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OSAMAT – post-project environmental monitoring in 2020

Interim report

July 2020

National Institute of Chemical Physics and Biophysics

1. Foreword

A contract between Eesti Energia AS and National Institute of Chemical Physics and Biophysics was signed in 05.05.2020 to conduct a follow-up monitoring of pilot road sections of OSAMAT-program in 2020.

Purpose of the contract was to evaluate and analyze environmental status of Narva-Mustajõe and Simuna-Vaiatu pilot road sections constructed by using partly oil shale ash (OSA). Second objective of the work is to verify possible environmental effects of utilizing the OSA in larger scale.

The environmental follow-up program consisted of analyzing of surface water and soil samples in order to validate the release of potentially toxic trace elements and selected anions from pilot road structures to the environment. Based on the results of follow-up monitoring it is possible give scientific data for assessing the environmental impacts and evaluation of potential risks associated with construction of roads with OSA material.

The interim report presents the results of environmental monitoring campaign of the pilot sections conducted in 17.05.2020.

2. Introduction

The preferred management option for ash flow from industrial combustion of solid fuels is utilization rather than landfilling. The production divisions of the Eesti Energia Narva power plants utilize Estonian oil shale (kukersite) to produce a total of about 9 TWh of electricity each year. At present, two different oil shale combustion processes are in use: pulverized firing (PF) and circulating fluidized-bed (CFB) combustion technologies. Due to high mineral content of kukersite (45-47 mass%) about six million tons of oil shale ash (OSA) is produced annually [1], which is mainly deposited in ash fields near to power plants. The reasons for low-level utilization of OSA in Estonia include inconsistency in the quality of OSA, high cost of transportation and partly by the fact that according to Estonian legislation OSA is considered as a hazardous waste [2] due to highly alkaline reaction in contact with water. At the moment the OSA deposits are huge and contain high volumes of important raw materials for civil engineering purposes [3].

The strategy of utilizing combustion ash in the entire world is in constant change. On one hand, it is advantageous to make commercial use of the by-products of energy production. On the other hand, the large-scale usage of very complex wastes like OSA raises questions about environmental impact of such activities. Thus, it is essential to monitor the environmental aspects of the process where OSA is brought back into the nature, including the fate of toxic elements.

In general, for risk assessments connected with utilizing of ash in road construction, it is important to know which compounds could be released into the environment. The leaching of soluble constituents upon contact with water is regarded as a main mechanism of release, which results in a potential risk to the environment. OSA contains major matrix elements such as Ca, Si, Al, and Fe together with significant amount of minor elements, *e.g*. Mg, K, P, S and negligible amounts of trace elements [4].

The release of potentially harmful compounds, such as heavy metals from OSA is relatively low and that the OSA could be safe for use civil engineering [5]. Still, the release of toxic heavy metals is strongly pH dependent [6] at conditions prevailing in soils and the release of toxic substances could become an environmental concern. Beneficial use of the OSA in road construction requires better knowledge of leaching of soil-ash systems in order to evaluate mobilization potential of metals during soil-ash water interaction. Therefore it is essential to monitor content of hazardous elements in water and soil in areas of large-scale utilization of OSA whenever possible.

The current environmental quality criteria for OSA to be utilized in bulk quantities are rather strict in Estonia. The follow-up monitoring program evaluates the impact to surrounding environment from a road sections constructed partly with OSA material from Narva Power Plants by comparing the content of selected parameters to natural background and legal limits.

3. Materials and methods

The pilot sections were constructed on two roads in Estonia in Narva-Mustajõe and Simuna-Vaiatu road (see osamat.ee). In the road sections three types of OSA from Baltic Power Plant were used

- Cyclone ash from oil shale pulverized firing boiler (Cyclone PF) 5% mixed with cement 5% + aggregates (oil shale mining waste aggregate and milled asphalt concrete)
- Ash from the electrostatic precipitator of oil shale pulverized firing boiler (EF PF) 6% mixed with cement 3% + aggregates (oil shale mining waste aggregate and milled asphalt concrete)
- Ash from the 1st field of electrostatic precipitators of oil shale circulated fluidized bed boiler (EF CFB) 9% mixed only with aggregate (oil shale mining waste aggregate and milled asphalt concrete)
- Complex stabilization (traditional method) with composite cement CEM II / B-M (T-L) 42.5R.

The recipes and stabilization methods used in road sections are described in progress report no. 4 of Osamat project (2013).

3.1 Sampling

Current follow-up monitoring campaign was carried out in both pilot sections in Narva-Mustajõe and Simuna-Vaiatu road in 17.05.2020.

The soil-sampling was carried out by the specialist from Estonian, Latvian & Lithuanian Environment OÜ by the accredited soil sampling method ISO 10381 (Accreditation see Appendix 1). Soil samples were taken from the depth of 0.1-0.2 m. Sampling reports are presented in Appendix 2. Exact co-ordinates of sampling points were following (locations see Figures 1 and 2):

NM2020-1	N: 59.330531, E: 27.945102
NM2020-2	N: 59.333663, E: 27.957735
NM2020-3	N: 59.335496, E: 27.964994
SV2020-1	N: 59.024400, E: 26.418641
SV2020-2	N: 59.022741, E: 26.422030
SV2020-3	N: 59.021018, E: 26.424070
SV2020-3	N: 59.019384, Y: 26.425163

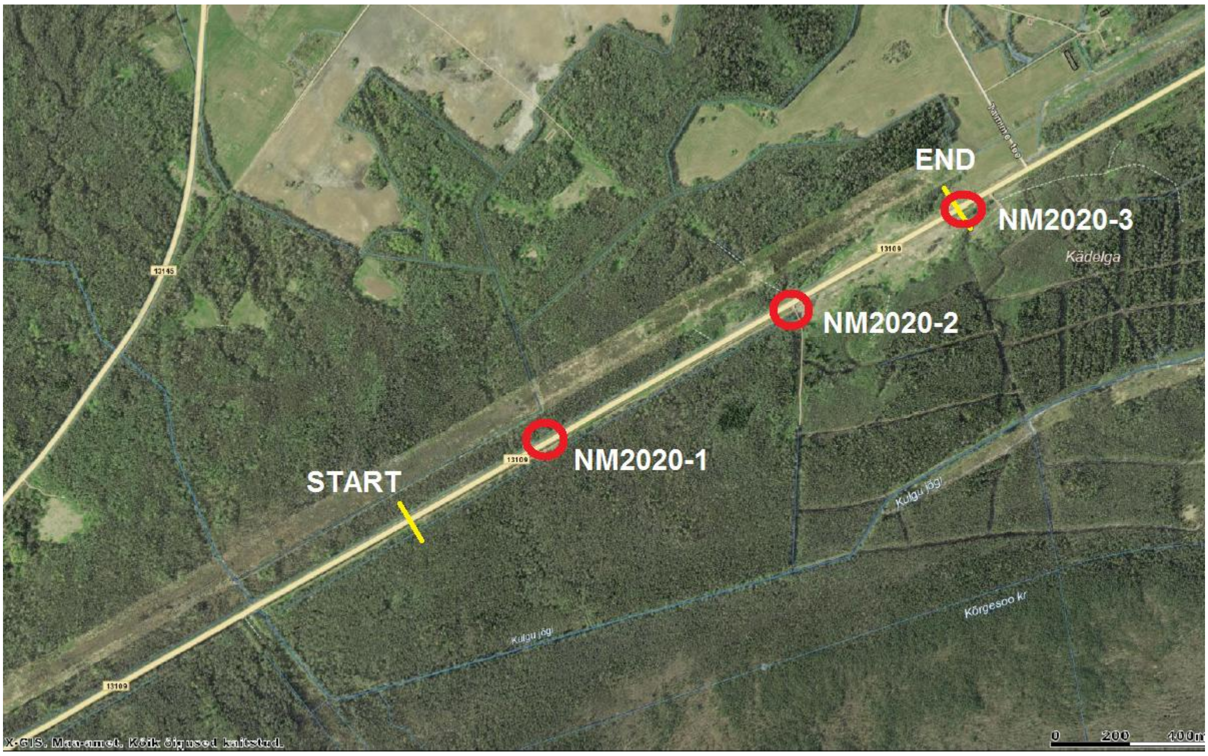


Figure 1. Locations of soil sampling points in Narva-Mustajõe pilot section.

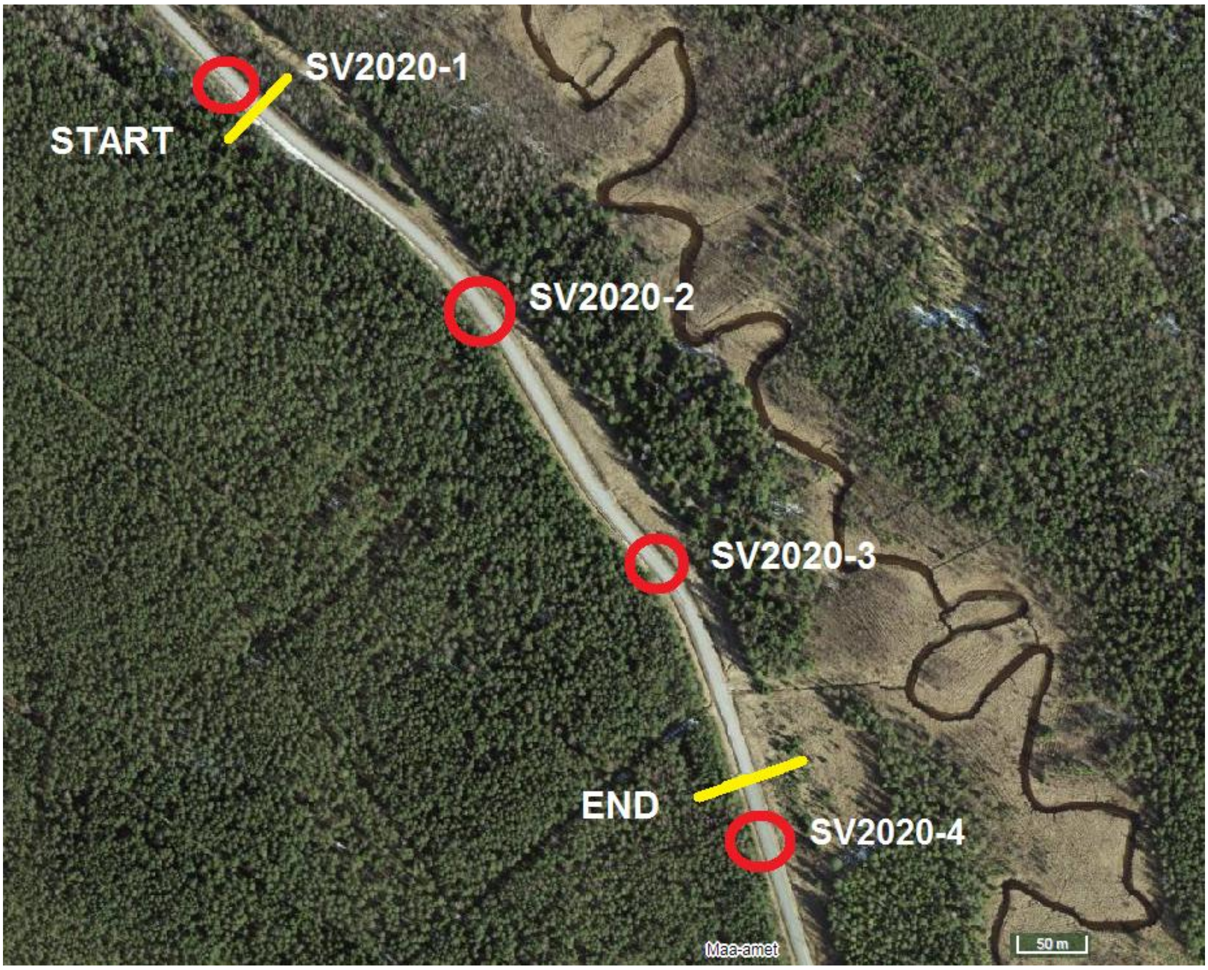


Figure 2. Locations of soil sampling points in Simuna-Vaiatu pilot section.

Surface water samples were taken by the specialist from Estonian, Latvian & Lithuanian Environment OÜ by the accredited method EN 5667 (Attestation No. 1394/16, see Appendix 1). Sampling campaign was conducted in 17.05.2020. Locations of surface water sampling points in Narva-Mustajõe and Simuna-Vaiatu pilot sections are presented in Figure 3 and 4. It was not possible to take surface water samples in points stated in the terms of reference due to dry season. Sampling reports are presented in Appendix 2. Exact co-ordinates of sampling points were following (locations see Figures 3 and 4):

NM-1	N: 59,329231	E: 27,939858
NM-2	N: 59,332394	E: 27,953106
NM-3	N: 59,333199	E: 27,956796
SV-1	N: 59,024206	E: 26,418978
SV-2	N: 59,022217	E: 26,422836
SV-3	N: 59,020697	E: 26,424561

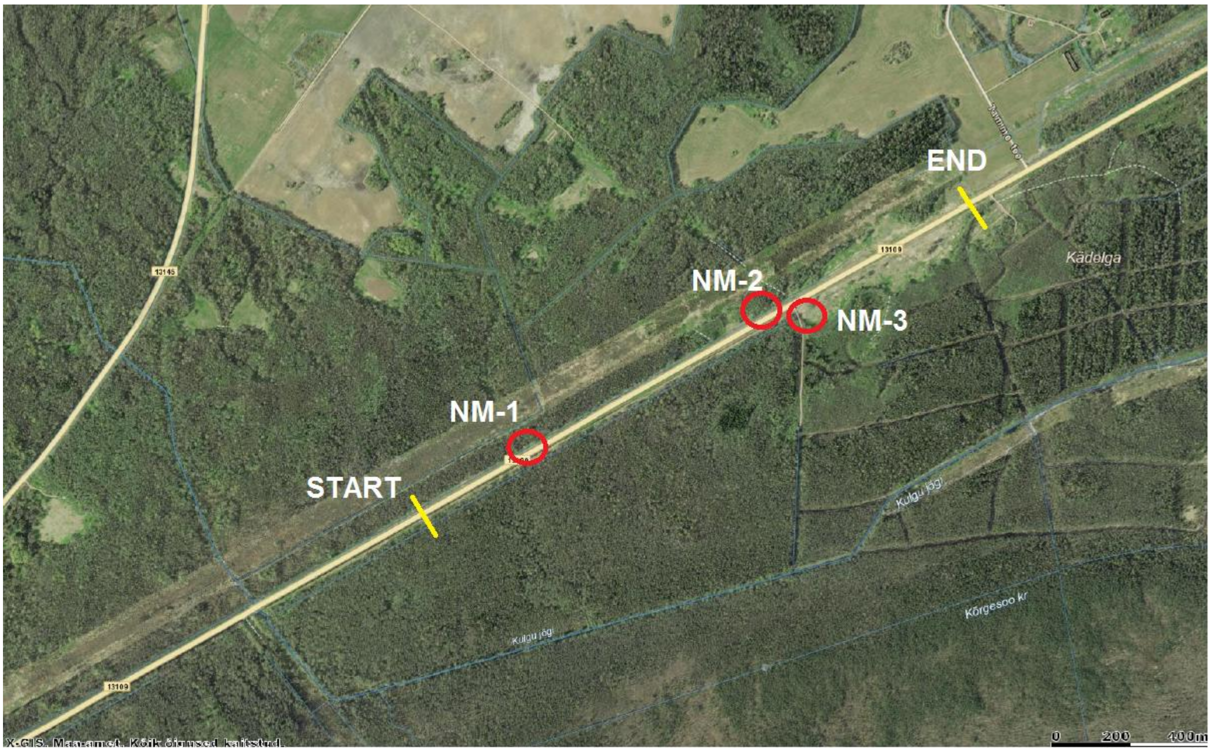


Figure 3. Locations of surface water sampling points in Narva-Mustajõe pilot section.

Figure 4. Locations of surface water sampling points in Simuna-Vaiatu pilot section.

3.2 Meteorological data

Data for daily precipitation and average daily temperature in May 2020 is obtained from the following closest meteorological stations to the pilot sections (Estonian Weather Service web page: www.ilmateenistus.ee):

For Narva-Mustajõe pilot section - Narva station N 59°23´22´´ E 28°06´33´´, distance ca 10 km,
For Simuna-Vaiatu pilot section – Väike-Maarja N 59°08´29´´ E 26°13´51´´, distance ca 10 km.

The stations are equipped with automatic precipitation sensors and the observation data is presented graphically in Figure 5.

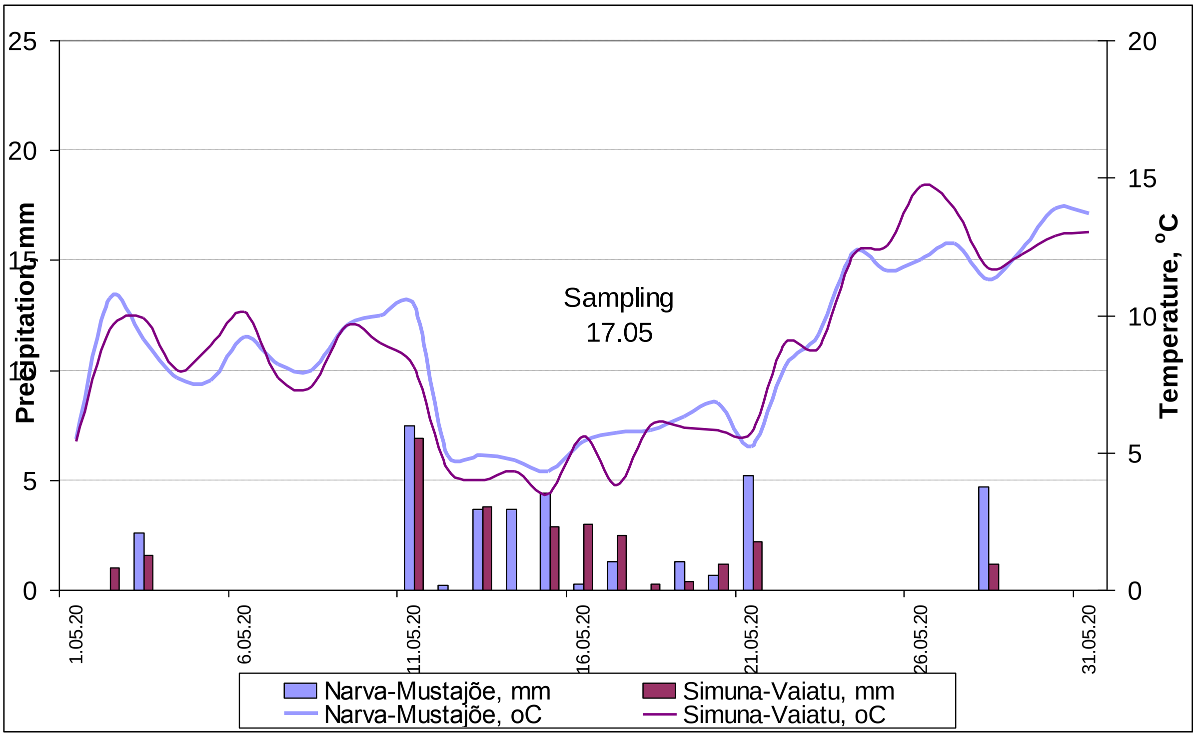


Figure 5. Daily precipitation and average daily temperature in pilot road section areas prior to sampling in May 2020
Data from:(http://www.ilmateenistus.ee/ilm/ilmavaatlused/vaatlusandmed/oopaevaandmed).

As can be seen from Figure 5 the surface water sampling was carried out in a period of relatively high precipitation and low surface evaporation.

3.3 Analysis of soil samples

Soil samples were analyzed in the laboratory of GBA Gesellschaft für Bioanalytik mbH (Pinneberg, Germany) by accredited methods (see

Table 1 and Appendix 1). Dry weight was determined by ISO 11465 with limit of quantification 0.40 wt%. Soil samples were digested according to EN 13657 and the determination of trace elements was carried out in diluted acid extracts of the samples according to following accredited methods (see Appendix 1):

Table 1. Selected trace elements analyzed in soil samples in the laboratory of GBA.

Element	Unit	Limit of quantification	Uncertainty (%)	Method
Mercury, Hg	mg/kg_{DW}	0.10	3.00	EN ISO 16171
Cadmium, Cd	mg/kg_{DW}	0.10	7.60	EN ISO 16171
Lead, Pb	mg/kg_{DW}	1.0	7.20	EN ISO 16171
Nickel, Ni	mg/kg_{DW}	1.0	7.60	EN ISO 16171
Antimony, Sb	mg/kg_{DW}	1.0	5.00	EN ISO 16171
Arsenic, As	mg/kg_{DW}	1.0	7.20	EN ISO 16171
Barium, Ba	mg/kg_{DW}	1.0	5.80	EN ISO 16171
Chromium, Cr total	mg/kg_{DW}	1.0	8.70	EN ISO 16171
Copper, Cu	mg/kg_{DW}	1.0	nd	EN ISO 16171
Molybdenum, Mo	mg/kg_{DW}	1.0	4.40	EN ISO 16171
Vanadium, V	mg/kg_{DW}	1.0	nd	EN ISO 16171
Zinc, Zn	mg/kg_{DW}	1.0	2.60	EN ISO 16171
Selenium, Se	mg/kg_{DW}	2.0	8.60	EN ISO 16171

nd – no data.

3.4 Analysis of surface water samples

Following parameters were measured *in-situ* by accredited methods during the sampling episodes (see Table 2, Appendix 1):

Table 2. Indicative parameters of surface water samples determined *in situ.*

Parameter	Unit	Uncertainty, *k=2*
pH		0.2
Electric conductivity, EC	µS/cm	0.5%
Temperature	^{o}C	0.2

YSI Professional Plus Multi-Parameter Water Quality Meter was used.

Following anions were analyzed in the laboratory of GBA Gesellschaft für Bioanalytik mbH (Pinneberg, Germany) accredited methods (see Table 3, Appendix 1)

Table 3. Anions quantified in surface water samples in the laboratory of GBA.

Anion	Unit	Limit of quantification	Method
Chloride	mg/L	0.6	ISO 10304-1:
Sulfate	mg/L	0.5	ISO 10304-1:
Fluoride	mg/L	0.15	ISO 10304-1:

Trace elements in filtrated water samples (0.45 µm) were analyzed in the laboratory of GBA Gesellschaft für Bioanalytik mbH (Pinneberg, Germany) by following accredited methods (see Table 4, Appendix 1).

Table 4. Selected trace elements analyzed in surface water samples in the laboratory of GBA.

Element	Unit	Limit of quantification	Uncertainty (%)	Method
Mercury, Hg	mg/L	0.00020	4.8	EN ISO 17294
Cadmium, Cd	mg/L	0.00030	5.3	EN ISO 17294
Lead, Pb	mg/L	0.0010	4.8	EN ISO 17294
Nickel, Ni	mg/L	0.0010	6.5	EN ISO 17294
Antimony, Sb	mg/L	0.0010	nd	EN ISO 17294
Arsenic, As	mg/L	0.00050	5.3	EN ISO 17294
Barium, Ba	mg/L	0.00050	nd	EN ISO 17294
Chromium, Cr total	mg/L	0.0010	7.2	EN ISO 17294
Copper, Cu	mg/L	0.0010	6.9	EN ISO 17294
Molybdenum, Mo	mg/L	0.0010	nd	EN ISO 17294
Vanadium, V	mg/L	0.0010	nd	EN ISO 17294
Zinc, Zn	mg/L	0.0050	8.4	EN ISO 17294

nd – no data.

3.5 Legal limits

Results of the analysis were compared against environmental quality standards. Among measured parameters there are no limit value for the temperature, electric conductivity, content of chloride and sulfate as well as content of following trace elements such as vanadium (V), antimony (Sb) and molybdenum (Mo) in surface water according to Estonian legal regulations. For these parameters the limit values for drinking and groundwater were used as indicative values (except V and Sb).

Selected trace elements in soil samples: (Table 5):
Regulation No 26 of the Estonian Ministry of Environment (adopted in 28.06.2019), Ohtlike ainete sisalduse piirväärtused pinnases (*Concentration limits of hazardous substances in the soil*), Riigi Teataja, I 2019, 04.07.2019, 6 (in Estonian).

Table 5. Target and permitted values of selected trace elements in soil.

Element	Unit	Target value*	Permitted value** in residential area	Permitted value** in industrial area
As	mg/kg	20	30	50
Pb	mg/kg	50	300	600
Cd	mg/kg	1	5	20
Cr	mg/kg	100	300	800
Cu	mg/kg	100	150	500
Ni	mg/kg	50	150	500
Hg	mg/kg	0.5	2	10
Zn	mg/kg	200	500	1000

Element	Unit	Target value*	Permitted value** in residential area	Permitted value** in industrial area
Sb	mg/kg	10	20	100
Ba	mg/kg	500	750	2000
Mo	mg/kg	10	20	200
V	mg/kg	50	300	1000

* target value shows the content below which the soil status is considered good.
** permitted value shows the content above which the soil is considered contaminated.

Electric conductivity, chloride and sulfate content in surface water are not regulated. Therefore the regulation on drinking water quality was used for indicative purposes (Table 6):

Regulation No 61 of the Ministry of Social Affairs (adopted 24.09.2019), Joogivee kvaliteedi- ja kontrollinõuded ning analüüsimeetodid (*Quality and control requirements for drinking water and methods of analysis*), Riigi Teataja I, 26.09.2019, 2 (in Estonian).

Table 6. Indication of limit values in drinking water.

Parameter	Unit	Limit value
Electric conductivity	µS/cm	2500
Temperature	^{o}C	-
Chloride	mg/L/	250
Sulfate	mg/L	250

pH in surface water has to be in a range of 6-9 in order to consider the status of the water body to be good:

Regulation No 19 of the Estonian Ministry of Environment (adopted in 16.04.2020), Pinnaveekogumite moodustamise kord ja nende pinnaveekogumite nimestik, mille seisundiklass tuleb määrata, pinnaveekogumite seisundiklassid ja seisundiklassidele vastavad kvaliteedinäitajate väärtused ning seisundiklasside määramise kord (*The procedure for the formation of surface water bodies and the list of these surface water bodies, which class status shall be determined, the status of surface water bodies and the quality indicators for the status of the corresponding water bodies and the procedure for determining the status*), Riigi Teataja I, 21.04.2020, 61 (in Estonian)

Content of priority substances in surface water samples (Table 7):

Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy..

Table 7. Environmental quality standards of priority hazardous metals in surface water.

Name of substance	Unit	AA-EQS*	MAC-EQS**
Hg	mg/L		0.00007
Cd**	mg/L	0.00015	0.0009
Pb	mg/L	0.0012****	0.014
Ni	mg/L	0.004****	0.034

* annual average value of the environmental quality standard;
** maximum allowable concentration of the environmental quality standard;

*** For Cd the EQS values vary depending on the hardness of the water. Hardness of the water was considered 100 to < 200 mg $CaCO_3$/L – class 4 [7];
**** bioavailable concentration.

Content of selected hazardous substances in surface water samples (Table 8)**:**
Regulation No 28 of the Estonian Ministry of Environment (adopted in 27.07.2019), Prioriteetsete ainete ja prioriteetsete ohtlike ainete nimekiri, prioriteetsete ainete, prioriteetsete ohtlike ainete ja teatavate muude saasteainete keskkonna kvaliteedi piirväärtused ning nende kohaldamise meetodid, vesikonnaspetsiifiliste saasteainete keskkonna kvaliteedi piirväärtused, ainete jälgimisnimekirjaga seotud tegevused (*The environmental quality limit values for the surface water*), Riigi Teataja I, 19.06.2020, 7 (in Estonian).

Table 8. Environmental quality standards of hazardous substances in surface water.

Name of substance	Unit	MAC-EQS
Fluoride	mg/L	1.5
As	mg/L	0.01
Ba	mg/L	0.1
Cr total	mg/L	0.005
Cu	mg/L	0.015

Content of molybdenum in surface water samples was indicatively compared to limit value in groundwater :0.07 mg/L according to Regulation No 39 of the Estonian Ministry of Environment (adopted in 04.09.2019), Ohtlike ainete põhjavee kvaliteedi piirväärtused (*The environmental quality limit values of the hazardous substances in groundwater*), Riigi Teataja I, 06.09.2019, 31 (in Estonian).

3.6 Previous monitoring

Whenever possible the results of previous monitoring programs were used to obtain natural background concentrations and to analyze the trends in contents of selected parameters in soil and surface water samples.

The results of contents of selected elements in soil samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections published in monitoring program carried out in 2012 [8], 2014-2015 [9] and 2018 [11] are presented in Appendix 3. The results of 2012 sampling can be considered as a natural background content of selected elements in the soil of pilot sections.

Surface water sampling has been previously carried out in Narva-Mustajõe and Simuna-Vaiatu pilot sections since 2011 (Figure 6). The results of previous sampling episodes are presented in Appendix 3 [8, 9, 11]. The results from year 2011 can be considered as a natural background of surface water in an area.

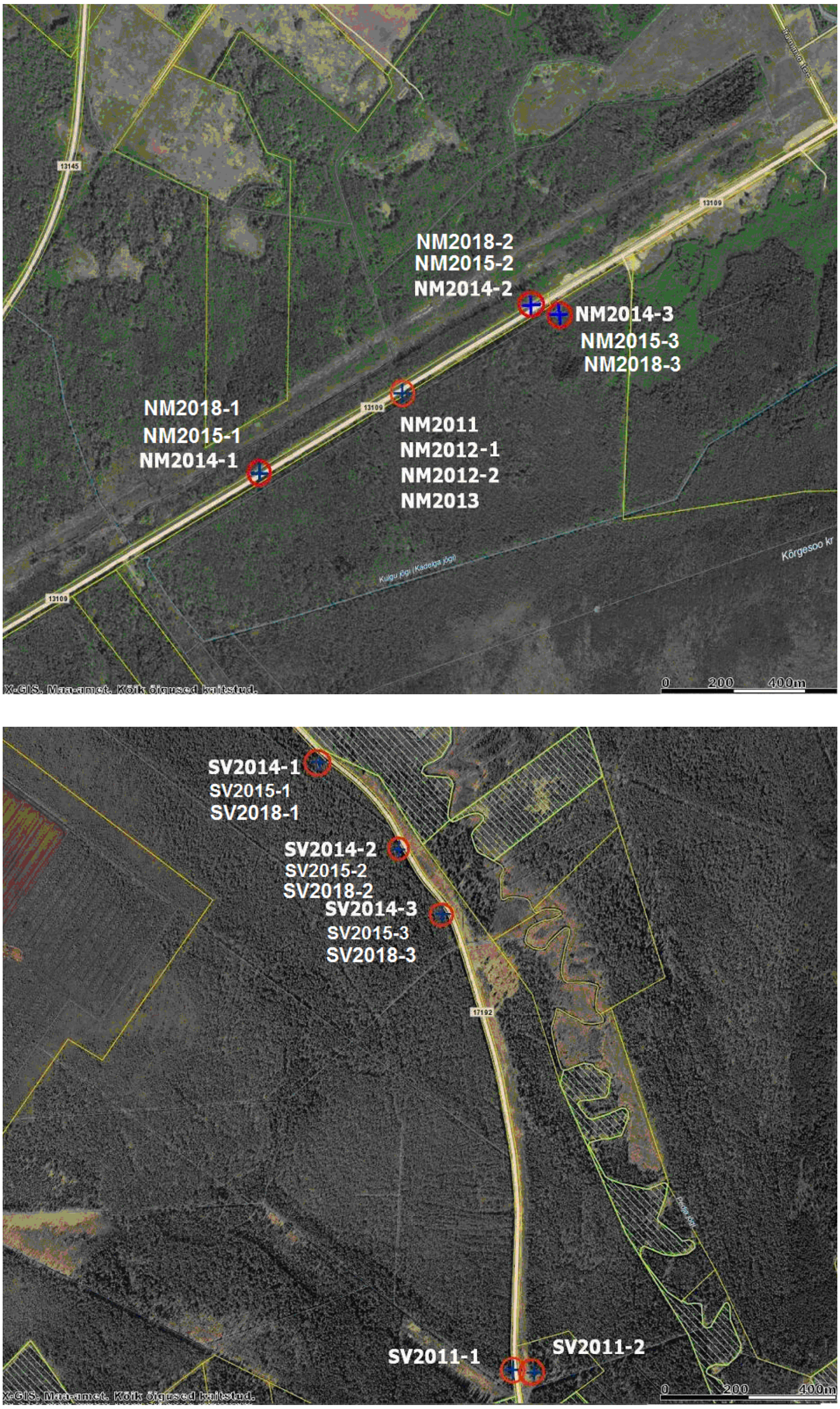


Figure 6. Surface water sampling points in previous sampling campaigns in Narva-Mustajõe (above) and Simuna-Vaiatu pilot sections (below),

4. Results of current sampling

4.1 Soil

Soil samples in current sampling campaign were taken in 17.05.2020.

- Locations see Figures 1 and 2,
- Results see Table 9 and 10.
- Sampling Plan see Appendix 2 (Proovivõtukava, *in Estonian*)
- Sampling protocols see Appendix 2,
- Chain of Custody see Appendix 2
- Laboratory Test Report No.: 2020P515909 / 1 see Appendix 2.

Table 9. Contents of selected elements in Narva-Mustajõe soil samples

Date			17.05.2020		
Sample name			NM-1	NM-2	NM-3
Parameter	Unit				
Sampling depth	m		0.1	0.15-0.2	0.2-0.25
Dry weight	mass-%	-	83.9	81.7	89.4
Element		TV*			
Arsenic, As	mg/kg	20	3.9	4.9	1.9
Lead, Pb	mg/kg	50	12	13	8.1
Cadmium, Cd	mg/kg	1	<0.10	0.12	<0.10
Chrome, Cr sum	mg/kg	100	14	18	8.2
Copper, Cu	mg/kg	100	11	11	8.2
Nickel, Ni	mg/kg	50	9.7	12	5.3
Mercury, Hg	mg/kg	0.5	<0.10	<0.10	<0.10
Zinc, Zn	mg/kg	200	38	43	25
Antimony, Sb	mg/kg	10	<1.0	<1.0	<1.0
Barium, Ba	mg/kg	500	73	93	27
Molybdenum, Mo	mg/kg	10	1.0	<1.0	<1.0
Vanadium, V	mg/kg	50	19	32	12
Selenium, Se	mg/kg	1	<2.0	<2.0	<2.0

Table 10. Contents of selected elements in Simuna-Vaiatu soil samples

Date			17.05.2020			
Sample name			SV-1	SV-2	SV-3	SV-4
Parameter	Unit					
Sampling depth	m		0.25-0.3	0.2-0.25	0.15-0.2	0.15-0.2
Dry weight	mass-%	-	90.1	92.4	89.5	92.1
Element		TV*				
Arsenic, As	mg/kg	20	2.3	2.6	2.4	2.2
Lead, Pb	mg/kg	50	6.0	6.0	6.5	4.7
Cadmium, Cd	mg/kg	1	<0.10	<0.10	<0.10	<0.10
Chrome, Cr sum	mg/kg	100	6.7	9.0	7.2	13
Copper, Cu	mg/kg	100	6.5	7.8	7.0	4.7
Nickel, Ni	mg/kg	50	3.8	6.0	5.3	3.9
Mercury, Hg	mg/kg	0.5	<0.10	<0.10	<0.10	<0.10
Zinc, Zn	mg/kg	200	18	21	17	16
Antimony, Sb	mg/kg	10	<1.0	<1.0	<1.0	<1.0
Barium, Ba	mg/kg	500	27	54	27	21
Molybdenum, Mo	mg/kg	10	<1.0	<1.0	<1.0	<1.0
Vanadium, V	mg/kg	50	10	14	.12	8.6
Selenium, Se	mg/kg	1	<2.0	<2.0	<2.0	<2.0

4.2 Surface water

Surface water samples in current sampling campaign were taken in 17.05.2020
Locations see Figures 3 and 4. It was not possible to take water samples as planned because of lack of water in ditches.
- Results are presented in Tables 11-13.
- Sampling protocols see Appendix 2,
- Laboratory Test Report No.: 2020P514719 / 1 see Appendix 2.

Table 11. Indicative parameters of surface water samples from Narva-Mustajõe and Simuna-Vaiatu pilot sections in 2020, comparison with indicators and natural background level. Sampling site locations are presented in Figure 3Figure .

Narva-Mustajõe sample name				NM-1		NM-2		NM2-3	
Date			27.07.11	17.05		17.05		17.05	
Parameter	Unit	Indicative value	Natural background						
pH		range 6-9	7.41	7.9		7.56		7.77	
Electric conductivity	µS/cm	max 2500	1034	564		497		546	
Chloride	mg/L/	max 250	44	21		118		3.8	
Sulfate	mg/L	max 250	<5	26		13		<0.5	
Fluoride	mg/L	max 1.5	nd	0.49		0.24		0.3	

Simuna-Vaiatu sample name				SV-1		SV-2		SV-3	
Date			27.07.11	17.05		17.05		17.05	
Parameter	Unit	Indicative value	Natural background						
pH		range 6-9	7.58	7.32		7.02		7.51	
Electric conductivity	µS/cm	max 2500	435	454		374		68	
Chloride	mg/L/	max 250	5.3	4.4		8.0		2.3	
Sulfate	mg/L	max 250	<5	42		15		3.0	
Fluoride	mg/L	max 1.5	nd	0.15		0.3		<0.15	

nd – no data

Table 12. Trace elements in filtrated (0.45 μm) surface water samples from Narva-Mustajõe pilot section in 2020 and comparison with EQS and available background level.

Sample name				NM-1		NM-2		NM-3	
Date			27.07.11	17.05		17.05		17.05	
Element	Unit	MAC-EQS*	Natural back-ground**						
Hg	mg/L	0.00007	nd	<0.00020		<0.00020		<0.00020	
Cd	mg/L	0.0009	nd	<0.00030		<0.00030		<0.00030	
Pb	mg/L	0.014	0.0077	<0.0010		<0.0010		<0.0010	
Ni	mg/L	0.034	nd	<0.0010		<0.0010		<0.0010	
As	mg/L	0.01	0.0081	0.00060		<0.00050		0.00074	
Ba	mg/L	0.1	**0.36*** **	**0.11**		0.050		0.053	
Cr sum	mg/L	0.005	0.78	<0.0010		<0.0010		<0.0010	
Cu	mg/L	0.015	nd	<0.0010		<0.0010		<0.0010	
Zn	mg/L	0.01	nd	<0.0050		<0.0050		<0.0050	
Mo	mg/L		0.00066	0.0012		<0.0010		<0.0010	
Sb	mg/L		nd	<0.0010		<0.0010		<0.0010	
V	mg/L		0.0013	<0.0010		<0.0010		<0.0010	

nd – no data
* MAC-EQS for priority substances Directive 2013/39/EU, other hazardous substances Regulation No 49 of the Estonian Ministry of Environment;
**2011 sampling episode (non-filtrated sample);
*** Sample NM-0 taken in 21.07.2015 for natural background level outside the pilot section area

Table 13. Trace elements in filtrated (0.45 μm) surface water samples from Simuna-Vaiatu pilot section in 2020 and comparison with EQS and available background level.

Sample name				SV-1		SV-2		SV-3	
Date			27.07.11	17.05		17.05		17.05	
Element	Unit	MAC-EQS*	Natural back-ground**						
Hg	mg/L	0.00007	nd	<0.00020		<0.00020		<0.00020	
Cd	mg/L	0.0009	nd	<0.00030		<0.00030		<0.00030	
Pb	mg/L	0.014	0.0056	<0.0010		<0.0010		<0.0010	
Ni	mg/L	0.034	nd	<0.0010		<0.0010		<0.0010	
As	mg/L	0.01	0.0009	0.00095		0.00078		<0.0005	
Ba	mg/L	0.1	nd	0.029		0.033		0.011	
Cr sum	mg/L	0.005	<0.0005	<0.0010		<0.0010		<0.0010	
Cu	mg/L	0.015	nd	<0.0010		<0.0010		<0.0010	
Zn	mg/L	0.01	nd	0.0064		<0.0050		<0.0050	
Mo	mg/L		0.00014	<0.0010		<0.0010		<0.0010	
Sb	mg/L		nd	<0.0010		<0.0010		<0.0010	
V	mg/L		0.0011	<0.0010		<0.0010		<0.0010	

nd – no data

* MAC-EQS for priority substances Directive 2013/39/EU, other hazardous substances Regulation No 49 of the Estonian Ministry of Environment;

**2011 sampling episode (non-filtrated sample);

*

5. Summary of the results and trends

During the course of the environmental monitoring in May 2020 following samples were collected and analyzed in the pilot sections of Narva-Mustajõe and Simuna-Vaiatu roads:

Seven soil samples and six surface water samples (see p. 3.1). Sampling reports as well as the results of analysis are presented in Appendix 2.

5.1 Soil

Soil samples were taken from the banks of both pilot road sections at depth 0.1-0.25 m in 17.05.2020. The content of trace elements in soil samples was compared to the legal limits and natural background level. Content of all trace elements was below target values set by the national regulation[1] in all samples.

In following tables the content of trace elements in composite sample taken in 2012 and mean content of elements in the soil samples taken in 2014, 2015, 2018 and 17.05.2020 are compared (Tables 14 and 15). For the sake of clarity also the mean content of the trace elements in Estonian soil is presented.

[1] No 38 of the Estonian Ministry of Environment (adopted in 11.08.2010), Ohtlike ainete sisalduse piirväärtused pinnases (Concentration limits of hazardous substances in the soil), Riigi Teataja, I 2010, 57, 373 (In Estonian)

Table 14. Average content of selected elements (mg/kg$_{dry}$) in Estonian soil according to literature compared to average content in Narva-Mustajõe soil samples.

		Previous monitoring				Current monitoring
Element	Estonian soil mean	Narva-Mustajõe composite 30.05.12	Narva-Mustajõe mean (n=3) 22.07.14	Narva-Mustajõe mean (n=3) 22.07.15	Narva-Mustajõe mean (n=6) 18.09. & 04.11.18	Narva-Mustajõe mean (n=3) 17.05.20
As	nd.	4.6	6.0	2.9	2.4	3.6
Pb	16	13	11.3	10.0	8.9	11.0
Cd	0.4	<0.2	0.1	0.12	<0.1	0.1
Cr_{sum}	42	18	15.5	7.4	6.8	13.4
Cu	11	<10	10.8	7.8	11.8	10.1
Ni	22	10	9.3	5.1	4.9	9.0
Hg	0.03	<0.1	<0.1	<0.1	<0.1	<0.1
Zn	37	40	39.7	35.7	22.7	35.3
Sb	nd	<0.5	<1.0	<1.0	<1.0	<1.0
Ba	383	76	86	35.8	46.7	64
Mo	1.3	<2	2.3	<1.0	<1.0	0.4
V	44	34	22.3	12.2	10.8	21.0
Se	nd	<1	<2.0	<2.0	<2.0	<2.0

nd – no data.

Table 15. Average content and range of selected elements (mg/kg$_{dry}$) in Estonian soil compared to average content in Simuna-Vaiatu soil samples.

		Previous monitoring				Current monitoring
Element	Estonian soil mean	Simuna-Vaiatu composite 30.05.12	Simuna-Vaiatu mean (n=2) 22.07.14	Simuna-Vaiatu mean (n=2) 22.07.15	Simuna-Vaiatu mean (n=8) 18.09. & 04.11.18	Simuna-Vaiatu mean (n=4) 17.05.20
As	nd.	3.5	2.2	4.5	1.8	2.3
Pb	16	15	5.2	10.1	4.3	5.8
Cd	0.4	0.26	<0.1	0.08	<0.1	<0.1
Cr_{sum}	42	7.3	6.3	7.1	3.6	8.9
Cu	11	<10	4.4	5.6	9.0	6.5
Ni	22	4.1	3.5	4	2.2	4.8
Hg	0.03	<0.1	<0.1	<0.1	<0.1	<0.1
Zn	37	24	23	28	12.1	18
Sb	nd	<0.5	<1.0	<1.0	<1.0	<1.0
Ba	383	65	22	40	13.6	32
Mo	1.3	<2	<1.0	0.6	<1.0	<1.0
V	44	11	9.4	9.4	6.0	8.2
Se	nd	<1	<2.0	<2.0	<2.0	<2.0

As can be seen from the tables 14 and 15 the mean content of analyzed trace elements in samples taken in 17.05.2020 is similar or lower compared when compared to values of samples taken in 2012, 2014, 2015 and 2018.

When compared the content of soil in current follow-up monitoring program to previous monitoring and to average content in Estonian soil following conclusions can be drawn:

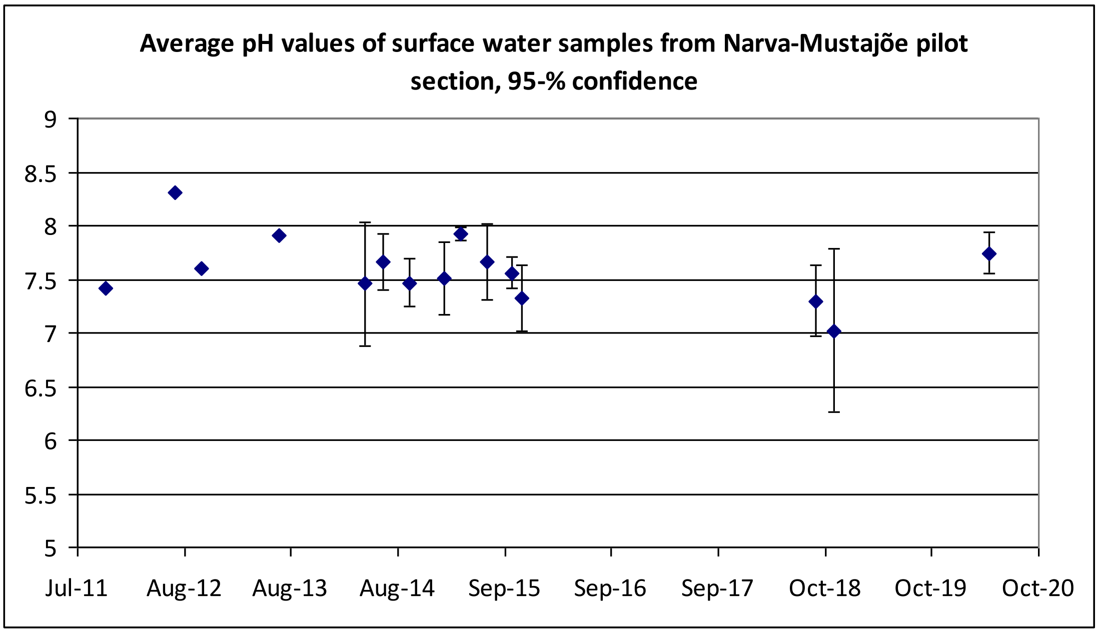
- the effect of OSA in road construction onto content of trace elements in soil is negligible.

5.2 Surface water

For following the long-term trends (2011-2020) of selected parameters in surface water in the pilot areas it is possible to use only those parameters that were measured in previous monitoring campaigns i.e. pH, EC, chloride, sulfate, As, Cr, Pb, Mo, V. Content of Cr and V in all water samples is below limits of detection therefore these metals are not included in the analysis. For the calculation of average concentrations, values below the limit of quantification were set to half of the value of the limit of quantification concerned [10].

5.2.1 Indicative parameters

Following indicative parameters are presented pH, electric conductivity, content of chlorides and sulfates (Figures 7-11). These indicative parameters were also monitored in previous environmental programs of two pilot sections.



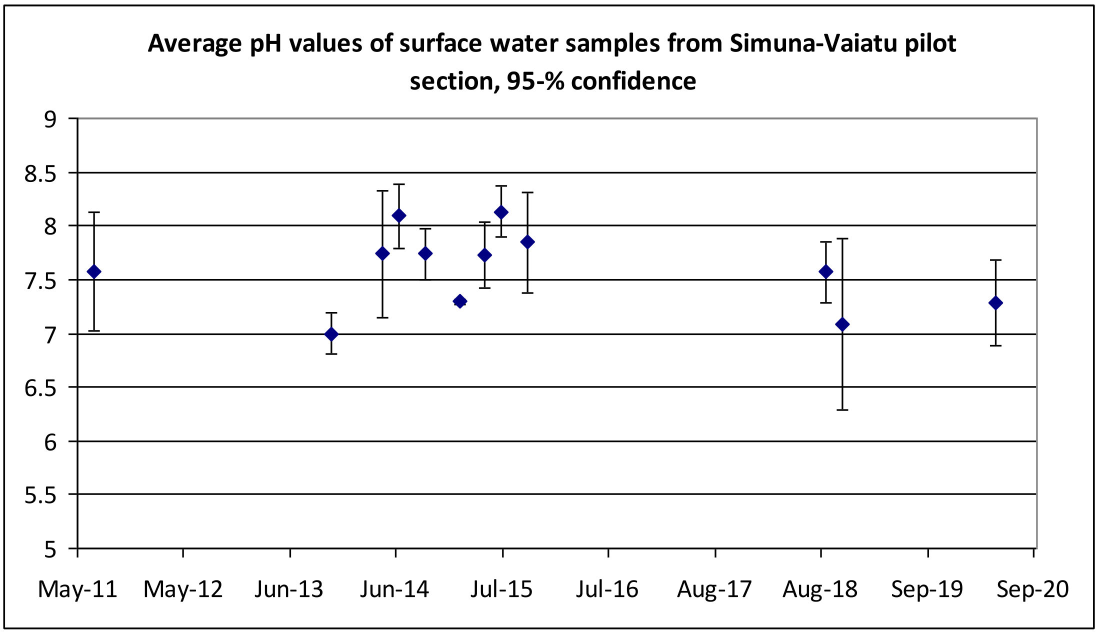
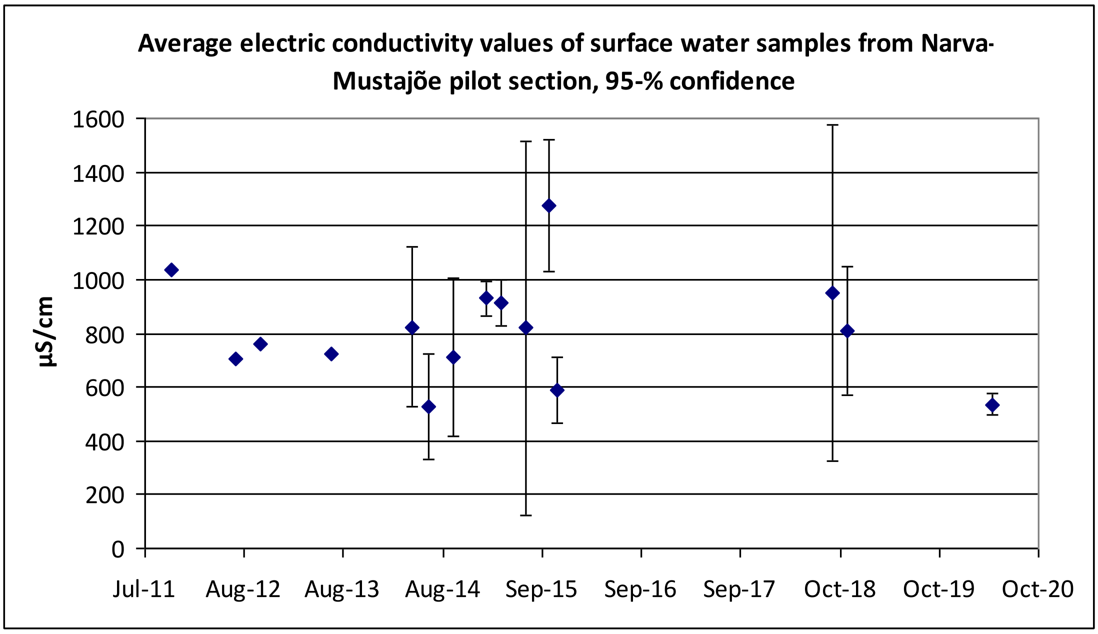


Figure 7. Observed pH values of water samples during monitoring of Narva-Mustajõe and Simuna-Vaiatu pilot sections.



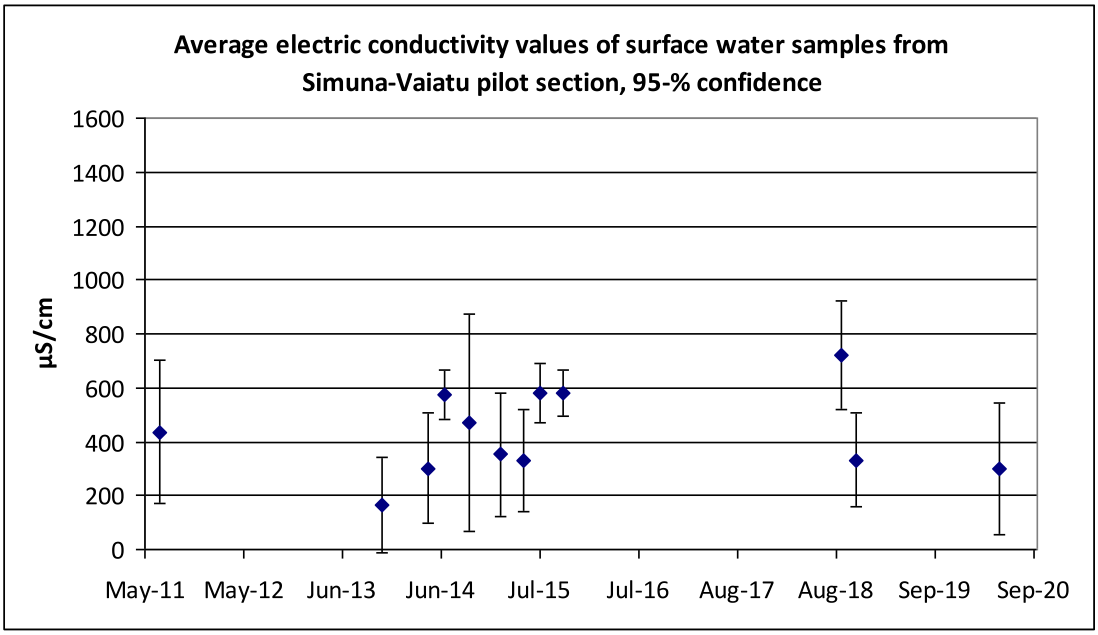
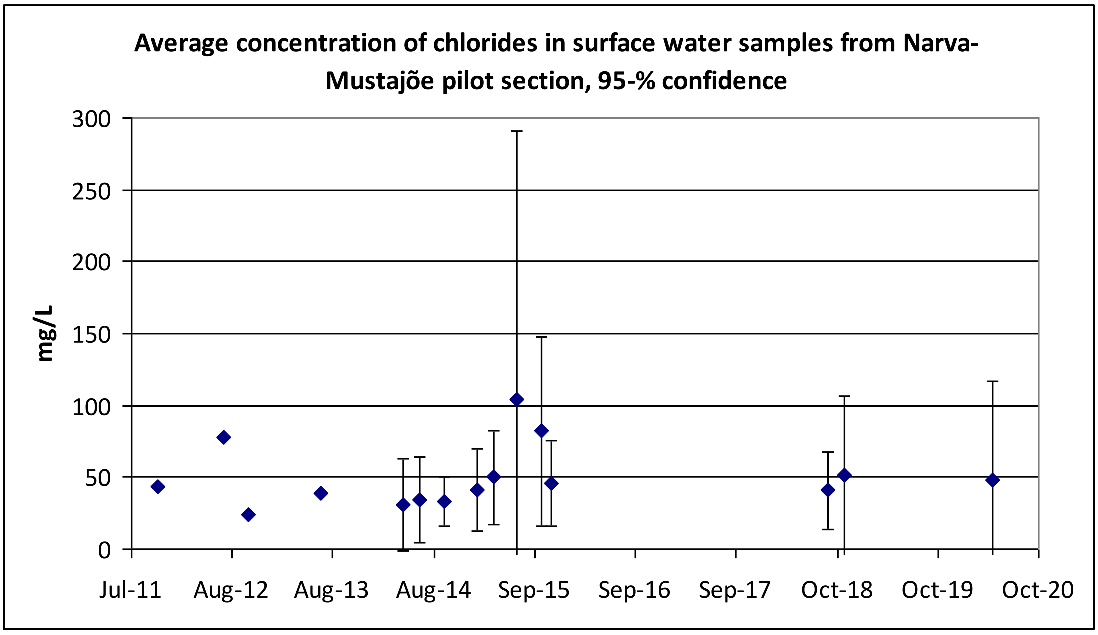


Figure 8. Observed electric conductivity values of water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections.



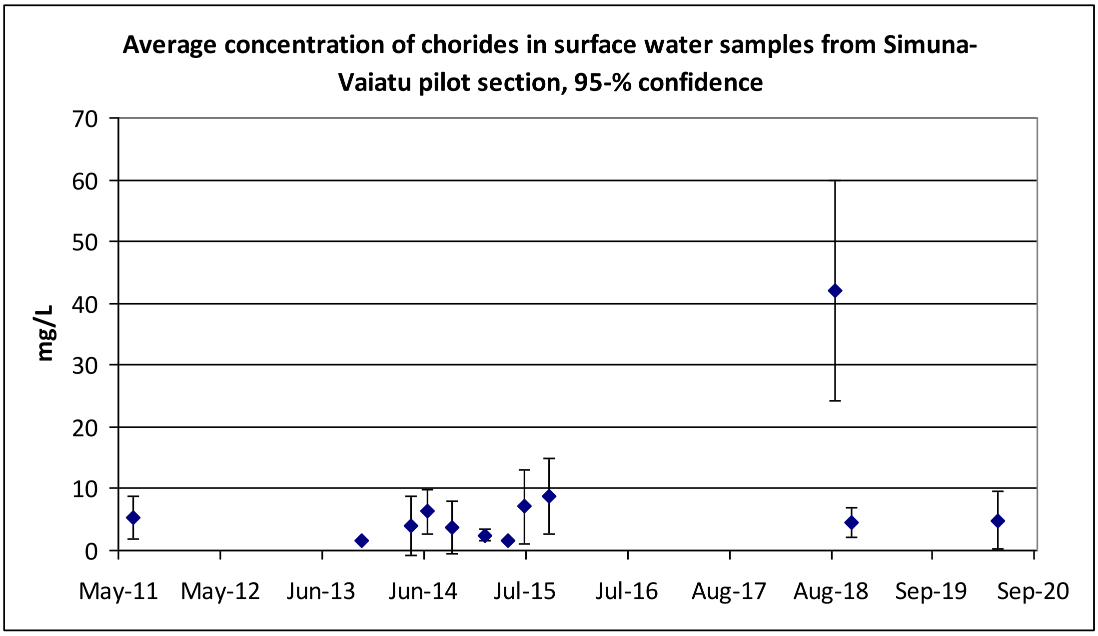
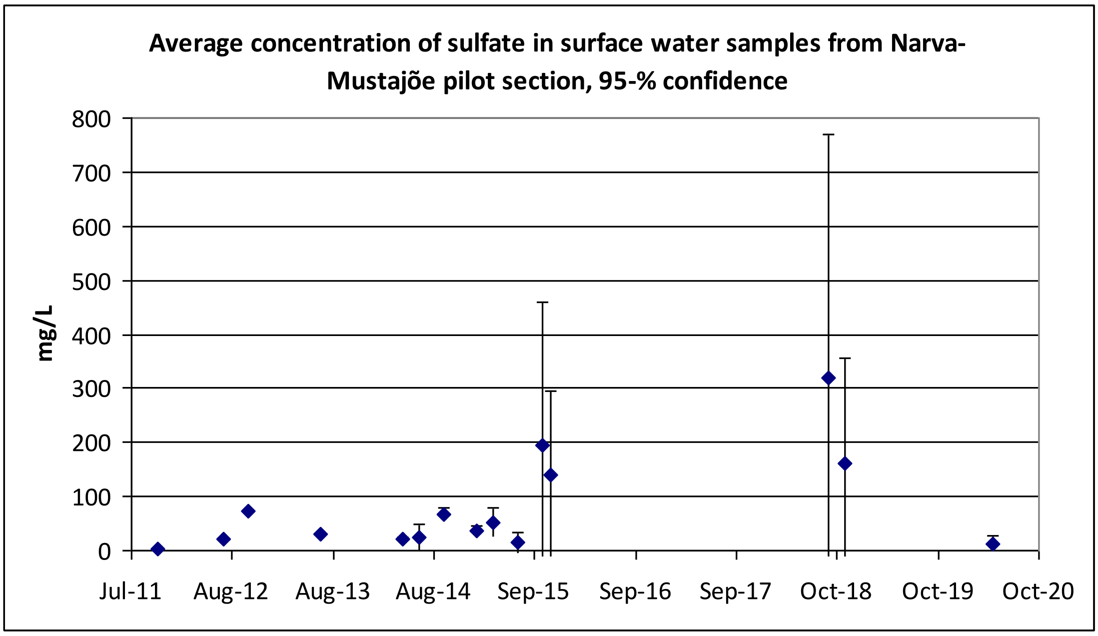


Figure 9. Observed content of chlorides in water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections. NB! Different scales.



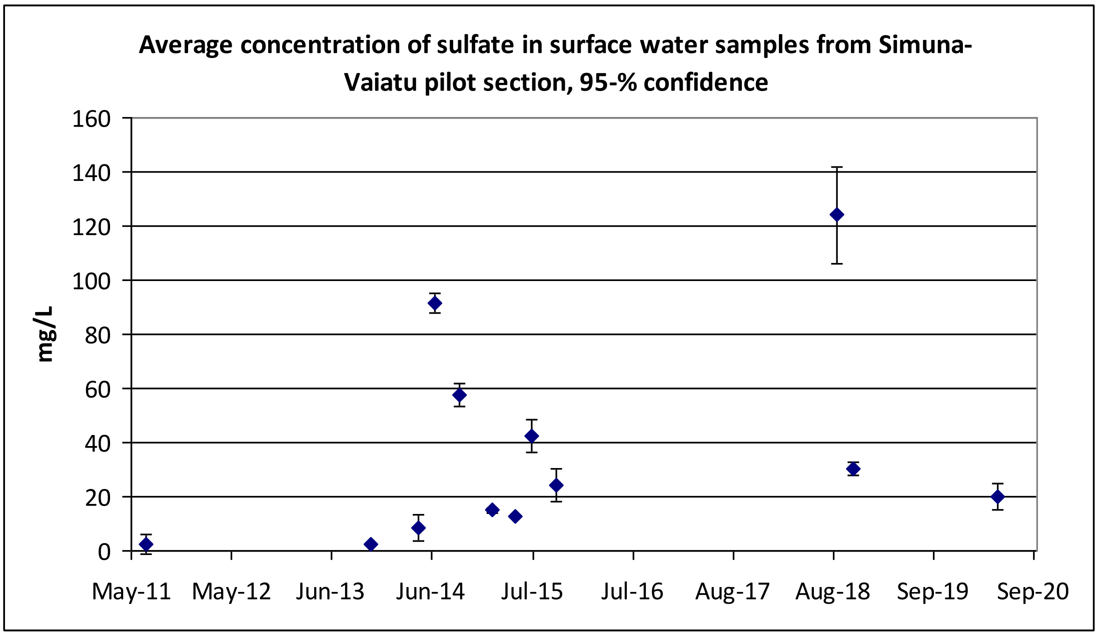


Figure 10. Observed content of sulfate in water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections. NB! Different scales.

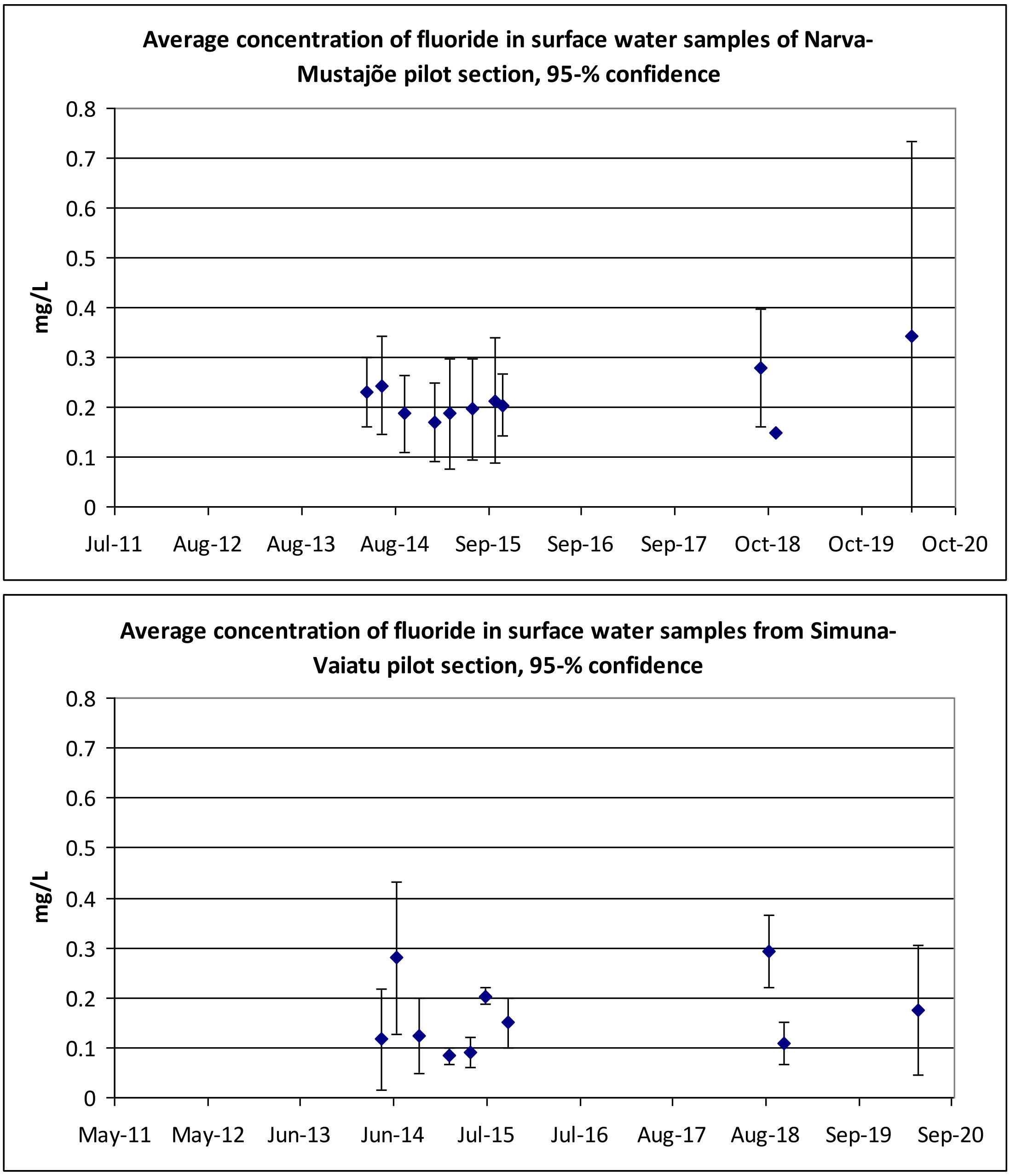
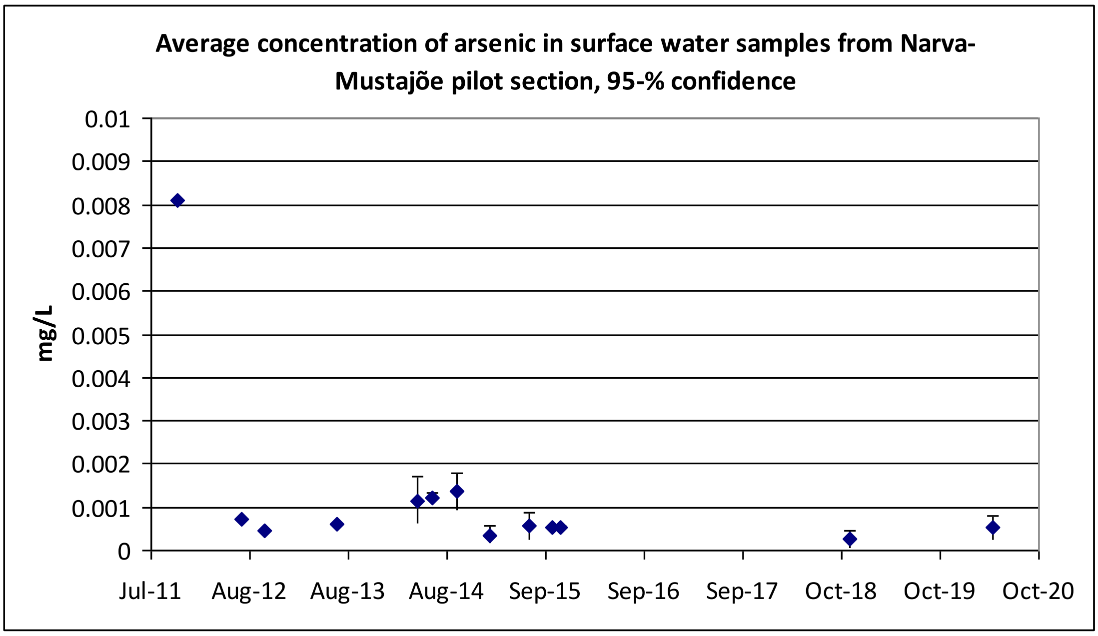


Figure 11. Observed content of fluoride in water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections (Limit concentration 1.5 mg/L).

As can be seen from Figure 10 the road construction with OSA has affected the content of sulfates in surface water in both pilot sections. The electric conductivity in surface water and concentration of chlorides can be considered as natural background. Content of fluoride in surface water is above limit concentration in both pilot sections. Still, the content of fluoride in water samples can be considered a natural background concentration

5.2.3 Trace elements

The concentration of most trace elements analyzed in the monitoring was below LOQ. Content of following trace elements detected is presented in following Figures 12-14 – arsenic, molybdenum and barium. Arsenic and molybdenum in surface water were monitored in previous programs and are natural constituents in the environment of two pilot sections. Although lead was found in pre-construction monitoring, its concentration throughout the follow up monitoring has been below LOQ and is therefore not presented in current report [11].



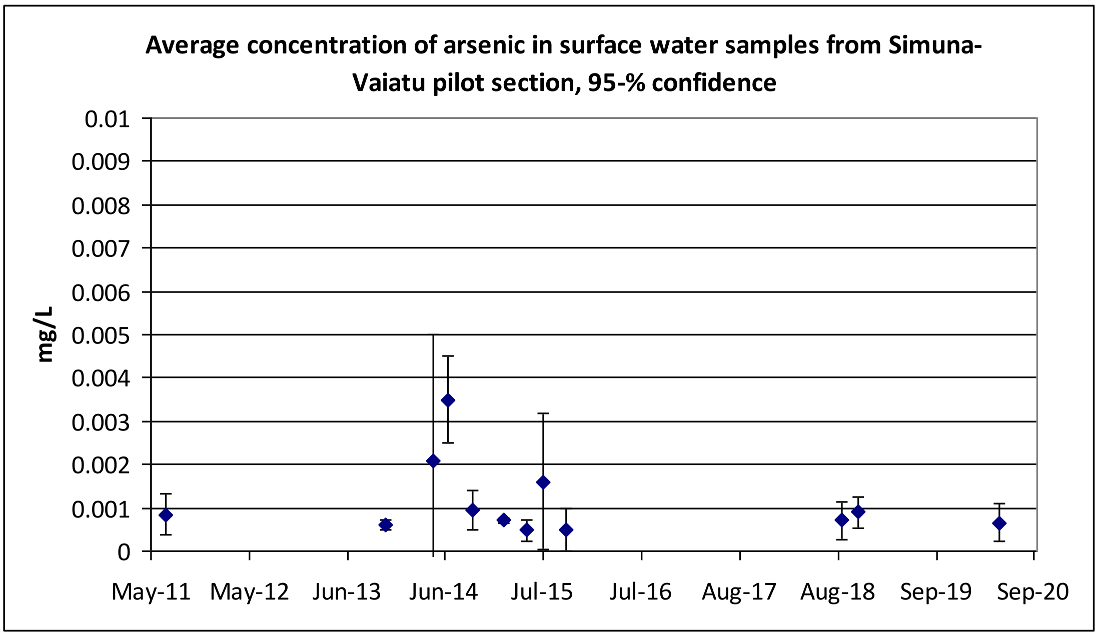
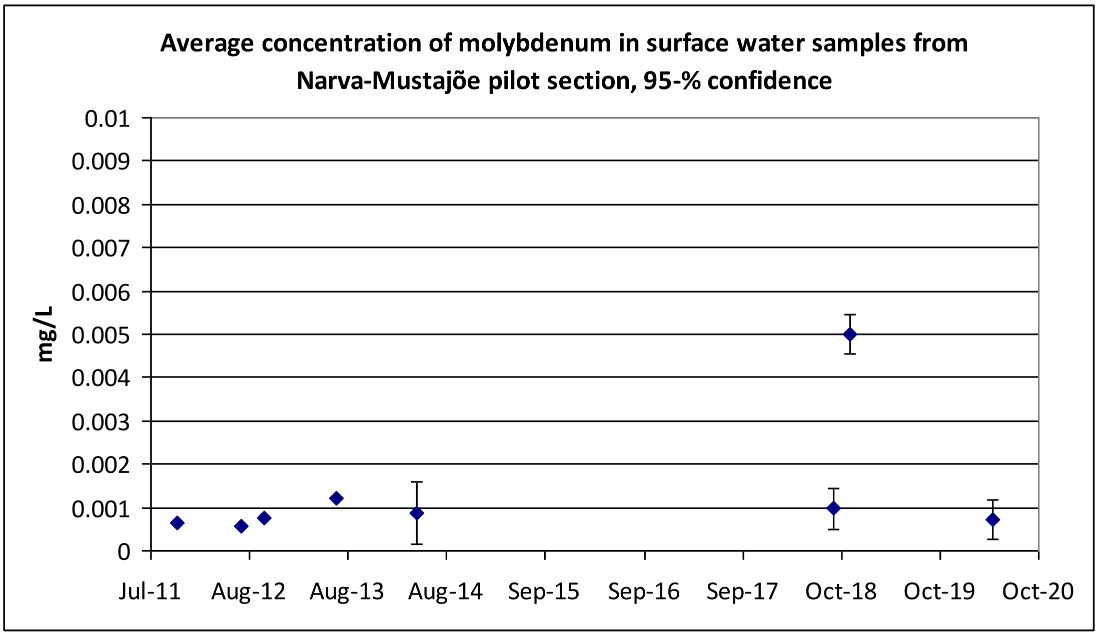


Figure 12. Observed content of arsenic in water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections (MAC-ECS for arsenic in surface water is 0.01 mg/L, 07.11 analysis from non-filtrated sample).



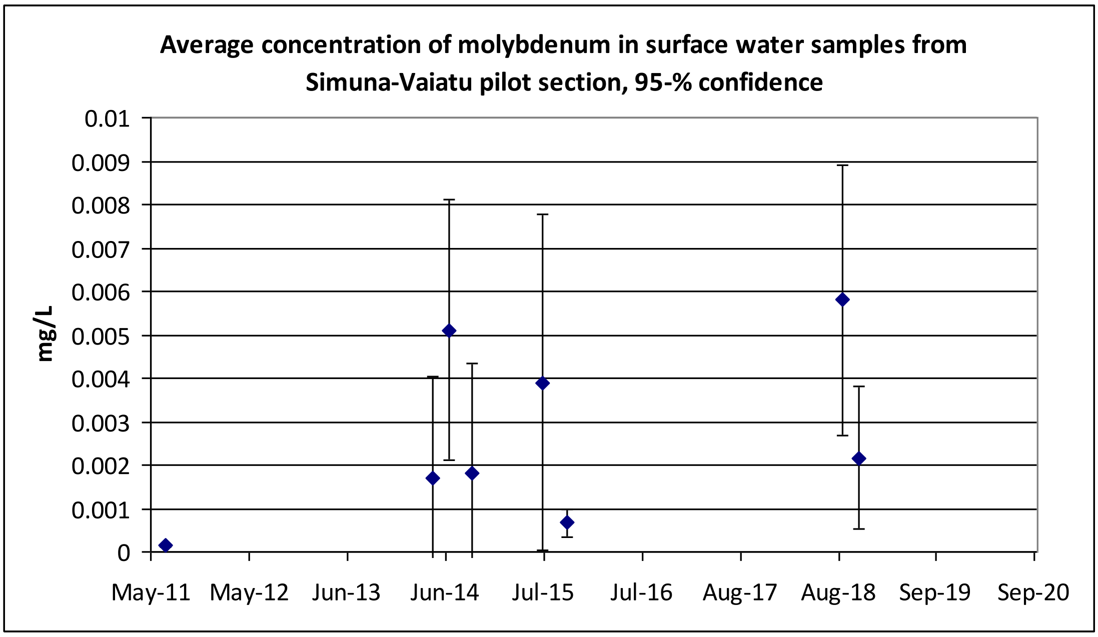
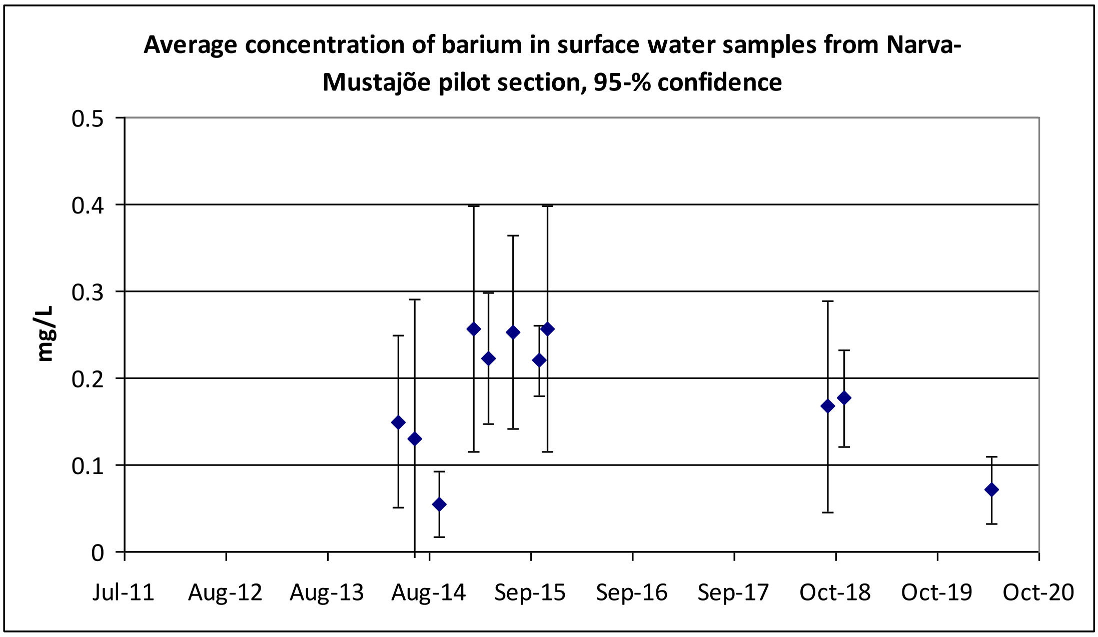


Figure 13. Observed content of molybdenum in water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections (Limit value in groundwater: 0.07 mg/L).



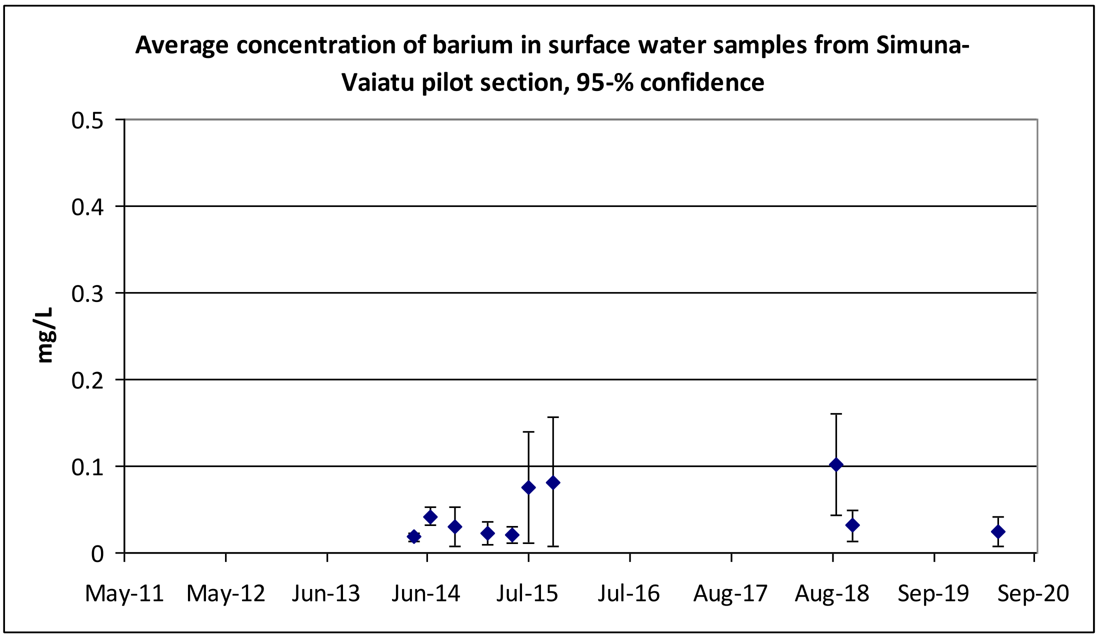


Figure 14. Observed content of barium in water samples of Narva-Mustajõe and Simuna-Vaiatu pilot sections (MAC-EQS for barium in surface water is 0.1 mg/L).

The content of arsenic in water samples is below environmental quality standards (Figure 12). Also the content of molybdenum is lower than limit value for groundwater (Figure 13).

The concentration of both arsenic and molybdenum in the surface water of both pilots sections is minimal and is not affected by the road construction. These concentrations can be considered as a natural background.

Throughout the follow-up monitoring the average concentration of barium has been mostly above the national legal limit (0.1 mg/L) in Narva-Mustajõe and below it in Simuna-Vaiatu pilot section (Figure 14). Still, the concentrations of barium in nearby ditches of both pilot sections have remained similar during the monitoring program.

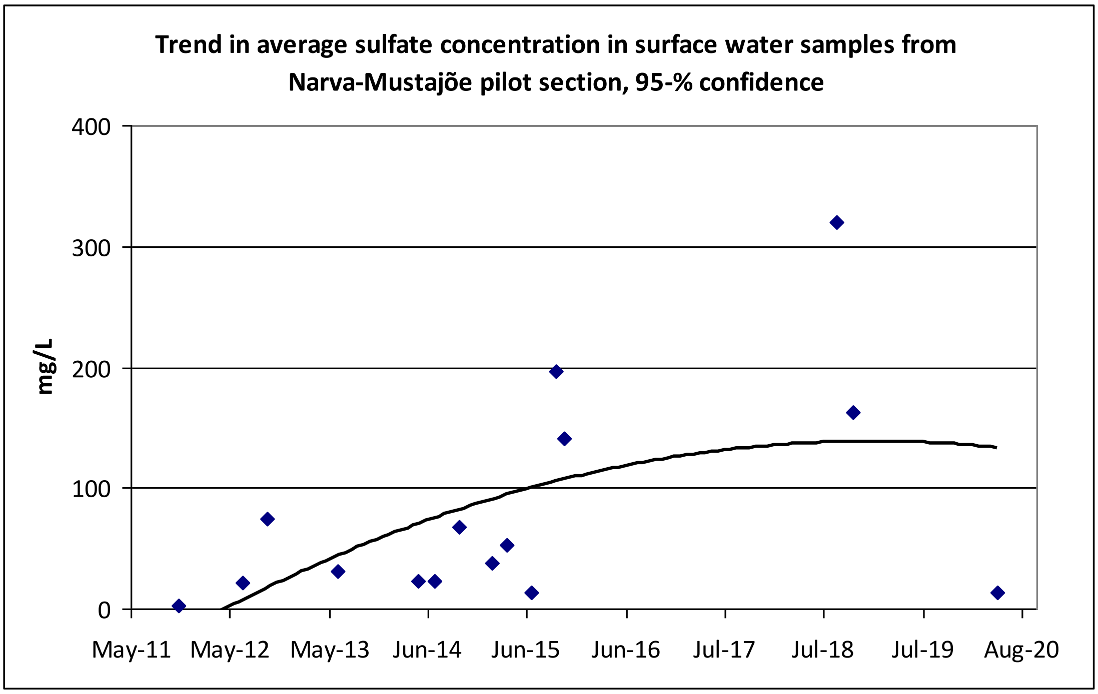
The United States Environmental Protection Agency has set the maximum barium level in drinking water 2 mg/L[2]

6. Conclusions

On the basis of the first sampling campaign in May 2020 following conclusions can be drawn:

- The content of all selected trace elements in soil samples remained below national environmental quality limits in both pilot sections. The road construction has not affected the soil quality and the soil is in good conditions in both pilot sections.
- The content of priority hazardous metals, mercury and cadmium was below limit of detection (LOQ) in all water samples taken in May 2020.
- Among priority substances the content of lead and nickel was below LOQ in all water samples
- Among hazardous substances following anions and elements were detected in water samples: fluoride, arsenic, barium, copper and zinc. Average concentration of barium in both pilot sections was below national environmental quality standard (0.1 mg/L)..
- The road construction has not affected the natural level of pH or electric conductivity of surrounding surface water. Electric conductivity of water is directly connected to dissolved solids or salts. Also content of chlorides and fluoride is similar to natural background level or with the observations made before road construction.
- Concentration of sulfate in water samples taken in May 2020 is lower compared to previous observations in 2014, 2015 and 2018. Most probably the content of sulfate ion in nearby surface water of the pilot sections in not affected by road construction anymore (Figure 15). Natural level of sulfate in Estonian surface water is 20-50 mg/L.

[2] National Primary Drinking Water Regulations, EPA 816-F-09-004, May 2009



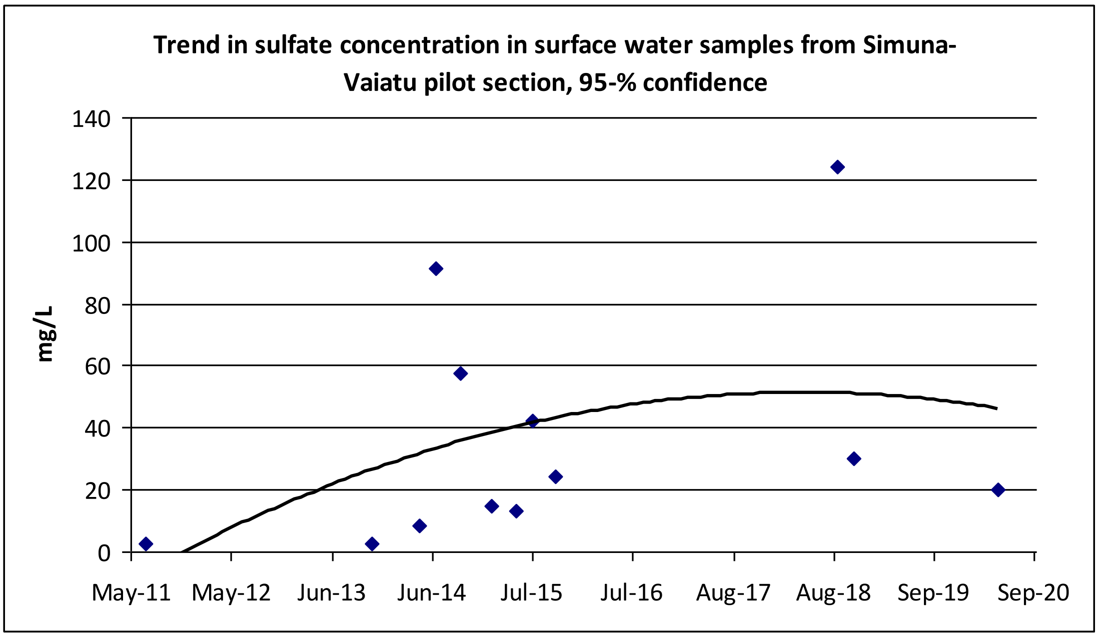


Figure 15. Trends in average sulfate concentrations in both pilot sections. Construction started in Narva-Mustajõe and Simuna-Vaiatu pilot sections in 2012 and 2013, respectively

7. References

1 R. Kuusik, M. Uibu, K. Kirsimäe, R. Mõtlep, T. Meriste, Open-air deposition of Estonian oil shale ash: formation, state of art, problems and prospects for the abatement of environmental impact, Oil Shale, 29 (2012), 376–403.

2 Government of the Republic Regulation No 102 (adopted 06.04.2004) Waste, including hazardous waste list (*Jäätmete, sealhulgas ohtlike jäätmete nimistu*)

3 osamat.ee/en (last accessed 01.12.2015)

4 J. Reinik, N. Irha, E. Steinnes, G. Urb, J. Jefimova, E. Piirisalu, J. Loosaar, Changes in trace element contents in ashes of oil shale fueled PF and CFB boilers during operation, Fuel Processing Technology, 115 (2013) 174-181.

5 J. Reinik, N. Irha, E. Steinnes, G. Urb, J. Jefimova, E. Piirisalu, Release of 22 elements from bottom and fly ash samples of oil shale fueled PF and CFB boilers by a two-cycle standard leaching test, Fuel Processing Technology, 124 (2014) 147-154.

6 V. Cappuyns, R. Swennen (2008) The application of pHstat leaching tests to assess the pH-dependent release of trace metals from soils, sediments and waste materials. J Haz Mat, 158, 185-195.

7 Monitoring and study of hazardous substances 2012-2013 (*Ohtlike ainete seire ja uuringud 2012-2013*), Estonian Environmental Research Centre, Central Lab, 2013 (in Estonian).

8 LIFE+ 2009: OSAMAT ONGOING SURVEY RESULTS / KÄIMASOLEVA SEIRE TULEMUSED, Survey report, Ramboll, 2014

9 OSAMAT – post-project environmental monitoring in 2014 and 2015, Final report, National Institute on Chemical Physics and Biophysics, 2015

10 COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC), Guidance Document No. 19 GUIDANCE ON SURFACE WATER CHEMICAL MONITORING UNDER THE WATER FRAMEWORK DIRECTIVE, Technical Report - 2009 – 025,

11 OSAMAT – post-project environmental monitoring in 2018, Final report, National Institute on Chemical Physics and Biophysics, 2018.

Appendix 1 Accreditations

Appendix 2 Sampling reports and results of analysis for 17.05.2020 sampling campaign

Appendix 4 Terms of Reference of the Contract