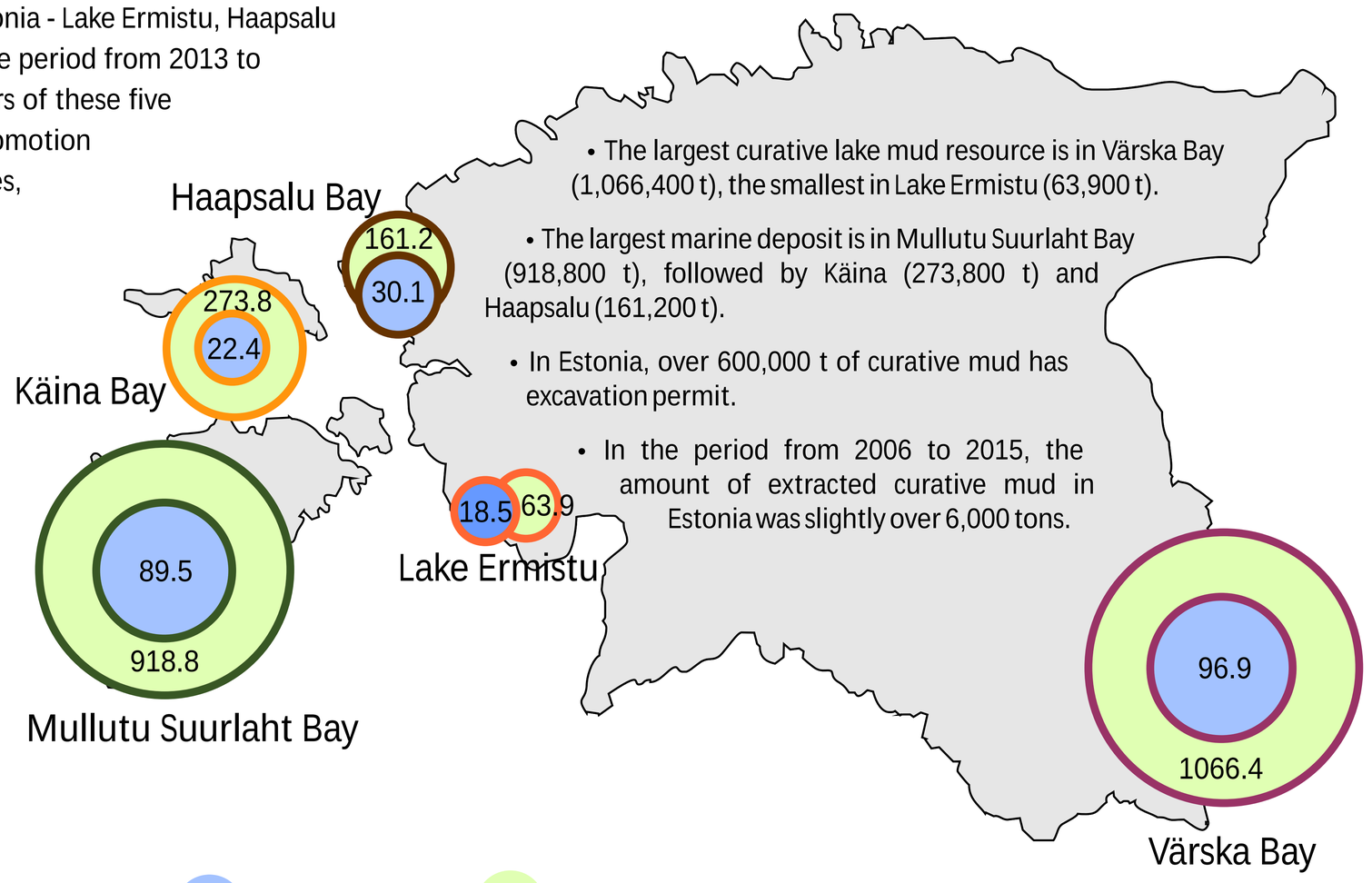
Curative mud in Estonia 2013-2014

Jaanus Terasmaa, Galina Kapanen, Agata Marzecova, Sander Rautam

Currently there are five deposits used for curative mud excavation in Estonia - Lake Ermistu, Haapsalu Tagalaht Bay, Mullutu Suurlaht Bay, Värska Bay and Käina Bay. In the time period from 2013 to 2014 a total of 145 samples were taken from the surface sediment layers of these five deposits in the study conducted by the Centre of Excellence in Health Promotion and Rehabilitation (TERE KK). The lithological composition of the samples, the content of heavy metals (Cd, Cr, Cu, Pb, Ni, Zn, Sr) and other elements were analyzed in the laboratory to determine the quality of the curative mud, their spatial and temporal variability, and compliance with environmental requirements.

The results confirm that the concentrations of potentially toxic heavy metals do not exceed the limit values (from which soil is considered polluted) established in Estonian regulations, but in some cases they are slightly over the soil's good status target number. Based on the low content of heavy metals, the sediments of Käina Bay are ecologically the cleanest. The spatial variability is highest in Mullutu Suurlaht Bay. Lithological composition is most uniform in the lake deposits. Mud is very organic-rich in Lake Ermistu and minerogenic in Käina Bay. In sea bays the organic matter content of the mud has increased in comparison with the 1990s (most of all in Haapsalu Bay), while in the lakes the amount of organic matter has remained the same or slightly decreased.



Surface area (ha) and volume (in 1000 tons) of economic proved reserves of curative mud.

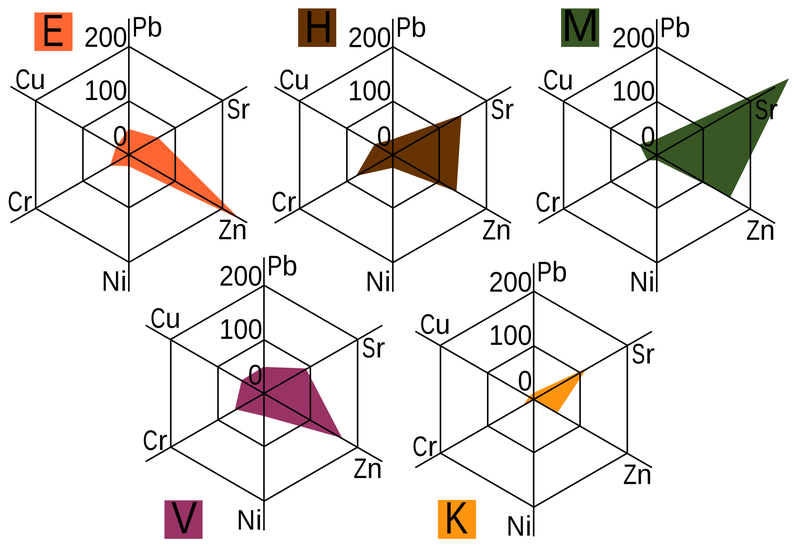
Ermistu (Lake Ermistu) is located in Southwest Estonia in Pärnu County. The river Tõstamaa flows out of the lake, water exchange takes place twice a year. In the northern part of the lake there is Kivisaar Island, in the southwest there are several small peat islets. The lake area is 450 ha, the average depth is 1.3 m, and the maximum depth is 2.9 m. It is considered a macrophyte lake. Lake Ermistu mud is organic-rich - on average 44.4% of the dry matter, while the mineral content is 55.6% and the carbonate content is 1.5%. The spatial distribution of heavy metals is not statistically related to sediment organic or mineral matter content, but correlates only with carbonates. In Lake Ermistu lead (Pb) has highest values among heavy metals, also zinc (Zn) values are very high - above the soil's target number. Copper (Cu) content is very limited. During the last 20 years, the average organic content of the mud has decreased by more than 15% (61.9% -> 44.4%).

Haapsalu Tagalaht Bay is the northeastern part of Haapsalu Bay located in Väinameri Sea. Haapsalu Bay is connected with Saunja and Tahu bays, there are also several streams flowing into the bay. The area is over 800 ha, the average depth 0.5-1 m, maximum depth 2 m. Due to the neotectonic uplift (2-3 mm/yr), the bay is gradually getting shallower. Because of high internal load of nutrients, the ecological state of the bay is deteriorating. The curative mud of Tagalaht Bay is very mineral - on average 87.8%, organic matter content is on average 10.9% and carbonate content 1.3%. All heavy metals other than strontium (Sr) are statistically significantly connected with sediment lithological content. Heavy metal content is within the limit values of regulations. During the last 20 years the highest increase in organic matter has occurred in Tagalaht Bay, where the previously measured maximum value (9.2%) was lower than the current average value (10.9%).

Mullutu Suurlaht Bay is located in Saaremaa, west of the town of Kuressaare. It was separated from the sea 1000-1500 years ago, is currently located about 2 km from the sea and has a connection with it through the Nasva River. Sea water reaches the bay only during the floods. Area is 590 ha, the average depth is 1 m, and the maximum depth is 2.1 m. Carbonate content is highest compared with other deposits - 14.6%. The mineral matter content is 51.6% and the organic matter content is 33.9%. The spatial distribution of heavy metals does not have a statistical relationship with organic matter, but with mineral matter and carbonates. The heavy metal content is below the limit values, in few spots exceeding the target numbers for lead (Pb) and nickel (Ni). Strontium (Sr) content is the highest in comparison to other deposits. Over time, the average organic content has increased (27.6% -> 33.9%), the minimum and maximum values have remained the same.

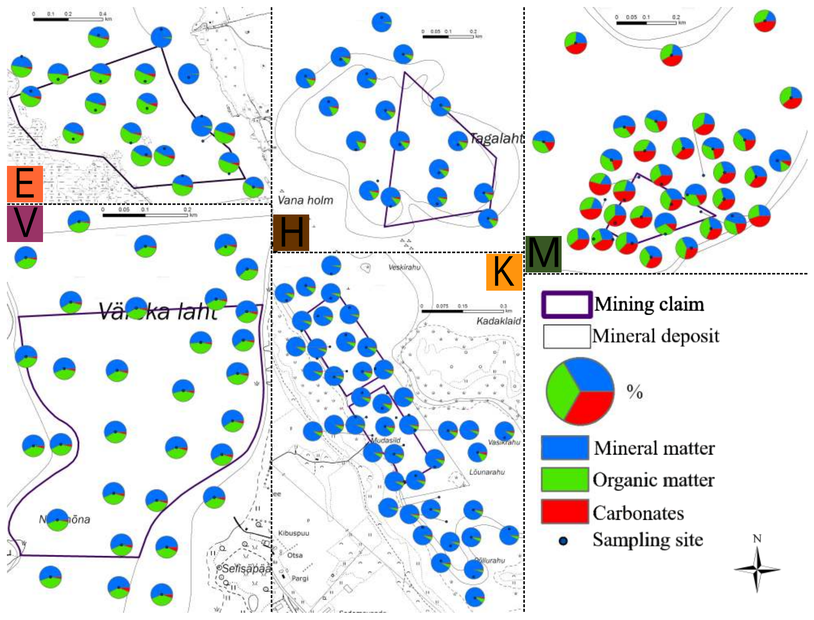
Värska Bay is located in the south-eastern part of Estonia, in the mouth of the Värska stream that flows into the Lake Pihkva (the bay is 1.3 km wide in the mouth). The area of the bay is 157 ha, the average depth is 1.4-1.7 meters and the maximum depth is 3 m. Near the mouth of the bay is Kolpin Island which belongs to Russia. For a lake ecosystem, the mud in Värska Bay is very minerogenic - on average of 59.6%. The content of the organic matter is 38.7% and the carbonate content is 1.7%. In Värska Bay, there is no statistically significant correlation between lithology and heavy metals. The lead (Pb) content exceeds the target values set for soil at several sampling points, but remains below limit values. Compared to other deposits, zinc (Zn) and nickel (Ni) have the highest values. Since the 1990s, the average organic matter content has decreased slightly, but the maximum value has increased (41.6% -> 45.7%).

Potential toxic heavy metals (ppm)



Käina Bay is a low bay in the south-east of Hiiumaa Island, which is separated from Väinameri by Kassari Island. The connection with the sea passes through the bridgeways of the dam, the seawater exchange is minimal (water salinity is 2-3 ‰). The area of Käina Bay is 900 hectares, the average depth is 0.3-0.5 m and the maximum depth is up to 1 meter. There are numerous small islets and reed-beds. Käina Bay has the most mineral mud among curative mud deposits - an average of 92.4% of the sediment is mineral, the organic content is 6.7% and the carbonate content is 0.9%. The lithological composition of mud is statistically connected to individual heavy metals (lead (Pb), zinc (Zn)). Concentrations of heavy metals are the lowest and below the limit values. Compared to the 1990s, Käina Bay mud has become slightly more organic (4.8% -> 6.7%).

Mud lithological composition



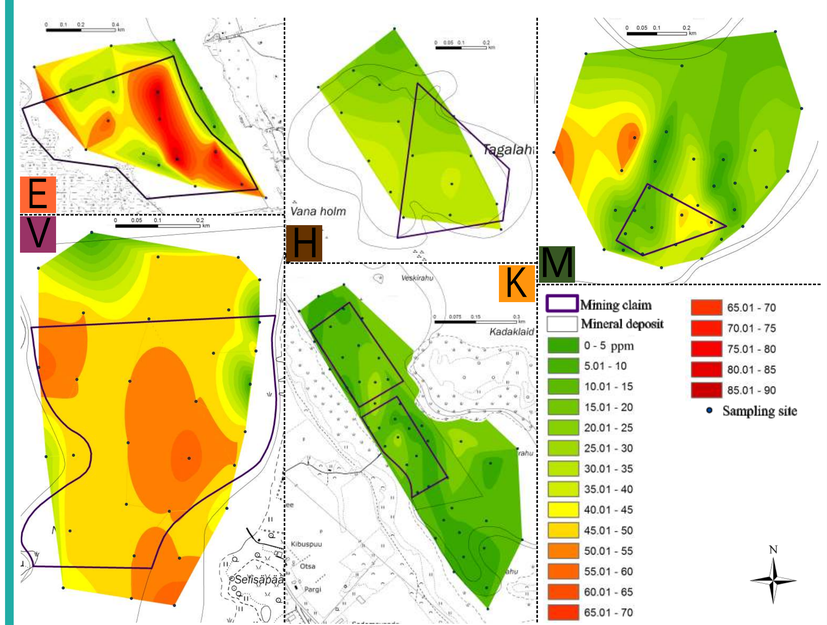
Mud chemical composition (average)

	Pb (PPM)	Cu (PPM)	Ni (PPM)	Zn (PPM)	Sr (PPM)	Cr (PPM)	Zr (PPM)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Cl (mg/g)	P (mg/g)	S (mg/g)
E	47.9	27.5	21.0	237	62.9	39.8	78.4	2.4	2.3	3.3	1.7	0.2	0.1	2.5	7.4
H	28.8	38.6	24.3	136	147	78.2	330	6.2	1.3	4.6	3.9	1.0	3.9	2.8	2.6
M	29.3	37.9	10.7	158	284	21.0	72.7	1.2	28.0	1.8	1.2	0.5	7.2	2.0	5.3
V	48.9	46.9	43.8	168	82.2	57.7	145	4.2	2.4	9.4	2.4	0.4	0.2	3.0	5.3
K	11.4	9.1	1.0	50.8	114	21.6	340	3.0	0.8	1.6	2.9	0.2	3.4	2.8	0.9

Temporal changes in content of organic matter

	Average (%)		Min. (%)		Max. (%)	
	1995-97	2013-14	1995-97	2013-14	1995-97	2013-14
E	61.9 ↓	44.4	60.7 ↓	1.4	63.0 ↓	56.2
H	8.1 ↑	10.9	7.0 ↓	3.3	9.2 ↑	14.9
M	27.6 ↑	33.9	15.0 →	15.0	40.2 →	40.8
V	41.2 ↓	38.7	40.7 ↓	35.9	41.6 ↑	45.7
K	4.8 ↑	6.7	2.0 ↑	3.1	7.5 ↑	9.9

Lead (Pb) content in mud



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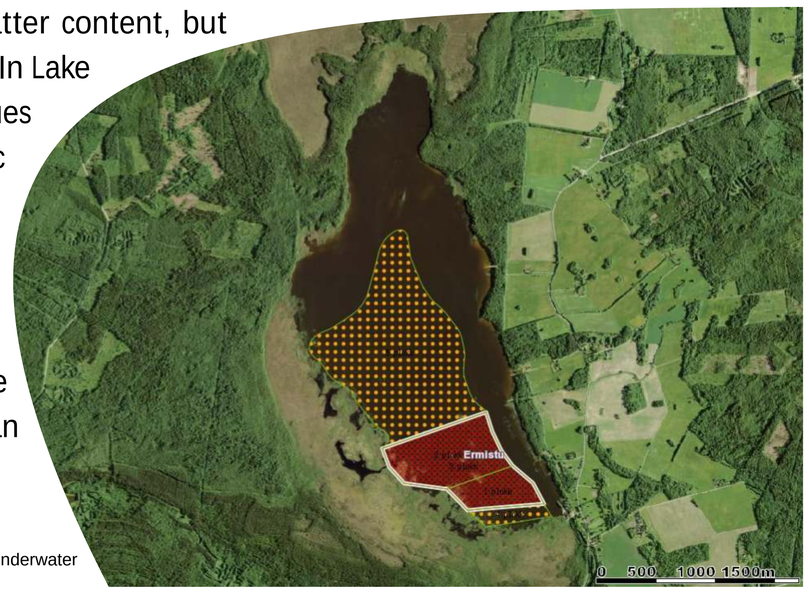
Curative mud in Estonia 2013-2014: Lake Ermistu

Jaanus Terasmaa, Galina Kapanen, Agata Marzecova, Sander Rautam

Ermistu (Lake Ermistu) is located in Southwest Estonia in Pärnu County. The river Tõstamaa flows out of the lake, water exchange takes place twice a year. In the northern part of the lake there is Kivisaar Island, in the southwest there are several small peat islets. The lake area is 450 ha, the average depth is 1.3 m, and the maximum depth is 2.9 m. It is considered a macrophyte lake. Lake Ermistu mud is organic-rich - on average 44.4% of the dry matter, while the mineral content is 55.6% and the carbonate content is 1.5%. The spatial distribution of heavy metals is not statistically related to sediment organic or mineral matter content, but correlates only with carbonates. In Lake Ermistu lead (Pb) has highest values among heavy metals, also zinc (Zn) values are very high - above the soil's target number. Copper (Cu) content is very limited. During the last 20 years, the average organic content of the mud has decreased by more than 15% (61.9% -> 44.4%).



- Mining claim
- Mine service plot
- Lake mud
- Sea mud
- Economic reserves underwater
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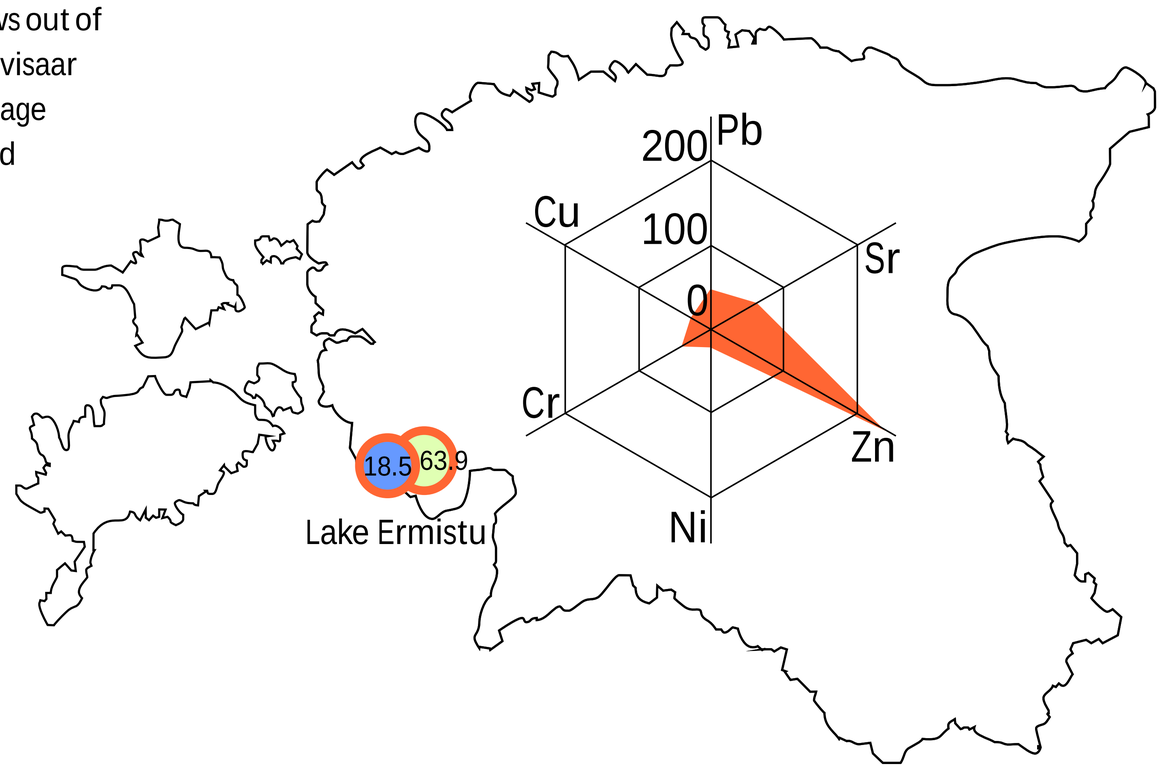
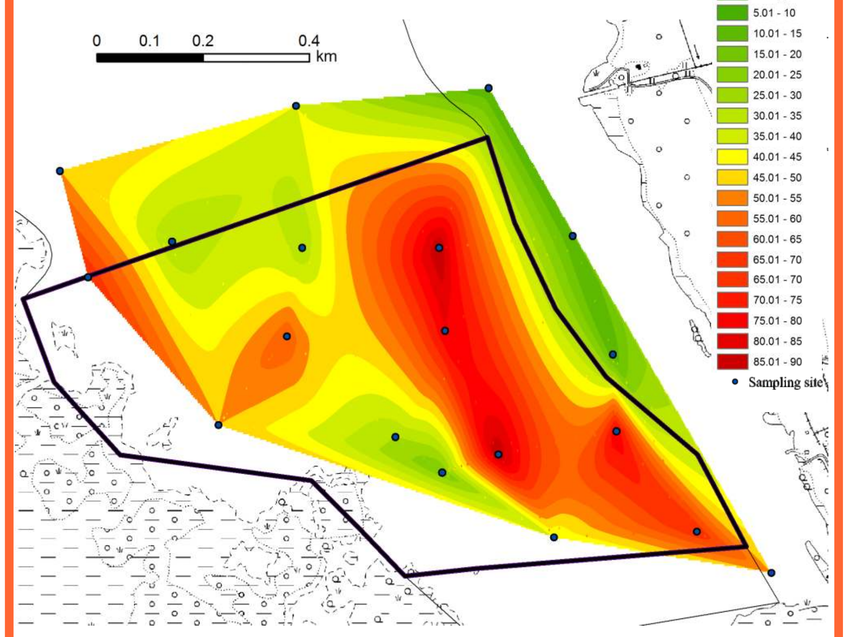
- Reconnaissance resources

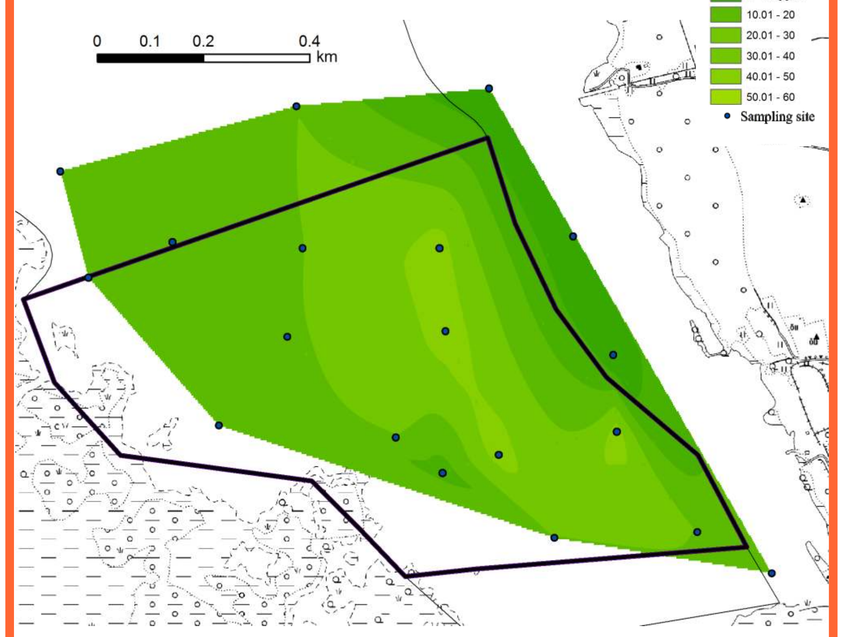


Surface area (ha) and volume (in 1000 tons) of economic proved reserves of curative mud.

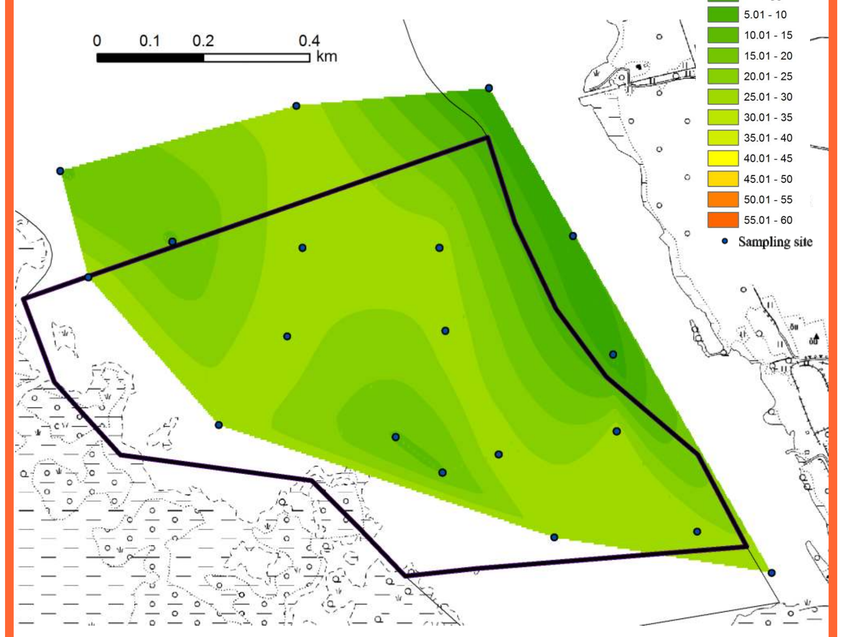
Lead (Pb)



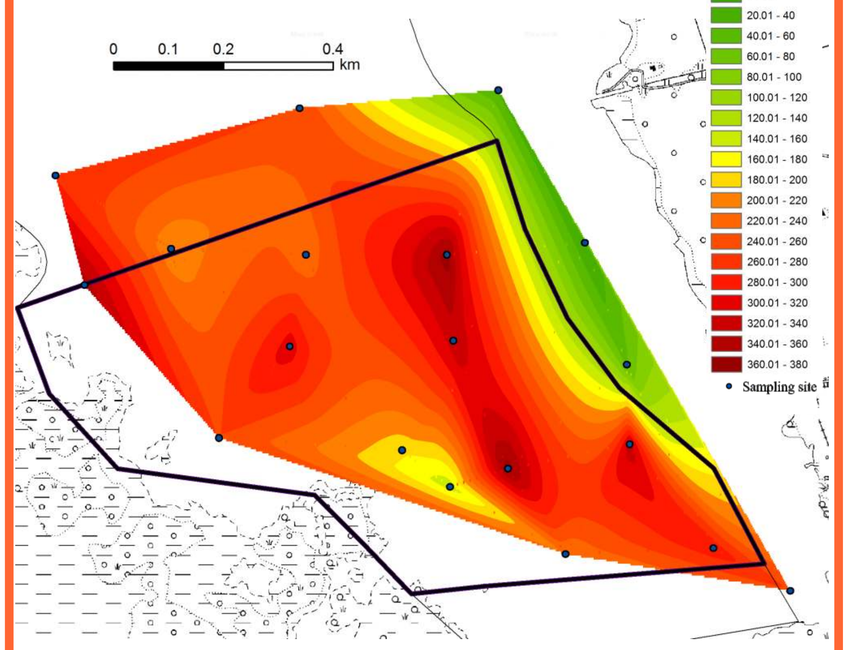
Copper (Cu)



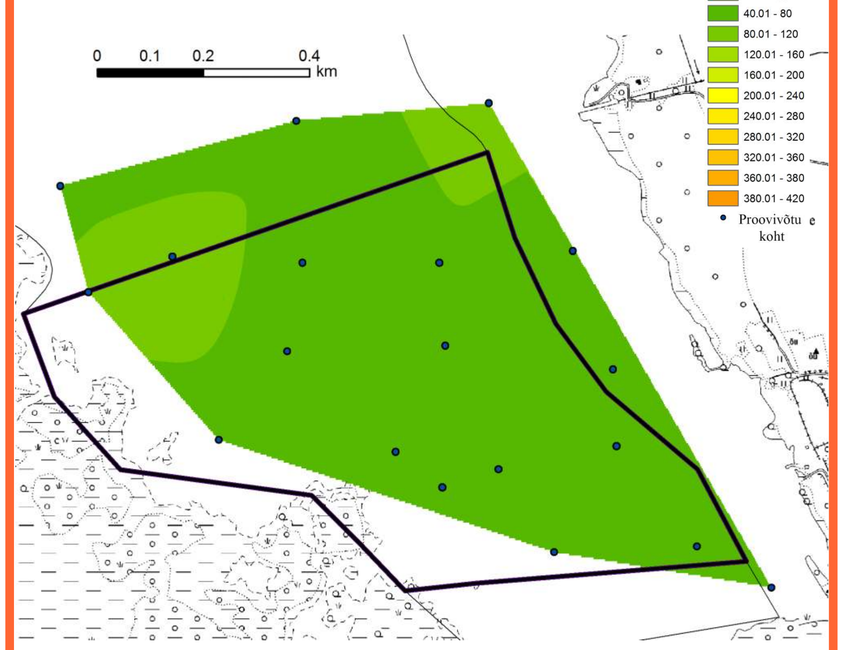
Nickel (Ni)



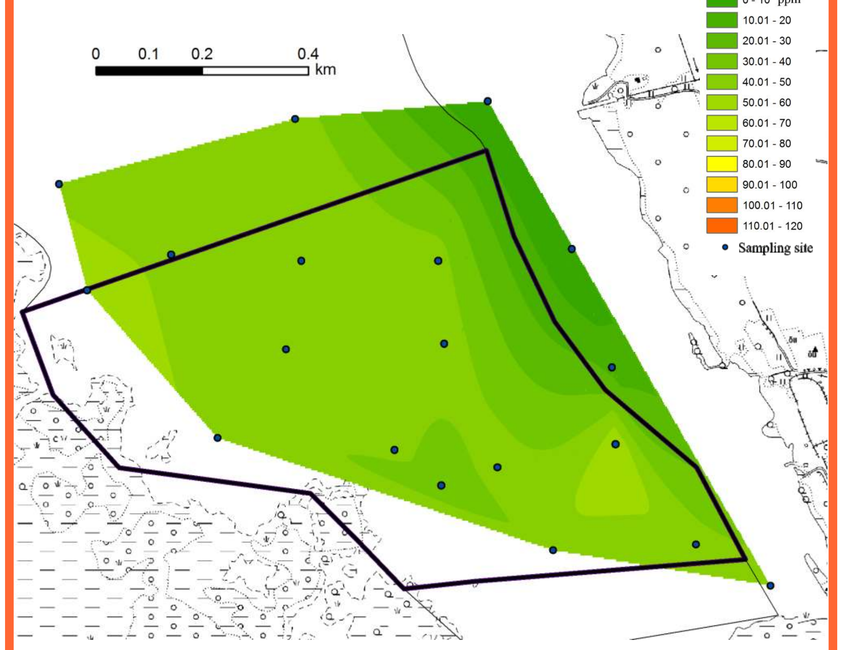
Zink (Zn)



Strontium (Sr)



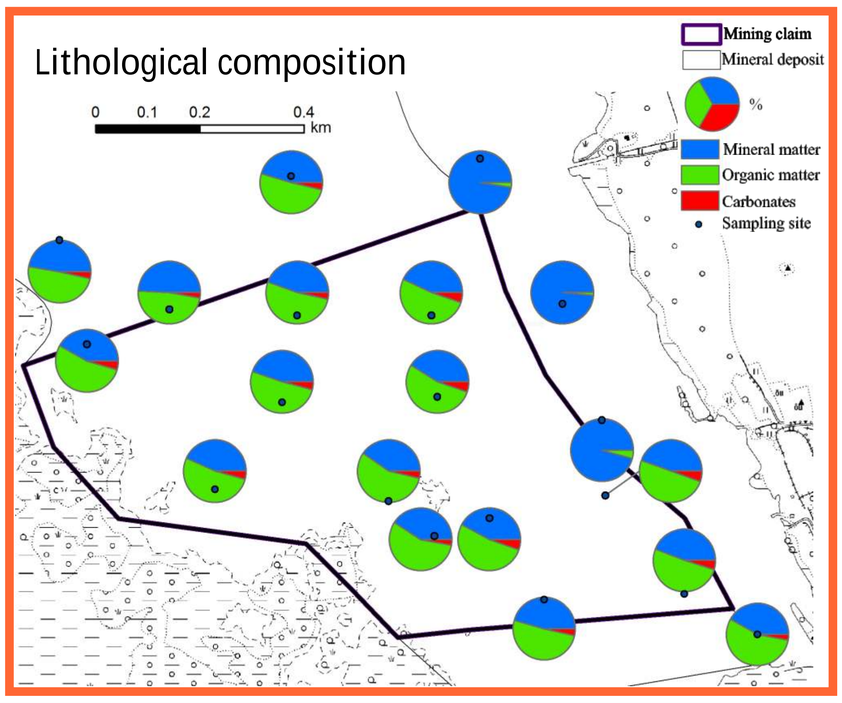
Chromium (Cr)



Mud composition

	Mineral matter (%)	Organic matter (%)	Carbonates (%)	Pb (PPM)	Cu (PPM)	Ni (PPM)	Zn (PPM)	Sr (PPM)	Cr (PPM)	Zr (PPM)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Cl (mg/g)	P (mg/g)	S (mg/g)
Average	55.6	44.4	1.5	47.9	27.5	21.0	237	62.9	39.8	78.4	2.4	2.3	3.3	1.7	0.2	0.1	2.5	7.4
Minimum	43.8	1.4	0.2	10.0	0.0	0.0	18.5	51.9	0.0	33.1	1.8	1.1	0.6	1.3	0.1	0.0	2.3	0.0
First quartile	46.9	49.7	1.3	30.0	29.9	14.3	194	51.9	45.3	66.2	2.3	2.1	3.2	1.6	0.2	0.1	2.5	6.0
Median	48.6	51.4	1.6	50.0	29.9	28.5	259	51.9	45.3	82.8	2.4	2.3	3.8	1.7	0.2	0.1	2.6	7.4
Third quartile	50.3	53.1	2.1	70.0	29.9	28.5	323	60.6	45.3	91.0	2.5	2.5	4.0	1.8	0.3	0.2	2.6	8.8
Maximum	98.6	56.2	2.3	90.0	44.8	28.5	369	121	60.4	116	2.7	2.9	4.6	1.8	0.3	0.2	2.7	14.5

Lithological composition



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Curative mud in Estonia 2013-2014: Haapsalu Tagalaht Bay

Jaanus Terasmaa, Galina Kapanen, Agata Marzecova, Sander Rautam

Haapsalu Tagalaht Bay is the northeastern part of Haapsalu Bay located in Väinameri Sea. Haapsalu Bay is connected with Saunja and Tahu bays, there are also several streams flowing into the bay. The area is over 800 ha, the average depth 0.5-1 m, maximum depth 2 m. Due to the neotectonic uplift (2-3 mm/yr), the bay is gradually getting shallower. Because of high internal load of nutrients, the ecological state of the bay is deteriorating. The curative mud of Tagalaht Bay is very mineral - on average 87.8%, organic matter content is on average 10.9% and carbonate content 1.3%. All heavy metals other than strontium (Sr) are statistically significantly connected with sediment lithological content. Heavy metal content is within the limit values of regulations. During the last 20 years the highest increase in organic matter has occurred in Tagalaht Bay, where the previously measured maximum value (9.2%) was lower than the current average value (10.9%).

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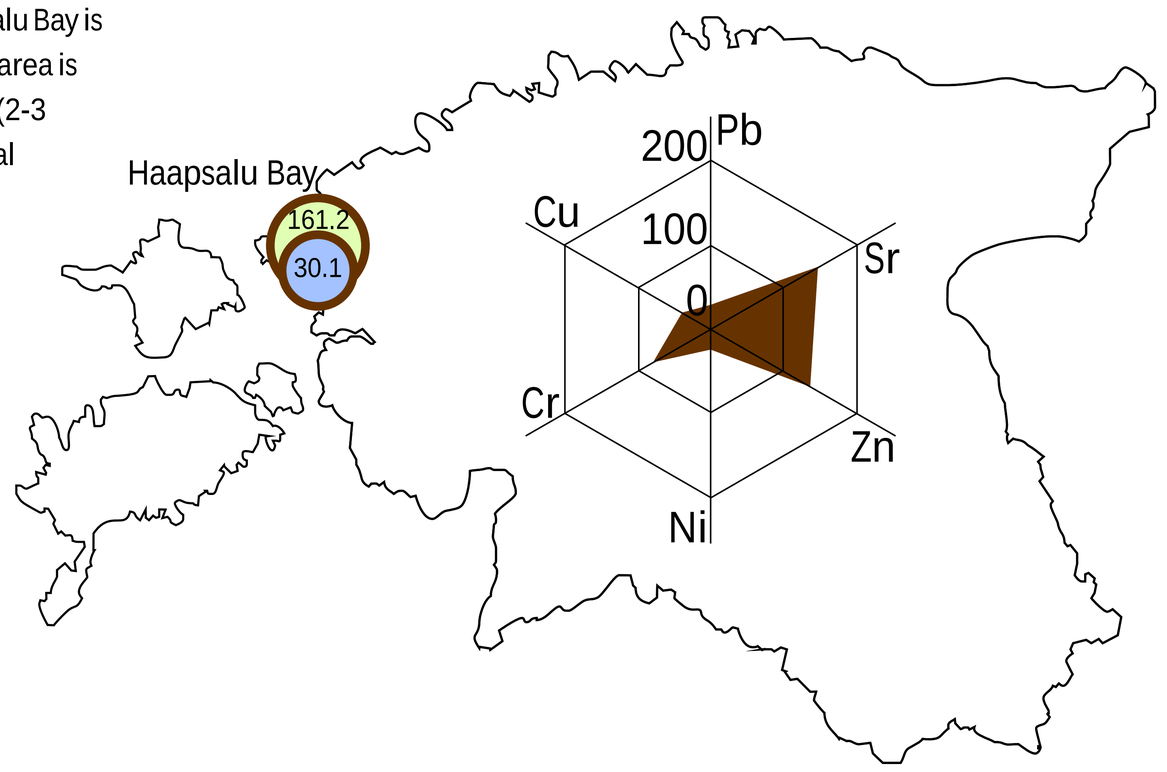
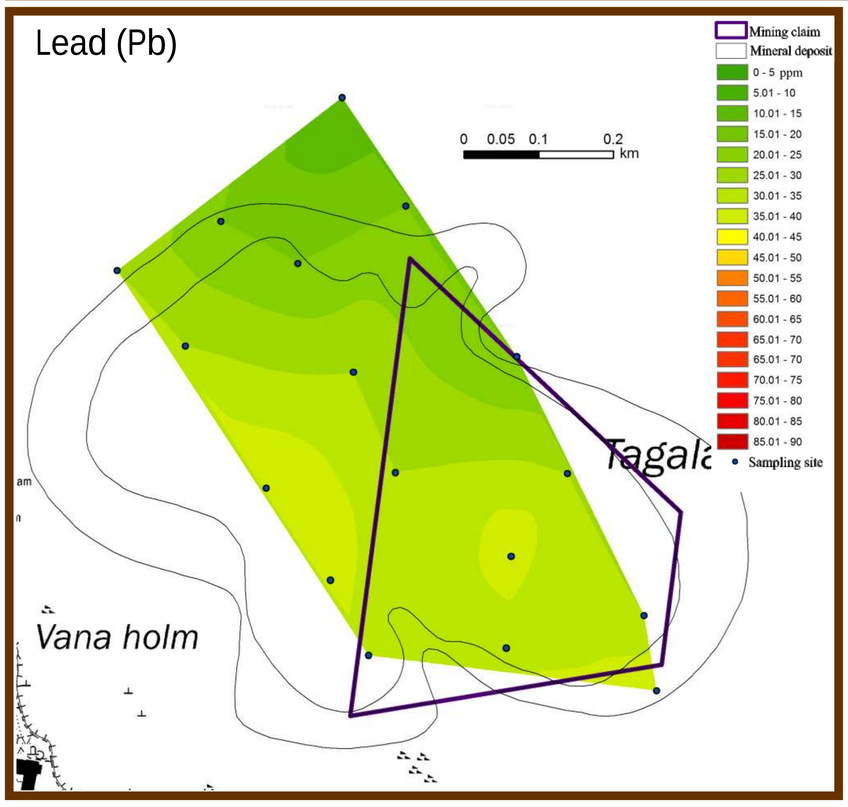
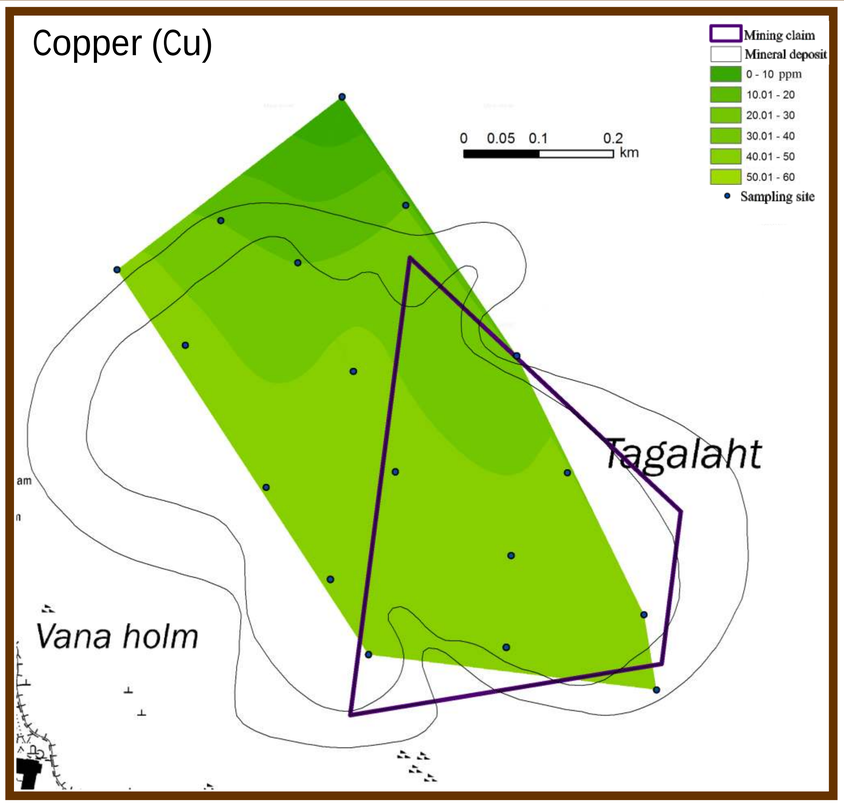


Surface area (ha) and volume (in 1000 tons) of economic proved reserves of curative mud.

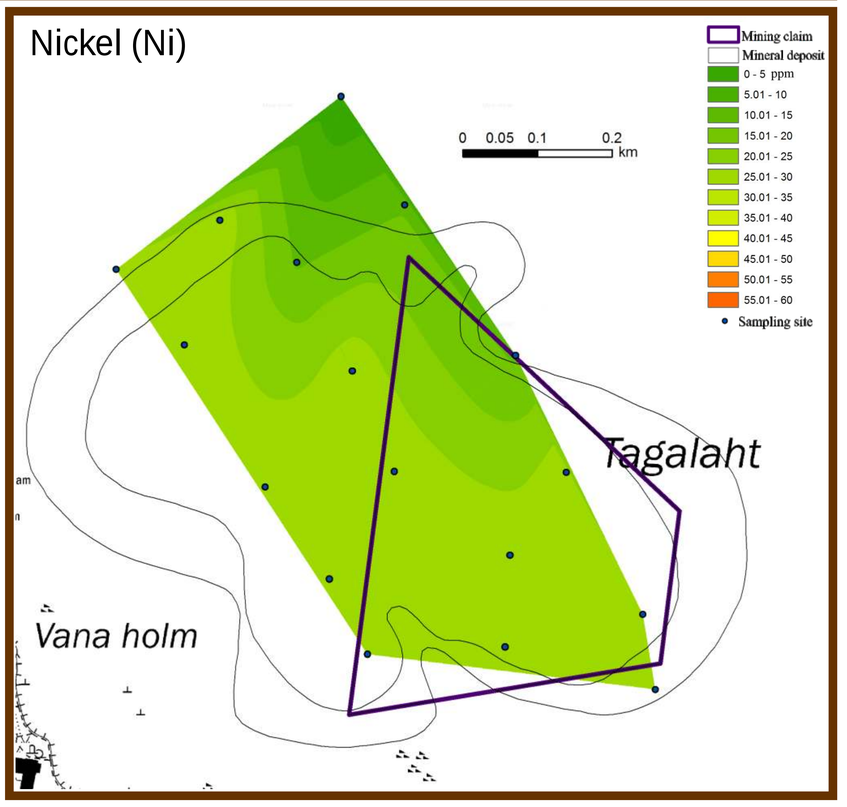
Lead (Pb)



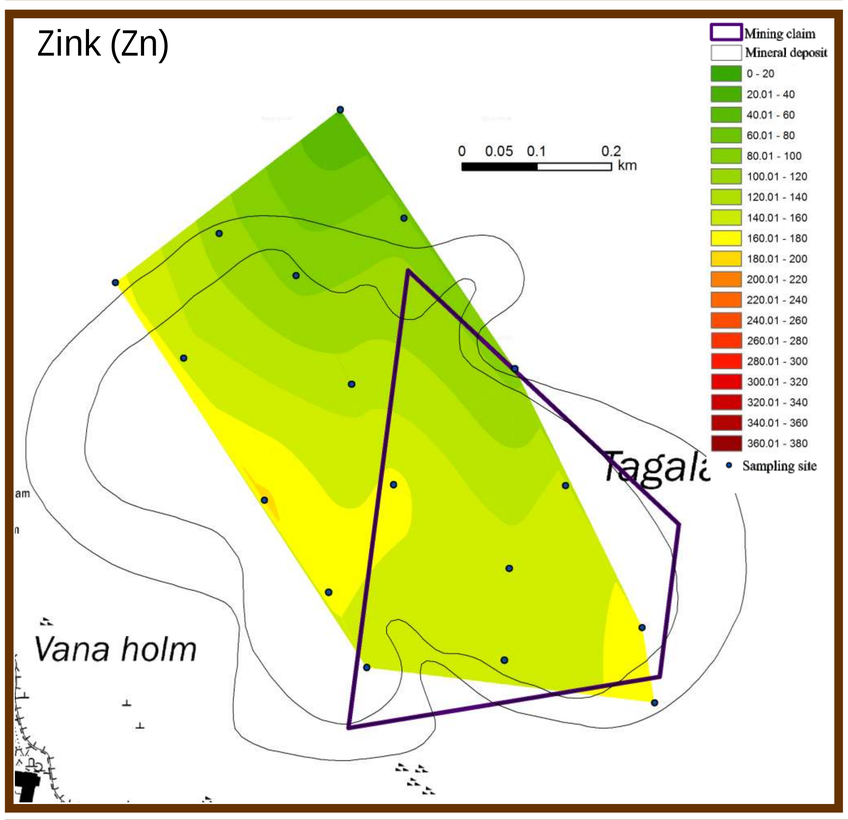
Copper (Cu)



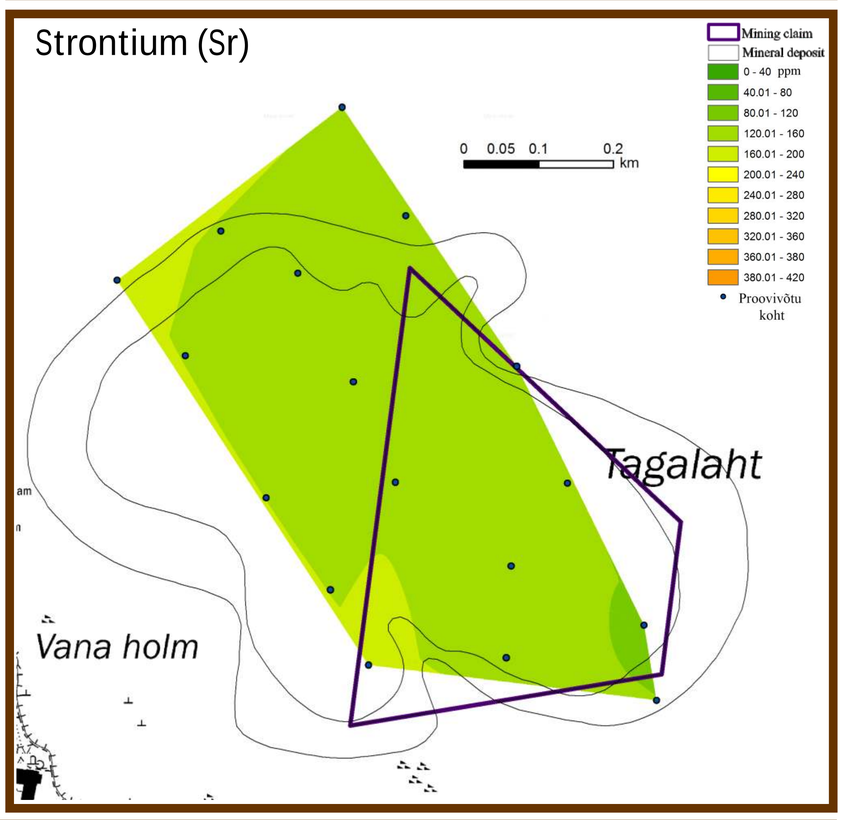
Nickel (Ni)



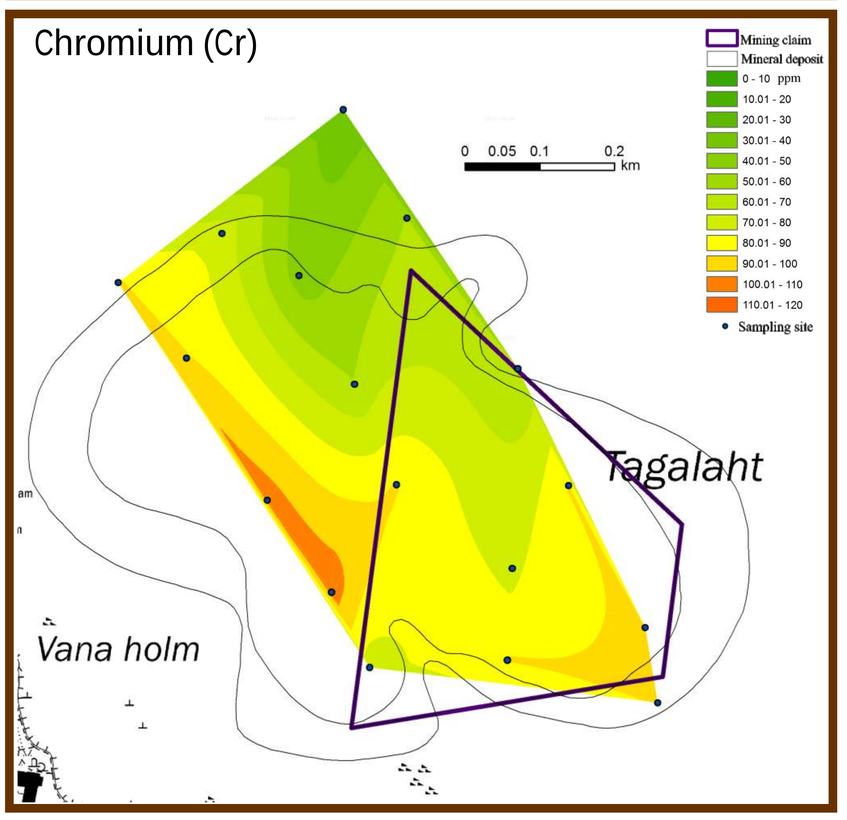
Zink (Zn)



Strontium (Sr)



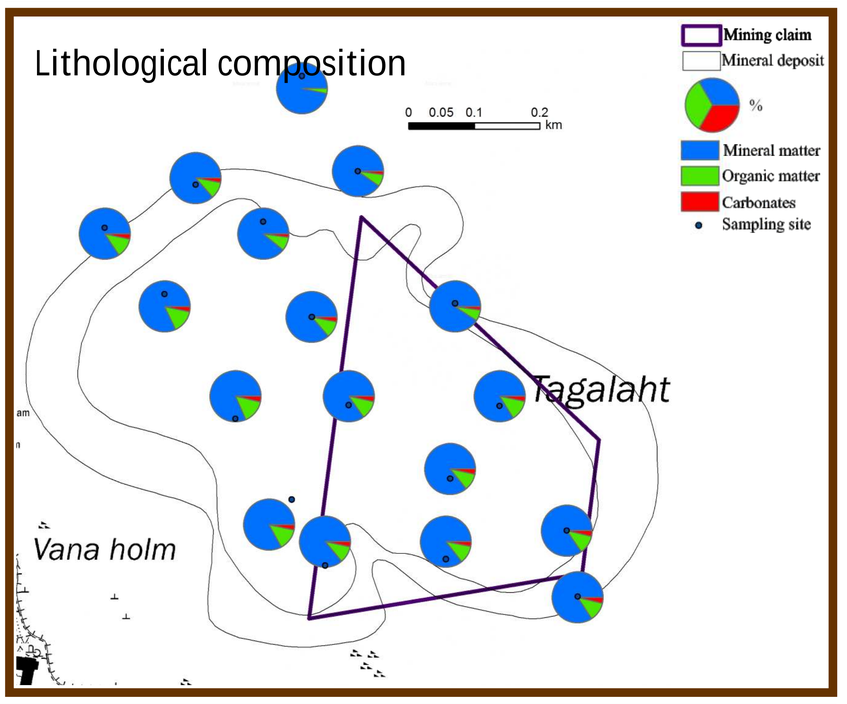
Chromium (Cr)



Mud composition

	Mineral matter (%)	Organic matter (%)	Carbonates (%)	Pb (PPM)	Cu (PPM)	Ni (PPM)	Zn (PPM)	Sr (PPM)	Cr (PPM)	Zr (PPM)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Cl (mg/g)	P (mg/g)	S (mg/g)
Average	87.8	10.9	1.3	28.8	38.6	24.3	136	147	78.2	330	6.2	1.3	4.6	3.9	1.0	3.9	2.8	2.6
Minimum	83.5	3.3	0.4	10.0	0.0	0.0	36.9	104	30.2	281	4.6	1.1	1.6	3.0	0.6	2.2	2.5	0.0
First quartile	86.1	10.5	1.3	20.0	29.9	28.5	111	138	60.4	314	5.7	1.2	4.3	3.7	0.9	3.5	2.8	2.2
Median	87.4	11.3	1.4	30.0	44.8	28.5	148	156	90.7	348	6.2	1.3	4.9	4.0	1.0	3.7	2.8	2.8
Third quartile	88.2	12.5	1.5	30.0	44.8	28.5	166	156	90.7	348	6.6	1.4	5.4	4.1	1.1	4.1	2.9	3.1
Maximum	96.3	14.9	1.6	40.0	44.8	28.5	185	173	106	364	7.8	1.7	6.1	4.5	1.4	6.1	3.1	4.1

Lithological composition



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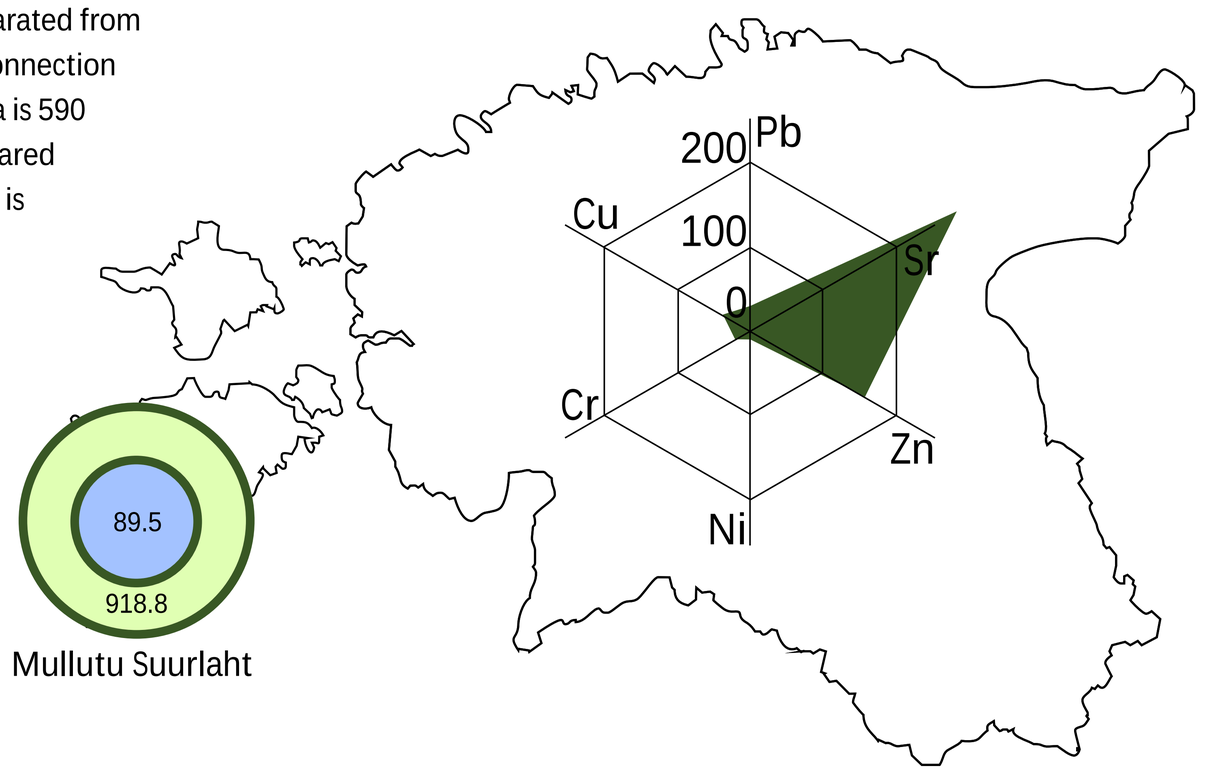

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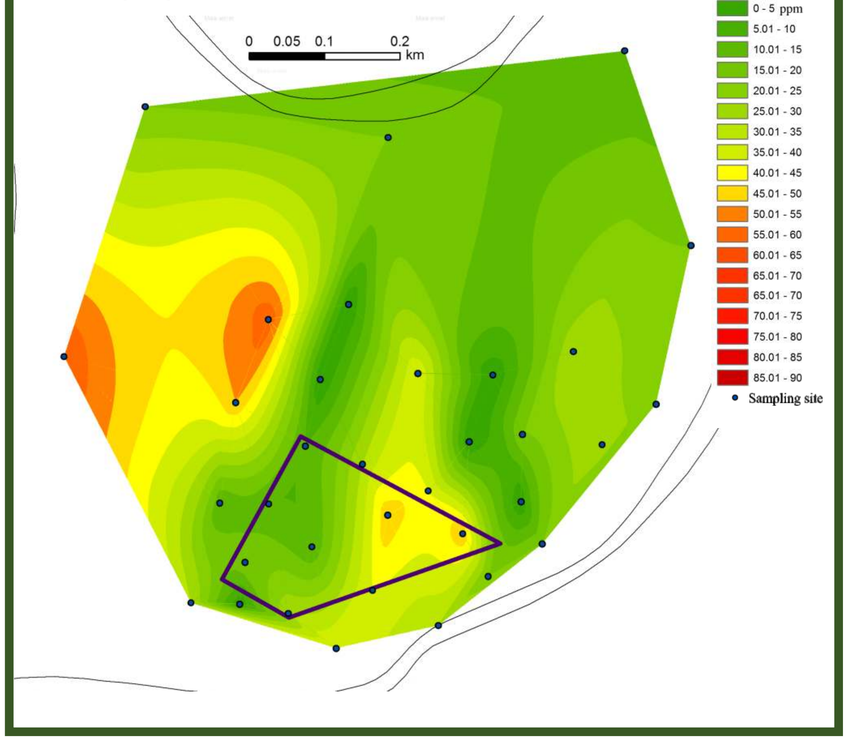
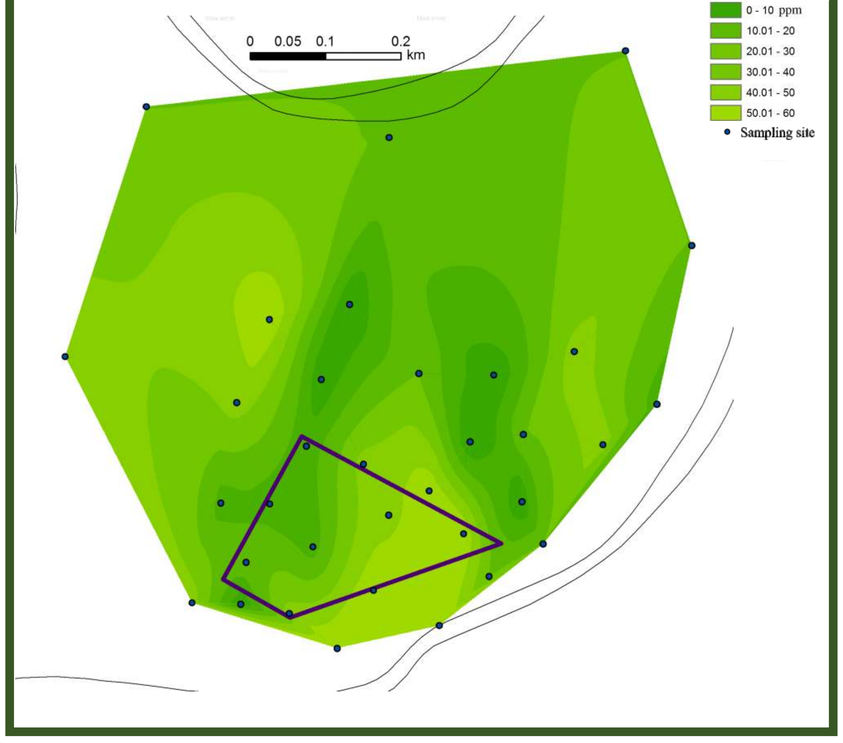
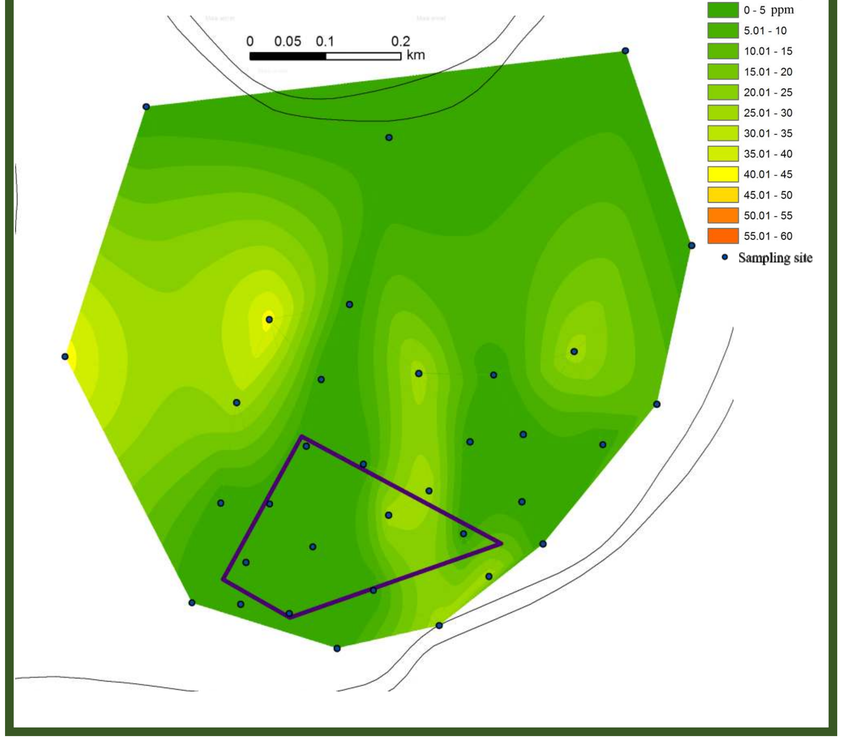
Lead (Pb)



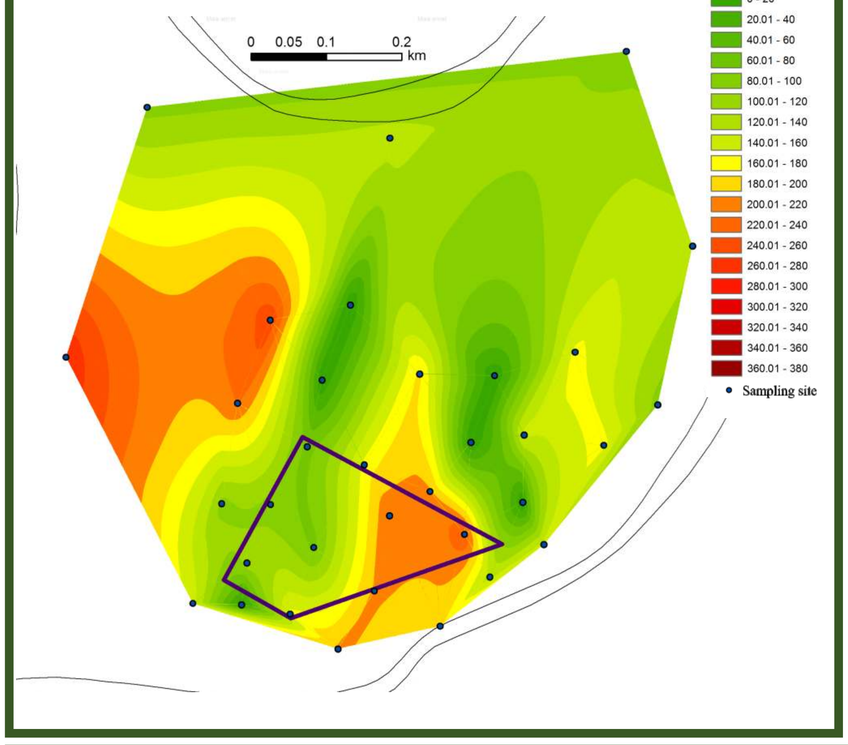
Copper (Cu)



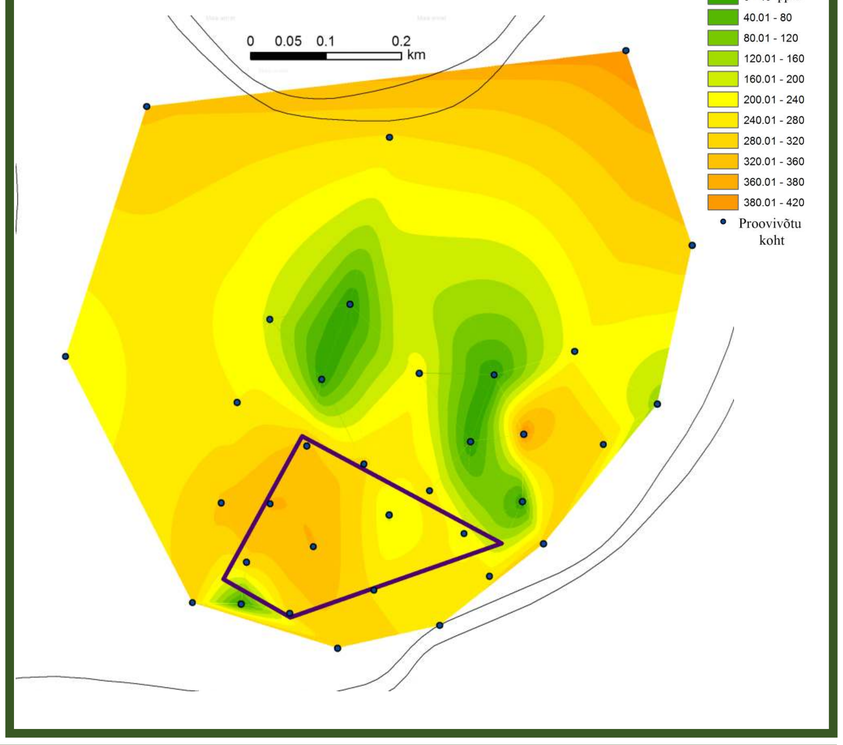
Nickel (Ni)



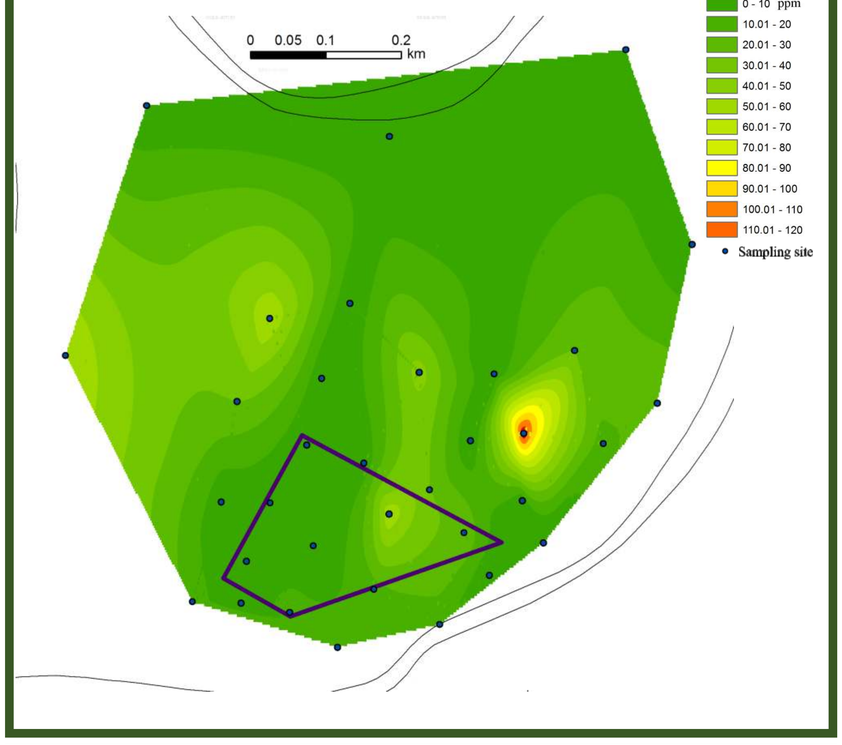
Zink (Zn)



Strontium (Sr)



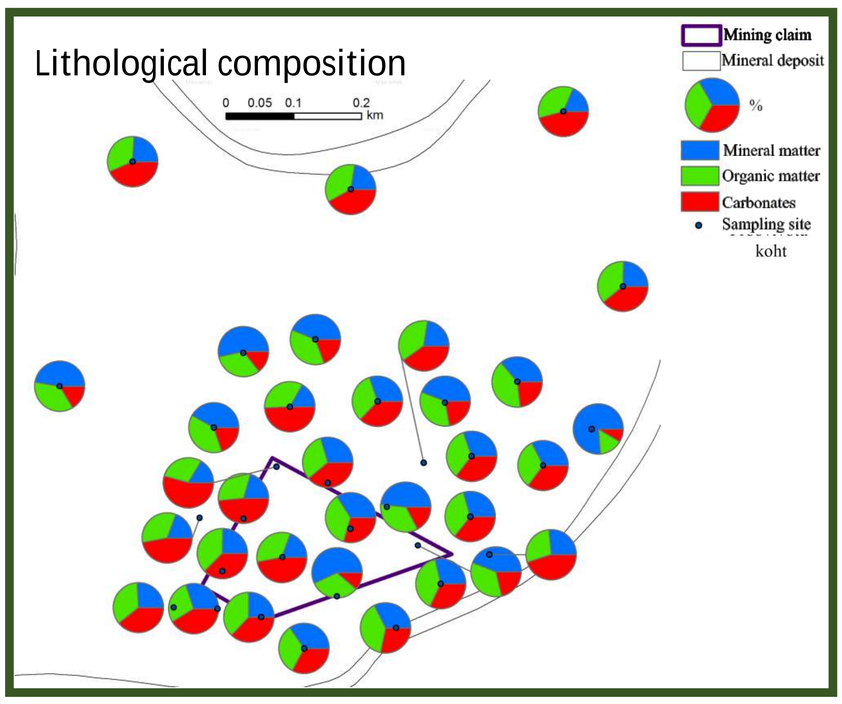
Chromium (Cr)



Mud composition

	Mineral matter (%)	Organic matter (%)	Carbonates (%)	Pb (PPM)	Cu (PPM)	Ni (PPM)	Zn (PPM)	Sr (PPM)	Cr (PPM)	Zr (PPM)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Cl (mg/g)	P (mg/g)	S (mg/g)
Average	51.6	33.9	14.6	29.3	37.9	10.7	158	284	21.0	72.7	1.2	28.0	1.8	1.2	0.5	7.2	2.0	5.3
Minimum	44.3	15.0	3.8	10.0	14.9	0.0	73.9	138	0.0	16.6	0.1	6.2	0.7	0.6	0.0	1.8	1.1	0.0
First quartile	46.5	32.3	10.0	20.0	29.9	0.0	106	238	0.0	33.1	0.7	22.9	1.2	0.9	0.5	6.0	1.9	4.4
Median	49.7	34.3	16.0	30.0	37.3	0.0	157	294	15.1	49.7	1.0	29.3	1.7	1.1	0.5	6.9	2.2	5.3
Third quartile	52.9	36.3	18.7	40.0	44.8	28.5	203	316	30.2	82.8	1.5	33.7	2.3	1.4	0.6	8.5	2.3	6.9
Maximum	81.2	40.8	23.9	60.0	59.7	42.8	277	415	121	397	2.9	39.7	3.6	2.2	0.8	14.1	2.4	8.4

Lithological composition



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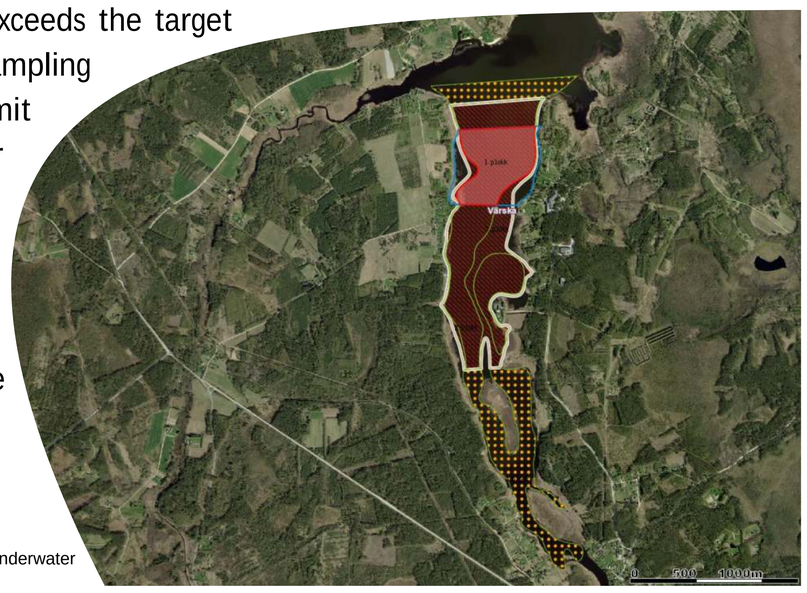
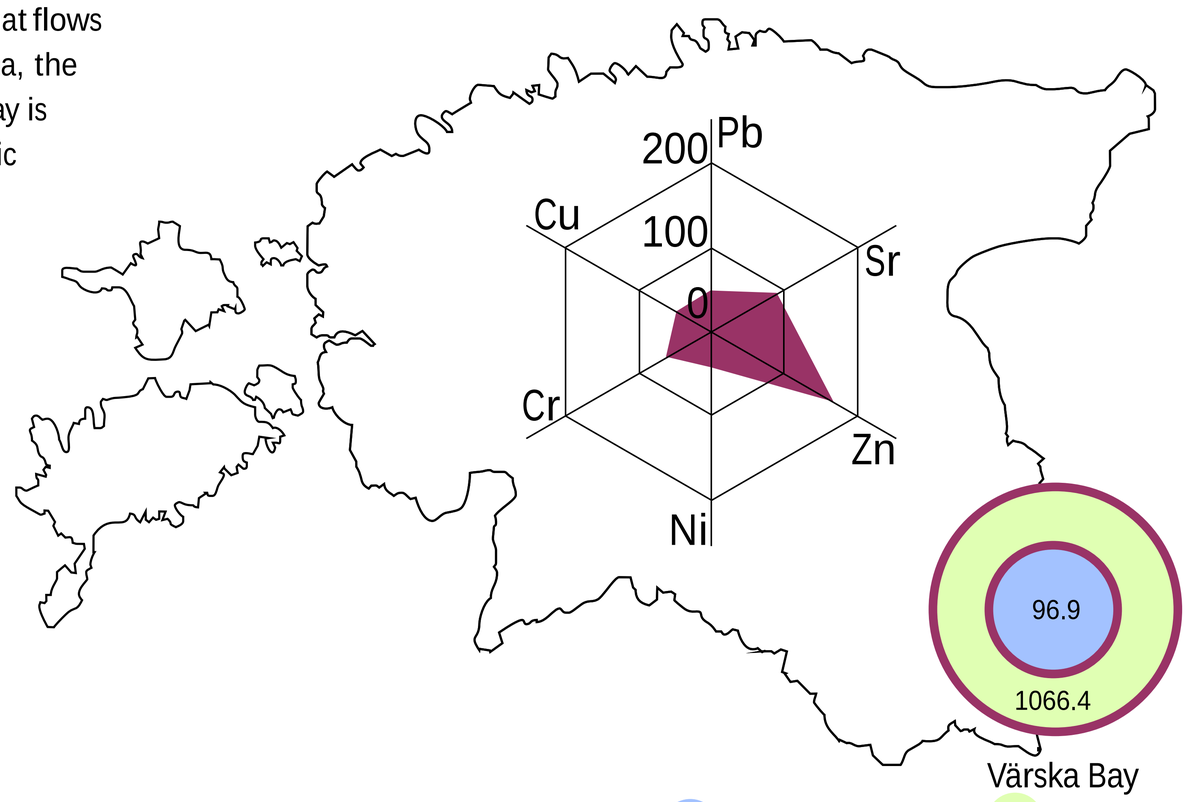
Curative mud in Estonia 2013-2014: Värska Bay

Jaanus Terasmaa, Galina Kapanen, Agata Marzecova, Sander Rautam

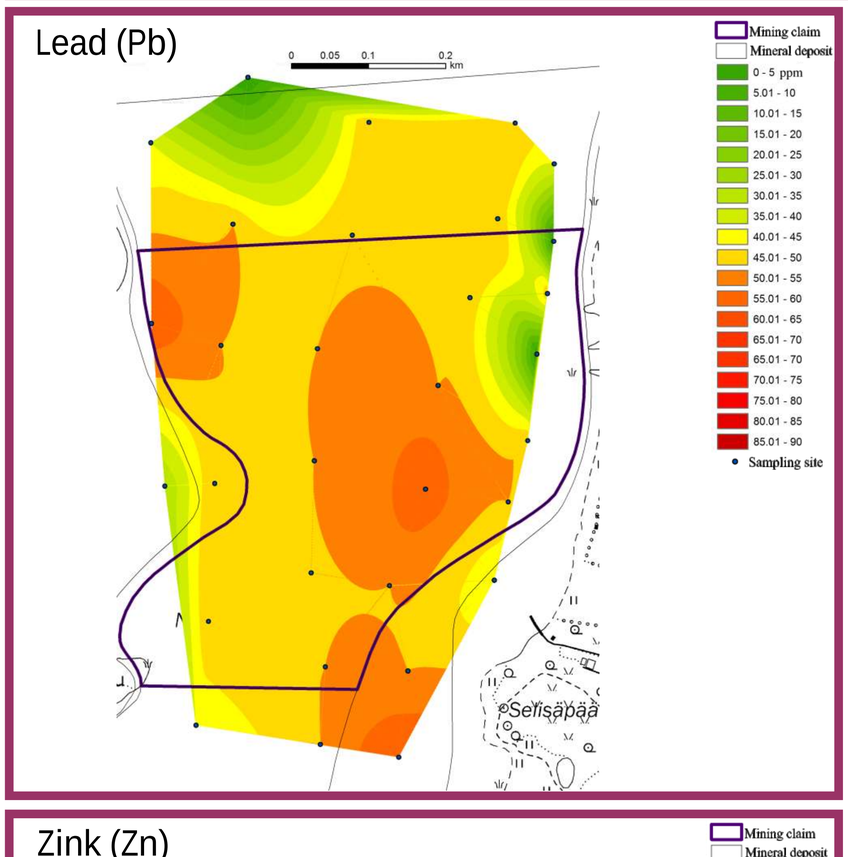
Värska Bay is located in the south-eastern part of Estonia, in the mouth of the Värska stream that flows into the Lake Pihkva (the bay is 1.3 km wide in the mouth). The area of the bay is 157 ha, the average depth is 1.4-1.7 meters and the maximum depth is 3 m. Near the mouth of the bay is Kolpin Island which belongs to Russia. For a lake ecosystem, the mud in Värska Bay is very minerogenic - on average of 59.6%. The content of the organic matter is 38.7% and the carbonate content is 1.7%. In Värska Bay, there is no statistically significant correlation between lithology and heavy metals. The lead (Pb) content exceeds the target values set for soil at several sampling points, but remains below limit values. Compared to other deposits, zinc (Zn) and nickel (Ni) have the highest values. Since the 1990s, the average organic matter content has decreased slightly, but the maximum value has increased (41.6% -> 45.7%).



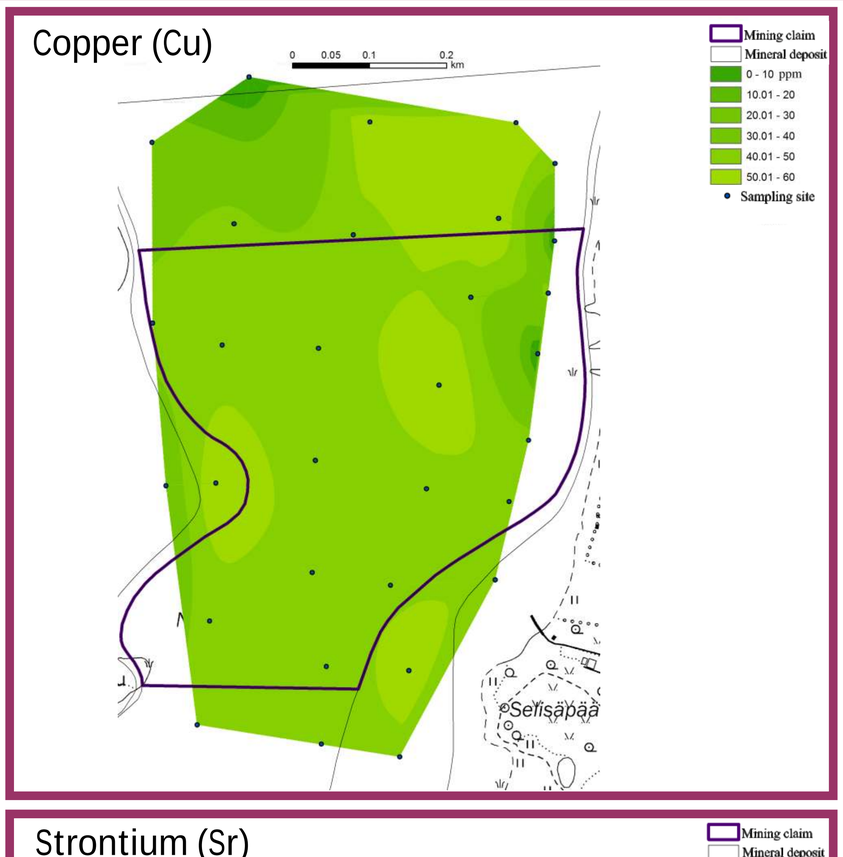


Surface area (ha) and volume (in 1000 tons) of economic proved reserves of curative mud.

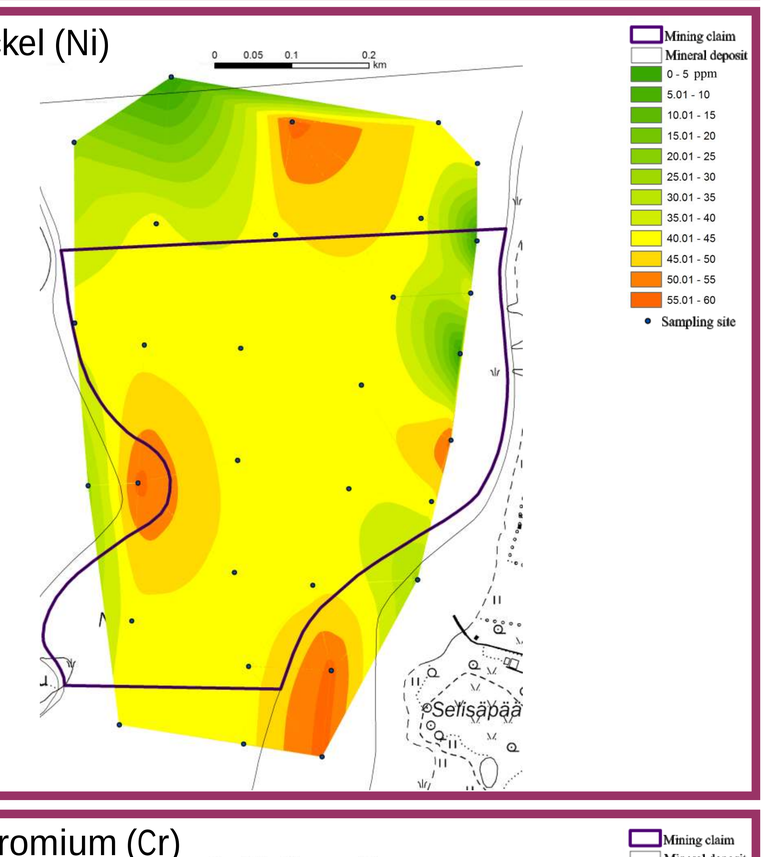
Lead (Pb)



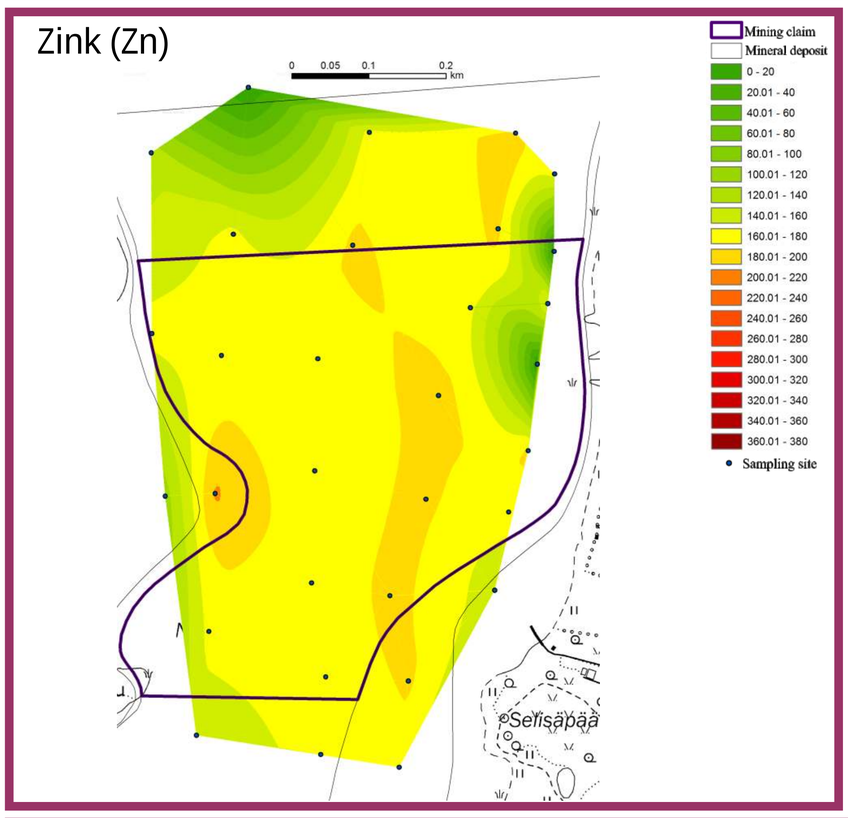
Copper (Cu)



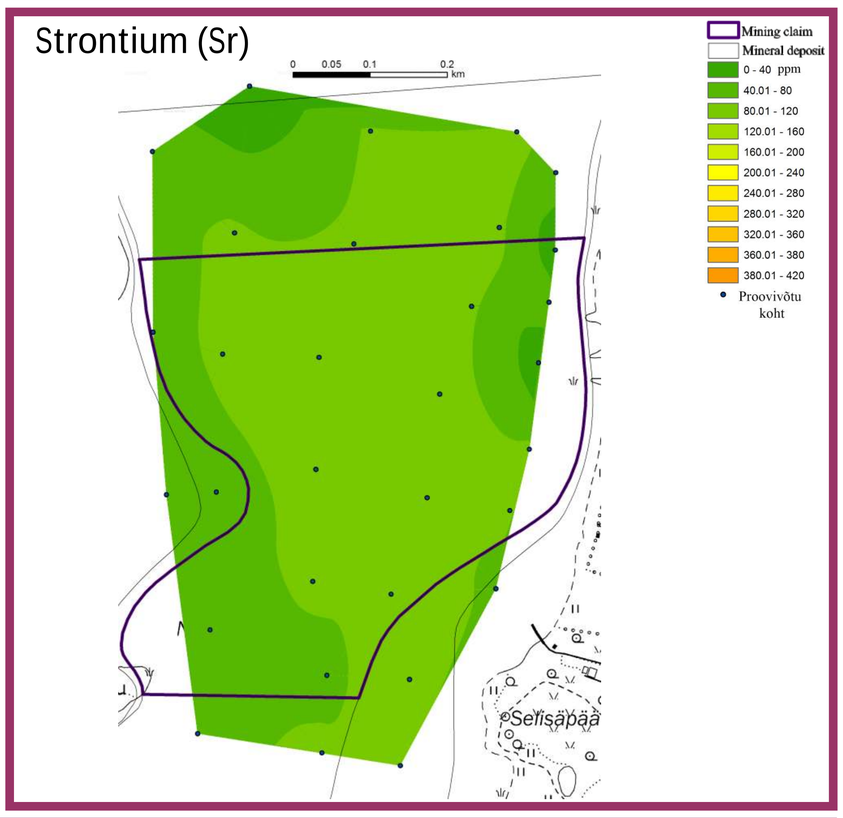
Nickel (Ni)



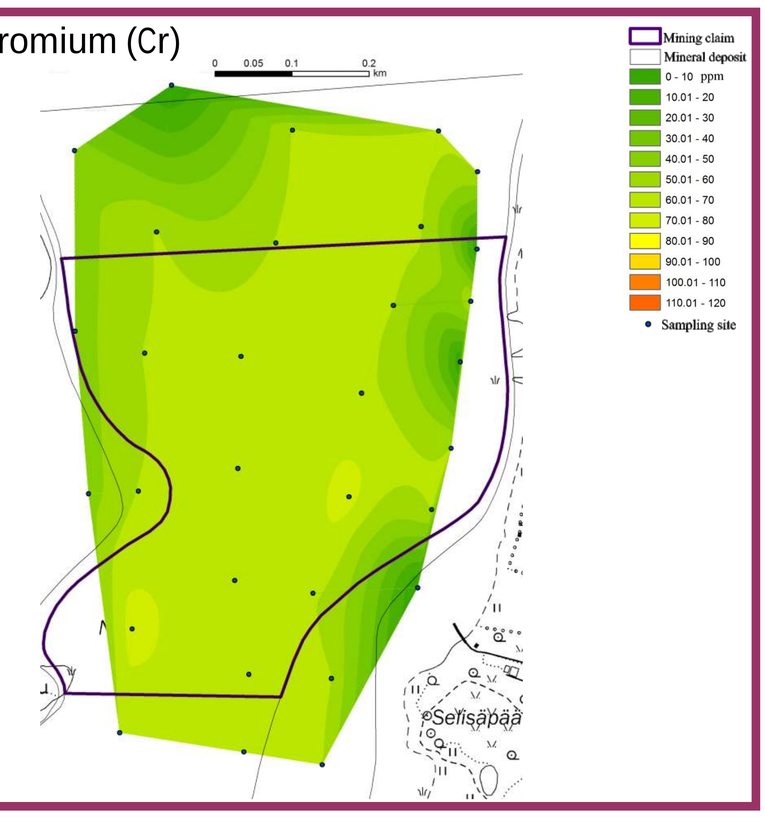
Zink (Zn)



Strontium (Sr)



Chromium (Cr)



Mud composition

	Mineral matter (%)	Organic matter (%)	Carbonates (%)	Pb (PPM)	Cu (PPM)	Ni (PPM)	Zn (PPM)	Sr (PPM)	Cr (PPM)	Zr (PPM)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Cl (mg/g)	P (mg/g)	S (mg/g)
Average	59.6	38.7	1.7	48.9	46.9	43.8	168	82.2	57.7	145	4.2	2.4	9.4	2.4	0.4	0.2	3.0	5.3
Minimum	53.0	35.9	0.9	30.0	29.9	28.5	111	51.9	0.0	116	3.7	1.7	5.0	2.2	0.3	0.0	2.3	0.0
First quartile	59.0	37.6	1.4	50.0	44.8	42.8	166	69.2	60.4	132	4.1	2.2	9.0	2.3	0.4	0.0	2.9	4.7
Median	59.8	38.4	1.6	50.0	44.8	42.8	166	86.5	60.4	149	4.2	2.3	9.9	2.4	0.4	0.0	3.0	5.3
Third quartile	60.7	39.3	1.8	50.0	44.8	42.8	185	86.5	60.4	149	4.3	2.6	10.4	2.4	0.5	0.2	3.2	5.9
Maximum	63.1	45.7	3.0	60.0	59.7	57.0	203	121	75.5	166	4.9	3.5	11.0	2.8	0.6	1.7	3.6	14.3

Lithological composition

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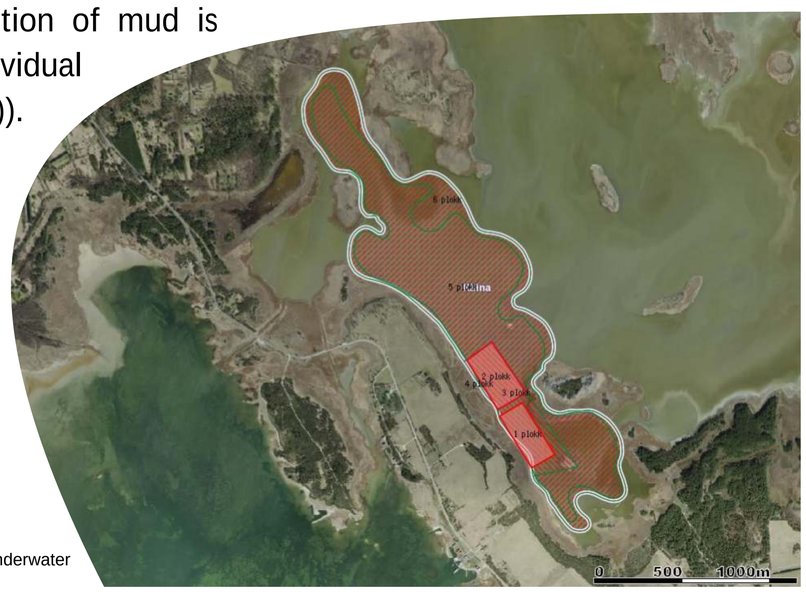
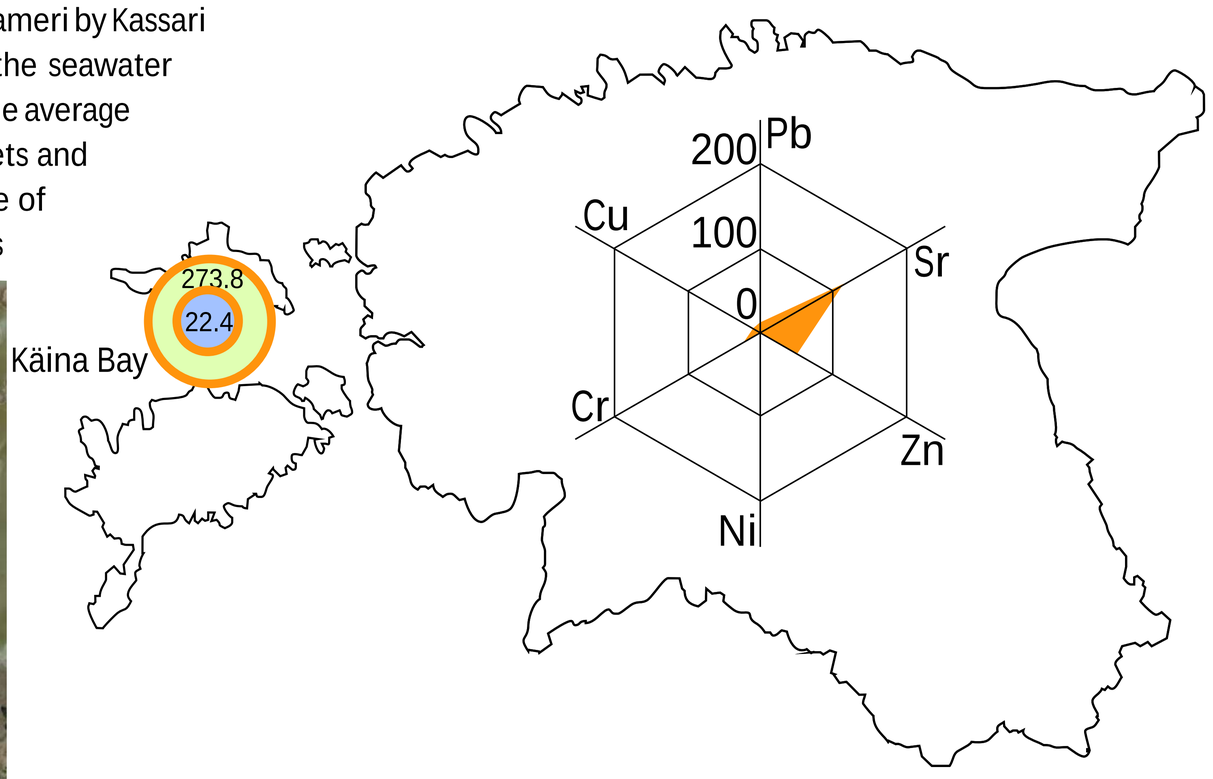
Curative mud in Estonia 2013-2014: Käina Bay

Jaanus Terasmaa, Galina Kapanen, Agata Marzecova, Sander Rautam

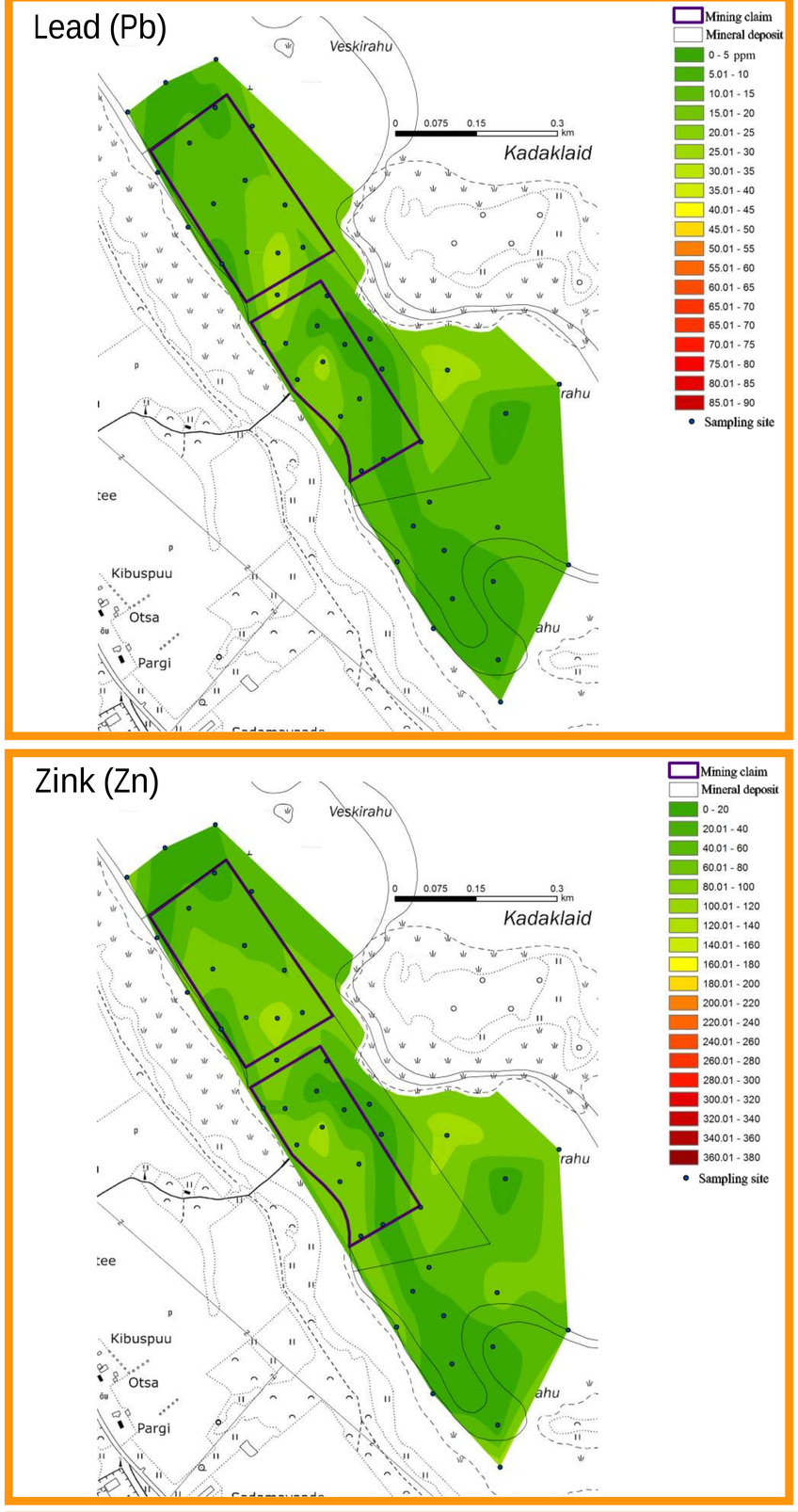
Käina Bay is a low bay in the south-east of Hiiumaa Island, which is separated from Väinameri by Kassari Island. The connection with the sea passes through the bridgeways of the dam, the seawater exchange is minimal (water salinity is 2-3 ‰). The area of Käina Bay is 900 hectares, the average depth is 0.3-0.5 m and the maximum depth is up to 1 meter. There are numerous small islets and reed-beds. Käina Bay has the most mineral mud among curative mud deposits - an average of 92.4% of the sediment is mineral, the organic content is 6.7% and the carbonate content is 0.9%. The lithological composition of mud is statistically connected to individual heavy metals (lead (Pb), zinc (Zn)). Concentrations of heavy metals are the lowest and below the limit values. Compared to the 1990s, Käina Bay mud has become slightly more organic (4.8% -> 6.7%).



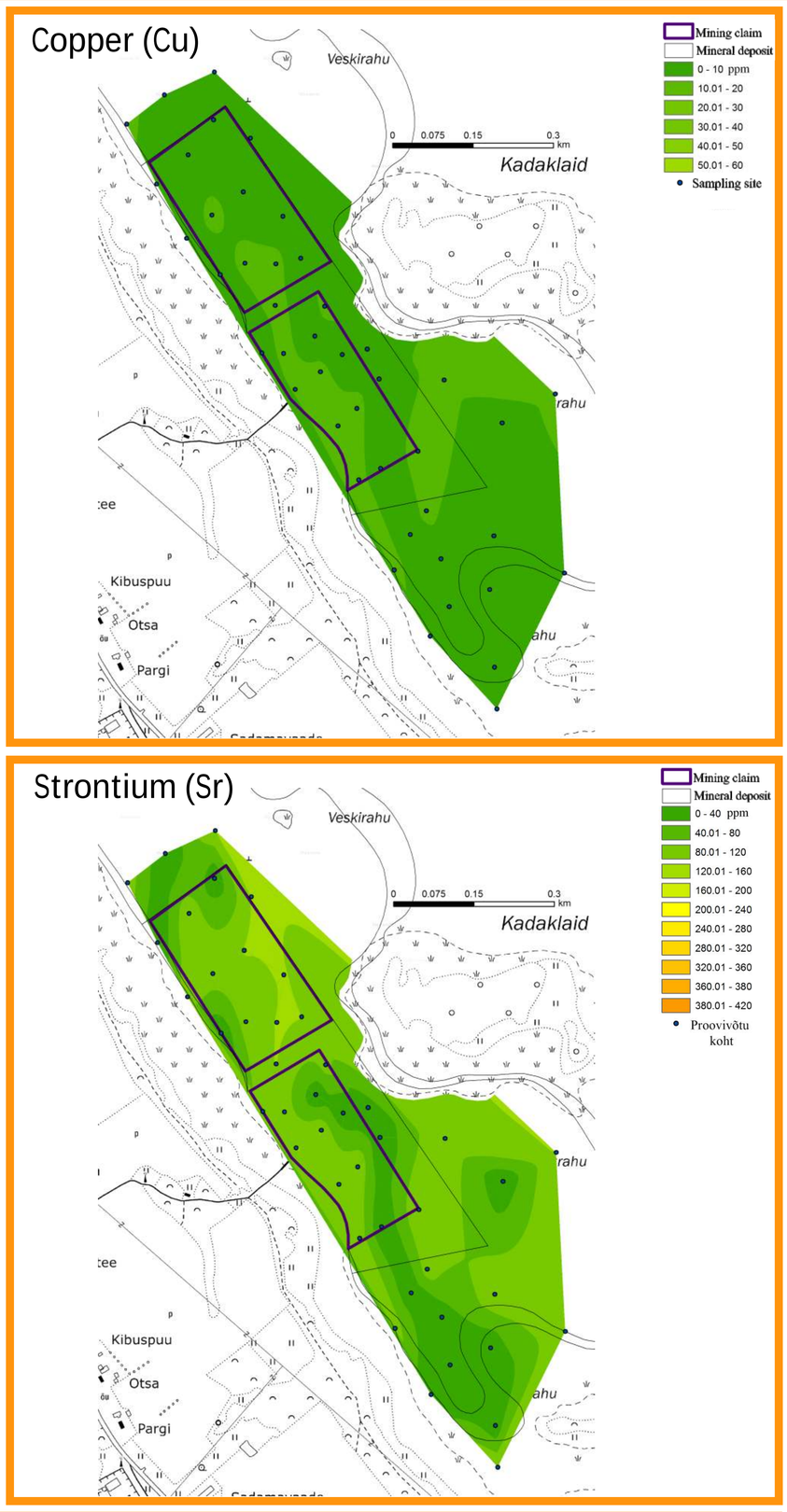


Surface area (ha) and volume (in 1000 tons) of economic proved reserves of curative mud.

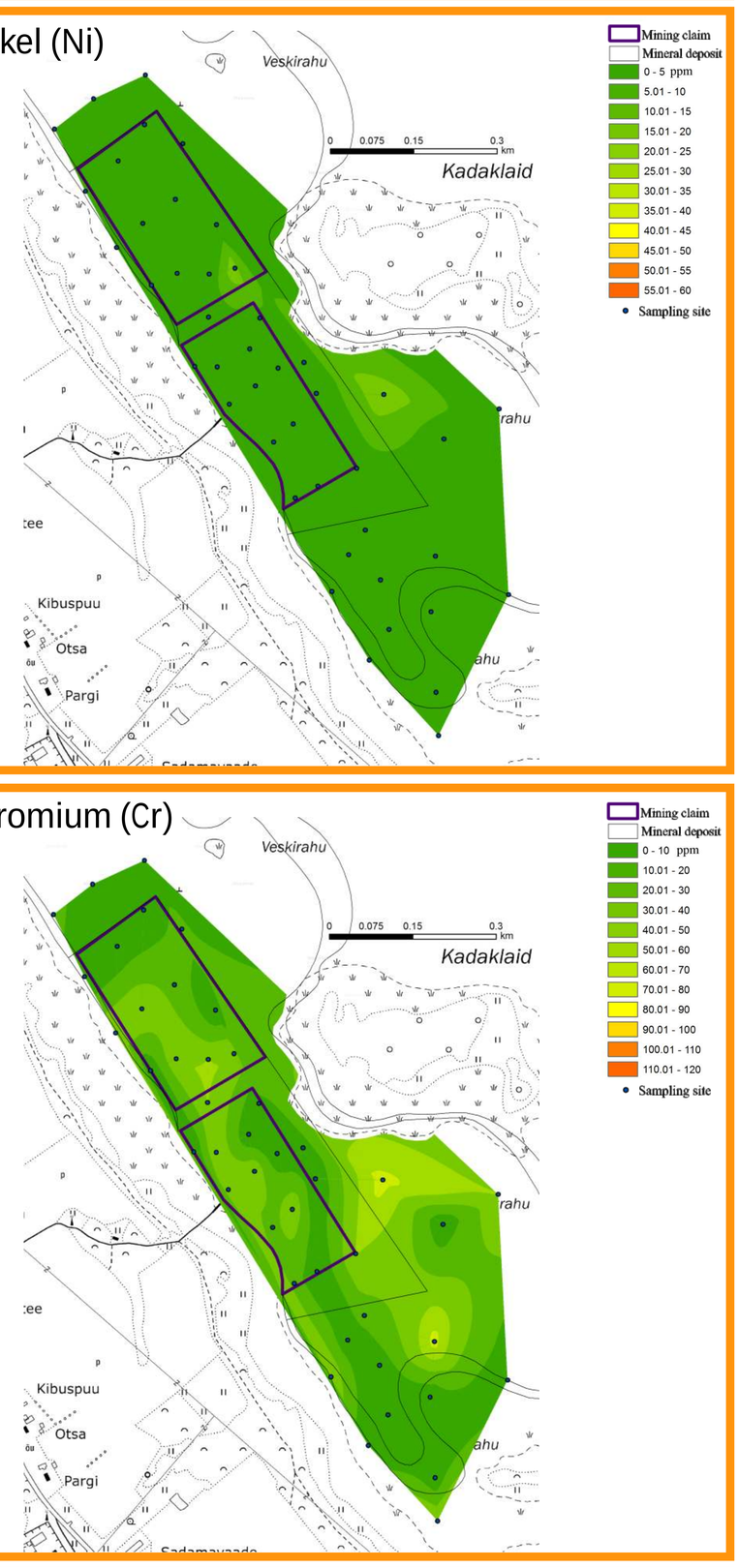
Lead (Pb)



Copper (Cu)



Nickel (Ni)



Zink (Zn)

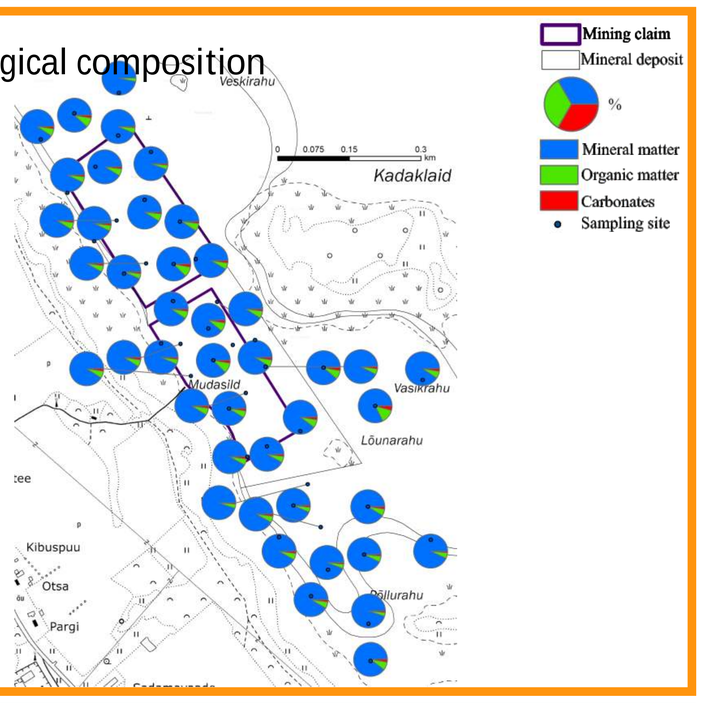
Strontium (Sr)

Chromium (Cr)

Mud composition

	Mineral matter (%)	Organic matter (%)	Carbonates (%)	Pb (PPM)	Cu (PPM)	Ni (PPM)	Zn (PPM)	Sr (PPM)	Cr (PPM)	Zr (PPM)	Al (%)	Ca (%)	Fe (%)	K (%)	Mg (%)	Cl (mg/g)	P (mg/g)	S (mg/g)
Average	92.4	6.7	0.9	11.4	9.1	1.0	50.8	114	21.6	340	3.0	0.8	1.6	2.9	0.2	3.4	2.8	0.9
Minimum	88.9	3.1	0.4	10.0	0.0	0.0	18.5	104	0.0	265	2.4	0.7	0.8	2.4	0.0	1.5	2.6	0.0
First quartile	91.8	6.0	0.8	10.0	0.0	0.0	36.9	104	15.1	298	2.8	0.8	1.3	2.8	0.1	2.8	2.7	0.0
Median	92.4	6.7	0.9	10.0	14.9	0.0	55.4	121	30.2	339	3.0	0.8	1.7	3.0	0.2	3.2	2.8	1.0
Third quartile	93.0	7.4	1.1	10.0	14.9	0.0	55.4	121	30.2	352	3.3	0.8	1.9	3.1	0.2	4.3	2.8	1.5
Maximum	96.5	9.9	1.3	20.0	14.9	14.3	73.9	121	45.3	480	3.8	1.2	2.6	3.2	0.4	5.5	2.9	2.0

Lithological composition



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