharges and made it more robust with the inclusion of cost recovery principles for water services (environmental and resource costs, economic analysis, and the polluter pays principle). Additionally, monitoring of surface and groundwater quality obtained a new meaning. [4]

Environmental Charges Act

At the beginning of reforms, polluters exceeded emissions standards were paying pollution tax based on the pollution load above the limit values. With the further revision to the Environment Charge Act, all users discharging pollutants into a water body need to pay the tax based on the full amount of discharged pollutants. In the case of discharging above the allowed limit, polluter was obliged to pay significantly higher, special fee. Different pollution tax rates were set for different pollutants. Also, a number of taxed pollutants continuously increased and additional polluters (fish farms, peat industry) were added to the list. [4]

The pollution and resource tax is based on the amount of water used, and pollution discharged into water bodies. Public Water Supply and Sewerage Act adoption obliged municipalities to establish and approve the price of water. Since 2004, calculating and publishing information on cost recovery of different polluters is also obligatory. The rate of cost recovery is calculated for 3 main sectors: households, industries, and agriculture. [4]

The revision of Environmental Charges Act made it stricter. The increase of tax amount with the inclusion of additional polluters is aimed to improve surface and groundwater quality control and protection. Another benefit is increased revenue into the environment fund. [4]

Public Water Supply and Sewerage Act

The first Public Water Supply and Sewerage Act was adopted in 1999. The Act regulates the organization of water supply, collection, and treatment of wastewater, rainwater, drainage water and other types of wastewater through the public water supply and sewerage system. It defines the rights and obligations of the state, local governments, water users and clients and regulates the price of water services.

A new amendment to the Water Supply and Sewerage Act was adopted in 2010, aimed for better regulation and control of water service price and protection water users in case of privatization of the municipal water companies. [4]

Its revision ensures more robust price-setting mechanism, protecting water users from arbitrariness from water companies. On the other hand, it is aimed to help water companies establishing more fair and transparent prices for water services. Another major benefit is the mechanism allowing restructuration of infrastructures, water companies, and service areas. [4]

Other instruments considered and proposed to comply with the environmental requirements: [4]

- Allowing the selection of the most appropriate requirements to meet environmental requirements – either to achieve a target value in mg/l or a given reduction percentage;
- Enabling the application of the most suitable standards for the specific pollution – either limit values per production unit, limit values for discharges, but also considering the best available technology (BAT) and best environmental practice (BEP);
- Introducing pollution charges substitution agreements to allow exemptions to the set requirements for a limited time, with the obligation to invest and achieve the desired status or values.

Mechanisms to trigger technological processes modification

Water Act discharge requirements for different pollution sources and substances were elaborated by the HELCOM and are based on the use of the BAT (best available technology) and BEP (best environmental practice). HELCOM recommendations also include precise descriptions of BAT for the food industry and special limit values for discharges. However, pollution reduction technologies are not predefined by Estonian legislation, instead only final result (concentration or reduction percent) is determined. [4]

Environmental Charges Act can be used as a tool for technological processes modification to reduce pollution discharged into the environment. According to the act, taxation is required to main pollutants (organic matter (BOD), phosphorus, nitrogen and the basic harmful substances). Tax is based on the amount (tons/year) of substances discharged. This environmental tax can be reduced by implementing a new or modified technological or wastewater treatment process, which will also reduce pollution loads to the environment. [4]

Water Act, Water Supply and Sewerage Act, and Environmental Charges Act reforms and elaboration of water use and protection measures impacted industries, agriculture, water enterprises and public resulting changes in the behavior of all types of users (industrial, agricultural and households) and service providers (water companies). [4]

Water Act related changes in water use and protection measures are based on: inclusion of "polluter pays" principle (§3^{4}(1)); obligation of efficient and economic water usage; obligation to follow established requirements for water discharges (§21, (1)); and catchment area protection needs from agricultural production pollution (§26^{1}). [4]

The biggest changes occurred in agriculture, where farmers are obliged to construct and reconstruct manure and silage storages and use fertilizers more efficiently (paragraph 26^{1} - "Protection of catchment areas against pollution arising from agricultural production"). Implementation of all measures set by the Water Act is aimed to reduce agricultural nutrient emissions and consequently, to reduce nitrogen compounds in groundwater. [4]

2.4. Special regulations for nitrate vulnerable zones

Water Framework Directive (2000/60/EEC) and Nitrate Directive (91/676/EEC) (supplemented by Marine Strategy Framework Directive (2008/56/EC)) are the main EU directives that regulate agro-environmental measures. The history of limiting the use of fertilizers and pesticides used in agriculture has long roots in Estonia, starting before the country joined the EU and importance of limiting the diffuse pollution from agriculture has risen in the last years. [6]

The first Good Agricultural Practice was issued in 2001 and the updated version completed in 2007. The latest version has a more precise approach to water protection issues. A separate chapter is dedicated to the Pandivere and Adavere-Põltsamaa nitrate vulnerable zone (NVZ). [6]

Pandivere and Adavere-Põltsamaa NVZ was established in 2003 for the protection of surface and groundwater in regions with intensive agricultural production ("Protection Rules for the Nitrate Vulnerable Pandivere and Adavere-Põltsamaa Area" (RT I 2003, 10, 49)). An NVZ is an area, where agricultural activities have and may cause an increase of nitrate over 50 mg/l, and where surface water bodies are subject of eutrophication. [7]

Pandivere and Adavere-Põltsamaa area is represented with the most fertile soils in Estonia and compared to the country's average, land use is 50% more there. The same applies to livestock farming - 35% of cattle, 30% of pigs and 12.5% of poultry in the country are raised within NVZ area. Cultivated lands of the nitrate vulnerable area are nearly 40% (1190 km^2 in total) of the whole territory. [6]

Since groundwater and surface water bodies in most cases are interconnected, any of them can be used as an indicator speaking about types and shares of pollution sources. Nitrogen and phosphorus in Estonian surface water bodies originated from agriculture diffuse losses were about 62% of N and 40% of P in 2004 and considered to be the major factor determining the quality of many groundwater bodies in Estonia. Their share is believed to be increased by now due to the improvement of industrial and municipal wastewater treatment, and in the specific case of Pandivere and Adavere-Põltsamaa NVZ - because of the constantly growing amount of applied fertilizers. [5] Therefore, agricultural practices have been a target of continuous attention by the authorities.

Requirements concerning the nitrate vulnerable area have been established by the Water Act and the secondary legislation based on it. Some requirements applicable to NVZ are stricter than for the rest of Estonian territory (where intensity of agriculture is in general lower), such as limitation of manure and mineral fertilizers, providing vegetation covers for arable lands in winter, limiting livestock units per hectare, use sewage sludge, fertilization and use of pesticides should not occur closer than 50 m of the karst funnels, etc. (See more detailed list of requirements below). [6]

Estonian Government has adopted the renewed action plan for the nitrate vulnerable area for the period 2016-2020, which supports river basin management plan achievements regarding maintaining the good status of groundwater and surface water bodies and inhabitants supply with drinking water. The Nitrates Directive has been integrated into legislation with Water Act, Sections 26^1 and 26^2, establishing general water protection measures from agricultural load and requirements for storing manure and liquid manure. Section 26^3 establishes water protection measures on Nitrate Vulnerable Zones, while subsection 12 establishes the NVZ action plan. [7]

Water Act establishes the following provisions for the transposition of the Nitrates Directive: [8]

- Sets specific time periods (from date - to date) and natural conditions (slope, flooded, snow-covered ground, etc.) when land application of different types of manures and mineral fertilizers are not allowed (and vice versa).
- Determines distances from different natural and water bodies, where usage of fertilizers, storage, composting and other agricultural activities are prohibited.
- Establishes requirements for the use and storage of manure, silage and other fertilizers and the measures for controlling the performance of such requirements.
- Demands usage of manure storages that will hold the manure, liquid manure and the sewage (if necessary) for a certain amount of time. Storages must leakproof and guarantee safety during the storage and operation activities;
- Keeping the amount of livestock that exceeds two LSUs for one hectare of agriculture land is not allowed without having proper capacity manure storage.
- At least 30% of the arable land used by a person engaged in agriculture, which is located in a Nitrate Vulnerable Zone, shall be covered with a vegetation cover in winter.
- In NVZ, where the groundwater is not protected, and the surface thickness is up to two meters and in karstic areas, the annual amount of fertilizers and livestock are limited to:

1) Annual average amount of nitrogen from mineral fertilizers – 100 kg (nitrogen from manure - 170 kg) per hectare of arable land;
2) Keeping of animals up to 1.5 LSU per one hectare of arable land;
3) Use of sewage sludge.

Another important measure ensuring good water quality is the training of farmers and advisers on the regulations and appropriate implementation. For "environmentally friendly management" measure mandatory training is a precondition for receiving support. This training covers 4 subjects: [6]

- Soil and nutrients (soil and its qualities, soil sampling and the interpretation and analysis of results, nutrient assimilation, soil protection and preparation, reduction in the loss of nutrients, selection of suitable machinery, etc.; successive cropping and crop rotation, environmentally-friendly fertilization; manure management (how to reduce the loss of nutrients);

- Environmentally friendly plant protection (weeds, their prevention, and control; pests and diseases, their prevention and control);
- Environmentally friendly grassland management (establishing and re-seeding of grasslands, seed blends; fertilization; mowing; grazing);
- Biological and landscape diversity.

3. Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone

Estonia is located in the catchment area of the Baltic Sea, which is highly sensitive to nutrients. Estonian land area is 45339 km^2. Around half of the territory is covered with forests, 23% - with wetlands and natural grasslands. The water balance is positive, although there are only 10 rivers longer than 100 km and about 15 rivers with a catchment of more than 1000 km^2. Approximately half of Europe's 5^{th} biggest freshwater lake (Lake Peipsi) is located on Estonian territory. At different times, different pressures were affecting the water environment and water sector. The main stressors on water resources have been pollution from the agricultural sector and chemical industries, high water consumption in energy production for cooling purposes, as well as pollution from municipal wastewater treatment plants. [4]

3.1. General Overview

Pandivere and Adavere-Põltsamaa NVZ was established in Estonia in 2003 by the adoption of the Order of the Protection rules of the Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone by the Estonian Government regulation. The regulation defines unprotected groundwater areas as areas with less than 2 m ground cover on the limestone plateau and establishes the extent of restrictions around springs and karst funnels. An area, where agricultural activities have caused or may cause the concentration of nitrate ions in groundwater to exceed 50 mg/l or where surface water bodies are eutrophic or in danger of becoming eutrophic, due to agricultural activities, is deemed to be a nitrate vulnerable zone. The objective of the NVZ is to protect ground and surface waters from intense agricultural production. [9]

The Estonian NVZ (Figure 3) can be geographically viewed as two separate regions, Pandivere zone (2382 km^2) and Põltsamaa-Adavere zone (667 km^2), which are connected by the Endla wetland area (201 km^2). The total area of 3250 km^2 forms 7.19% of Estonian land territory. Pandivere is an important groundwater area for the whole of Estonia. The plain of central Estonia is a local groundwater area and a transit and outlet area. But due to the karst phenomenon, the groundwater is poorly protected and thus vulnerable to pollution. [6]

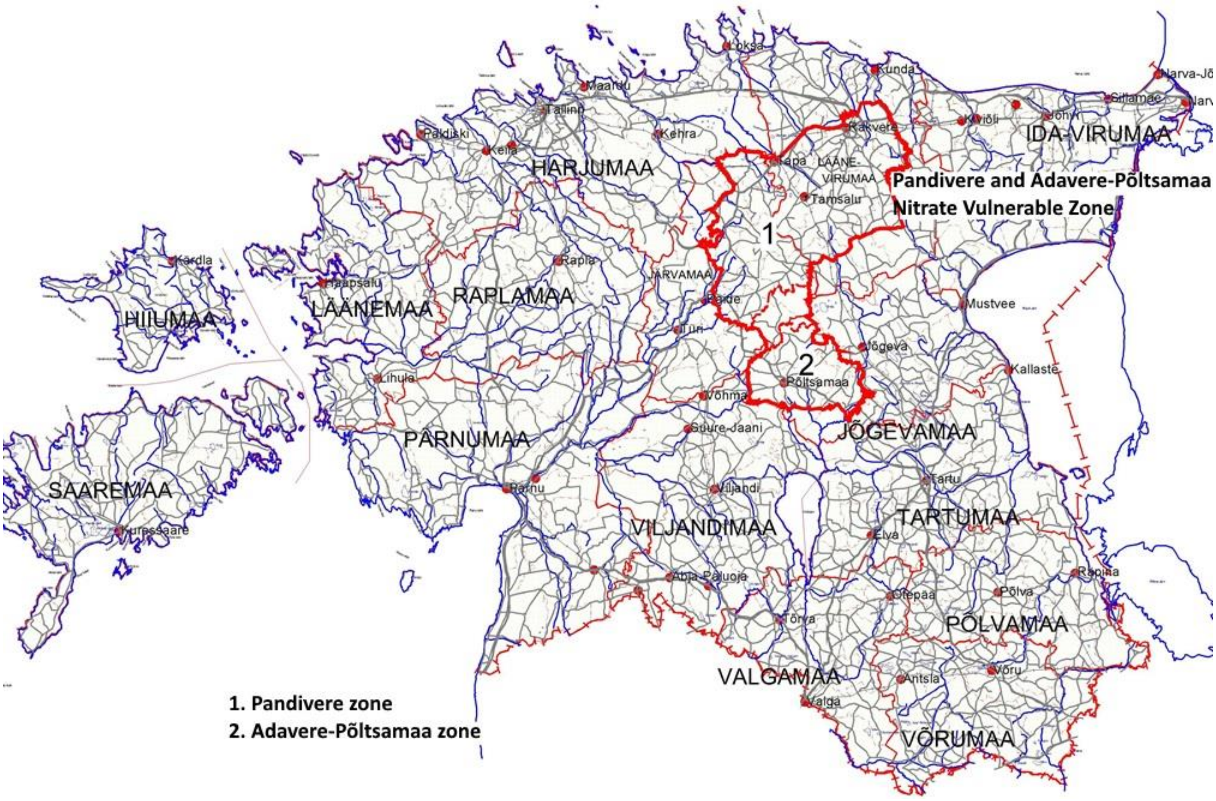


Figure 3. Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone
(Source: Sall, M., Peterson, K., Kuldna, P. 2012)

3.2. Natural Conditions

Pandivere and Adavere-Põltsamaa area needs protection because of its unique landscape and hydro-geological conditions. According to landscape, the NVZ area can be divided into two: Pandivere Upland and Adavere-Põltsamaa plain. For the whole of Estonia, Pandivere is an important groundwater infiltration area whereas the plain of Central Estonia is a transit and outlet area: [9]

a) **Pandivere Upland** – the highest area of Northern Estonia is also the largest groundwater accumulation area in Estonia. Overall watersheds of rivers, originated from the Pandivere area, cover 32% of Estonian territory. In comparison with the surrounding area, an abundance of precipitation, 714 karst funnels, and 135 springs form a great resource for rivers. Groundwater discharges as springs on the slopes of the upland forming a great source for river flow. These springs are a starting point for a series of large rivers in Estonia: Pärnu, Põltsamaa, Pedja, Jägala, Loobu, Kunda, Valgejõgi etc. Because of the karstification, few lakes are located in the Pandivere area, Porkuni and Äntu Sinijärv are the two most known.

Less than 2 m ground cover of limestone plateau leaves groundwater scarcely protected. Groundwater depth is usually between 4–5 and 20 meters. Unprotected groundwater area forms 19% (447.5 km^2) of Pandivere Upland territory). [9]

b) **Adavere-Põltsamaa area** has relatively thin soil cover on the limestone bedrock plateau of Central Estonia, mostly a local groundwater infiltration area, but important transit and outlet area of rivers. Ground moraine cover thickness is mainly 2-5 meters, but partly thinner than 1 meter. Because of its landscape, Adavere-Põltsamaa plain as a water outlet area is often more severely polluted by nutrients than Pandivere. Groundwater usually lies between 2–5 meters from the ground, thus unprotected groundwater area forms 18 % (119.7 km^2) of the Adavere-Põltsamaa territory. [9]

The Nitrate Vulnerable Zone water supply relies on the Silur-Ordovician water body, which consists of limestone and dolomites, strongly fractured and karstified to the extent of 30 meters. [9]

Figures 4 and 5 represent groundwater protection status within Pandivere and Adavere-Põltsamaa NVZ, springs and karst areas as well as monitoring points locations.

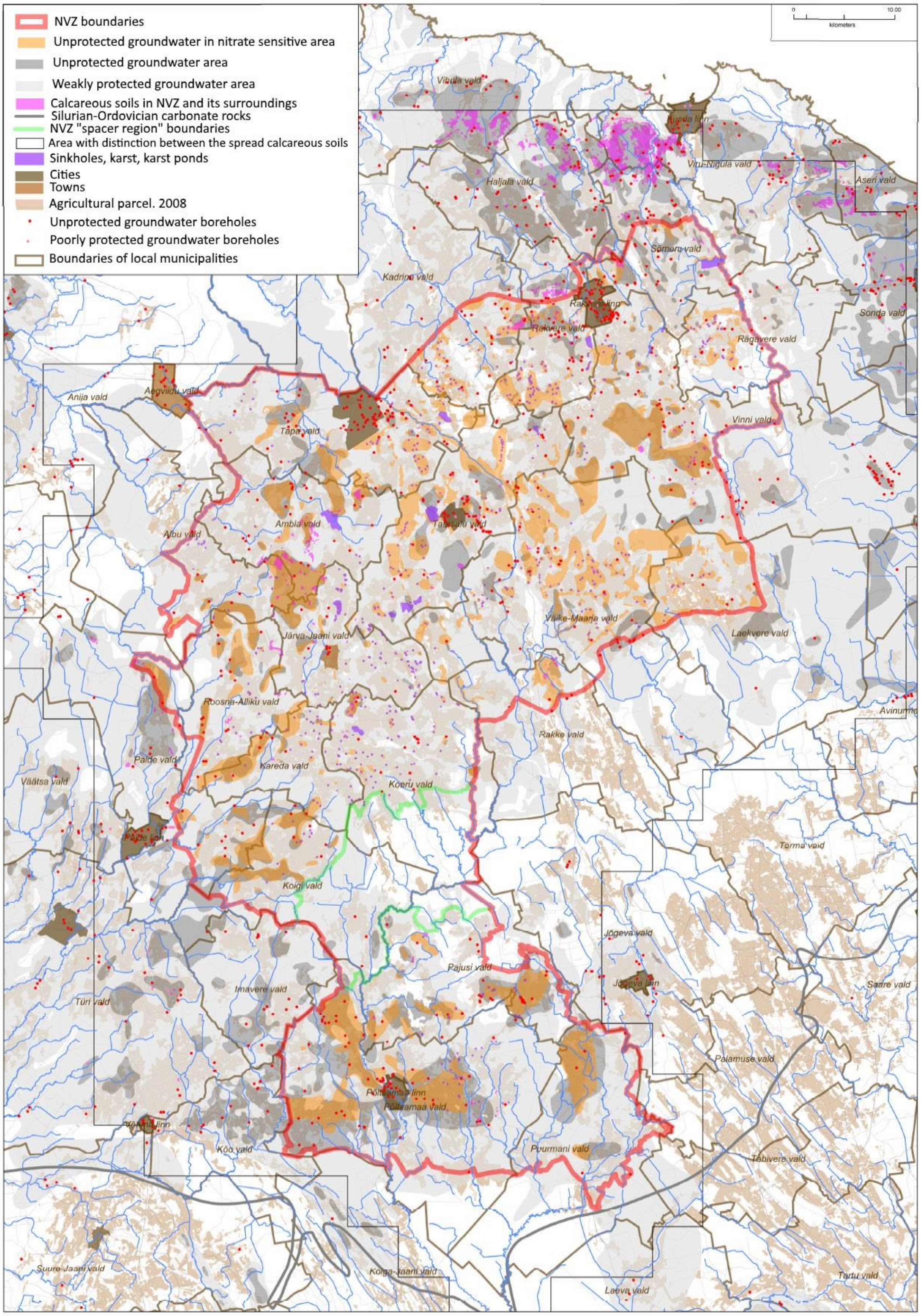


Figure 4. Unprotected and poorly protected groundwater areas in NVZ and its vicinity (AS Maves) (Source: Nitraaditundliku ala 2011 aasta uuringu .., 2015)

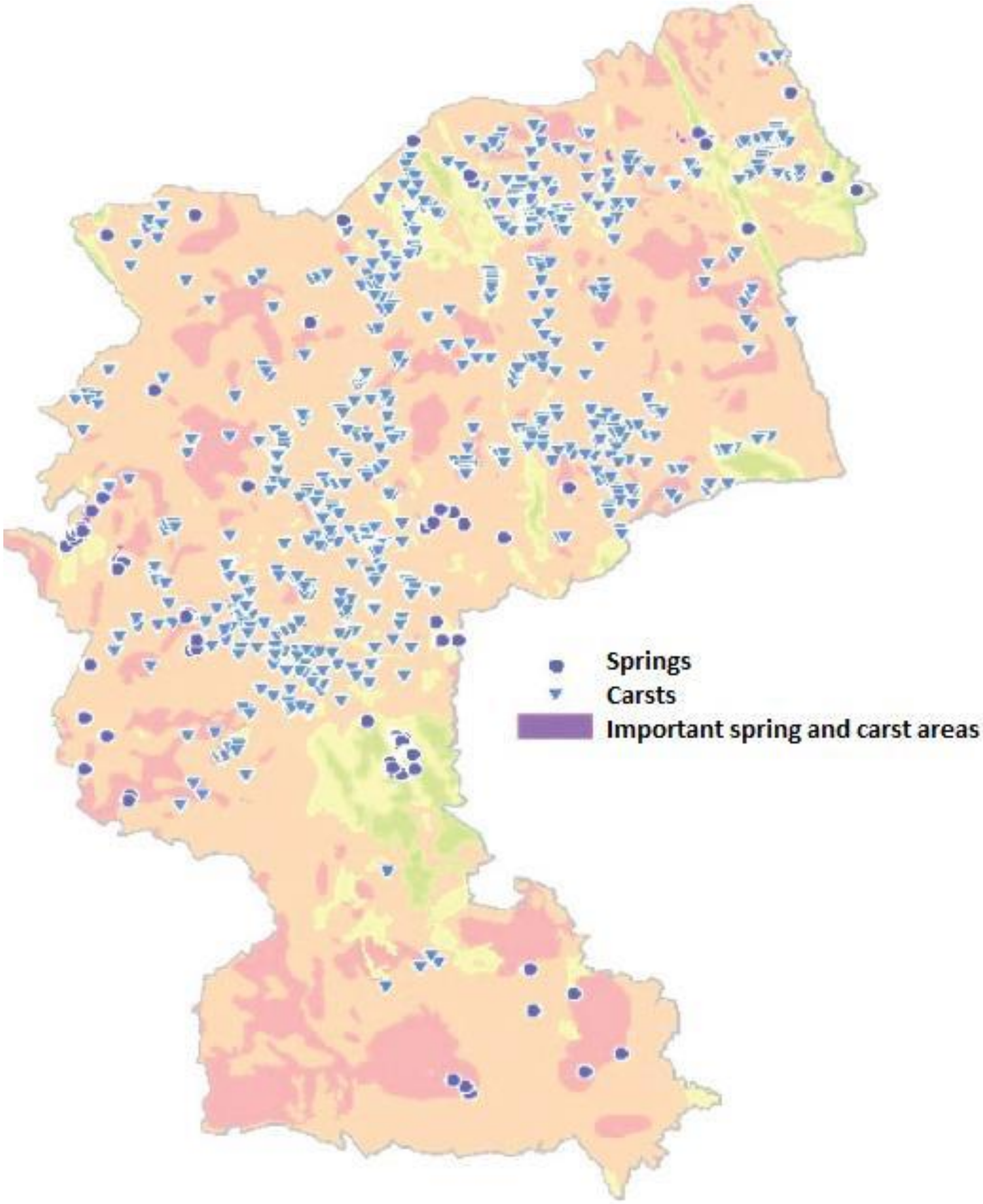


Figure 5. Pandivere and Adavere-Põltsamaa NVZ springs and karst areas
(Source: Industrial Animal Farming in Estonia. 2012)

The description of NATURA 2000 protection sites of the NVZ is represented in Table 1. 17 rivers and 4 streams, that lie entirely or partly in the NVZ area, are confirmed as significant habitat and spawn area for salmon. Endla-, Sirtsi-, Alam-Pedja- and Kõrvemaa NATURA bird sites cover 1.7% of the NVZ area and NATURA Habitat sites cover 4.2% of the NVZ. [9]

Table 1. Natura 2000 protected sites on NVZ
(Source: Sall, M., Peterson, K., Kuldna, P. 2012)

	Area on NVZ (ha)	The total area of rivers on NVZ (ha)	The total area of lakes on NVZ (ha)	The total area of arable land on NVZ (ha)
Natura Habitat sites (38)	13579.39	69.2	104.49	935.66
Natura Bird sites (4)	5644.89	43.17	1.62	95.32
Salmon rivers and streams (21)				

3.3. Nitrate content in surface and groundwater bodies within NVZ

Due to high vulnerability of Pandivere and Adavere-Põltsamaa regions and at the same time the high concentration of agricultural activities, it is under special and continuous attention by the authorities. Lots of surface and groundwater monitoring points are located throughout the whole area.

Groundwater monitoring of NVZ is divided into: 1) Main monitoring, carried out four times a year (including regular monitoring in 55 monitoring points, 16 springs, 2 karstic forms and 18 wells in Pandivere region, 4 springs and 15 wells in Adavere-Põltsamaa region); and 2) supporting monitoring, carried out once per year (58 sampling stations, 5 springs and 33 wells in Pandivere region, 20 wells in Adavere region). [7]

The number of groundwater monitoring sites in NVZ is: [16]

- Previous reporting period (2008-2011) – 282;
- New reporting period (2012-2015) – 115;
- Common sites for two periods – 108.

Comparison of nitrate content trends within groundwater sampling sites between 2008-2011 and 2012-2015 reporting periods are provided in Table 2 below.

Table 2. Trends in nitrates content in groundwater sampling sites in 2012-2015 compared to the previous reporting period (2008-2011) (percentage of monitoring stations) (source: Nõukogu direktiivi 91/676/EMÜ. 2016)

Change	Location	Based on maximum concentrations, 2008-2011	Based on annual average, 2008-2011
Increase			
Strong (>5 mg NO_3/l)	Pandivere	39	20
	Adavere	44	39
	Throughout NVZ	41	26
Little (1-5 mg NO_3/l)	Pandivere	18	22
	Adavere	13	11
	Throughout NVZ	17	19
Stable (±1 mg NO_3/l)	Pandivere	7	18
	Adavere	22	22
	Throughout NVZ	11	19
Decrease			
Strong (>5 mg NO_3/l)	Pandivere	15	8
	Adavere	8	14
	Throughout NVZ	13	10
Little (1-5 mg NO_3/l)	Pandivere	21	32
	Adavere	13	14
	Throughout NVZ	18	26

Considering longer period, nitrate contents dynamic changes for the Pandivere region in represented in Figure 6. As it was mentioned in previous chapters, after collapsing of the Soviet Union and the start of the first phase of water sector reforms in Estonia, nitrate concentrations first dropped after 1990, then maintained in more or less the same level during 90's and early 2000's. 2007-2008 years are another peak period, which follows with a sharp decrease (2009-2010) and a constant increase trend in last years.

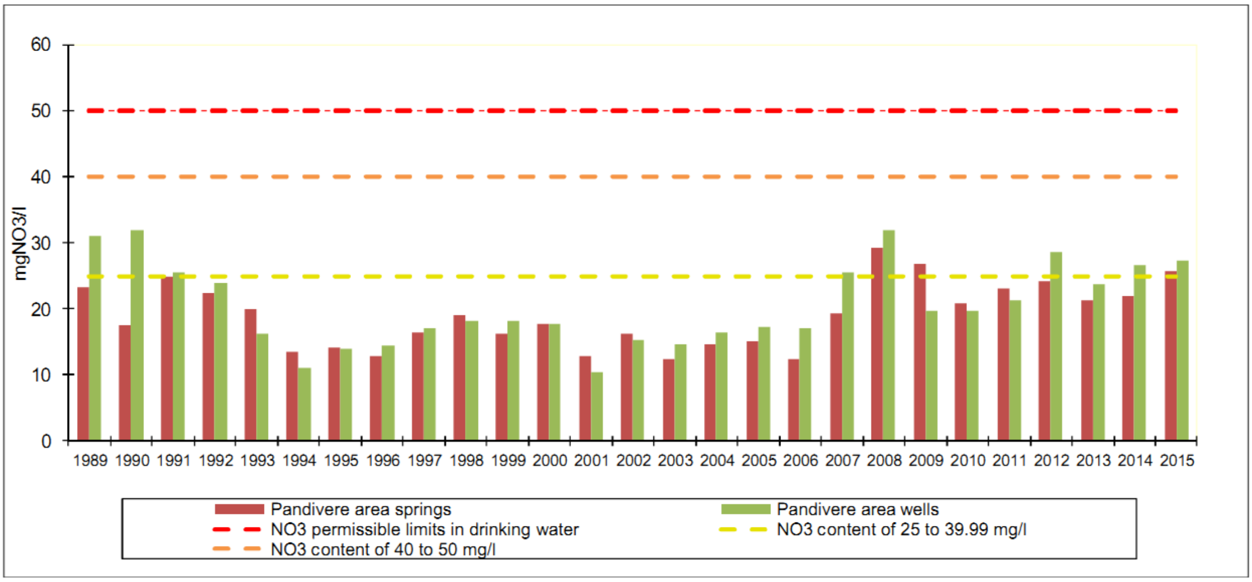


Figure 6. The dynamics of nitrate contents in groundwater for Pandivere region in 1989-2015 period (source: Nõukogu direktiivi 91/676/EMÜ. 2016)

In 2014, 25.7% of wells in the Adavere region had average nitrate content (average value of four samples) above 50 mg/l and in 39.5% wells - only one out of four samples exceeded that limit. A number of wells, with such nitrate content samples, has increased in the past years. In the Pandivere region, 50 mg/l limit was exceeded by 2% and 18% of existing wells (with average and single samples respectively). At the same time, no nitrate content in monitoring springs was above that limit value. [7]

The number of monitoring points in 40-50 mg/l nitrate content range has increased throughout the NVZ - 8 monitoring points in 2011 and 19 monitoring points in 2014. Compared to the previous reporting period, the NO_3 content has decreased in 35.35% of all NVZ monitoring points, including in 36.6% points in Pandivere and 33.3% points in the Adavere region, but increased in 50%, 51% and 49% of points respectively. [7]

Speaking of surface water, there are 51 river water bodies in NVZ, and based on date of 2011 the majority of them (53%) have a good status, however, 45% of them have either a moderate or poor status (Figure 7). There are no river bodies that are classed as bad status, yet only one of them (Kaave river body) has a high status. On the other side, 472 km of rivers are in moderate condition, that is 43% of the total length of river bodies in the NVZ (Figure 8). [9]

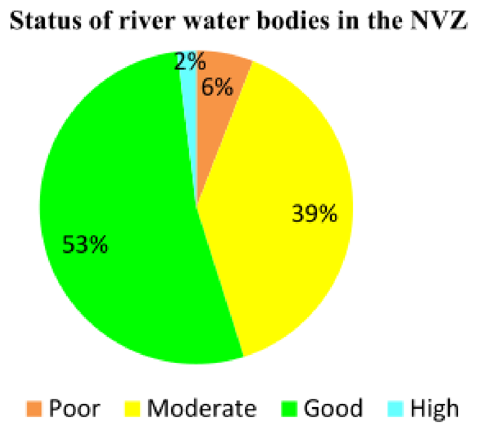


Figure 7. The allocation of river bodies according to the status class by 2011
(Source: Sall, M., Peterson, K., Kuldna, P. 2012)

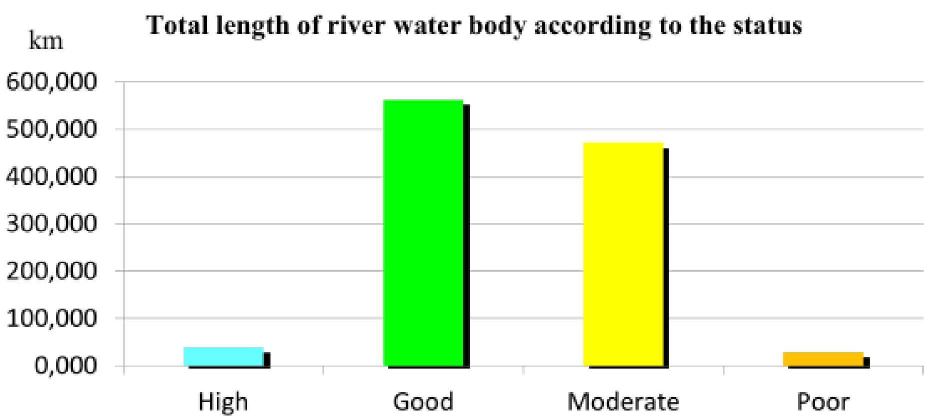


Figure 8. The total length of river bodies according to the status class by 2011
(Source: Sall, M., Peterson, K., Kuldna, P. 2012)

Surface water bodies - 4 rivers within NZV area, during the 1992-2013 period, have the following trends: nitrate contents increased in Pedja and Preedi rivers (by 0.006 and 0.345 units respectively) and decreased in Kunda and Valgejõgi rivers (by 0.001 and 0.424 units respectively). However, from all of them only Pedja and Kunda rivers have statistically significant trends: first one - increasing, and second - decreasing. [14]

Nitrate contents data from more rivers in NVZ can be seen in Figure 9 below. Most of them have increasing trends.

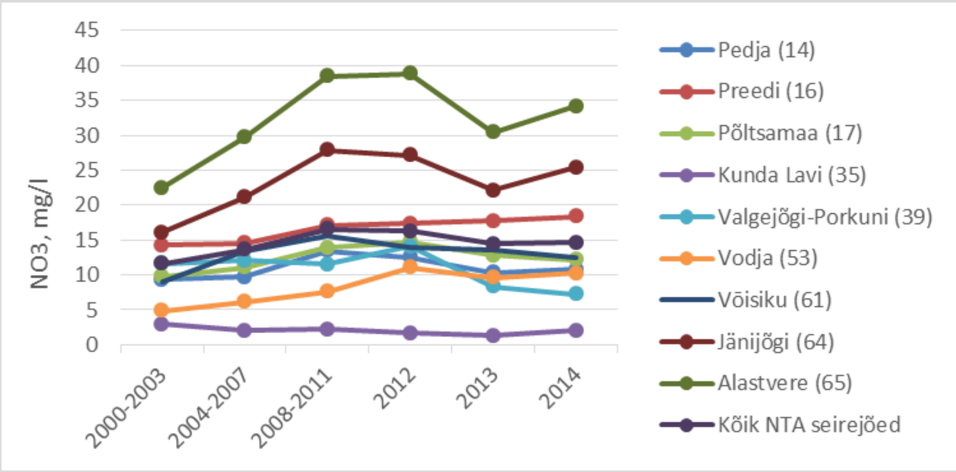


Figure 9. Mean nitrate contents in rivers within NVZ during different periods between 2000-2014 (Source: Nitraaditundliku ala 2011 aasta uuringu .., 2015)

3.4. Socio-economic conditions

Agriculture was the sector of the economy, which undergone significant changes during Estonia's transition period. Despite the decreased share of agriculture in the Estonian economy, it kept a key role in supplying the rural population with food, in the rural enterprise, and in shaping the cultural landscape. In 1997 value added production per person engaged in agriculture was about 27% lower than in the overall economy, while in 2005 this percentage changed to 54%. The competitiveness of Estonian agriculture has been low from the beginning of the 1990's, when there were no opportunities for the necessary investments. Thus, 50% of the fixed assets used by agricultural producers have overextended their service life. [6]

However, the joining of Estonia to the EU in 2004 has brought about substantial changes to the economy, including agriculture. The subsidies and payments under the RDP (Rural Development Plan) have promoted the modernization of infrastructure and farming techniques and the development of the rural economy. [6]

Agricultural impacts on the environment have changed over the decades. In the 1970's and 1980's the lakes in Estonia were strongly affected by fertilizers and farm sewage waters, which caused rapid eutrophication of water bodies. Starting from the 1990's, after the collapse of the collective farming system and the decline in agricultural production, the state of lakes (especially smaller ones) started to improve [6]. The eutrophication rate became slower and the nitrogen content in the water of lakes decreased. Due to the improvement of the economic situation and the subsidies of the Rural Development Plan (RDP), it is expected that the use of fertilizers and plant protection products will rise, but will still stay considerably lower than the EU average. [6]

Besides its unique landscape, the NVZ is located on the best agricultural soils in Estonia, with the largest fields suitable for cereal production (Figure 10). When an average soil fertility rating (arable lands) in Estonia is 40 points, then in the NVZ there are three municipalities, where the rating exceeds 50 points, and even the lowest municipal average rating (42.5) is clearly above the country average. The need for drainage is minimal, and the average size of the field is the largest in Estonia. Therefore, agriculture forms an important part of the economic sector in the NVZ. [9]

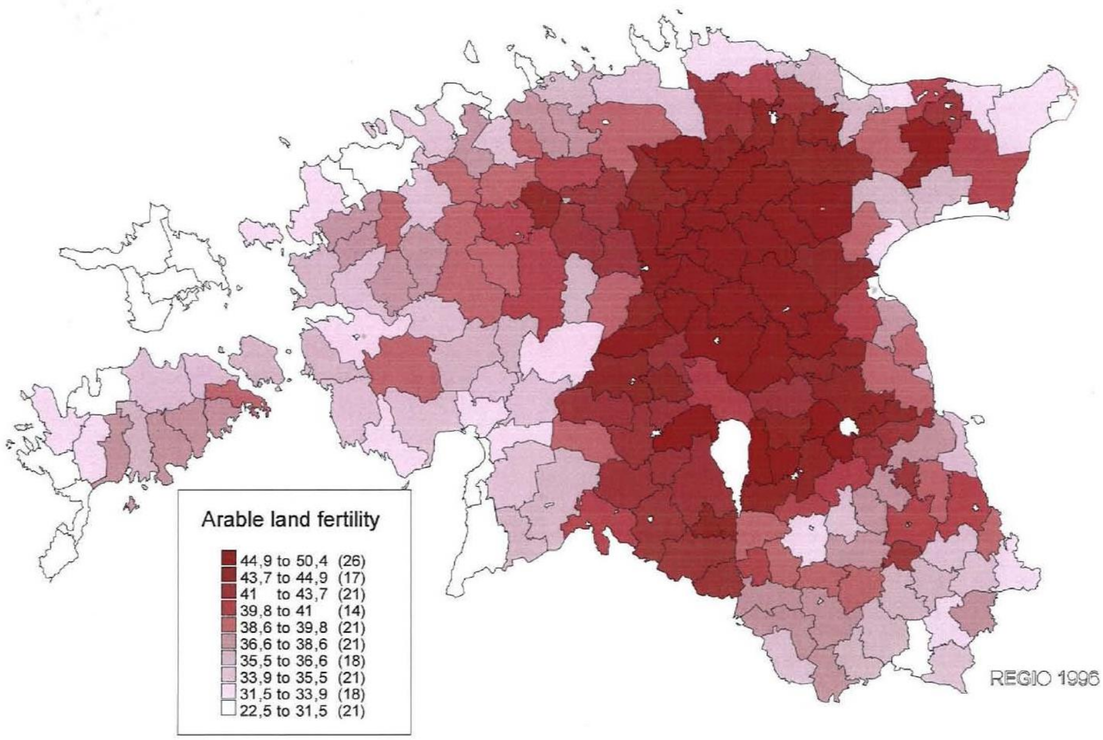


Figure 10. Map of arable land fertilities in Estonia
(Source: Industrial Animal Farming in Estonia. 2012)

The share of agricultural land is about one third, which considerably exceeds the Estonian average of one-fifth. The total agricultural land, which has received support under the Single Area Payment Scheme (SAPS) in 2010 in the NVZ was 128.5 thousand hectares (ha), which forms 39% of the NVZ area. The Estonian average, agricultural land under subsidies, was only 19%. The total NVZ agricultural land, which has received agricultural subsidies in 2011 was a bit smaller, 127563 ha (Table 3). [9]

Table 3. Agricultural land in Panidvere and Adavere--Põltsamaa NVZ (Source: Sall, M., Peterson, K., Kuldna, P. 2012)

NVZ	Crop (ha)	Permanent pasture (ha)	Natural grassland (ha)	Black fallow (ha)	Permanent crop (ha)
2011*	105754	18328	2170	1174	137

* - based on the data of Agriculture Registers and Information Board (PRIA)

Figures that best describe the agricultural production and land use in Pandivere and Adavere-Põltsamaa NVZ are reflected in Table 3 and Table 4. Corine land cover (2006) illustration about the NVZ is reflected in Figure 11. It must be noted, that according to Agricultural Registers and the Information Board (PRIA), agricultural land consists of the crop, permanent pasture, natural grassland, black fallow and permanent crop (basically arable land and pastures). According to Corine land cover (2006), agricultural land consists of non-irrigated arable land, fruit trees and berry plantations, pastures, complex cultivation patterns, land principally occupied by agriculture, with significant areas of natural vegetation. Natural grasslands are not considered as agricultural lands under this classification scheme. [9]

Table 4. Agricultural land in Pandivere and Adavere-Põltsamaa NVZ according to Corine land cover (2006) (Source: Sall, M., Peterson, K., Kuldna, P. 2012)

Non-irrigated arable land (ha)	97902
Fruit trees and berry plantations (ha)	141
Pastures (ha)	27780
Complex cultivation patterns (ha)	21964
Land principally occupied by agriculture, with significant areas of natural vegetation (ha)	17923
TOTAL (ha)	165709
Natural grasslands (ha)	935

Considering fertile soils of the area in one hand, and unique geological construction, which leaves groundwater unprotected, on the other hand, it is evident, that Pandivere and Adavere-Põltsamaa area needs protection. The conflict of issues between food production and water protection is relatively sharp and thus needs to be addressed with appropriate measures to reduce the sources of agricultural diffuse pollution in a manner that does not undermine yield size. [9]

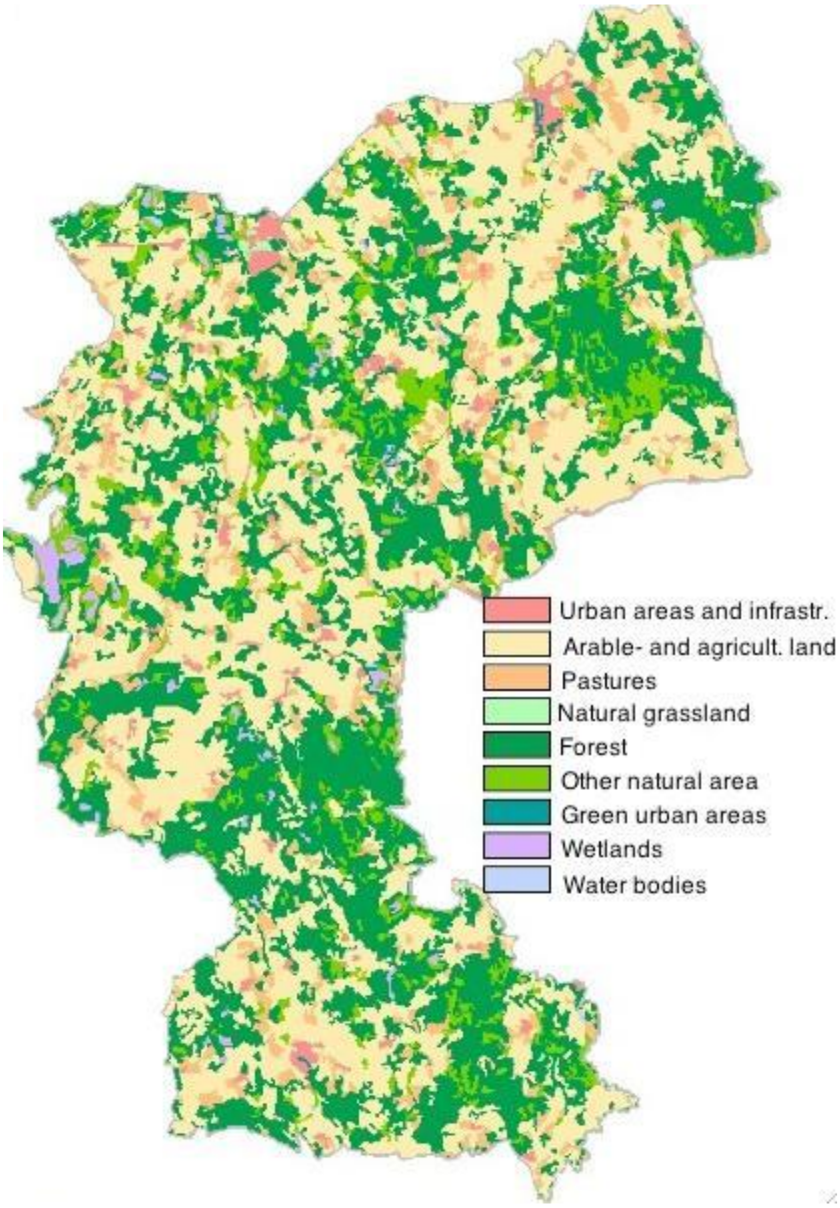


Figure 11. Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone land cover (Source: Sall, M., Peterson, K., Kuldna, P. 2012)

Speaking about agricultural activities in Estonia, they have a significant impact on environmental state and in particular, on nitrate pollutions. So, currently, fertilizer usage is restricted around spring and karst holes in zones with 10 m diameter (GO No 17 from 21 Jan 2003).

Areas under cereal production for 2003-2014 years period (Figure 12, Annex - Table 6) shows that it has an increasing trend, with the exception of 2008-2010 period, when grow rate first lowered and then dropped by 13% (which seems to be a result of 2008 economic crisis). [10]

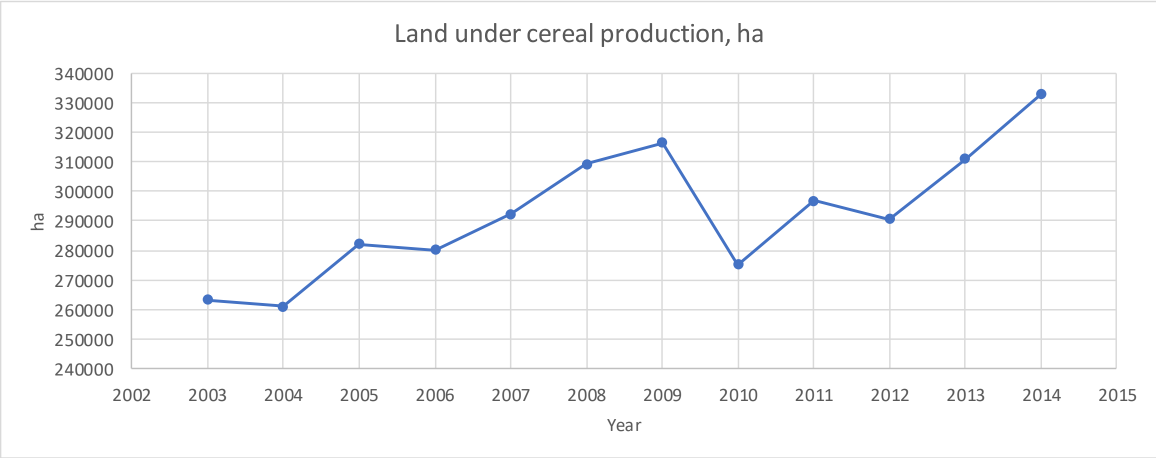


Figure 12. Land under cereal production (hectares) 2003-2014
(based on data from: Knoema. World Data Atlass, Estonia)

A similar picture is observed for fertilizer consumption during the same period of time (Figure 13, Annex - Table 6) – at first, usage increased and peaked in 2008 after economic crisis dropped by 31% and continued to grow from 2010. [11]

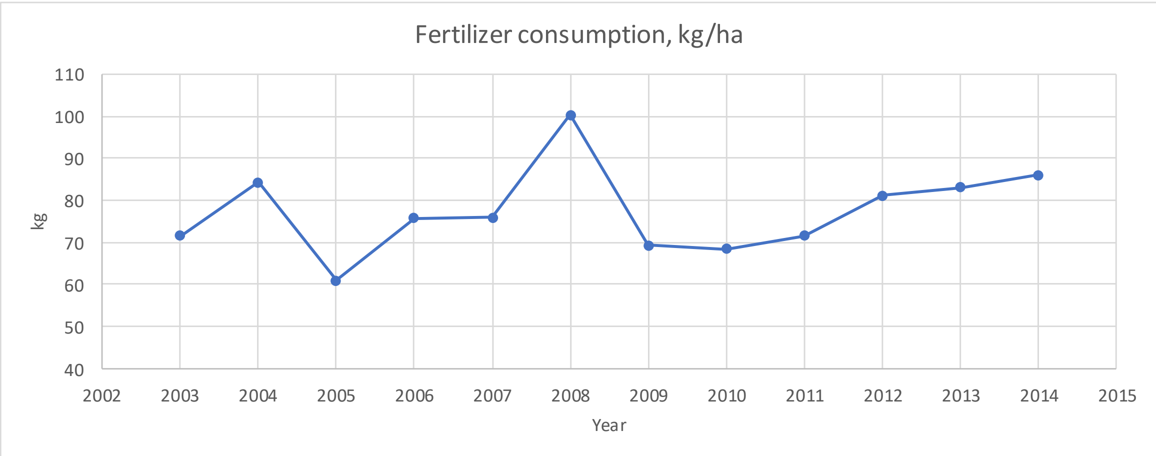


Figure 13. Fertilizer consumption (kilograms per hectare of arable land) 2003-2014
(based on data from: Knoema. World Data Atlass, Estonia)

Above mentioned results are in correlation with nitrogen input and output, which is the target indicator for current study – it has constant growth trend, interrupted only in 2008 (Figure 14). [12]

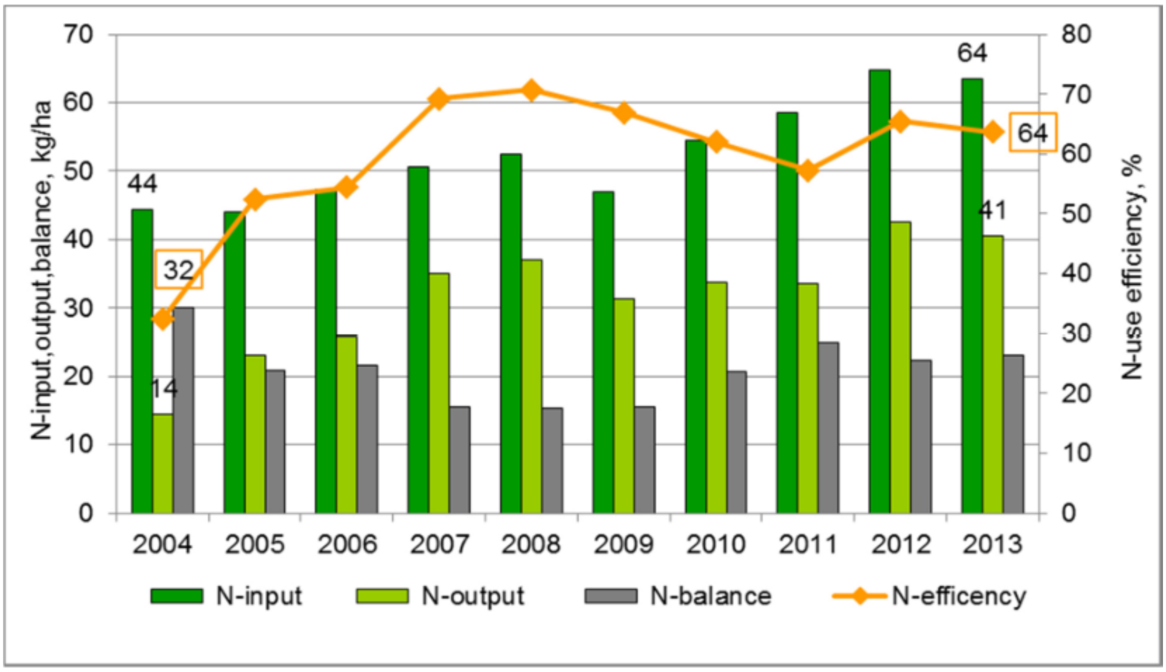


Figure 14. Farm gate nitrogen balance, input, output, and efficiency in the period 2004-2013 by Estonian Agricultural Research Centre

(Source: Status of nutrient accounting and bookkeeping in Estonia. 2015)

4. Monitoring results of NVZ groundwater samples for 2001-2016 period

4.1. Methodology and selection criteria

For analyzing changes in nitrate content throughout Pandivere and Adavere-Põltsamaa Nitrate Vulnerable Zone, representative groundwater monitoring points were selected and numerical data obtained from Estonian National Environmental Monitoring Program database (Nitraaditundliku ala põhjavee seire. http://seire.keskkonnainfo.ee). [13]

Monitoring data in most cases consists of 4 measurements per year per monitoring point. Obtained values were grouped by years and chronologically provided in separate tables for each monitoring point. Additional tables for Annual average nitrate content were also created based on real data (see Annex, Tables 7-17).

These tables were used to create scatter charts for both raw and annual average nitrate content per monitoring point. Furthermore, exponential trendline was added to each chart, in order to show general trends in nitrate concentration change.

Selection criteria for monitoring points were based on 4 general statements:

1. Various locations, to cover as much NVZ area as possible;
2. Continuous monitoring data during target period of 15 years (2001-2016);
3. Nitrate content of >10 mg/l (in order to make changes detection easier); and
4. Different well depths (<5, 5-15, 15-30, >30 m) plus karst springs.

The main criteria was continuous monitoring data existence within the target period. Because of many monitoring points have changed, only limited number of such “long-time” monitoring points were available (it was especially complicated for Adavere-Põltsamaa region, where changing of monitoring sites have been typical to occur). The second was nitrate content - more than 10 mg/l, which was selected because it is easier to track nitrate changes and exclude natural fluctuations. Different well depths were also important to compare nitrate changes between karst springs and various deep wells and make a conclusion about the correlation of depth and pollution trends. And finally, monitoring points were selected in order to cover more or less all NVZ to be able speaking about a general trend within the whole area.

4.2. Selected monitoring points

Based on abovementioned criteria, 20 different monitoring points were selected: 2 karst springs and 18 wells. Their locations within NVZ area are represented in Figure 15 below.

Figure 15. Schematic locations of selected monitoring points

They were divided into 5 separate groups, based on their depths (see Table 5): Group I - 2 karst springs (depth 0 m); Group II - 8 wells (depth <5 m); Group III - 4 wells (depth 5-15 m); Group IV - 3 wells (depth 15-30 m); Group V - 3 wells (depth >30 m).

Monitoring data from 13 points are available for whole target period. Other 7 wells are missing several years data, however, were selected regardless, since they are best representatives in their groups (1 well from Group II, all 4 wells from Group III and 2 wells from Group V). 3 wells from Group II are missing raw data of 2003-2005 years, but Annual averages are available.

Table. 5. Selected monitoring points, including their depths, station IDs, KKR codes, location, and coordinates. (Data source: Nitraaditundliku ala põhjavee seire)

Depth, m	**Station ID**	**Monitoring Point Code KKR**	**Location**	**Coordinates**	
				X	**Y**
0 m	SJA9099000	PAKarst-25	Muru karst	6585196	644931
0 m	SJA7345000	PAKarst-32	Saueaugu karst	6576785	636304
<5 m	SJA8397000	AA1003	Järva-Jaani allikas	6545915	607805
<5 m	SJA9787000	PAA15 (A-1005)	Aravete allikas	6558020	600201
<5 m	SJA8334000, SJA5970000	PAA22 (A-1007)	Roosna-Alliku allikas	6543917	597915
<5 m	SJA5718000	PAA1009	Kiigumõisa Külmaallikas	6546619	594883
<5 m	SJA6327000	PAA1013	Valgma allikas	6526878	594980
<5 m	SJA6562000, SJA3851000	PAA19 (A-11)	Kiltsi allikas	6550877	625757
<5 m	SJA9896000	PAA14	Tõrma allikas	6577205	632162
<5 m	SJA4579000	PAA16	Rahkla allikas	6582757	647750
5-15 m	SJA1743000	AD1395	Kalme küla, Uue-Lipno talu	6507520	610800
5-15 m	SJA8442000	ADKK21	Kõrkküla, Kuusiku talu	6518581	615134
5-15 m	SJA8263000	AD14525	Tõrve küla, Mäe talu	6499138	637274
5-15 m	SJA6316000	AD93	Vitsjärve küla, Sääsemetsa talu	6503105	607809
15-30 m	SJA1170000	PAK-169 (K-169)	Karinu küla, Tammiku talu	6544594	612096
15-30 m	SJA5293000	PAK-17 (K-17)	Ammuta küla, Pihlaka talu	6539768	606238
15-30 m	SJA5316000	PAK-70	Vuti küla, Peegi talu	6539786	612141
>30 m	SJA5002000	PAPK-10 (PK-10)	Assamalla PK, elamu	6567366	629420
>30 m	SJA2763000	PAA31 (A-1011)	Prandi allikas	6524051	598483
>30 m	SJA7505000	PAK-5	Udeva küla, Väljaotsa talu	6534358	616126

4.3. Monitoring data analysis

Group I

Group I is represented with 2 karst springs: PAKarst-25 and PAKarst-32, located at Pandivere upland.

Available raw and annual average data is represented in Tables 7 and 8 (Annex).

PAKarst-25

Monitoring data for PAKarst-25 was available for whole 2001-2016 years period (Annex, Tables 7, 8). Average nitrate content for target period was 12.4 mg/l.

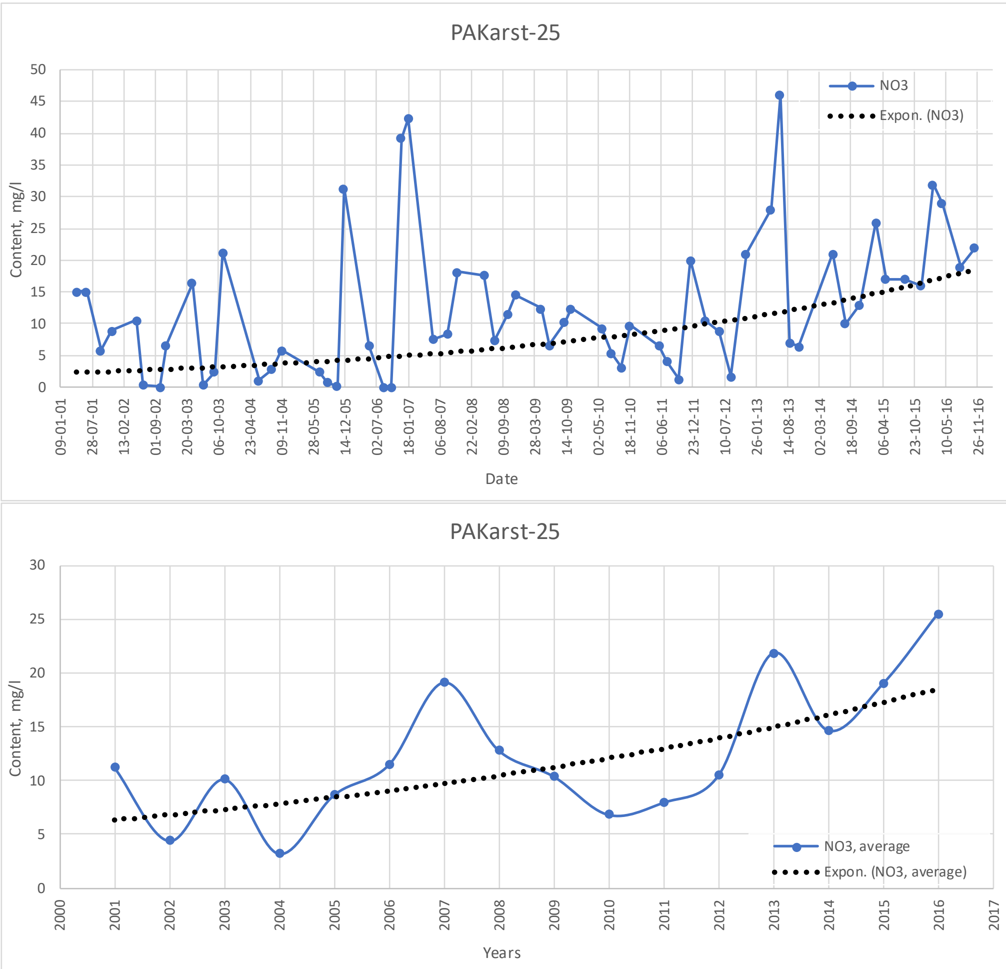


Figure 16. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 16) can be seen that nitrate content in PAKarst-25 groundwater has a tendency to increase over time during target period (raw data). In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008, 2013 and 2016. However general growth trend still remains – from 6 mg/l to 18 mg/l in average numbers, or from 11.2 to 25.5 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped to approximately initial levels by 2010 and then started increasing again.

PAKarst-32

Monitoring data for PAKarst-32 was available for whole 2001-2016 years period (Annex, Tables 7, 8). Average nitrate content for target period was 22.5 mg/l.

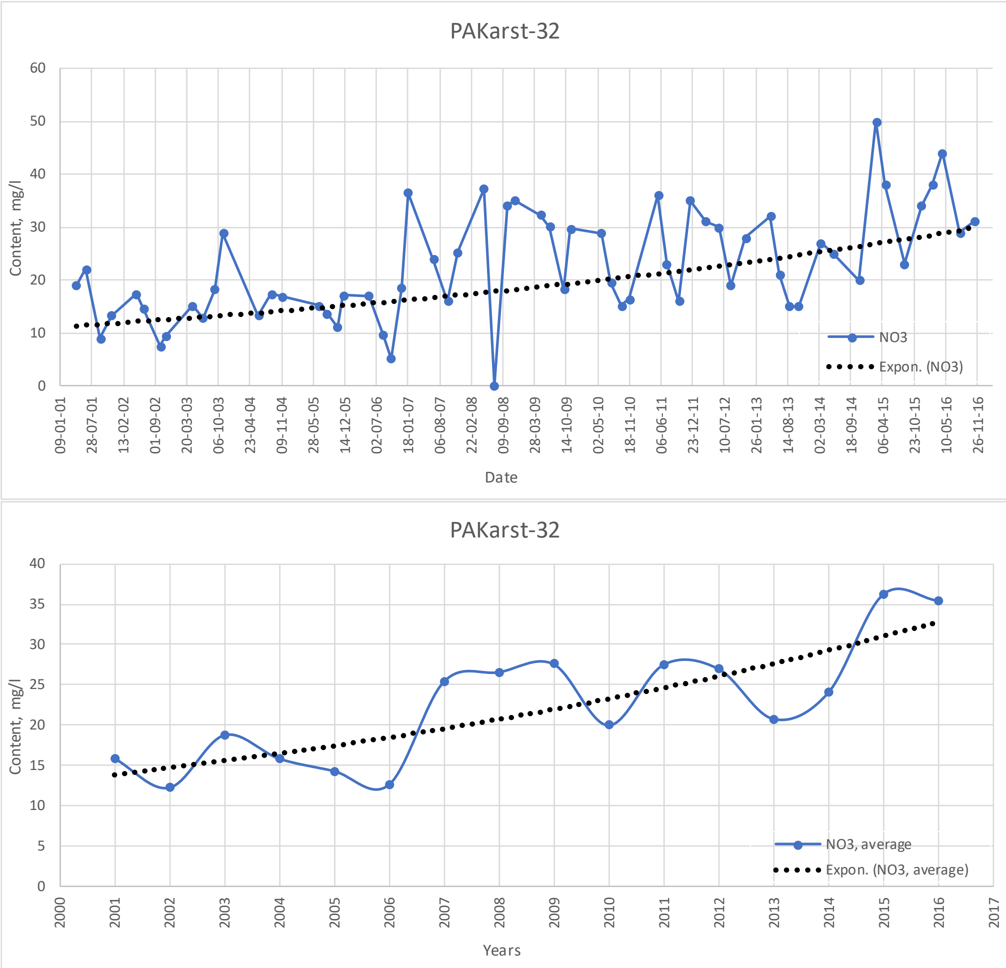


Figure 17. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 17) can be seen that nitrate content in PAKarst-32 groundwater has a tendency to increase over time during target period (raw data). In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2009, 2011 and 2015. However general growth trend still remains – from 14 mg/l to 33 mg/l in average numbers, or from 15.8 to 35.5 mg/l in real values.

Target period can be divided into 3 parts: 2001-2006, 2007-2014 and 2015-2016. First two parts are characterized by stable nitrate content with abrupt increase in between. After 2014, concentration peaked again significantly.

Group II

Group II is represented with 8 wells, with depths up to 5m: AA1003, PAA15 (A-1005), PAA22 (A-1007), PAA1009, PAA1013, PAA19 (A-11), PAA14 and PAA16, located at Pandivere upland.

Available raw and annual average data is represented in Tables 9, 10 and 11 (Annex).

AA1003

Monitoring data for AA1003 was available for whole 2001-2016 years period (Annex, Tables 9, 11). Average nitrate content for target period was 22.9 mg/l.

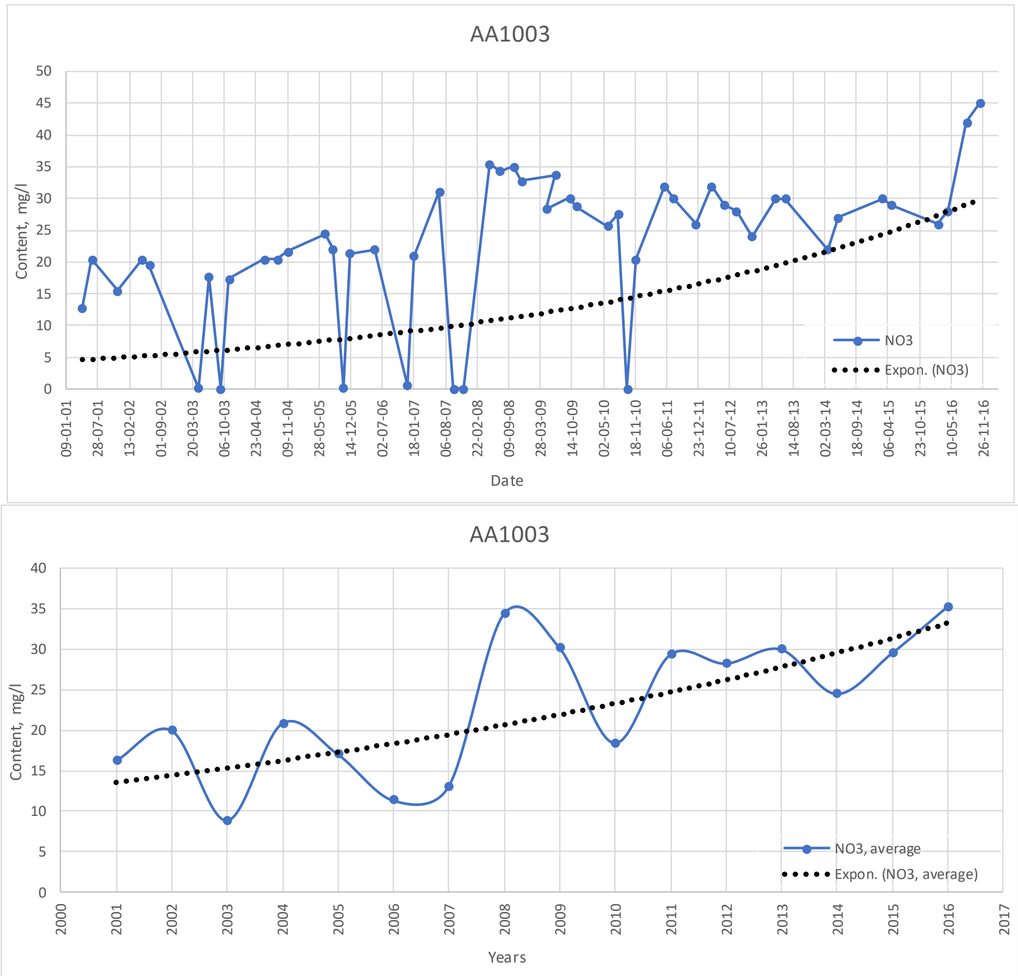


Figure 18. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 18) can be seen that nitrate content in AA1003 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 14 mg/l to 33 mg/l in average numbers, or from 16.2 to 35.3 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped to approximately initial levels by 2010 and then started increasing again.

PAA15 (A-1005)

Monitoring data for PAA15 (A-1005) was available for whole 2001-2016 years period, with the exception of 2003-2005 years, which is only represented by average values (Annex, Tables 9, 11). Average nitrate content for target period was 26.5 mg/l.

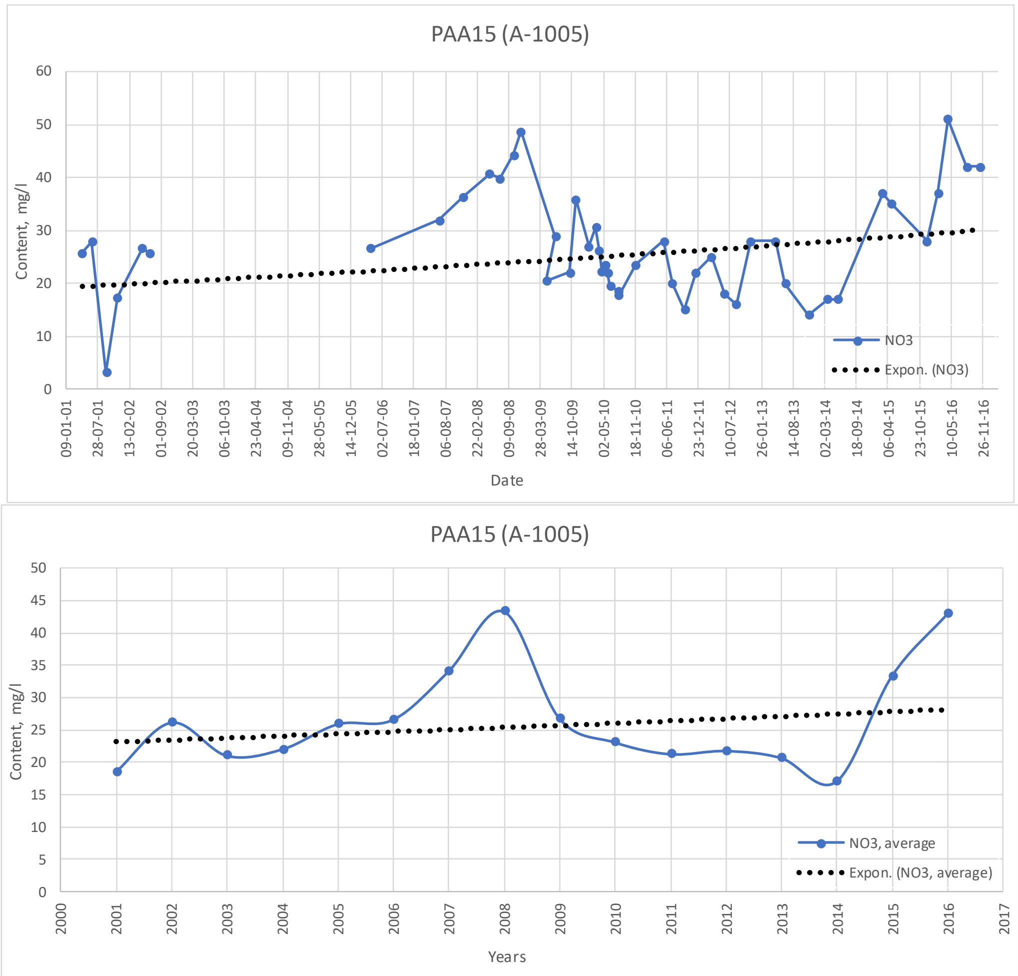


Figure 19. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 19) can be seen that nitrate content in PAA15 (A-1005) groundwater has a tendency to increase over time during the target period. However, there was no raw data included for 2003-2005 years. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 23 mg/l to 38 mg/l in average numbers, or from 18.5 to 43 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped to approximately initial levels by 2014 and then started increasing again.

PAA22 (A-1007)

Monitoring data for PAA22 (A-1007) was available for whole 2001-2016 years period, with the exception of 2003-2005 years, which is only represented by average values (Annex, Tables 9, 11). Average nitrate content for target period was 16.7 mg/l.

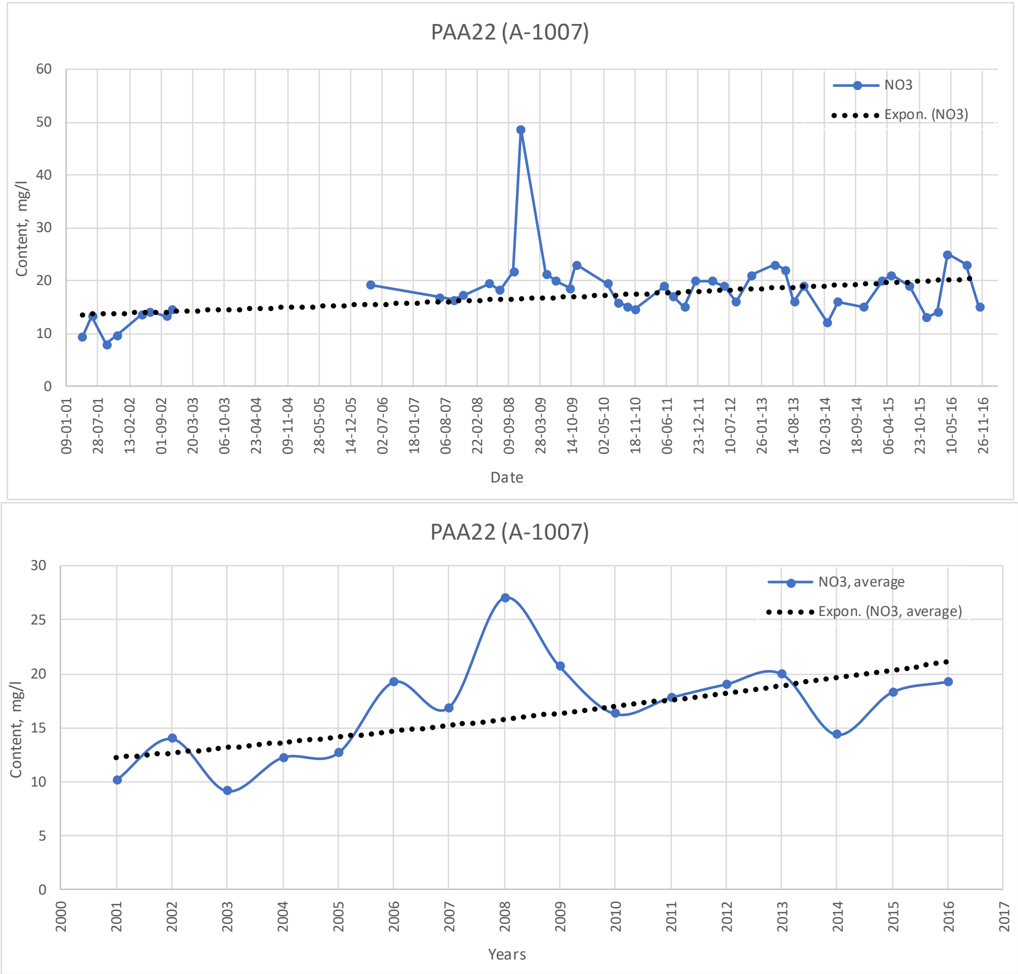


Figure 20. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 20) can be seen that nitrate content in PAA22 (A-1007) groundwater has a tendency to increase over time during the target period. However, there was no raw data included for 2003-2005 years. In order to obtain more reliable results, annual averages were calculated, and relevant chart created (including 2003-2005 years averages), where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008. However general growth trend still remains – from 12.5 mg/l to 22 mg/l in average numbers, or from 10.1 to 19.3 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped by 2010 and then started slightly increasing again.

PAA1009

Monitoring data for PAA1009 was available for whole 2001-2016 years period (Annex, Tables 9, 11). Average nitrate content for target period was 15.7 mg/l.

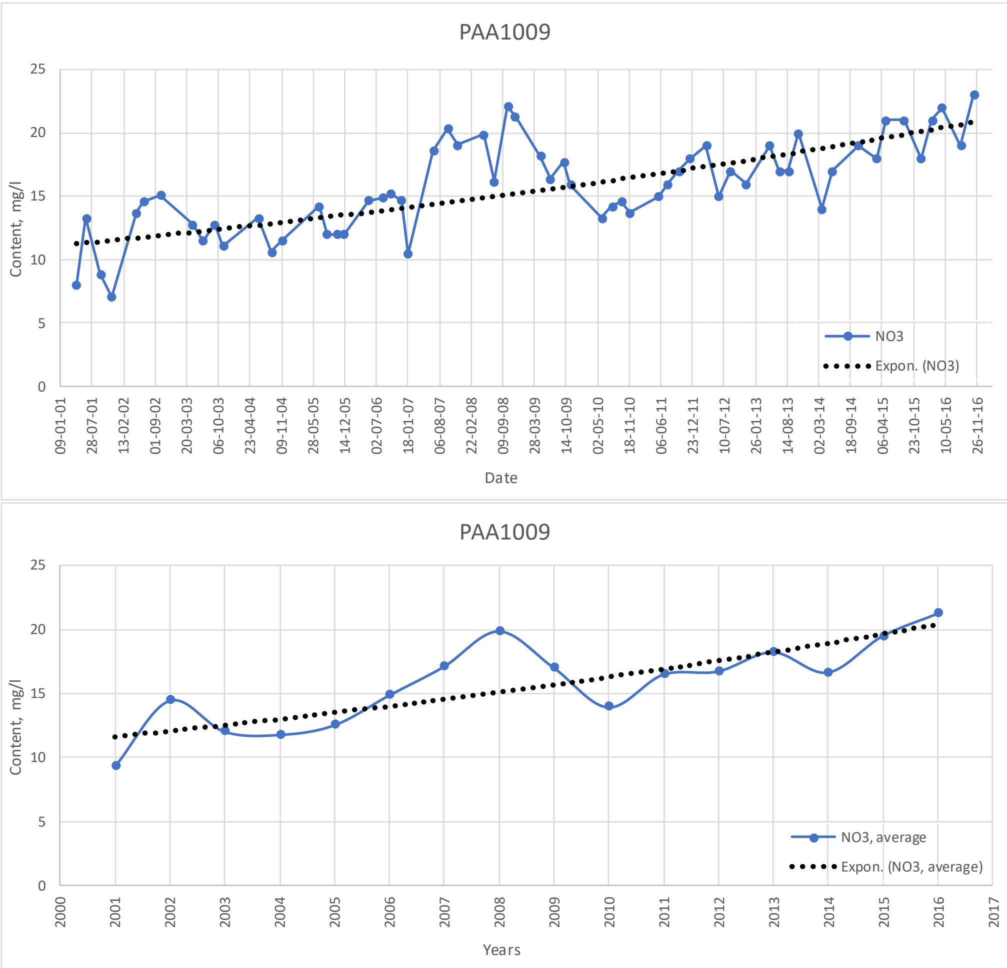


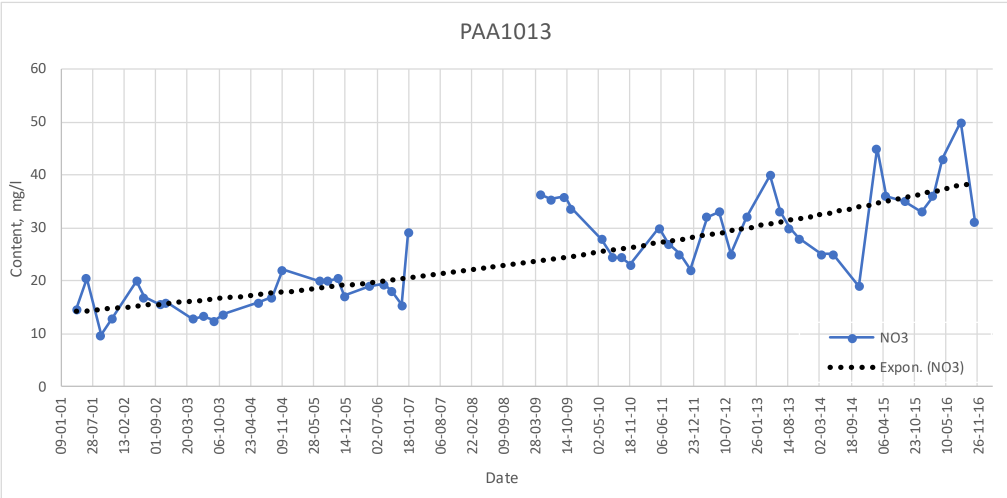
Figure 21. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 21) can be seen that nitrate content in PAA1009 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 12 mg/l to 20.5 mg/l in average numbers, or from 9.3 to 21.3 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped by 2010 and then started increasing again.

PAA1013

Monitoring data for PAA1013 was available for 2001-2007, 2009-2016 years period (Annex, Tables 10, 11). Average nitrate content for target period was 25.3 mg/l.



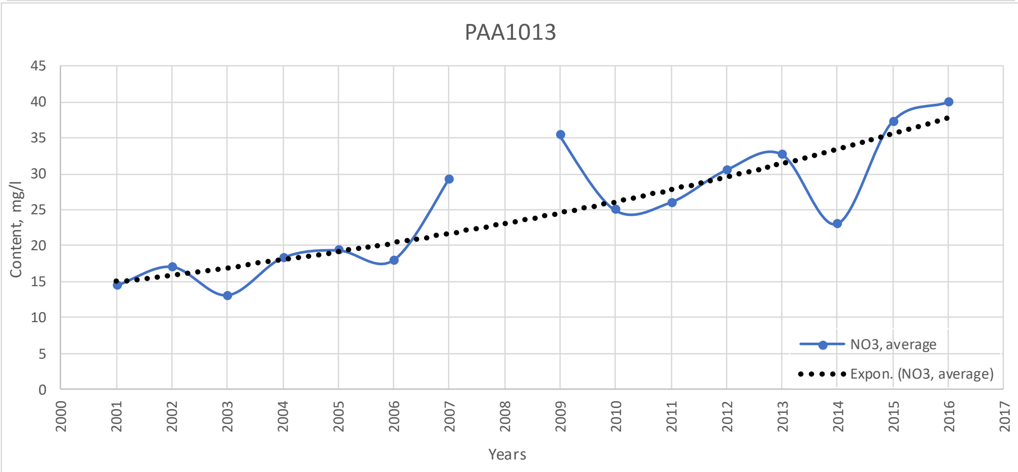


Figure 22. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 22) can be seen that nitrate content in PAA1013 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2009 and 2016. However general growth trend still remains – from 15 mg/l to 38 mg/l in average numbers, or from 14.4 to 40 mg/l in real values.

Target period can be divided into 2 parts: 2001-2009 and 2010-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2009. After this, its content dropped by 2010 and then started increasing again.

PAA19 (A-11)

Monitoring data for PAA19 (A-11) was available for whole 2001-2016 years period, with the exception of 2003-2005 years, which is only represented by average values (Annex, Tables 10, 11). Average nitrate content for target period was 16.8 mg/l.

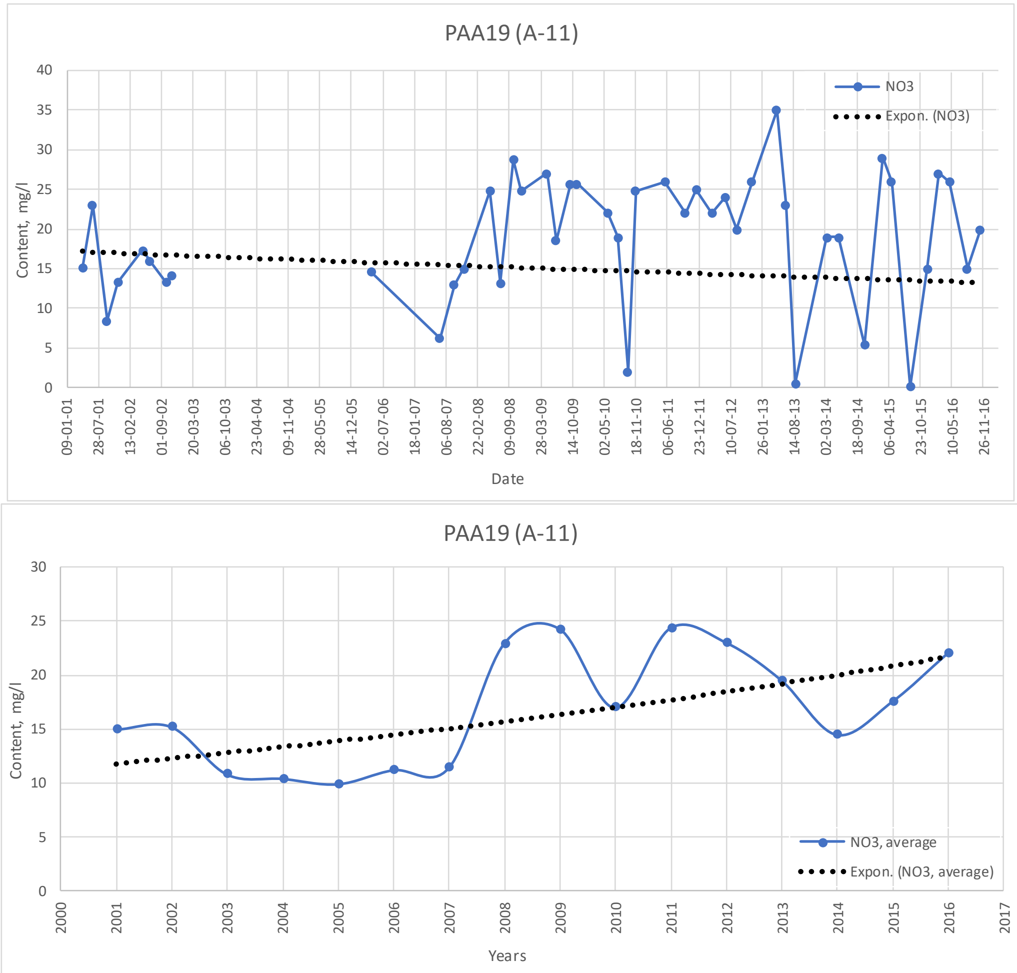


Figure 23. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 23) can be seen that nitrate content in PAA19 (A-11) groundwater has a tendency to decrease over time during the target period. However, there was no raw data included for 2003-2005 years. In order to obtain more reliable results, annual averages were calculated, and relevant chart created (including 2003-2005 years averages), where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2009, 2011 and 2016. Unlike the previous chart, nitrate concentration growth trend is observed (which is due to additional data for 2003-2005) – from 12 mg/l to 22 mg/l in average numbers, or from 15 to 22 mg/l in real values.

Target period can be divided into 3 parts: 2001-2007, 2008-2014 and 2015-2016. First part is characterized by stable nitrate content, second - with the abrupt increase and slight overall decrease tendency. After 2014, concentration peaked again significantly.

PAA14

Monitoring data for PAA14 was available for whole 2001-2016 years period (Annex, Tables 10, 11). Average nitrate content for target period was 28.6 mg/l.

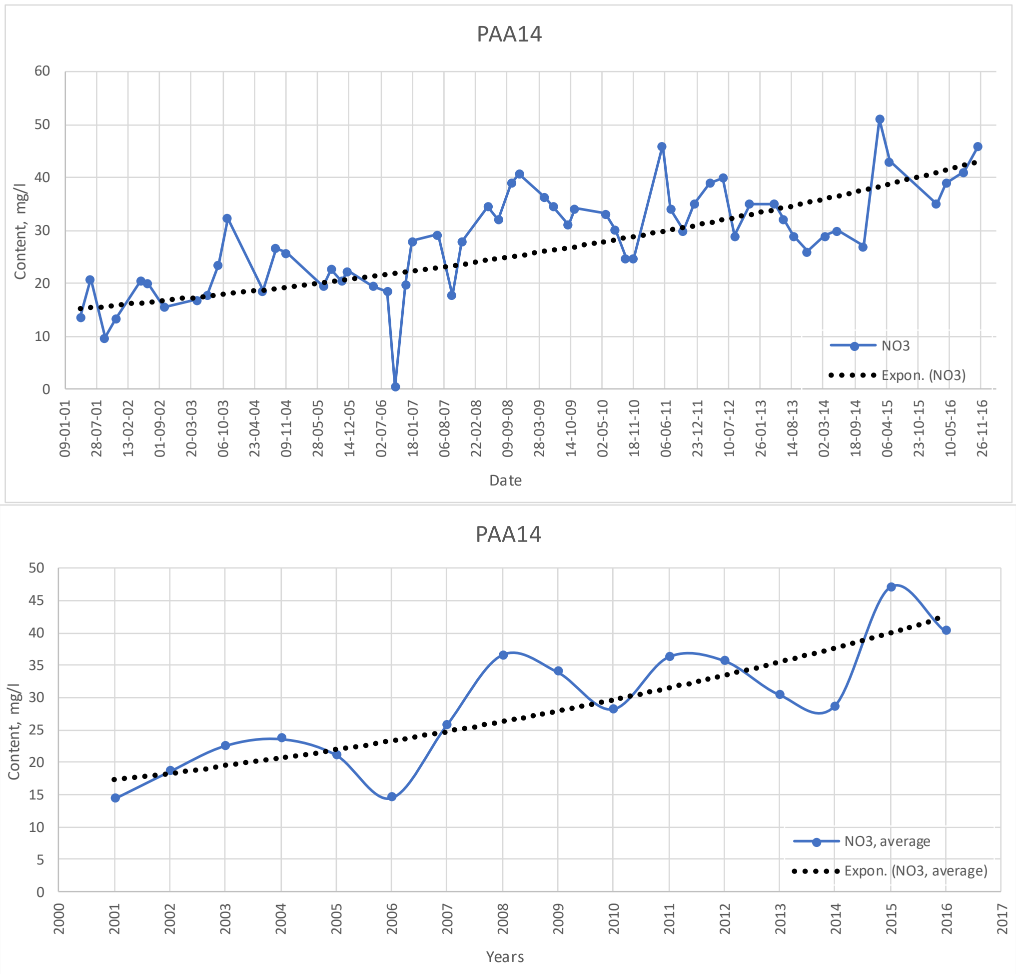


Figure 24. Charts of raw and annual average nitrate content changes during 2001-2016 period.

From the charts above (Figure 24) can be seen that nitrate content in PAA14 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008, 2011 and 2015. However general growth trend still remains – from 17.5 mg/l to 42.5 mg/l in average numbers, or from 14.4 to 40.3 mg/l in real values.

Target period can be divided into 3 parts: 2001-2007, 2008-2014 and 2015-2016. First part is characterized by a slight increase of nitrate content, second - with the abrupt increase and slight overall decrease tendency. After 2014, concentration peaked again significantly.

PAA16

Monitoring data for PAA16 was available for whole 2001-2016 years period (Annex, Tables 10, 11). Average nitrate content for target period was 9 mg/l.

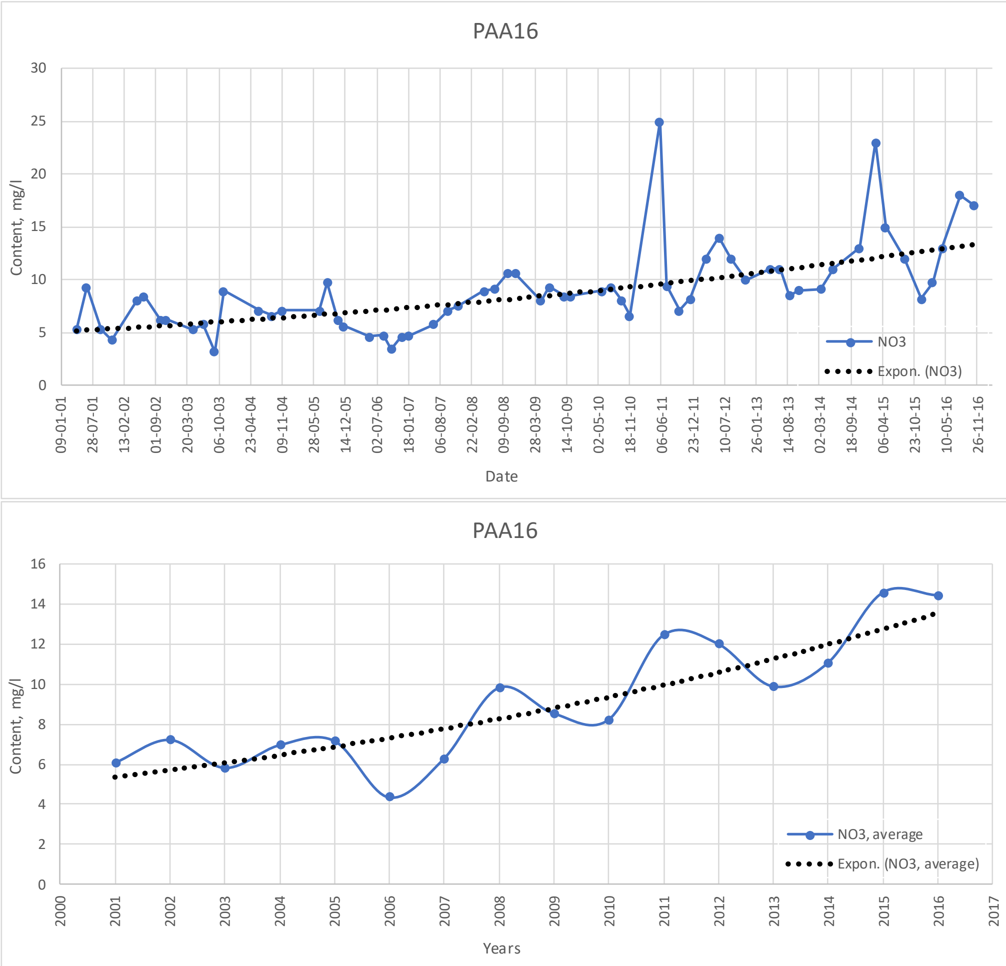


Figure 25. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 25) can be seen that nitrate content in PAA16 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008, 2011 and 2015. However general growth trend still remains – from 5.3 mg/l to 13.7 mg/l in average numbers, or from 6.1 to 14.4 mg/l in real values.

Target period can be divided into 2 parts: 2001-2007 and 2008-2016. First part is characterized by stable nitrate content, second - with overall increase tendency with several fluctuations.

Group III

Group III is represented with 4 wells, with depths 5-15 m: AD1395, ADKK21, AD14525 and AD93, located at Adavere plateau.

Available raw and annual average data is represented in Tables 12 and 13 (Annex).

AD1395

Monitoring data for AD1395 was available for 2010-2016 years period (Annex, Tables 12, 13). Average nitrate content for target period was 19.1 mg/l.

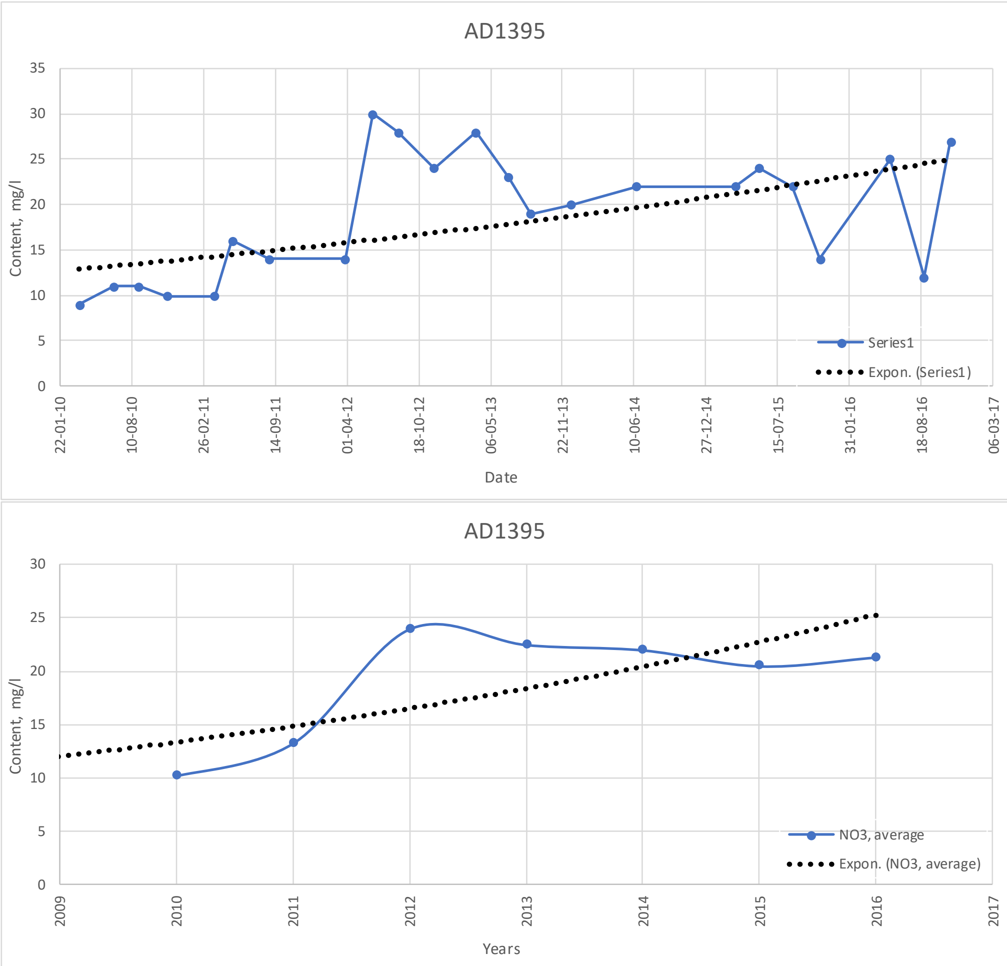


Figure 26. Charts of raw and annual average nitrate content changes during 2010-2016 period

From the charts above (Figure 26) can be seen that nitrate content in AD1395 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008. General growth trend still remains – from 13.5 mg/l to 25 mg/l in average numbers, or from 10.2 to 21.3 mg/l in real values.

Target period can be divided into 2 parts: 2010-2012 and 2013-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2012. After this, its contents have a slight decreasing tendency.

ADKK21

Monitoring data for ADKK21 was available for 2005, 2007 and 2009-2016 years period (Annex, Tables 12, 13). However, measurements in 2005 and 2007 are way different from the rest of data, and they change average nitrate content for the whole period a lot - 44.8 mg/l versus 31.5 mg/l without these years.

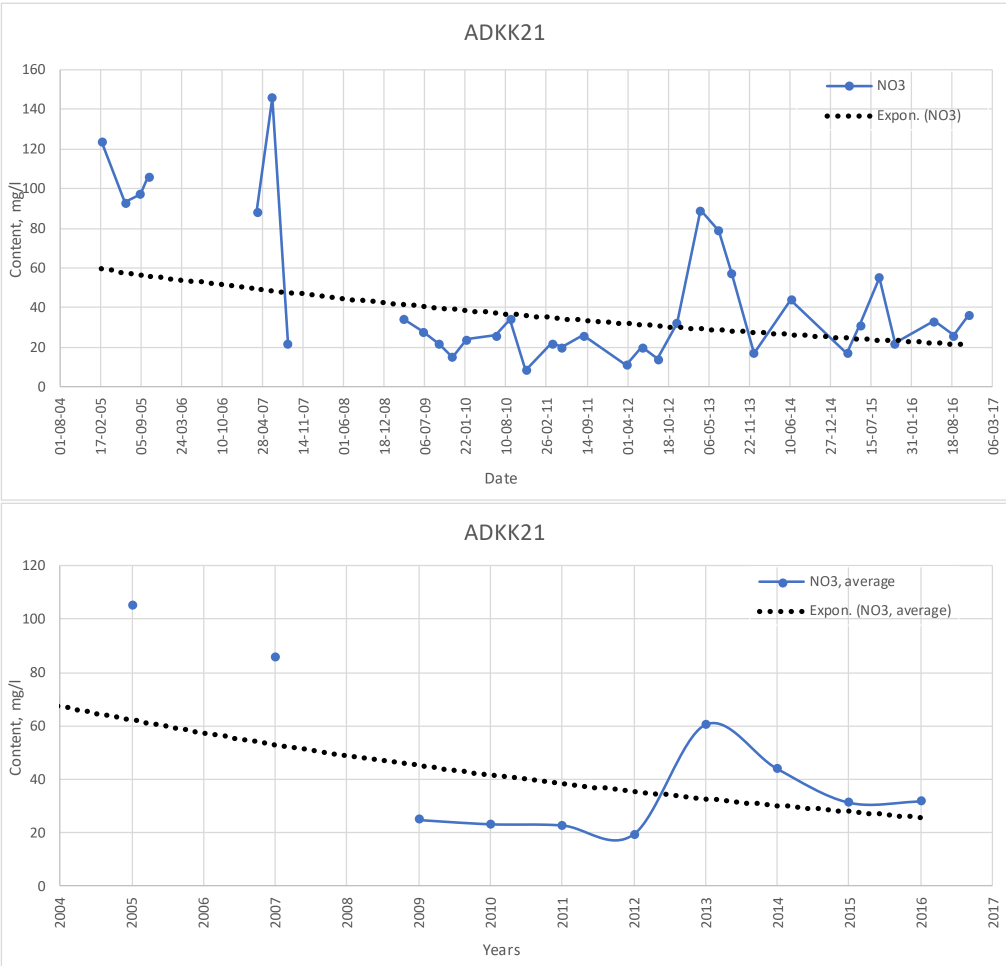
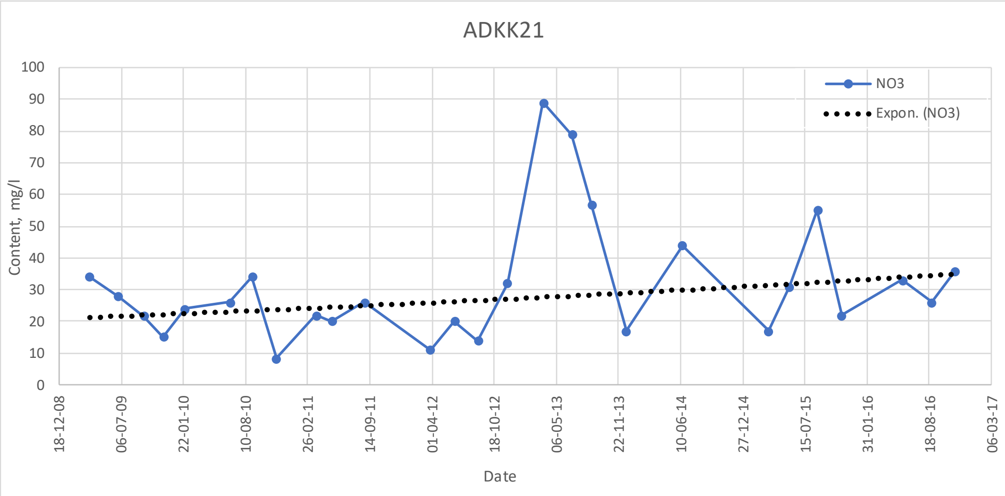


Figure 27. Charts of raw and annual average nitrate content changes during 2005-2016 period

From the charts above (Figure 27) can be seen that nitrate content in ADKK21 groundwater has a tendency to increase over time during the target period. Nevertheless, as it was mentioned, without 2005 and 2007 data, this trend is opposite – nitrate contents increase over time (Figure 28).



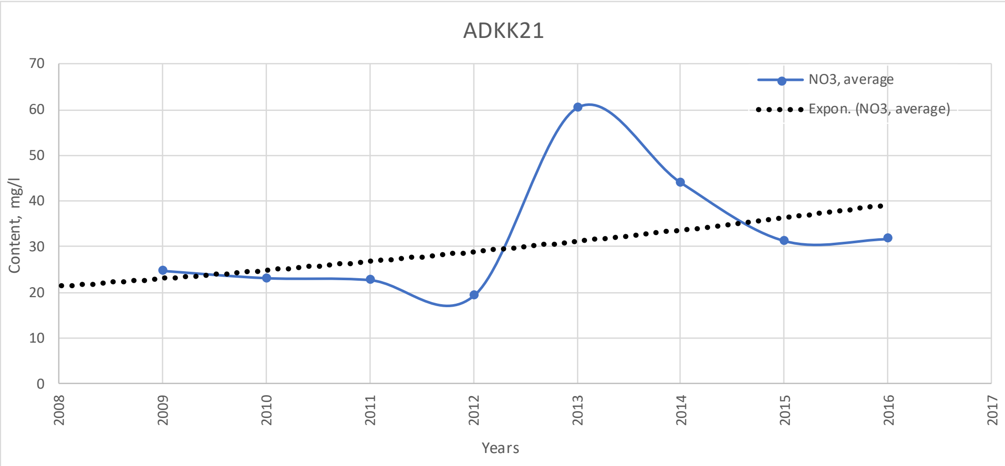


Figure 28. Charts of raw and annual average nitrate content changes during 2009-2016 period

In order to obtain more reliable results, annual averages were calculated, and relevant charts created, where contents are represented smoother, which makes it easier to analyze. Considering only 2009-2016 years period, it is clearly visible that nitrate concentrations peaked in 2013. General growth trend still remains – from 23.5 mg/l to 40 mg/l in average numbers, or from 24.7 to 31.7 mg/l in real values.

Target period can be divided into 2 parts: 2009-2012 and 2013-2016. Both parts are characterized by a decrease of nitrate contents, with an abrupt increase between.

AD14525

Monitoring data for AD14525 was available for 2010-2016 years period (Annex, Tables 12, 13). Average nitrate content for target period was 40.7 mg/l.

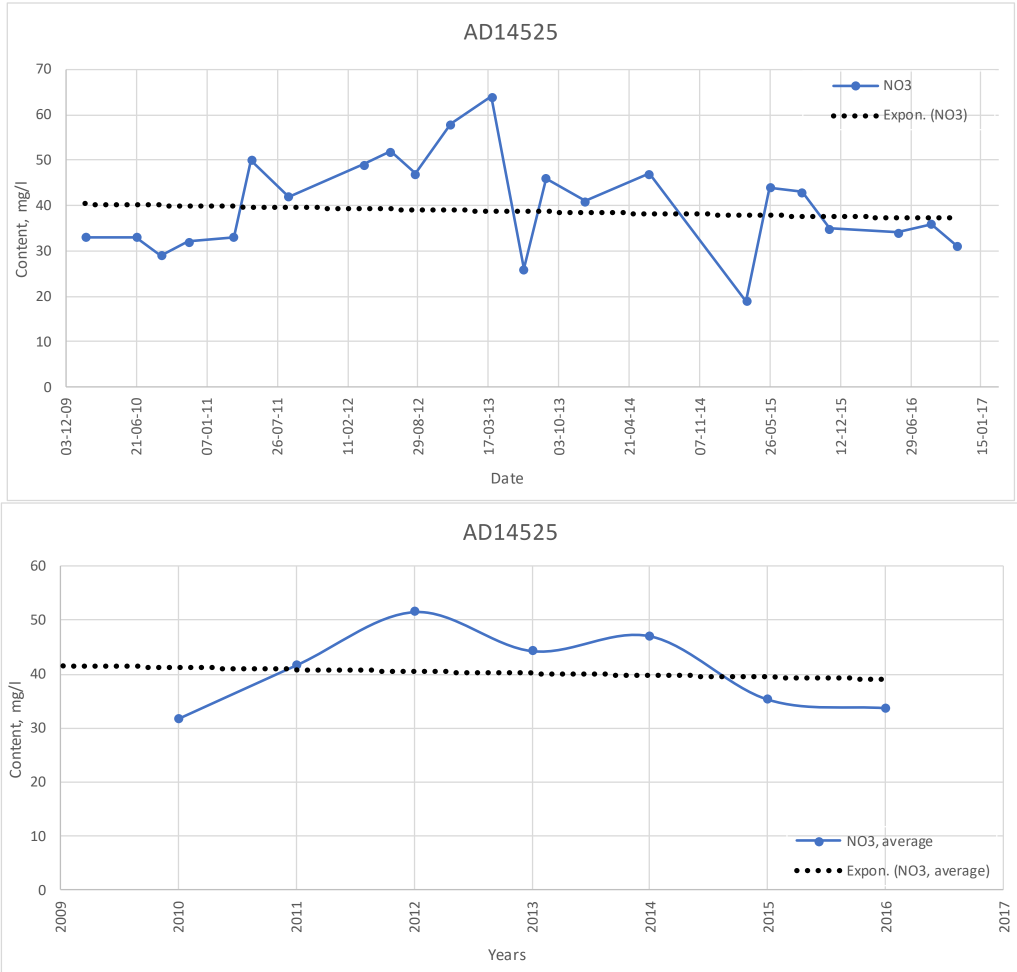


Figure 29. Charts of raw and annual average nitrate content changes during 2010-2016 period

From the charts above (Figure 29) can be seen that nitrate content in AD14525 groundwater has slight tendency to decrease over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2012. General decrease trend still remains – from 41 mg/l to 39 mg/l in average numbers.

Target period can be divided into 2 parts: 2010-2012 and 2013-2016. First part is characterized by increasing of nitrates, with a peak position in 2012. After this, its contents have a decreasing tendency.

AD93

Monitoring data for AD93 was available for 2002-2016 years period (Annex, Tables 12, 13). Average nitrate content for target period was 15.5 mg/l.

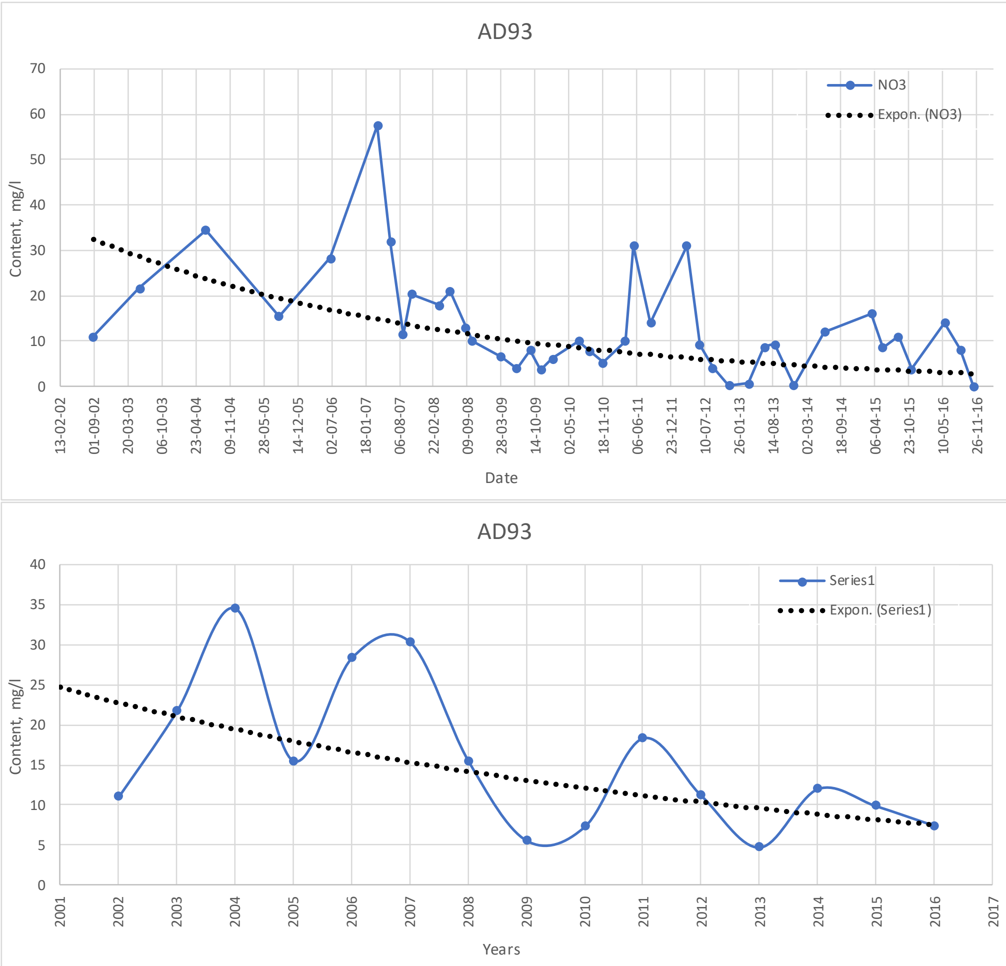


Figure 30. Charts of raw and annual average nitrate content changes during 2002-2016 period

From the charts above (Figure 30) can be seen that nitrate content in AD93 groundwater has a tendency to decrease over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2004, 2007 and 2011. General decrease trend still remains – from 23 mg/l to 7.5 mg/l in average numbers, or from 11 to 7.4 mg/l in real values.

Target period can be divided into 2 parts: 2002-2004 and 2005-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2004. After this, its contents have a slight decreasing tendency with several fluctuations.

Group IV

Group IV is represented with 3 wells, with depths 15-30 m: PAK-169 (K-169), PAK-17 (K-17) and PAK-70, located at Pandivere upland.

Available raw and annual average data is represented in Tables 14 and 15 (Annex).

PAK-169 (K-169)

Monitoring data for PAK-169 (K-169) was available for whole 2001-2016 years period (Annex, Tables 14, 15). Average nitrate content for target period was 25.4 mg/l.

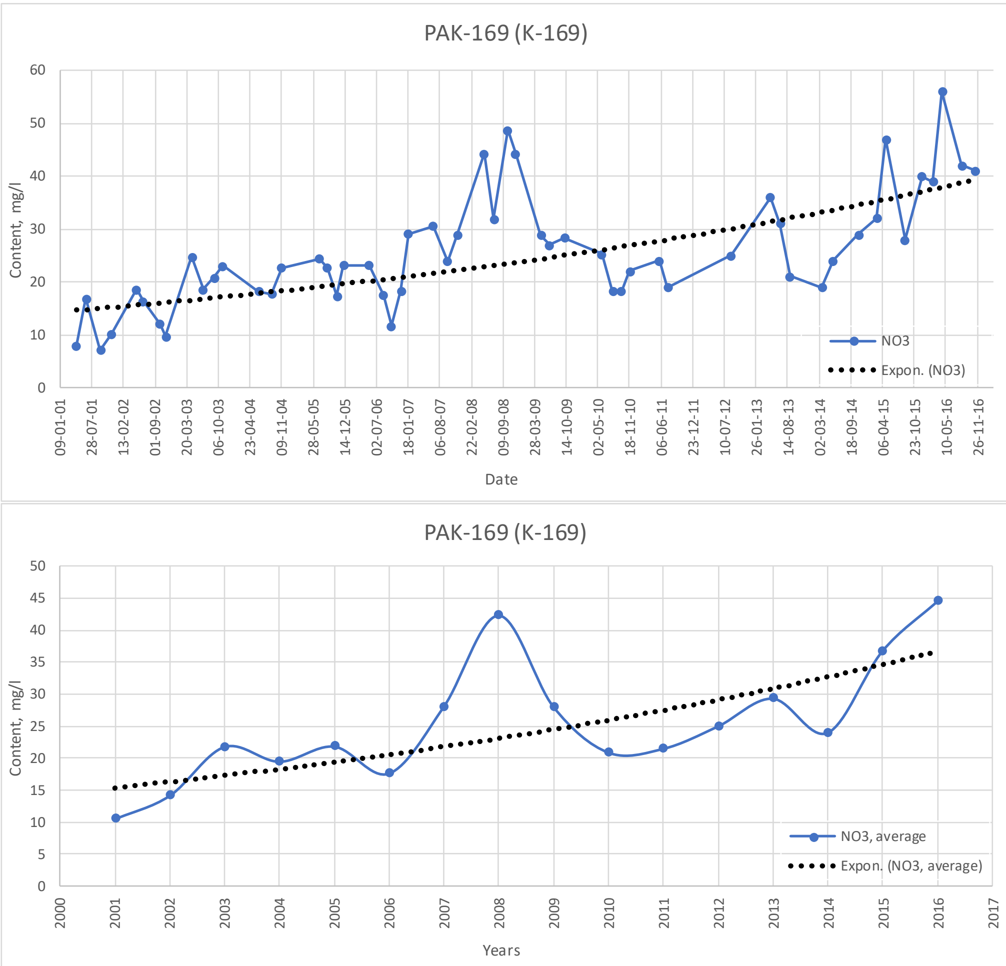


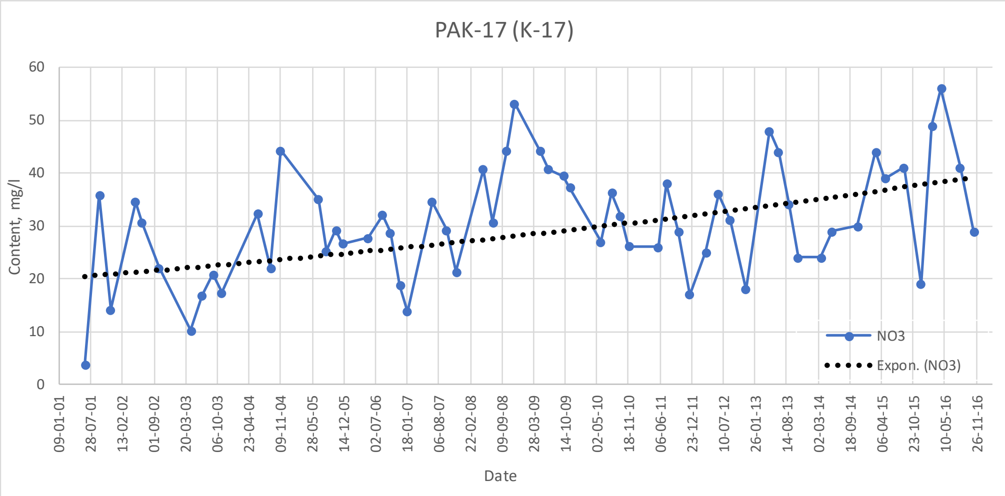
Figure 31. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 31) can be seen that nitrate content in PAK-169 (K-169) groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 15 mg/l to 36.5 mg/l in average numbers, or from 10.5 to 44.5 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped by 2010 and then started increasing again.

PAK-17 (K-17)

Monitoring data for PAK-17 (K-17) was available for whole 2001-2016 years period (Annex, Tables 14, 15). Average nitrate content for target period was 30.6 mg/l.



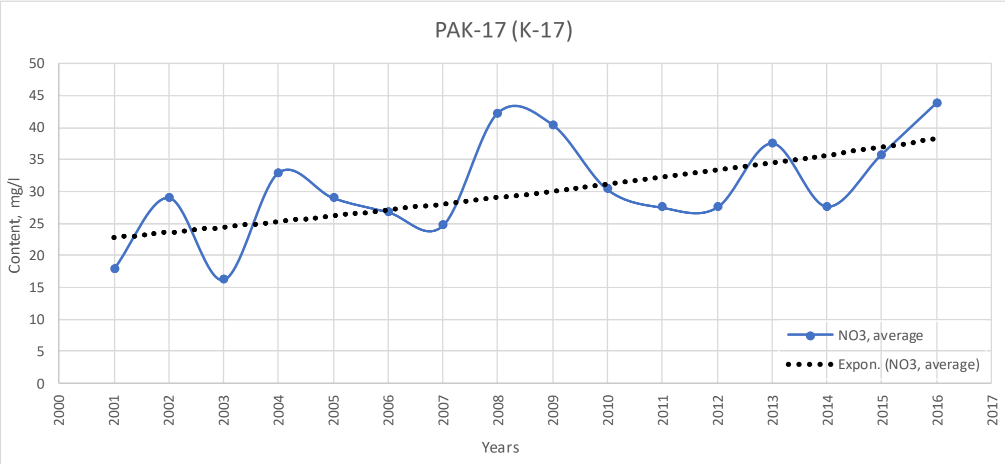


Figure 32. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 32) can be seen that nitrate content in PAK-17 (K-17) groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 23.5 mg/l to 38 mg/l in average numbers, or from 17.9 to 43.8 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped by 2011 and then started increasing again.

PAK-70

Monitoring data for PAK-70 was available for whole 2001-2016 years period (Annex, Tables

14, 15). Average nitrate content for target period was 24.3 mg/l.

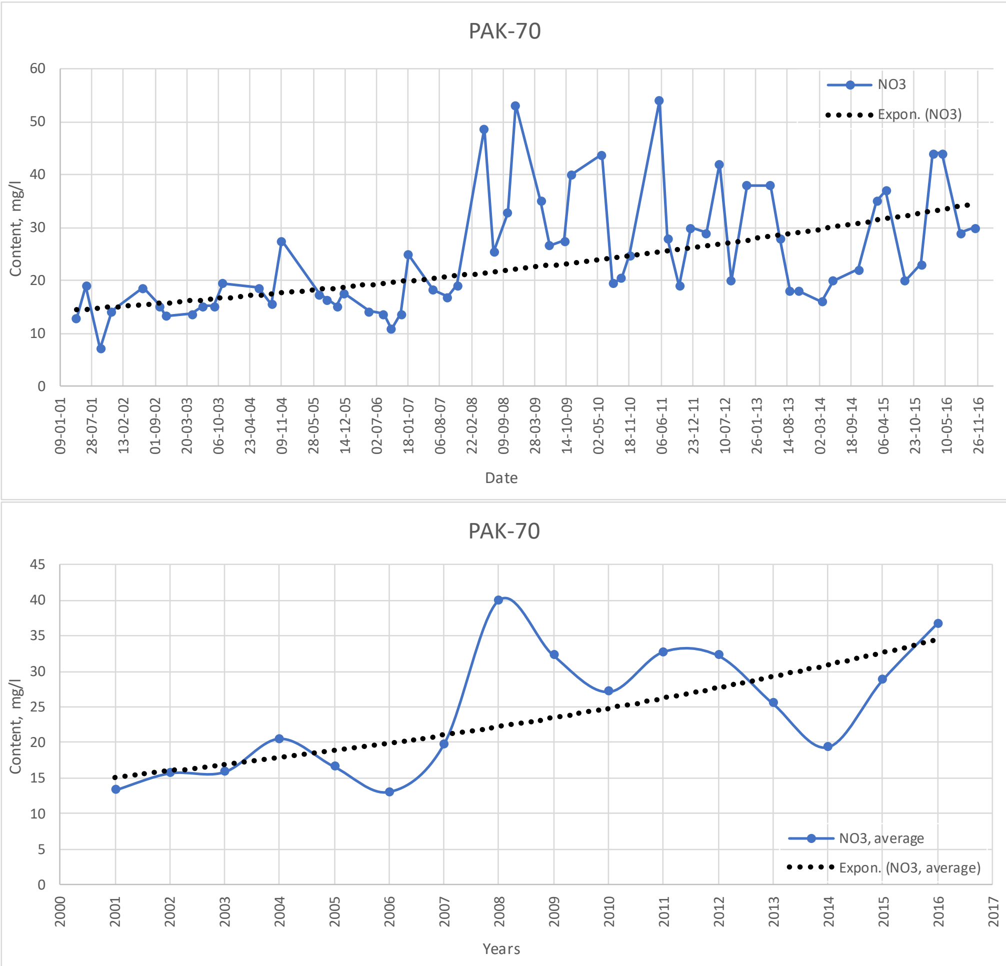


Figure 33. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 33) can be seen that nitrate content in PAK-70 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 15 mg/l to 34 mg/l in average numbers, or from 13.3 to 36.8 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped by 2010 and then started increasing again.

Group V

Group V is represented with 3 wells, with depths >30 m: PAPK-10 (PK-10), PAA31 (A-1011), PAK-5, located at Pandivere upland.

Available raw and annual average data is represented in Tables 16 and 17 (Annex).

PAPK-10 (PK-10)

Monitoring data for PAPK-10 (PK-10) was available for whole 2001-2016 years period (Annex, Tables 16, 17). Average nitrate content for target period was 27.9 mg/l.

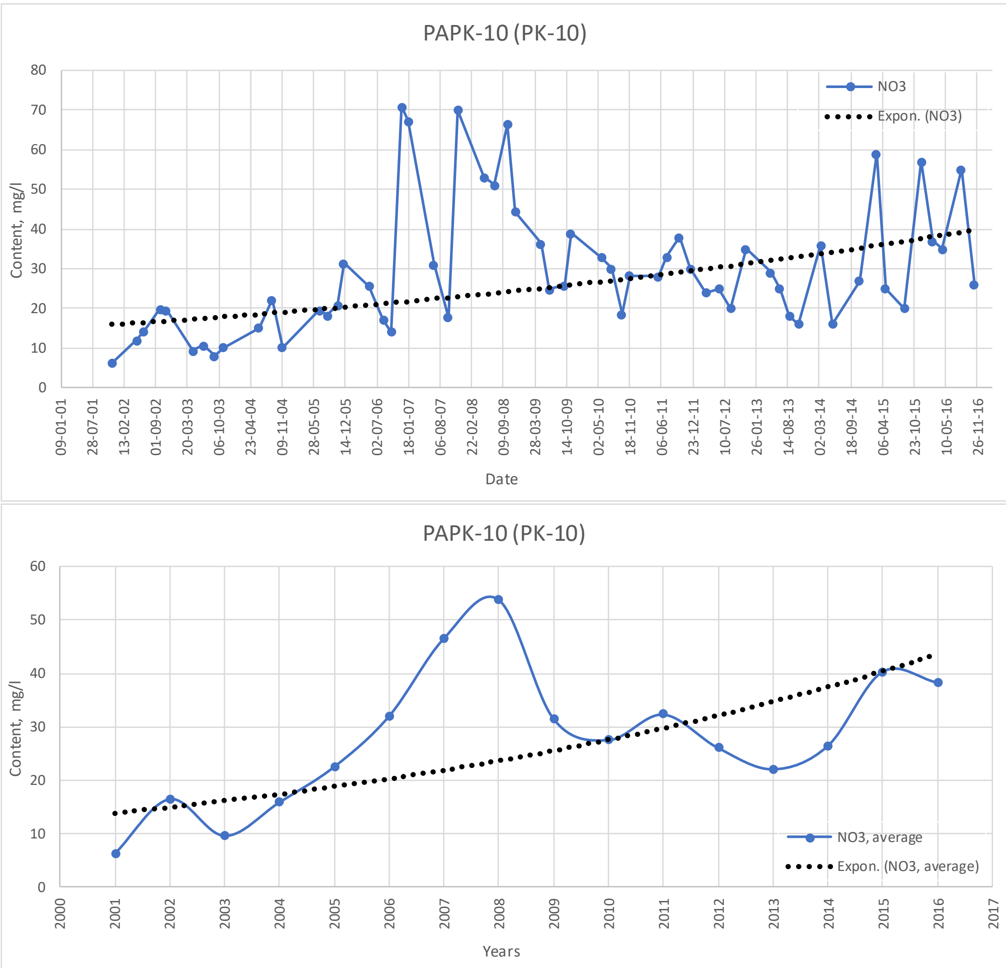


Figure 34. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 34) can be seen that nitrate content in PAPK-10 (PK-10) groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008 and 2016. However general growth trend still remains – from 14 mg/l to 44 mg/l in average numbers, or from 6.2 to 38.3 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. First part is characterized with significant increasing of nitrates, with a peak position in 2008. After this, its content dropped by 2010 and then started increasing again.

PAA31 (A-1011)

Monitoring data for PAA31 (A-1011) was available for whole 2006-2007, 2009-2016 years period (Annex, Tables 16, 17). Average nitrate content for target period was 28.9 mg/l.

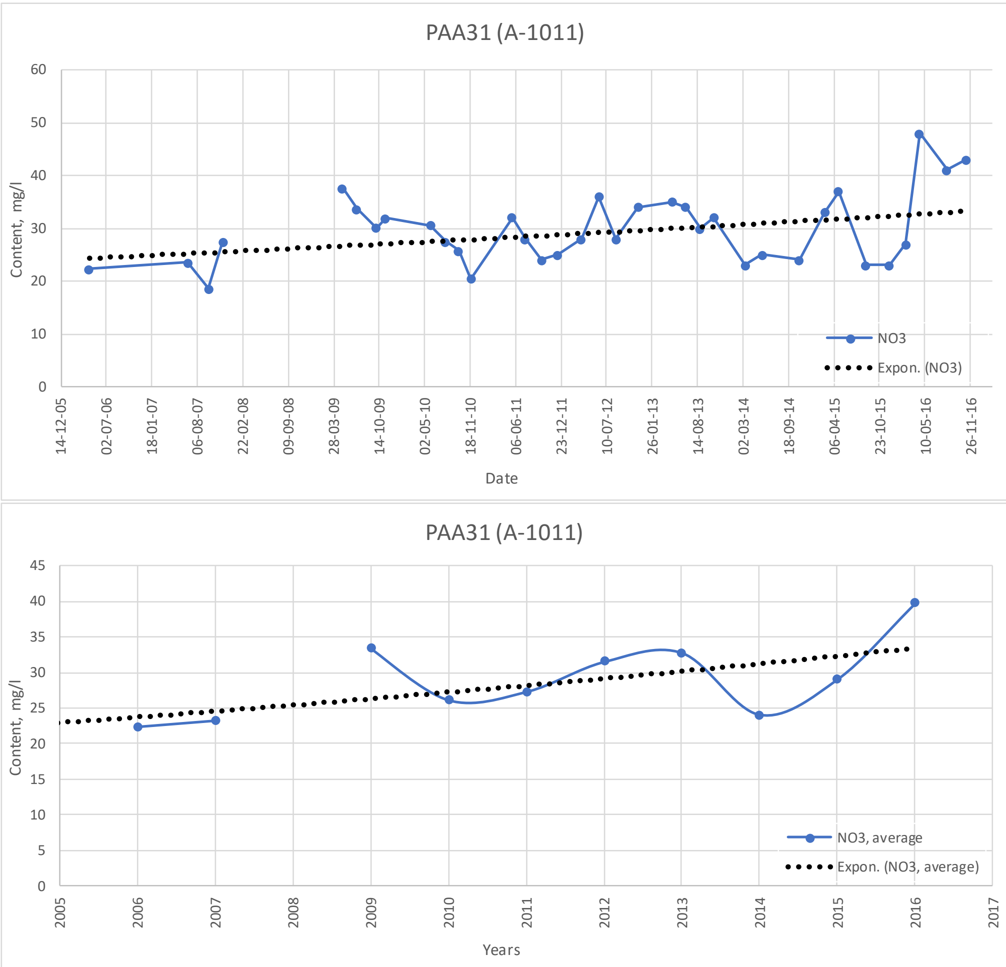


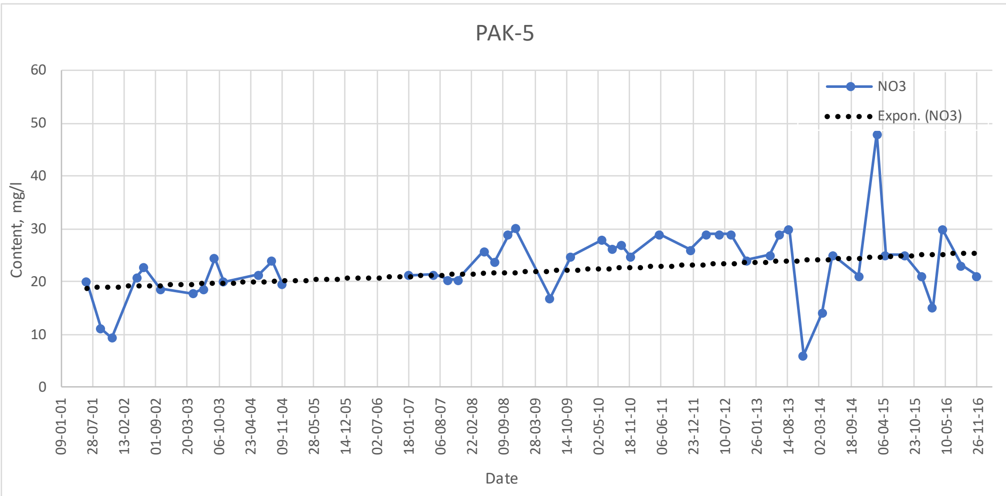
Figure 35. Charts of raw and annual average nitrate content changes during 2006-2016 period

From the charts above (Figure 35) can be seen that nitrate content in PAA31 (A-1011) groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2009 and 2016. However general growth trend still remains – from 24 mg/l to 33.5 mg/l in average numbers, or from 22.3 to 39.8 mg/l in real values.

Target period can be divided into 2 parts: 2006-2009 and 2010-2016. First part is characterized by increasing of nitrates, with a peak position in 2009. After this, its content dropped by 2010 and then started increasing again.

PAK-5

Monitoring data for PAK-5 was available for 2001-2004 and 2007-2016 years period (Annex, Tables 16, 17). Average nitrate content for target period was 22.9 mg/l.



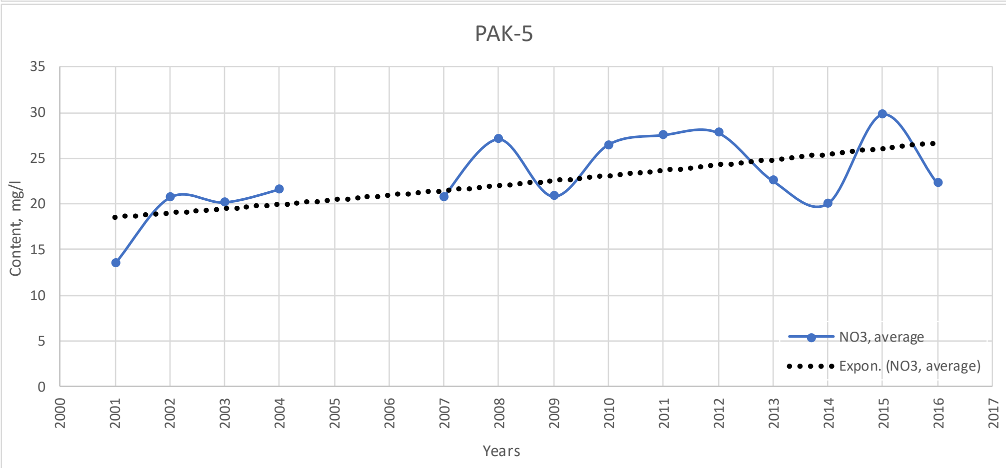


Figure 36. Charts of raw and annual average nitrate content changes during 2001-2016 period

From the charts above (Figure 36) can be seen that nitrate content in PAK-5 groundwater has a tendency to increase over time during the target period. In order to obtain more reliable results, annual averages were calculated, and relevant chart created, where contents are represented smoother, which makes it easier to analyze. It is clearly visible that nitrate concentrations peaked in 2008,2011 and 2015. However general growth trend still remains – from 18 mg/l to 27 mg/l in average numbers, or from 13.4 to 22.3 mg/l in real values.

Target period can be divided into 2 parts: 2001-2008 and 2009-2016. Both parts are characterized by constantly increasing nitrate content with several fluctuations.

5. Conclusions and recommendations

Water quality problems in are mostly related to excessive pollution loads from point and diffuse sources. Diffuse source pollution, which originates mostly from agricultural areas, forestry or fish farms is the main source for nitrate-containing compounds in the target area (Pandivere and Adavere-Põltsamaa nitrate vulnerable zone). [4]

To deal with this problem, various reforms were focused on legislation, infrastructure management, and water services from the beginning of the 1990's.

The biggest changes were made in agriculture. Estonian Water Act forced farmers to reduce agricultural pollution from silage storages, to construct and reconstruct manure storages and to use fertilizers more efficiently, following the targets set by law. The implementation of the measures was aimed to reduce nutrient emissions from agriculture and consequently, to reduce nitrogen compounds in groundwater.

The Water Act establishes several provisions for the transposition of the Nitrates Directive, including limiting applied fertilizer amounts and time periods, distances to water bodies, sinkholes and wells, limiting manure storage locations and durations, limiting livestock amount, demanding vegetation cover for arable land and use of sewage sludge. [8]

Other approaches are the usage of the best available technology (BAT) and best environmental practice (BEP). However, Estonian legislation does not predefine any kind of technologies for pollution reduction. Only the final result (concentration or reduction percent) is determined by regulations. Though, it is clear that implementation of a new or modified technological process to reduce the pollution load to the environment will eventually reduce the environmental costs for farmers as well.

Training of farmers and advisers on the regulations and the appropriate implementation is also important measure to ensure good water quality by implementing environmentally friendly management, covering subjects as: Soil and nutrients, plant protection, grassland management and biological and landscape diversity in a way to obtain advanced knowledge in seed blends and fertilization, manure management, prevention and control of weeds and pesticides, re-seeding of grasslands, mowing, grazing, etc. [6]

To summarize all above mentioned in simple paragraphs, generally 4 actual approaches are available to reduce nitrogen load in NVZ groundwater:

1. Reduction of nitrogen input (manure and mineral fertilizers) by limiting them;
2. Reduction of animal produced manure by limiting LSU per ha or improving manure and sewage storage and removal;
3. Implementing best available technology (BAT) and best environmental practice (BEP) to keep nitrogen loads low while maintaining production yield;
4. Training of farmers and advisers in order to introduce environmentally friendly management principles.

However, current results of all described measures are not promising, as well as forecasting, if no additional actions will be taken in the near future.

Based on groundwater data analysis of selected 20 monitoring points for 2001-2016 years period, an increase of nitrates are clearly observed in practically all Pandivere and Adavere-Põltsamaa NVZ:

1. Only 2 out of 20 monitoring points have nitrate content decrease tendency (AD14525 and AD93);
2. Additionally, one well (ADKK21) has a similar tendency if extremely high 2005 and 2007 data are also taken into account. If not, it also has increasing trend;
3. All mentioned monitoring points are 5-15 m deep wells located in Põltsamaa-Adavere limestone plateau;
4. The rest 17 monitoring point have clear tendency of nitrate increase trend, especially evident within Pandivere upland;
5. In majority of cases, there is a peak nitrate concentration in around the year of 2008, which is followed sharp decrease in following years;
6. After 2009-2010 years nitrate contents are starting increasing and last peaks coincide with the period of 2016 and 2016 years.

Comparing average initial and final values of increase trendlines for 17 monitoring points, general percentages can be calculated: they range from 28.4 to 68.2% increase in nitrate content for the target period of time. The average number is 50.6%.

Adavere-Põltsamaa area is represented by 4 wells with 5-15 m depth. Two wells have 41.3 and 46% increase trend in nitrate content, while other two got decrease trend (from slight -5.1% for AD14525 to significant -206.7% for AD93). An average number of this region is -31.1% (decrease trend).

Speaking about nitrate content changes within different depths of monitoring points, average trends for each group was calculated and compared:

- Group I (0 m, karst springs) seems to be the most sensitive – average increase trend in nitrate content is 62.1%;
- Group II (<5 m, wells) and Group IV (15-30 m, wells) have similar average number of 51% increase trend;
- Group V (>30 m, wells) average increase trend in nitrate content is 43.3%
- As for Group III (5-15 m, wells), the average trend of two wells with increased nitrate content is very similar to Group V - 43.6%. However, if all four wells are considered, then decrease average trend is observed -31.1%.

From these results, it can be concluded that karst springs have the highest trend of nitrate content increase – 62% (seems due to the fact that they characterize overall situation and impacts to ground water quality in larger areas), followed by <5 m deep, shallow wells and 15-30 m deep wells. Difference between their trends is around 10 percentage points (51%). Wells with 5-15 and >30 m deep have another 10 percentage points lower (43%) nitrate increase trend (excluding two wells with decrease trends).

Even though target monitoring points were selected with initially high nitrate content, the observed trend can be applicable to the whole NVZ, because of a full range covering groundwater depths (from natural springs to wells up to 30 m and more) and whole NVZ area (both Pandivere and Adavere-Põltsamaa).

Comparing to surface water bodies, most of NVZ rivers have nitrate content increasing trends (Figure 9), but similarities to groundwater points trends are not very clear. Perhaps it is due to more complicated nitrogen transportation mechanism of rivers, which highly depends on natural conditions, including weather, precipitations, river discharge rate and other sources of nitrogen pollution in them.

Another conclusion is the clear linear connection between nitrogen input and nitrate content in groundwater. In majority cases, there is a peak nitrate concentration in around the year of 2008, which is followed the sharp decrease in following years and from around 2010 nitrate content are starting to increase again. This behavior corresponds to fertilizer consumption and cereal production for the same period (Figures 12, 13) as well as more precise nitrogen input/output data (Figure 14), which can be considered as the target indicator in the current scenario.

Based on all above, and considering mentioned 4 general approaches for nitrate reduction, seems that from an only direct decrease of nitrogen input is the most effective. This can be achieved either by further limiting fertilizer input per ha of arable land or more effective implementation of BAT and BEP which will lead to the same by reducing fertilizer losses while maintaining production yield. And of course, training will also be beneficial for the more efficient adoption of new techniques and environmentally friendly management principles.

Such conclusions are made based on data analysis of 20 monitoring points only, so in order to obtain more precise and trustful results and cover all possible means for NVZ groundwater protection, additional, deeper and wide range studies are required.

6. References

1. Meriliis Kotkas, Maret Merisaar. 2012. Industrial Animal Farming in Estonia in 2012. Estonian Green Movement. Tallinn;
2. Arvo Iital, Karin Pachel. 2011. Nitraaditundliku ala (NTA) laiendamisvajaduse analüüs. Tallinn. 113p;
3. Margus Kört, Katri Vooro, Madis Osjamets. 2010. Nitraaditundliku ala põhjavee seire 2010. MAVES. Tallinn. 43p;
4. Ain Lääne, Rene Reisner. 2011. WATER SECTOR REFORMS IN ESTONIA. A Background paper for the OECD Global Forum on Environment: Making Water Reform Happen. OECD Conference Centre, Paris, 25-26 October 2011. 20p;
5. Karin Pachel. 2010. Water Resources, Sustainable Use and Integrated Management in Estonia. Tallinn, 171p;
6. Helen Poltimäe, Kaja Peterson. 2010. Report on implementability of agro-environmental targets in Estonia. Tallinn, November 2010. 16p;
7. Action plan for the nitrate vulnerable Pandivere and Andavere-Põltsamaa area for 2016-2020. Tallinn, 2016;
8. Water Act. In force from: 06.01.2017, English translation published: 12.01.2017 (https://www.riigiteataja.ee/en/eli/512012017001/consolide);
9. Sall, M., Peterson, K., Kuldna, P. 2012. The Role of River Basin Management Plans in addressing diffuse pollution from agriculture to limit the eutrophication of the Baltic Sea. National Report of Estonia. Baltic Compass project, SEI Tallinn, 110p;
10. Knoema. World Data Atlass, Estonia (https://knoema.com/atlas/Estonia/Land-under-cereal-production);
11. Knoema. World Data Atlass, Estonia (https://knoema.com/atlas/Estonia/Fertilizer-consumption);
12. Livi Rooma. 2015. Status of nutrient accounting and bookkeeping in Estonia. HELCOM. Oldenburg, 28-29 April 2015;
13. Nitraaditundliku ala põhjavee seire. http://seire.keskkonnainfo.ee;
14. Arvo Iital, Karin Pachel, Kristjan Piirimäe. 2015. Nitraaditundliku ala 2011 aasta uuringu "Nitraaditundliku ala laiendamisvajaduse analüüs" ajakohastamine. Tallinn. 41p;
15. Nõukogu direktiivi 91/676/EMÜ, veekogude kaitsmise kohta põllumajandusest

lähtuva nitraadireostuse eest, täitmine Eestis 2012-2015, 2016. Keskkonnaministeerium, Maaeluministeerium, keskkonnaagentuur, 85 p.

Annex

Table 6. Fertilizer consumption (kilograms per hectare of arable land) and land under cereal production (hectares) in 2003-2014, with change rates (Data source: Knoema. World Data Atlass, Estonia)

Year	Fertilizer consumption		Land under cereal production	
	kg/ha	Change, %	ha	Change, %
2003	71.6		263166	
2004	84.3	17.74	260979	-0.83
2005	61	-27.64	282094	8.09
2006	75.7	24.10	280235	-0.66
2007	75.9	0.26	292236	4.28
2008	100.4	32.28	309300	5.84
2009	69.4	-30.88	316413	2.30
2010	68.4	-1.44	275274	-13.00
2011	71.5	4.53	296924	7.86
2012	81.1	13.43	290500	-2.16
2013	83.1	2.47	311100	7.09
2014	86.1	3.61	332900	7.01

Table 7. Nitrate content in PAKarst-25 and PAKarst-32 springs for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

Years	PAKarst-25		PAKarst-32	
	Date	Nitrate, mg/l	Date	Nitrate, mg/l
2001	19-04-01	15.1	19-04-01	19.0
	20-06-01	15.1	20-06-01	22.1
	19-09-01	5.8	19-09-01	8.9
	28-11-01	8.9	28-11-01	13.3
2002	06-05-02	10.6	06-05-02	17.3
	18-06-02	0.4	18-06-02	14.6
	02-10-02	0.1	02-10-02	7.5
	07-11-02	6.6	07-11-02	9.3
2003	23-04-03	16.4	23-04-03	15.1
	01-07-03	0.4	01-07-03	12.8
	10-09-03	2.4	10-09-03	18.2

	04-11-03	21.3	04-11-03	28.8
2004	16-06-04	1.1	16-06-04	13.3
	07-09-04	2.8	07-09-04	17.3
	10-11-04	5.8	10-11-04	16.8
2005	05-07-05	2.4	05-07-05	15.1
	24-08-05	0.8	24-08-05	13.7
	27-10-05	0.2	27-10-05	11.1
	06-12-05	31.3	06-12-05	17.1
2006	15-05-06	6.5	15-05-06	17.0
	14-08-06	0.0	14-08-06	9.6
	02-10-06	0.1	03-10-06	5.1
	06-12-06	39.3	06-12-06	18.5
2007	18-01-07	42.3	18-01-07	36.4
	26-06-07	7.5	26-06-07	23.9
	25-09-07	8.4	25-09-07	15.9
	26-11-07	18.2	26-11-07	25.2
2008	12-05-08	17.7	12-05-08	37.2
	16-07-08	7.4	16-07-08	0.0
	08-10-08	11.5	08-10-08	34.1
	27-11-08	14.6	27-11-08	35.0
2009	07-05-09	12.4	07-05-09	32.3
	30-06-09	6.6	30-06-09	30.1
	01-10-09	10.2	01-10-09	18.2
	12-11-09	12.4	12-11-09	29.7
2010	26-05-10	9.3	26-05-10	28.8
	28-07-10	5.3	27-07-10	19.5
	29-09-10	3.1	29-09-10	15.1
	18-11-10	9.7	18-11-10	16.4
2011	26-05-11	6.5	19-05-11	36.0
	11-07-11	4.1	12-07-11	23.0
	27-09-11	1.3	27-09-11	16.0
	07-12-11	20.0	07-12-11	35.0
2012	14-03-12	10.4	14-03-12	31.0
	06-06-12	8.8	06-06-12	30.0
	21-08-12	1.7	21-08-12	19.0
	22-11-12	21.0	21-11-12	28.0

2013	29-04-13	28.0	29-04-13	32.0
	26-06-13	46.0	26-06-13	21.0
	28-08-13	7.0	28-08-13	15.0
	23-10-13	6.4	23-10-13	15.0
2014	29-05-14	21.0	12-03-14	27.0
	13-08-14	10.0	29-05-14	25.0
	12-11-14	13.0	12-11-14	20.0
2015	25-02-15	26.0	25-02-15	50.0
	27-04-15	17.0	27-04-15	38.0
	24-08-15	17.0	24-08-15	23.0
	08-12-15	16.0	08-12-15	34.0
2016	17-02-16	32.0	17-02-16	38.0
	18-04-16	29.0	18-04-16	44.0
	09-08-16	19.0	10-08-16	29.0
	08-11-16	22.0	08-11-16	31.0

Table 8. Annual average nitrate content in PAKarst-25 and PAKarst-32 springs for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	PAKarst-25	PAKarst-32
Years	**NO_3, average**	**NO_3, average**
2001	11.2	15.8
2002	4.4	12.2
2003	10.1	18.7
2004	3.2	15.8
2005	8.7	14.3
2006	11.5	12.6
2007	19.1	25.4
2008	12.8	26.6
2009	10.4	27.6
2010	6.9	20.0
2011	8.0	27.5
2012	10.5	27.0
2013	21.9	20.8
2014	14.7	24.0
2015	19.0	36.3
2016	25.5	35.5

Average	12.4	22.5

Table 9. Nitrate content in AA1003, PAA15 (A-1005), PAA22 (A-1007) and PAA1009 wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

Years	AA1003		PAA15 (A-1005)		PAA22 (A-1007)		PAA1009	
	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l
2001	19-04-01	12.8	19-04-01	25.7	19-04-01	9.3	19-04-01	8.0
	20-06-01	20.4	20-06-01	27.9	20-06-01	13.3	20-06-01	13.3
	28-11-01	15.5	19-09-01	3.2	19-09-01	8.0	19-09-01	8.9
	-	-	28-11-01	17.3	28-11-01	9.7	28-11-01	7.1
2002	06-05-02	20.4	06-05-02	26.6	06-05-02	13.7	06-05-02	13.7
	18-06-02	19.5	18-06-02	25.7	18-06-02	14.2	18-06-02	14.6
	-	-	-	-	02-10-02	13.3	02-10-02	15.1
	-	-	-	-	07-11-02	14.6	-	-
2003	23-04-03	0.2	-	-	-	-	23-04-03	12.8
	01-07-03	17.7	-	-	-	-	01-07-03	11.5
	10-09-03	0.1	-	-	-	-	10-09-03	12.8
	04-11-03	17.3	-	-	-	-	04-11-03	11.1
2004	16-06-04	20.4	-	-	-	-	16-06-04	13.3
	07-09-04	20.4	-	-	-	-	07-09-04	10.6
	10-11-04	21.7	-	-	-	-	10-11-04	11.5
2005	05-07-05	24.4	-	-	-	-	05-07-05	14.2
	24-08-05	22.1	-	-	-	-	24-08-05	12.0
	27-10-05	0.2	-	-	-	-	27-10-05	12.0
	07-12-05	21.4	-	-	-	-	07-12-05	12.0
2006	15-05-06	22.0	18-04-06	26.6	18-04-06	19.2	15-05-06	14.7
	06-12-06	0.6	-	-	-	-	14-08-06	14.9
	-	-	-	-	-	-	02-10-06	15.2
	-	-	-	-	-	-	06-12-06	14.7
2007	18-01-07	21.0	27-06-07	31.9	27-06-07	16.8	18-01-07	10.5
	26-06-07	31.0	27-11-07	36.3	26-09-07	16.4	27-06-07	18.6
	26-09-07	0.0	-	-	27-11-07	17.3	26-09-07	20.4
	27-11-07	0.0	-	-	-	-	27-11-07	19.0
2008	12-05-08	35.4	12-05-08	40.7	12-05-08	19.5	12-05-08	19.9
	15-07-08	34.3	16-07-08	39.8	16-07-08	18.2	16-07-08	16.2

	09-10-08	35.0	09-10-08	44.3	09-10-08	21.7	09-10-08	22.1
	29-11-08	32.8	26-11-08	48.7	26-11-08	48.7	26-11-08	21.3
2009	01-07-09	33.7	01-07-09	28.8	07-05-09	21.3	07-05-09	18.2
	07-05-09	28.3	07-05-09	20.4	08-07-09	19.9	08-07-09	16.4
	01-10-09	30.1	01-10-09	22.1	01-10-09	18.6	01-10-09	17.7
	12-11-09	28.8	09-11-09	35.9	12-11-09	23.0	12-11-09	15.9
2010	27-05-10	25.7	27-01-10	27.0	27-05-10	19.5	27-05-10	13.3
	03-08-10	27.5	17-03-10	30.6	03-08-10	15.9	04-08-10	14.2
	28-09-10	0.0	05-04-10	26.1	28-09-10	15.1	28-09-10	14.6
	22-11-10	20.4	22-04-10	22.2	22-11-10	14.6	22-11-10	13.7
	-	-	13-05-10	23.5	-	-	-	-
	-	-	27-05-10	22.1	-	-	-	-
	-	-	14-06-10	19.5	-	-	-	-
	-	-	02-08-10	18.6	-	-	-	-
	-	-	05-08-10	17.7	-	-	-	-
	-	-	22-11-10	23.5	-	-	-	-
2011	23-05-11	32.0	19-05-11	28.0	23-05-11	19.0	23-05-11	15.0
	18-07-11	30.0	11-07-11	20.0	18-07-11	17.0	18-07-11	16.0
	08-12-11	26.0	27-09-11	15.0	28-09-11	15.0	28-09-11	17.0
	-	-	07-12-11	22.0	08-12-11	20.0	08-12-11	18.0
2012	15-03-12	32.0	15-03-12	25.0	20-03-12	20.0	20-03-12	19.0
	06-06-12	29.0	06-06-12	18.0	06-06-12	19.0	06-06-12	15.0
	21-08-12	28.0	21-08-12	16.0	21-08-12	16.0	21-08-12	17.0
	27-11-12	24.0	19-11-12	28.0	27-11-12	21.0	27-11-12	16.0
2013	25-04-13	30.0	25-04-13	28.0	25-04-13	23.0	25-04-13	19.0
	25-06-13	30.0	25-06-13	20.0	25-06-13	22.0	25-06-13	17.0
	-	-	21-11-13	14.0	22-08-13	16.0	22-08-13	17.0
	-	-	-	-	21-10-13	19.0	21-10-13	20.0
2014	20-03-14	22.0	20-03-14	17.0	20-03-14	12.0	20-03-14	14.0
	27-05-14	27.0	27-05-14	17.0	27-05-14	16.0	27-05-14	17.0
	-	-	-	-	06-11-14	15.0	06-11-14	19.0
2015	02-03-15	30.0	02-03-15	37.0	02-03-15	20.0	02-03-15	18.0
	28-04-15	29.0	28-04-15	35.0	28-04-15	21.0	28-04-15	21.0
	-	-	09-12-15	28.0	25-08-15	19.0	25-08-15	21.0
	-	-	-	-	09-12-15	13.0	09-12-15	18.0
2016	17-02-16	26.0	18-02-16	37.0	17-02-16	14.0	17-02-16	21.0

	18-04-16	28.0	18-04-16	51.0	18-04-16	25.0	18-04-16	22.0
	17-08-16	42.0	17-08-16	42.0	15-08-16	23.0	15-08-16	19.0
	08-11-16	45.0	08-11-16	42.0	09-11-16	15.0	09-11-16	23.0

Table 10. Nitrate content in PAA1013, PAA19 (A-11), PAA14 and PAA16 wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

Years	**PAA1013**		**PAA19 (A-11)**		**PAA14**		**PAA16**	
	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l
2001	19-04-01	14.6	19-04-01	15.1	19-04-01	13.7	19-04-01	5.3
	20-06-01	20.4	20-06-01	23.0	20-06-01	20.8	20-06-01	9.3
	19-09-01	9.7	19-09-01	8.4	19-09-01	9.7	19-09-01	5.3
	28-11-01	12.8	28-11-01	13.3	28-11-01	13.3	28-11-01	4.3
2002	06-05-02	19.9	06-05-02	17.3	06-05-02	20.4	06-05-02	8.0
	18-06-02	16.8	18-06-02	15.9	18-06-02	19.9	18-06-02	8.4
	02-10-02	15.5	02-10-02	13.3	02-10-02	15.5	02-10-02	6.2
	07-11-02	15.9	07-11-02	14.2	-	-	07-11-02	6.2
2003	23-04-03	12.8	-	-	23-04-03	16.8	23-04-03	5.3
	01-07-03	13.3	-	-	01-07-03	17.7	01-07-03	5.8
	10-09-03	12.4	-	-	10-09-03	23.5	10-09-03	3.2
	04-11-03	13.7	-	-	04-11-03	32.3	04-11-03	8.9
2004	16-06-04	15.9	-	-	16-06-04	18.6	16-06-04	7.1
	07-09-04	16.8	-	-	07-09-04	26.6	07-09-04	6.6
	10-11-04	22.1	-	-	10-11-04	25.7	10-11-04	7.1
2005	05-07-05	19.9	-	-	05-07-05	19.5	05-07-05	7.1
	24-08-05	19.9	-	-	24-08-05	22.6	24-08-05	9.7
	27-10-05	20.4	-	-	27-10-05	20.4	27-10-05	6.2
	07-12-05	17.1	-	-	06-12-05	22.3	06-12-05	5.6
2006	15-05-06	18.9	18-04-06	14.6	15-05-06	19.4	15-05-06	4.6
	14-08-06	19.3	-	-	14-08-06	18.5	14-08-06	4.7
	02-10-06	18.1	-	-	02-10-06	0.4	02-10-06	3.4
	06-12-06	15.4	-	-	06-12-06	19.8	06-12-06	4.6
2007	18-01-07	29.2	26-06-07	6.2	18-01-07	28.0	18-01-07	4.7
	-	-	25-09-07	13.0	26-06-07	29.2	26-06-07	5.8
	-	-	26-11-07	15.0	25-09-07	17.7	25-09-07	7.1

	-	-	-	-	26-11-07	27.9	26-11-07	7.5
2008	-	-	12-05-08	24.8	12-05-08	34.5	12-05-08	8.9
	-	-	16-07-08	13.2	16-07-08	32.1	16-07-08	9.1
	-	-	08-10-08	28.8	08-10-08	39.0	08-10-08	10.6
	-	-	27-11-08	24.8	27-11-08	40.7	27-11-08	10.6
2009	07-05-09	36.3	07-05-09	27.0	07-05-09	36.3	07-05-09	8.0
	08-07-09	35.4	01-07-09	18.6	30-06-09	34.5	30-06-09	9.3
	01-10-09	35.9	01-10-09	25.7	01-10-09	31.0	01-10-09	8.4
	12-11-09	33.7	12-11-09	25.7	12-11-09	34.1	12-11-09	8.4
2010	27-05-10	27.9	26-05-10	22.1	26-05-10	33.2	26-05-10	8.9
	04-08-10	24.4	29-07-10	19.0	27-07-10	30.1	28-07-10	9.3
	27-09-10	24.4	29-09-10	2.0	29-09-10	24.8	29-09-10	8.0
	22-11-10	23.0	18-11-10	24.8	18-11-10	24.8	18-11-10	6.6
2011	23-05-11	30.0	23-05-11	26.0	19-05-11	46.0	26-05-11	25.0
	19-07-11	27.0	28-09-11	22.0	12-07-11	34.0	11-07-11	9.4
	29-09-11	25.0	08-12-11	25.0	27-09-11	30.0	27-09-11	7.1
	08-12-11	22.0	-	-	08-12-11	35.0	07-12-11	8.2
2012	20-03-12	32.0	15-03-12	22.0	14-03-12	39.0	14-03-12	12.0
	07-06-12	33.0	07-06-12	24.0	07-06-12	40.0	06-06-12	14.0
	21-08-12	25.0	21-08-12	20.0	21-08-12	29.0	21-08-12	12.0
	27-11-12	32.0	21-11-12	26.0	21-11-12	35.0	22-11-12	10.0
2013	25-04-13	40.0	29-04-13	35.0	29-04-13	35.0	29-04-13	11.0
	25-06-13	33.0	26-06-13	23.0	26-06-13	32.0	26-06-13	11.0
	21-08-13	30.0	27-08-13	0.5	27-08-13	29.0	28-08-13	8.5
	24-10-13	28.0	-	-	21-11-13	26.0	23-10-13	9.0
2014	13-03-14	25.0	13-03-14	19.0	12-03-14	29.0	12-03-14	9.1
	27-05-14	25.0	28-05-14	19.0	29-05-14	30.0	29-05-14	11.0
	06-11-14	19.0	06-11-14	5.4	12-11-14	27.0	12-11-14	13.0
2015	26-02-15	45.0	26-02-15	29.0	25-02-15	51.0	25-02-15	23.0
	28-04-15	36.0	27-04-15	26.0	27-04-15	43.0	27-04-15	15.0
	24-08-15	35.0	25-08-15	<0.1	-	-	24-08-15	12.0
	08-12-15	33.0	08-12-15	15.0	-	-	08-12-15	8.2
2016	17-02-16	36.0	17-02-16	27.0	17-02-16	35.0	17-02-16	9.7
	18-04-16	43.0	27-04-16	26.0	18-04-16	39.0	18-04-16	13.0
	15-08-16	50.0	17-08-16	15.0	10-08-16	41.0	09-08-16	18.0
	09-11-16	31.0	08-11-16	20.0	08-11-16	46.0	08-11-16	17.0

Table 11. Annual average nitrate content in Group II wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	AA1003	PAA15 (A-1005)	PAA22 (A-1007)	PAA1009	PAA1013	PAA19 (A-11)	PAA14	PAA16
Years	**NO_3, average**	**NO_3, average**	**NO_3, average**	**NO_3, average**	**NO_3, average**	**NO_3, average**	**NO_3, average**	**NO_3, average**
2001	16.2	18.5	10.1	9.3	14.4	15.0	14.4	6.1
2002	20.0	26.2	14.0	14.5	17.0	15.2	18.6	7.2
2003	8.8	21.0	9.1	12.1	13.1	10.8	22.6	5.8
2004	20.8	22.0	12.2	11.8	18.3	10.4	23.6	6.9
2005	17.0	25.9	12.6	12.6	19.3	9.9	21.2	7.2
2006	11.3	26.6	19.2	14.9	17.9	11.2	14.5	4.3
2007	13.0	34.1	16.8	17.1	29.2	11.4	25.7	6.3
2008	34.4	43.4	27.0	19.9	-	22.9	36.6	9.8
2009	30.2	26.8	20.7	17.1	35.3	24.3	34.0	8.5
2010	18.4	23.1	16.3	14.0	24.9	17.0	28.2	8.2
2011	29.3	21.3	17.8	16.5	26.0	24.3	36.3	12.4
2012	28.3	21.8	19.0	16.8	30.5	23.0	35.8	12.0
2013	30.0	20.7	20.0	18.3	32.8	19.5	30.5	9.9
2014	24.5	17.0	14.3	16.7	23.0	14.5	28.7	11.0
2015	29.5	33.3	18.3	19.5	37.3	17.5	47.0	14.6
2016	35.3	43.0	19.3	21.3	40.0	22.0	40.3	14.4
Average	**22.9**	**26.5**	**16.7**	**15.7**	**25.3**	**16.8**	**28.6**	**9.0**

Table 12. Nitrate content in Group III wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	AD1395		**ADKK21**		**AD14525**		**AD93**	
Years	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l
2001	-	-	-	-	-	-	28-08-02	11.0
2002	-	-	-	-	-	-	27-05-03	21.7
2003	-	-	-	-	-	-		
2004	-	-	-	-	-	-	18-06-04	34.5
2005	-	-	21-02-05	124.0	-	-	25-08-05	15.5
	-	-	17-06-05	93.0	-	-	-	-

	-	-	29-08-05	97.4	-	-	-	-
	-	-	10-10-05	106.3	-	-	-	-
2006	-	-	-	-	-	-	26-06-06	28.3
2007	-	-	29-03-07	88.6	-	-	29-03-07	57.6
	-	-	13-06-07	146.1	-	-	13-06-07	31.9
	-	-	28-08-07	22.0	-	-	29-08-07	11.5
	-	-	-	-	-	-	16-10-07	20.4
2008	-	-	-	-	-	-	27-03-08	18.0
	-	-	-	-	-	-	30-05-08	21.0
	-	-	-	-	-	-	29-08-08	13.0
	-	-	-	-	-	-	08-10-08	10.0
2009	-	-	25-03-09	34.1	-	-	26-03-09	6.6
	-	-	25-06-09	27.9	-	-	26-06-09	3.9
	-	-	15-09-09	21.7	-	-	15-09-09	8.0
	-	-	17-11-09	15.1	-	-	17-11-09	3.7
2010	16-03-10	9.0	26-01-10	24.0	26-01-10	33.0	26-01-10	6.2
	21-06-10	11.0	21-06-10	26.0	21-06-10	33.0	28-06-10	10.0
	30-08-10	11.0	30-08-10	34.0	30-08-10	29.0	30-08-10	7.8
	16-11-10	9.9	16-11-10	8.4	16-11-10	32.0	16-11-10	5.2
2011	28-03-11	9.9	24-03-11	22.0	24-03-11	33.0	28-03-11	10.0
	17-05-11	16.0	13-05-11	20.0	12-05-11	50.0	17-05-11	31.0
	26-08-11	14.0	26-08-11	26.0	26-08-11	42.0	26-08-11	14.0
2012	26-03-12	14.0	26-03-12	11.0	26-03-12	49.0	26-03-12	31.0
	11-06-12	30.0	11-06-12	20.0	11-06-12	52.0	11-06-12	9.2
	21-08-12	28.0	27-08-12	14.0	21-08-12	47.0	27-08-12	4.1
	28-11-12	24.0	29-11-12	32.0	29-11-12	58.0	28-11-12	0.3
2013	25-03-13	28.0	25-03-13	89.0	25-03-13	64.0	25-03-13	0.6
	25-06-13	23.0	25-06-13	79.0	25-06-13	26.0	25-06-13	8.7
	26-08-13	19.0	26-08-13	57.0	26-08-13	46.0	27-08-13	9.3
	16-12-13	20.0	16-12-13	17.0	16-12-13	41.0	17-12-13	< 0.2
2014	16-06-14	22.0	16-06-14	44.0	16-06-14	47.0	16-06-14	12.0
2015	19-03-15	22.0	19-03-15	17.0	19-03-15	19.0	19-03-15	16.0
	25-05-15	24.0	25-05-15	31.0	25-05-15	44.0	25-05-15	8.6
	25-08-15	22.0	24-08-15	55.0	24-08-15	43.0	25-08-15	11.0
	10-11-15	14.0	10-11-15	22.0	10-11-15	35.0	10-11-15	3.8
2016	23-05-16	25.0	23-05-16	33.0	23-05-16	34.0	23-05-16	14.0

	25-08-16	12.0	25-08-16	26.0	25-08-16	36.0	26-08-16	8.1
	09-11-16	27.0	09-11-16	36.0	09-11-16	31.0	09-11-16	<0.1

Table 13. Annual average nitrate content in Group III wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	AD1395	ADKK21	AD14525	AD93
Years	**NO_3, average**	**NO_3, average**	**NO_3, average**	**NO_3, average**
2001	-	-	-	11.0
2002	-	-	-	21.7
2003	-	-	-	
2004	-	-	-	34.5
2005		105.2	-	15.5
2006	-	-	-	28.3
2007	**-**	85.6	-	30.3
2008	-	-	-	15.5
2009	**-**	24.7	-	5.6
2010	10.2	23.1	31.8	7.3
2011	13.3	22.7	41.7	18.3
2012	24.0	19.3	51.5	11.1
2013	22.5	60.5	44.3	4.7
2014	22.0	44.0	47.0	12.0
2015	20.5	31.3	35.3	9.9
2016	21.3	31.7	33.7	7.4
Average	**19.1**	**44.8**	**40.7**	**15.5**

Table 14. Nitrate content in Group IV wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

Years	**PAK-169 (K-169)**		**PAK-17 (K-17)**		**PAK-70**	
	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l
2001	19-04-01	8.0	20-06-01	3.7	19-04-01	12.8
	20-06-01	16.8	19-09-01	35.9	20-06-01	19.0
	19-09-01	7.1	28-11-01	14.2	19-09-01	7.1
	28-11-01	10.2	-	-	28-11-01	14.2
2002	06-05-02	18.6	06-05-02	34.5	18-06-02	18.6
	18-06-02	16.4	18-06-02	30.5	02-10-02	15.1

	02-10-02	12.0	02-10-02	22.1	07-11-02	13.3
	07-11-02	9.7	-	-	-	-
2003	23-04-03	24.8	23-04-03	10.2	23-04-03	13.7
	01-07-03	18.6	01-07-03	16.8	01-07-03	15.1
	10-09-03	20.8	10-09-03	20.8	10-09-03	15.1
	04-11-03	23.0	04-11-03	17.3	04-11-03	19.5
2004	16-06-04	18.2	16-06-04	32.3	16-06-04	18.6
	07-09-04	17.7	07-09-04	22.1	07-09-04	15.5
	10-11-04	22.6	10-11-04	44.3	10-11-04	27.5
2005	05-07-05	24.4	05-07-05	35.0	05-07-05	17.3
	24-08-05	22.6	24-08-05	25.2	24-08-05	16.4
	27-10-05	17.3	27-10-05	29.2	27-10-05	15.1
	07-12-05	23.1	07-12-05	26.6	07-12-05	17.6
2006	15-05-06	23.1	15-05-06	27.7	15-05-06	14.1
	14-08-06	17.5	14-08-06	32.1	14-08-06	13.7
	03-10-06	11.7	03-10-06	28.7	03-10-06	10.8
	06-12-06	18.3	06-12-06	18.7	06-12-06	13.6
2007	18-01-07	29.1	18-01-07	13.7	18-01-07	24.8
	26-06-07	30.6	27-06-07	34.5	26-06-07	18.2
	26-09-07	23.9	26-09-07	29.2	26-09-07	16.8
	27-11-07	28.8	27-11-07	21.3	27-11-07	19.0
2008	12-05-08	44.3	12-05-08	40.7	12-05-08	48.7
	15-07-08	31.9	15-07-08	30.7	15-07-08	25.4
	09-10-08	48.7	09-10-08	44.3	09-10-08	32.8
	26-11-08	44.3	26-11-08	53.1	26-11-08	53.1
2009	07-05-09	28.8	07-05-09	44.3	07-05-09	35.0
	01-07-09	27.0	01-07-09	40.7	01-07-09	26.6
	01-10-09	28.3	01-10-09	39.4	01-10-09	27.5
	-	-	12-11-09	37.2	12-11-09	39.9
2010	27-05-10	25.2	27-05-10	27.0	27-05-10	43.8
	04-08-10	18.2	04-08-10	36.3	04-08-10	19.5
	28-09-10	18.2	28-09-10	31.9	28-09-10	20.4
	22-11-10	22.1	22-11-10	26.1	22-11-10	24.8
2011	23-05-11	24.0	23-05-11	26.0	23-05-11	54.0
	18-07-11	19.0	18-07-11	38.0	18-07-11	28.0
	-	-	28-09-11	29.0	28-09-11	19.0

	-	-	08-12-11	17.0	08-12-11	30.0
2012	21-08-12	25.0	20-03-12	25.0	15-03-12	29.0
	-	-	06-06-12	36.0	07-06-12	42.0
	-	-	21-08-12	31.0	21-08-12	20.0
	-	-	27-11-12	18.0	27-11-12	38.0
2013	25-04-13	36.0	25-04-13	48.0	25-04-13	38.0
	25-06-13	31.0	25-06-13	44.0	25-06-13	28.0
	26-08-13	21.0	26-08-13	34.0	26-08-13	18.0
	-	-	24-10-13	24.0	24-10-13	18.0
2014	20-03-14	19.0	20-03-14	24.0	20-03-14	16.0
	27-05-14	24.0	27-05-14	29.0	27-05-14	20.0
	06-11-14	29.0	06-11-14	30.0	06-11-14	22.0
2015	02-03-15	32.0	02-03-15	44.0	02-03-15	35.0
	28-04-15	47.0	28-04-15	39.0	28-04-15	37.0
	26-08-15	28.0	25-08-15	41.0	24-08-15	20.0
	09-12-15	40.0	09-12-15	19.0	08-12-15	23.0
2016	17-02-16	39.0	17-02-16	49.0	18-02-16	44.0
	18-04-16	56.0	18-04-16	56.0	18-04-16	44.0
	17-08-16	42.0	16-08-16	41.0	10-08-16	29.0
	09-11-16	41.0	09-11-16	29.0	09-11-16	30.0

Table 15. Annual average nitrate content in Group IV wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	PAK-169 (K-169)	PAK-17 (K-17)	PAK-70
Years	**NO_3, average**	**NO_3, average**	**NO_3, average**
2001	10.5	17.9	13.3
2002	14.2	29.0	15.7
2003	21.8	16.3	15.9
2004	19.5	32.9	20.5
2005	21.9	29.0	16.6
2006	17.7	26.8	13.1
2007	28.1	24.7	19.7
2008	42.3	42.2	40.0
2009	28.0	40.4	32.3
2010	20.9	30.3	27.1
2011	21.5	27.5	32.8

2012	25.0	27.5	32.3
2013	29.3	37.5	25.5
2014	24.0	27.7	19.3
2015	36.8	35.8	28.8
2016	44.5	43.8	36.8
Average	**25.4**	**30.6**	**24.3**

Table 16. Nitrate content in Group V wells for 2001-2016 years period

(Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	PAPK-10 (PK-10)		**PAA31 (A-1011)**		**PAK-5**	
Years	Date	Nitrate, mg/l	Date	Nitrate, mg/l	Date	Nitrate, mg/l
2001	28-11-01	6.2	-	-	20-06-01	19.9
	-	-	-	-	19-09-01	11.1
	-	-	-	-	28-11-01	9.3
2002	06-05-02	12.0	-	-	06-05-02	20.8
	18-06-02	14.2	-	-	18-06-02	22.6
	02-10-02	19.9	-	-	02-10-02	18.6
	07-11-02	19.5	-	-		
2003	23-04-03	9.3	-	-	23-04-03	17.7
	01-07-03	10.6	-	-	01-07-03	18.6
	10-09-03	8.0	-	-	10-09-03	24.4
	04-11-03	10.2	-	-	04-11-03	19.9
2004	16-06-04	15.1	-	-	16-06-04	21.3
	07-09-04	22.1	-	-	07-09-04	23.9
	10-11-04	10.2	-	-	10-11-04	19.5
2005	05-07-05	19.5	-	-	-	-
	24-08-05	18.2	-	-	-	-
	27-10-05	20.8	-	-	-	-
	06-12-05	31.3	-	-	-	-
2006	15-05-06	25.6	18-04-06	22.3	-	-
	14-08-06	17.1	-	-	-	-
	03-10-06	14.1	-	-	-	-
	06-12-06	70.9	-	-	-	-
2007	18-01-07	67.3	26-06-07	23.5	18-01-07	21.2
	26-06-07	31.0	26-09-07	18.6	26-06-07	21.3
	25-09-07	17.7	27-11-07	27.5	26-09-07	20.4

	26-11-07	70.0	-	-	27-11-07	20.4
2008	12-05-08	53.1	-	-	12-05-08	25.7
	16-07-08	51.2	-	-	15-07-08	23.6
	08-10-08	66.4	-	-	09-10-08	28.8
	27-11-08	44.3	-	-	26-11-08	30.1
2009	07-05-09	36.3	07-05-09	37.6	01-07-09	16.8
	30-06-09	24.8	08-07-09	33.7	12-11-09	24.8
	01-10-09	25.7	01-10-09	30.1	-	-
	12-11-09	39.0	12-11-09	31.9	-	-
2010	26-05-10	32.8	27-05-10	30.6	27-05-10	27.9
	27-07-10	30.1	03-08-10	27.5	03-08-10	26.1
	29-09-10	18.6	28-09-10	25.7	28-09-10	27.0
	18-11-10	28.3	22-11-10	20.4	22-11-10	24.8
2011	19-05-11	28.0	23-05-11	32.0	23-05-11	29.0
	12-07-11	33.0	19-07-11	28.0	08-12-11	26.0
	28-09-11	38.0	29-09-11	24.0	-	-
	08-12-11	30.0	08-12-11	25.0	-	-
2012	15-03-12	24.0	20-03-12	28.0	15-03-12	29.0
	07-06-12	25.0	07-06-12	36.0	07-06-12	29.0
	21-08-12	20.0	21-08-12	28.0	21-08-12	29.0
	22-11-12	35.0	27-11-12	34.0	25-11-12	24.0
2013	30-04-13	29.0	25-04-13	35.0	25-04-13	25.0
	26-06-13	25.0	25-06-13	34.0	25-06-13	29.0
	27-08-13	18.0	26-08-13	30.0	22-08-13	30.0
	23-10-13	16.0	24-10-13	32.0	22-11-13	6.0
2014	13-03-14	36.0	13-03-14	23.0	20-03-14	14.0
	28-05-14	16.0	27-05-14	25.0	27-05-14	25.0
	12-11-14	27.0	06-11-14	24.0	09-11-14	21.0
2015	26-02-15	59.0	26-02-15	33.0	02-03-15	48.0
	27-04-15	25.0	28-04-15	37.0	28-04-15	25.0
	25-08-15	20.0	24-08-15	23.0	25-08-15	25.0
	08-12-15	57.0	08-12-15	23.0	08-12-15	21.0
2016	18-02-16	37.0	17-02-16	27.0	17-02-16	15.0
	20-04-16	35.0	18-04-16	48.0	18-04-16	30.0
	17-08-16	55.0	15-08-16	41.0	16-08-16	23.0
	08-11-16	26.0	09-11-16	43.0	26-11-16	21.0

Table 17. Annual average nitrate content in Group V wells for 2001-2016 years period (Data source: keskkonnainfo. Nitraaditundliku ala põhjavee seire)

	PAPK-10 (PK-10)	PAA31 (A-1011)	PAK-5
Years	**NO_3, average**	**NO_3, average**	**NO_3, average**
2001	6.2	-	13.4
2002	16.4	-	20.7
2003	9.5	-	20.2
2004	15.8	-	21.6
2005	22.5	-	-
2006	31.9	22.3	-
2007	46.5	23.2	20.8
2008	53.8	-	27.1
2009	31.5	33.3	20.8
2010	27.5	26.1	26.5
2011	32.3	27.3	27.5
2012	26.0	31.5	27.8
2013	22.0	32.8	22.5
2014	26.3	24.0	20.0
2015	40.3	29.0	29.8
2016	38.3	39.8	22.3
Average	**27.9**	**28.9**	**22.9**