Human impact on the groundwater management in North Estonia.

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Abstract

Due to extensive economic activities and high vulnerability of the uppermost aquifer, the shallow groundwater is in places heavily polluted and unfit for drinking. The uppermost aquifer in erosional uplands and limestone plateau has no natural protection or is poorly protected against pollution. The main problems of human impact are related to industry and mining, past pollution from military objects and intensive agriculture of the former Soviet Union.

Key words: shallow groundwater, pollution, industry, mining, past pollution, agriculture, Kurtna Kame Field, Kunda area, Pakri Peninsula.

Introduction

Due to a thin aeration zone (mainly 1.5-3 m) the unconfined groundwater in northern Estonia is generally weakly protected against surface pollution. The problems are especially acute in the areas where the Quaternary cover is less than 2 m thick. In vast areas the Quaternary cover is practically missing and the fissured and highly cavernous limestones crop out on the surface.

On the basis of experimental data (Kink, 1995) groundwater is considered unprotected on alvars and in the areas where aquifers are covered with an up-to-2-m-thick layer of sand or sandy loam. It is weakly protected when the thickness of the confining layer of sandy loam ranges from 2-10 m, or the loam or clay layer is less than 2 m thick. In the case of intensive water consumption, these criteria should be corrected, because under such conditions the transport velocity of pollutants in soil may increase noticeably.

Study area

For the investigation three geologically different areas in North Estonia were chosen. The Kurtna Kame Field is situated in the northeastern part of the Estonian oil shale deposit area. The kame field is surrounded oil shale mining and pit on west and east sides (Fig. 1). In the west the kame field borders on an oil shale mine; in the east on an oil shale open pit. The area (30 km^2) contains 40 lakes, which are more or less influenced by mining. The state of the lake ecosystems is, first of all, determined by the groundwater regime. Therefore, the study of the influence of the oil shale mining and water consumption in the Vasavere intake is of great importance.

The Kunda area lies within two landscape regions – the North Estonian Coastal Plain and the Viru Plateau. The surrounding of Kunda has long been known as a region of cement industries, founded in 1870. Industrial limestone use started in 1911, when the Kunda - Aru quarry was put into operation. Oil shale has been mined at Vanamõisa and Ubja during 1923-

1957 for the Kunda cement plant. The mining of clay was started in the Lontova quarry in 1870 (Raukas, 1993).

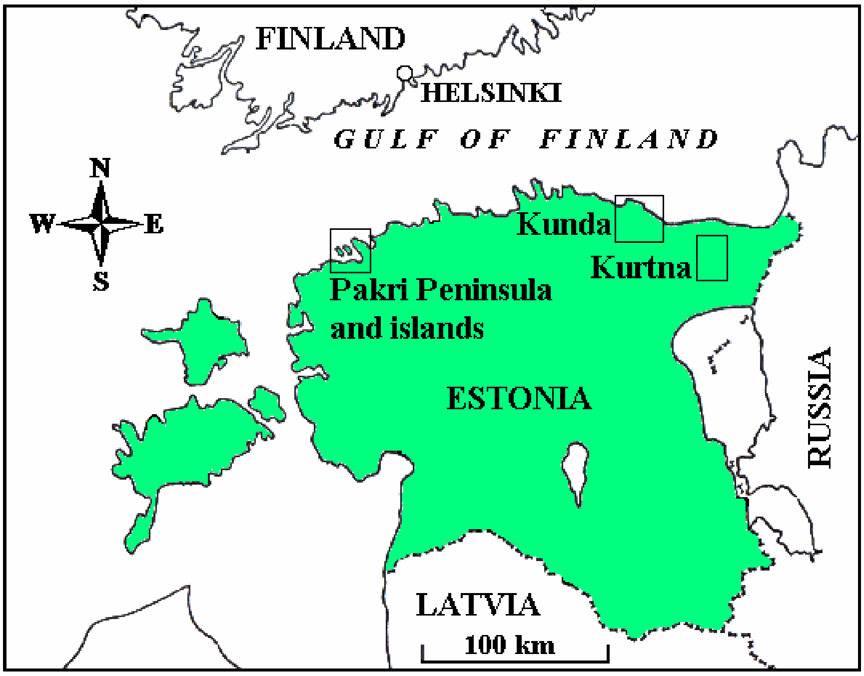

Fig. 1. Location map of the three reference areas in North Estonia

There were 1565 military objects of the former Soviet Union in Estonia with the total area of 87 000 hectares, i.e. 1.9 per cent of Estonian territory (Raukas, 1999). The concentration of military units was highest on the Pakri Peninsula and Pakri Islands.

Human impact on surface and groundwater management in the Kurtna Kame Field

Until 1946, the changes in the hydrological and hydrogeological regime were caused mostly by peat cutting drainage. Since the fifties the water level has fallen considerably in 24 lakes because of the drainage of the oil shale pit in Sirgala, peat cutting in Oru, oil shale extraction in the Ahtme mine, sand production in the Pannjärve quarry and water consumption (Fig. 2).

The drainage divide lies much closer to the eastern slope of the kame field than to its western slope. The impacts of the oil shale mining upon the groundwater regime are accordingly different. The groundwater regime in the central part of the kame field is influenced by the water consumption of the Vasavere intake. The surface and groundwater regimes are upset everywhere in the Kurtna Kame Field, but the disturbances vary.

The content of sulphate in the surface and groundwater indicate directly the influence of the mining water. Oxidation of the pyrite contained in Ordovician rocks, serves as a source of this compound, and concentrations up to 500 mg l^{-1} have been found in mining waters. In 1937 (Table 1) the lakes were in natural condition, the sulphate was in the range of 1.0-6.7 mg l^{-1}. Variations of this value seem to have been caused mainly by natural factors. In recent years the sulphate content has increased sharply both in the closed lakes and in those influenced by mining waters. This rise has been especially high in the lakes influenced directly or indirectly by mining waters, having recently the sulphate values in the range of 160-270 mg l^{-1} and by water table rise in Lake Konsu. When, for example, in 1937 the sulphate content in lakes

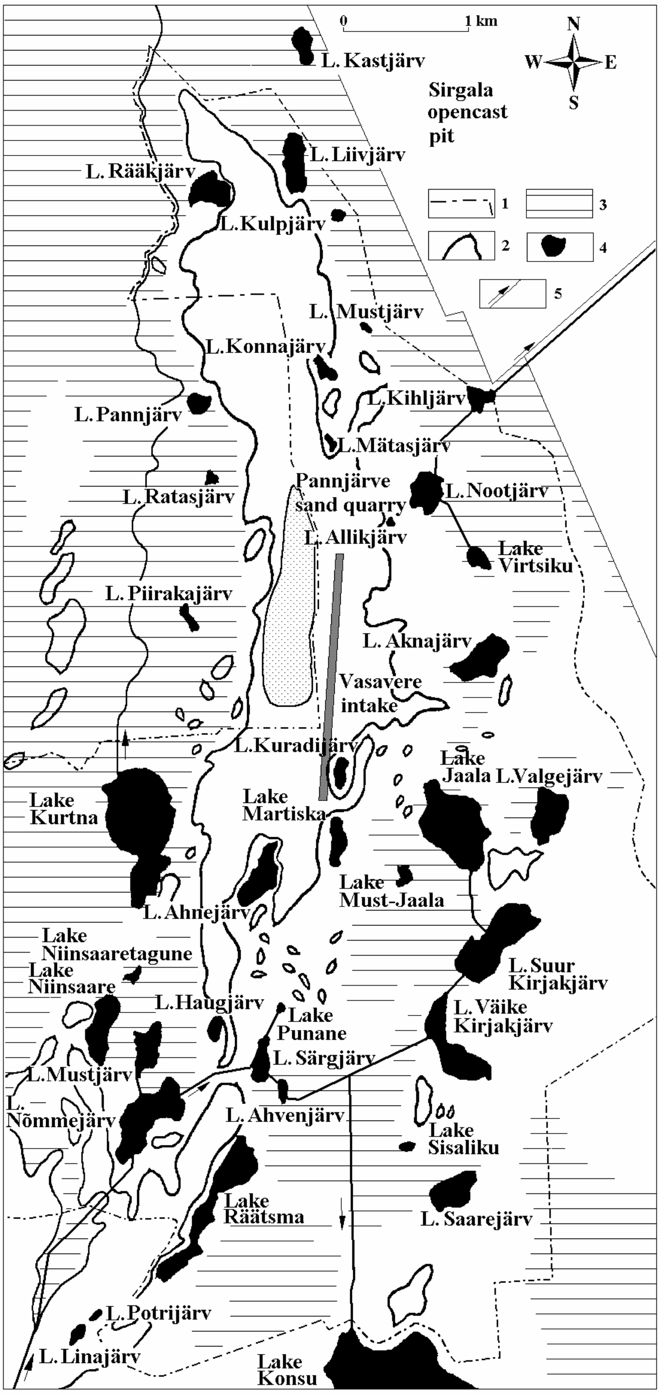

Fig. 2. Kurtna Kame Field. 1 – border of protection area, 2 – contour line 50 m above sea level, 3 – mire, 4 – lake, 5 – flow direction.

Nõmmejärv and Konsu was 5.8 and 2.9 mg l^{-1}, then in 1996 the corresponding values were 273 and 190 mg l^{-1}, respectively (Table 1). To some extent, the rise of the sulphate content in closed lakes also reflects the atmospheric source as its constituent. Characteristic sulphate values for these lakes lie in the range of 6-50 mg l^{-1}. Seasonal variations in the sulphate content do not exceed 20-30%.

Table 1. Temporal changes of sulphate content and water table change in surface and groundwater of Kurtna Kame Field (Riikoja, 1940; Varvas, 1994; Groundwater state in 1996, 1997).

Lake	1937	1989	1996	Change of water table 1946-1996
L. Kastjärv	4.8	171.7	-	-3.9
L. Rääkjärv	6.7	205.0	247.3	-2.2
L. Pannjärv	4.8	213.1	335.1	-0.9
L. Valgejärv	5.8	17.1	17.8	-1.9
L. Jaala järv	3.8	18.9	18.9	-0.8
Lake Suur-Kirjaku	4.8	160.5	232.1	-1.8
Lake Väike-Kirjaku	6.7	207.6	235.2	-1.6
L. Mustjärv	2.9	33.2	46.9	-1.5
L. Kuradijärv	2.9	7.5	14.0	-4.7
L. Martiskajärv	1.9	18.9	22.3	-5.0
L. Ahnejärv	5.8	13.3	14.5	-5.2
L. Nõmmejärv	5.8	259.0	273.1	-0.5
L. Särgjärv	2.9	208.5	262.1	-1.0
L. Ahvenjärv	6.7	239.3	252.6	-0.8
L. Saarejärv	4.8	10.2	9.9	-2.7
Lake Niinsaare	2.9	23.7	46.6	-1.2
Lake Kurtna	1.0	27.0	63.2	-2.9
Lake Räätsma	4.8	25.6	32.0	-1.0
Lake Konsu	2.9	184.8	190.0	+5.6
Vasavere intake well 212	-	67.2	38.4	-4.8

Human impact on surface and groundwater management in the Kunda area

The area is situated in the catchment of the Kunda (529.8 km^2) and Toolse (84.7 km^2) rivers. The annual discharge of the Kunda river is 11.4 $l/sec*km^2$. Groundwater is stored in the Quaternary cover (the thickness of water-bearing strata is 1-5 metres), Lower Ordovician (40 m), Ordovician-Cambrian (25 m) and Cambrian-Vendian aquifers. The thick clay layer divides the last aquifer system into two parts with the thickness of 15-24 and 40-60 metres correspondingly.

In 1990, a monitoring system was laid out at Kunda aimed at research into the air, water, soil, coastal geological processes, ecosystems and the health of the population. Water monitoring includes research into the quality and quantity of ground and surface water and wastewater. In consideration of the impact of the Aru quarry and the closed Ubja mine monitoring was carried out on the Toolse and Kunda rivers. The groundwater composition was studied in the town of Kunda in bored wells (to a depth of 150 m, Є-V). Wastewater monitoring covered all wastewater discharges.

As a result of limestone excavation in the Aru quarry a depression funnel (14 m in depth) has formed (Fig. 3) (Metslang, 1994). The town of Kunda and the cement plant are supplied with drinking water from the Cambrian-Vendian aquifer. The main problem is the heightened concentration of Cl and Ba (Kink, 1995).

The depression funnel exerts an impact on the Kunda and Toolse rivers. The concentration of nitrogen in the surface water has decreased. This is evidently due to the decrease of the large-

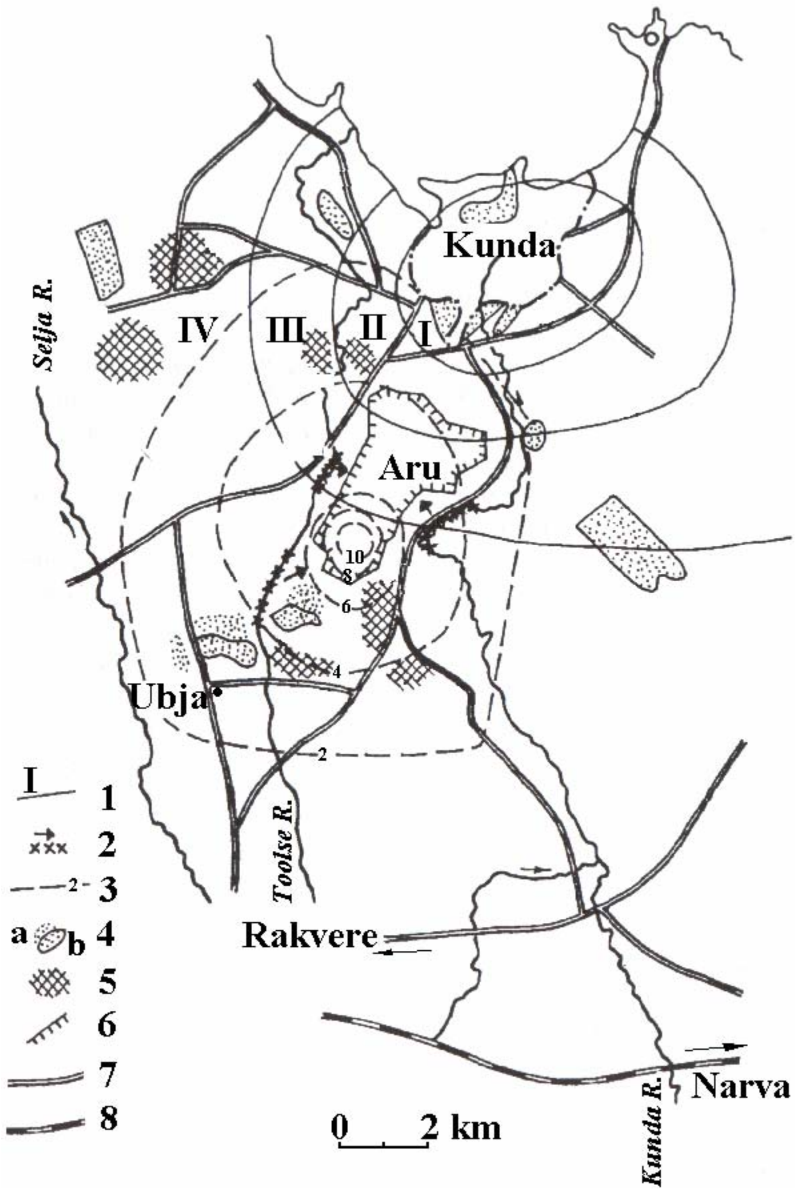

Fig. 3. Environment of the Kunda area: 1 – rates of affected vegetation (I-IV), 2 – infiltration of the surface water, 3 – lowering of the groundwater table, 4 – artificial topography: partially (a), totally (b), 5 – groundwater pollution, 6 – Aru limestone quarry 7 – road, 8 – railway.

scale agriculture. The concentration of SO_4 is still high in the Aru quarry and Toolse River (Fig. 4). In trems of fishery the Kunda and Toolse rivers ranked among the watercourses of the highest category. Unpurifed water reaches the Kunda river from the old dumping site (filtrate).

As a result of the studies, scientifically grounded recommendations were worked out for the further management of the area (Kink, 1995). On the basis of the research data the Kunda region may be classified as follows: areas under strong human impact, preservation areas and areas of regulation used (water resources are unprotected) and areas with general regime (Kink, 1995).

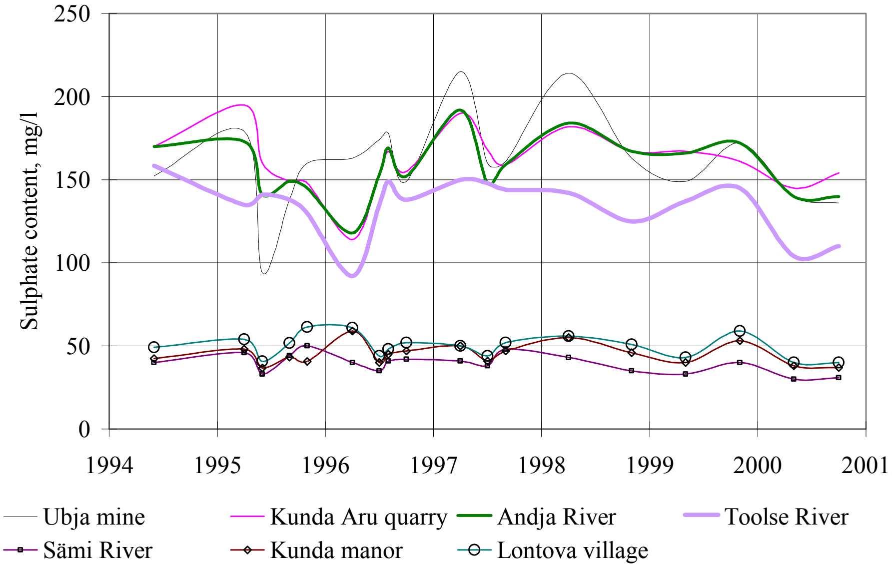

Fig. 4. Sulphate content (mg l^{-1}) in the Kunda area.

Human impact on surface and groundwater management in the Pakri Peninsula and islands of Pakri

The Pakri Peninsula, 40 km^2 in area, is situated on the limestone plateau between Pakri and Lahepere bays on the Estonian north coast. The islands of Väike-Pakri (12.9 km^2) and Suur-Pakri (11.7 km^2) are located in the Gulf of Finland, 2-3 km west of the town of Paldiski. The

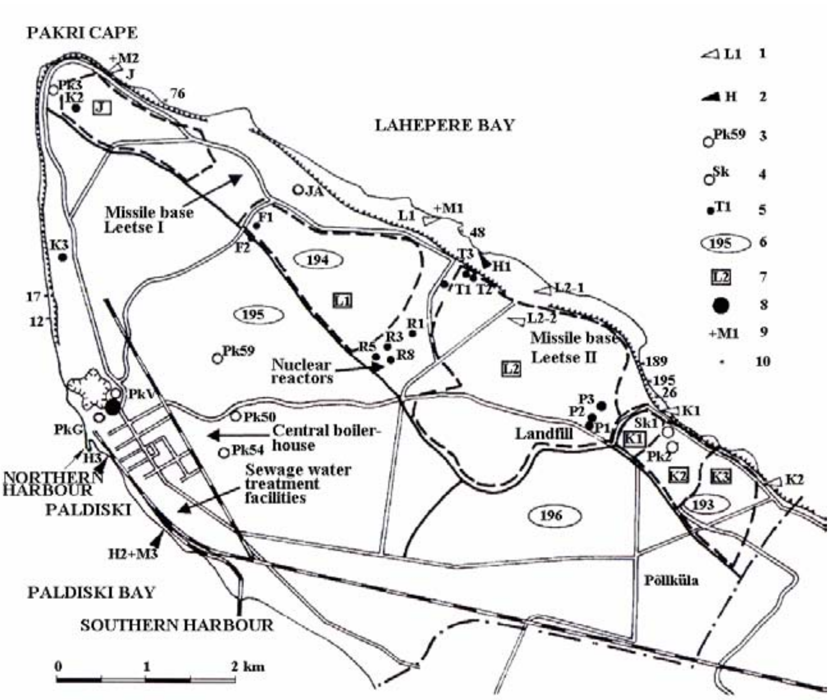

Fig. 5. Monitoring network in the Pakri Peninsula. 1 – surface water measuring point, 2 – sewage water measuring point, 3 – water supply well, 4 – dug well, 5 – observation well, 6 – catchment area, 7 – sub-catchment area, 8 – meteorological station, 9 – seawater observation point, 10 – spring

nature of the peninsula and islands is picturesque and agile with a steep limestone cliffed coast, pine forests and beautiful beaches. Geologically, the peninsula and islands consist of the Vendian and Palaeozoic clastic and carbonate rocks. The Quaternary cover is thin and in places entirely lacking. There are three groundwater aquifer systems: the uppermost is situated in the Ordovician limestones, the second in Ordovician-Cambrian and the third in Cambrian-Vendian sandstones. The aquifers are at the depth of 20, 50 and 200 m, correspondingly. Waters, excluding the third aquifer, are practically unprotected. There are neither long rivers nor large lakes. The length of the brooks is 1-2 km and they are mostly dry during the low-water stand (Kink, Metsur, Miidel, 1995).

On the Pakri Peninsula (Fig. 5) Naval Forces, Missile Forces and Coast guards of the former Soviet Union were stationed. The objects posing the greatest threat to the environment included the reactors of the Submariners Training Centre, the missile bases Leetse I and II, the harbours, the central landfill, the contaminated land and marine area. Pakri islands were used as a practice bombing range by Soviet air forces (Miidel, 1996).

A monitoring system was laid out in 1996 (Fig. 6). The Ordovician limestone and sandstone usually contain HCO_3-SO_4-Ca-Mg type of water. In the Pakri Peninsula we have four types of groundwater: one of those is natural, while the remaining three show signs of contamination (Environmental…, 1998).

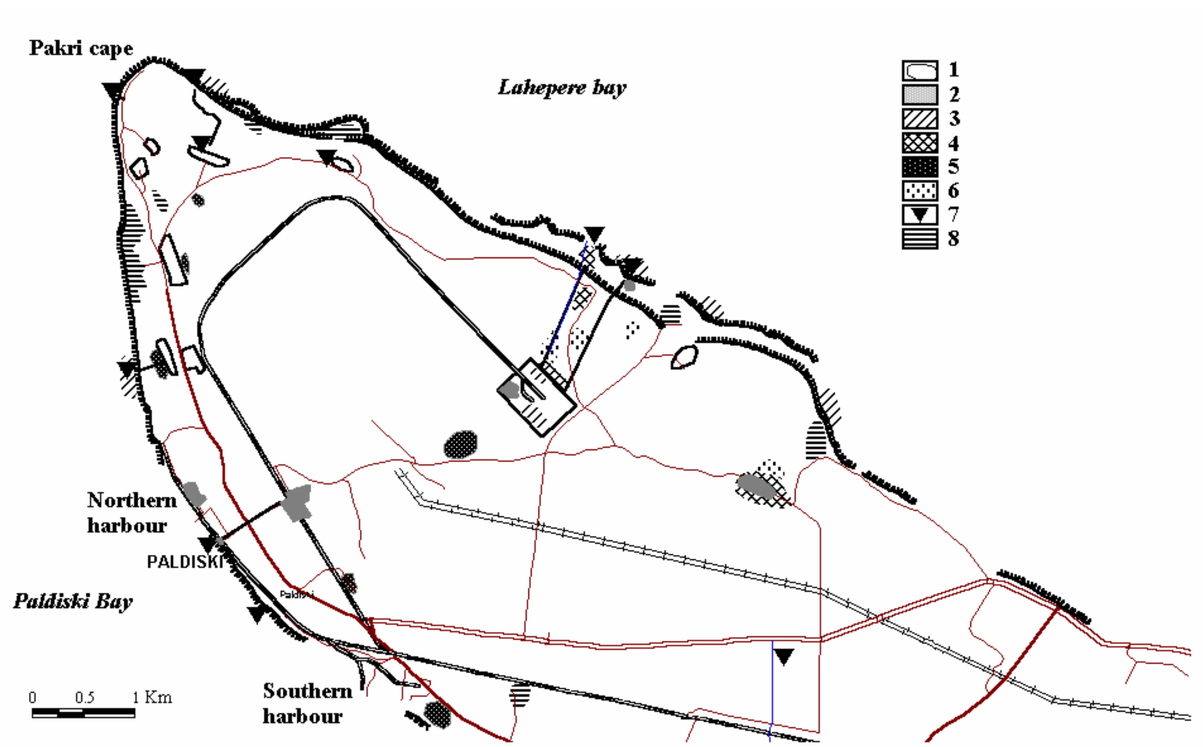

Fig. 6. Past pollution from military objects in the Pakri Peninsula. 1 – pollution with oil products in 1994, 2 - pollution with oil products in 1998 as past pollution, 3 – high concentration of heavy metals in water, 4 - high concentration of heavy metals in soil, 5 – high concentration of heavy metals in moss, 6 – high Ca concentration in water, 7 – discharge of waste water, 8 – mechanical damage of soil.

Groundwater is polluted near the landfill (the high concentration of oil products) and in the area with two closed reactors. The type of surface water is HCO_3, and there is also high concentration of Ca, SO_4 and Fe ions. The brooks that flow from the reactors and landfill catchment areas contain Mo and Ba. The wastewater from the Nuclear Object was contaminated with organic substances and fuel oils, it also contains heavy metals (Cr, Ni, Ba, Mo). In several places the mosses and soils are contaminated with heavy metals. The major threats to the environment of the Pakri Peninsula include the danger of radioactive pollution, pollution of soil and waters with fuels, solvents, heavy metals, solid and liquid wastes.

The surface and groundwater is relatively pure on the islands (Miidel, 1998), of heavy metals only barium (Ba) was detected. The higher concentrations of heavy metals (Ni, Pb, Cd) in the soil are resulting from military pollution.

The islands have long been a natural source of tularaemia bacterial in Estonia. Water voles and ticks carry this severe infectious disease. It is assumed that the Soviet Army has used bacteriological and chemical weapons on Pakri islands.

Conclusions

In Estonia environmental strategy, priority has been given to the problems of groundwater protection, the most important being elimination of sources of groundwater pollution and regulation of groundwater use. Our investigations in the three above-discussed areas clearly demonstrate that every area needs its own nature protection strategy and specific monitoring system.

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