Oil Shale, 2011, Vol. 28, No. 3, pp. 447–463
doi: 10.3176/oil.2011.3.07 ISSN 0208-189X

INFLUENCE OF WATER DISCHARGING ON WATER BALANCE AND QUALITY IN THE TOOLSE RIVER IN UBJA OIL SHALE MINING REGION

K. ROBAM,* I. VALGMA, R. ISKÜL

Department of Mining, Tallinn University of Technology
5 Ehitajate Rd., 19086 Tallinn, Estonia

The extraction of mineral resources below the groundwater table is related to water removal from surface and underground mines. Water drainage is considered the main process for keeping mining sites dry or suitable for mining. Parameters of depression cone and its impact radius are factors influencing decision makers. Water collection system, pumping station and sedimentation ponds are the main tools for water drainage. The quantity of drainage water depends on the amount of precipitation, surface water, soil water and groundwater. Water table in wells, the amount of pumped-out water and the amount of water in the Toolse River have been measured from 2005 to 2009, and chemical components in river water have been analysed. Analyses have shown that water is often repumped from the mining sites. Operating surface mines in the Ubja region act as water reservoirs. Accumulated water is directed to the Toolse River increasing its flow. Quality indicators in the Toolse River of the Ubja region are in accordance with water normatives except total P content downstream the Toolse River.

Introduction

In Estonia mineral resources are often located below the groundwater table. For mining limestone and oil shale, water has to be removed from mining face. Water pumping creates three main problems – a depression cone forms, water balance in groundwater and in surface water as well as water quality change. Groundwater table around the mining area lowers and water removal forms a depression cone. The depression cone is a problem for local people because it may dry household wells. There is always a discussion concerning the needs to discharge water for mining activity and to keep water balance unchanged. For establishing real amounts and reasons of local pollution, a research program has been started considering several parts of the Estonian oil shale deposit. The increase in environmental taxes on water quantity and

* Corresponding author: e-mail *karin.robam@ttu.ee*

quality enforces mining industry to elucidate the process of dewatering and decrease the amount of water being handled.

A relatively high water discharge rate from oil shale mines in Estonia is caused by high groundwater table. Water pumping from oil shale mining workings influences the Ordovician aquifer system that is comprised of Nabala-Rakvere, Keila-Kukruse and Lasnamäe-Kunda aquifers. The quantity of drainage water depends on the amount of precipitation, surface water, soil water and groundwater. Water level in the mines is regulated by pumping water to the sedimentation ponds, ditches or rivers and by changing natural surface water balance at mining sites. After abandoning mines, a technogenic water body has formed in underground mines or inside spoils, channels or pits of surface mines.

The purpose of the present study is to elucidate the influence of water pumped from Aru-Lõuna limestone and Ubja oil shale surface mines on the surface water quality and quantity as well as the influence of mining activity on the Toolse River in the Ubja region.

Methods

The western part of the Estonian oil shale deposit in the Ubja region has been chosen for measurement, mapping and analysing the problems of water removal.

Study area

The Ubja area is located in northern slope of the Pandivere Upland, south of the northern coast of Estonia (Figs 1 and 2). The area is characterized by a gradual increase in elevation from the sea shore in the southern direction up to Kunda at 70–80 m above sea level at the Ubja oil shale surface mine. The length of the river is 23.9 km and its catchment area is 84.7 km^2. The bedrock in the Ubja area is covered by Quaternary glacial sediments (till) and glacial meltwater sediments (sand and gravel). Thickness of Quaternary sediments is about 5 m, the thickness increases in the southern direction, reaching 10–20 m [1]. Bedrock layers are tilted slightly to south, an average of 3 m per km. The base of the Kukruse stage is formed by clayey limestone body of the Uhaku stage, in which kukersite layers occur. The bottom of the Uhaku stage is formed by relatively massive gray limestone. The Uhaku stage is a relative aquitard in the Lasnamäe-Ordovician aquifer system between the Lasnamäe-Kunda and Keila-Kukruse water bearing horizon. The next layer of thickness 8.6 m is represented by building limestone of the Väo formation in the Lasnamäe stage, which is sometimes dolomitized. Cement and building limestone are mined in the Aru-Lõuna limestone quarry together with the upper part of Aseri and Kunda stage. The thickness of mined layers in the Aru-Lõuna limestone quarry is about 12 m. The Lasnamäe-Kunda water bearing horizon is located in the layers where the water level is lowered [2].

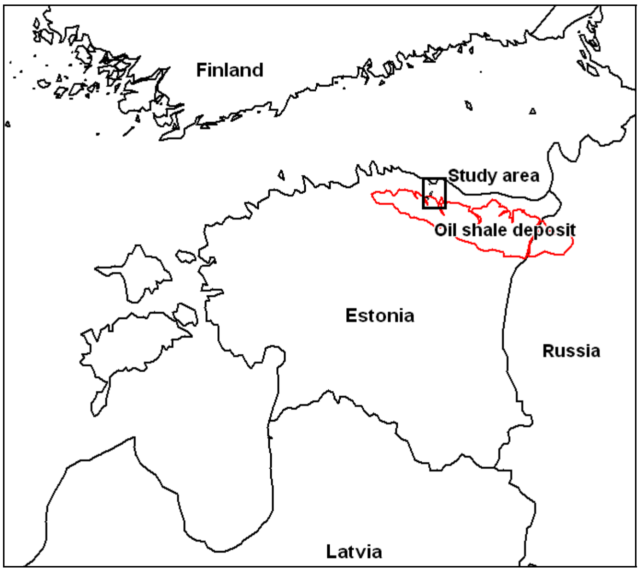

Fig. 1. Location of the study area.

The Aru-Lõuna limestone quarry is situated relatively close to the sea in the heigth range between 40–60 m, the Ubja oli shale surface mine is situated in the range of 60–80 m.

Oil shale from the Ubja surface mine is used as fuel for heating clinker kilns of the Kunda Nordic Cement Corporation. Limestone from the Aru-Lõuna limestone quarry is used as raw material and aggregate for cement.

The study concentrates on the Ubja mining region close to the Kohala field (with Ubja, Aru and Toolse mining sites. The Ubja surface mine is located close to the abandoned Ubja underground oil shale mine and abandoned historical Ubja and Vanaküla surface mines (see Fig. 2 and Table 1). Aru-Lõuna limestone quarry, Mereäärse clay pit and waste disposal pit are located in the vicinity of Toolse River as well.

Mining technology that is applied in the Ubja oil shale surface mine is open-cast stripping. The trenches are located in eastern side of the mine field (left in Fig. 3). Oil shale is crushed, stored and loaded in the western part of the mining field (right in Fig. 3). Oil shale is transported by railway to the cement plant. The total territory of the Ubja oil shale surface mine is 154 ha. The depth of trench is 10 m, thickness of the overburden is 8–8.5 m and thickness of the mined oil shale seam 1.5–2 m. The depression cone extends 2 km north and 3 km south around the mined-out area [4].

Mining front moves in southern direction (down in Fig. 4). The total area of the Aru-Lõuna limestone quarry is 317.34 ha. Extraction depth is 15 m, thickness of the limestone layer is 10–11 m and thickness of the overburden material is 0.3–4.2 m. Limestone layers are tilted slightly to south, averagely 5–6 m per km. The depression cone extends 2.5 km around the mined-out area [4].

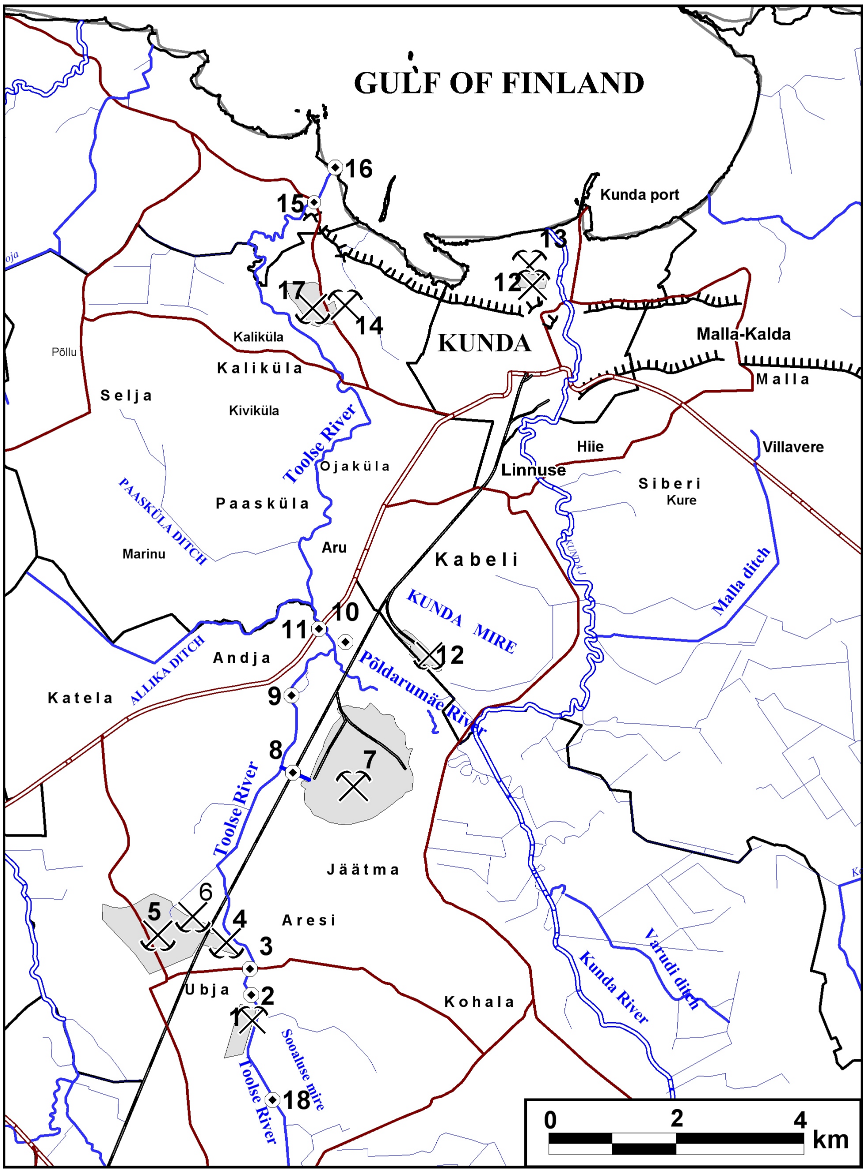

Fig. 2. Study area in the Ubja region.

Thresholds of the Toolse River were chosen because the flow can be measured as accurately as possible and water chemical analyses provide an opportunity to monitor the quality of river water along the Toolse River. Water velocity was measured and chemical components were analyzed in critical riverpoints. Outflows from the Ubja oil shale surface mine, abandoned Ubja underground mine and Aru-Lõuna limestone quarry were kept under observation (Fig. 5). Depth of the Toolse River bed is 1.5–2 m. The river flows into Kunda Bay.

Table 1. **Measuring points in the Ubja region (according to Fig. 2.)**

Point	Location in map
1	Ubja oil shale surface mine
2	Sampling point (outflow from Ubja oil shale surface mine)
3	Sampling point (Aresi tube)
4	Abandoned Vanamõisa oil shale surface mine
5	Abandoned Ubja oil shale underground mine
6	Abandoned Ubja oil shale surface mine
7	Aru-Lõuna limestone quarry
8	Mining water inflow into the Toolse River
9	Sampling point (Andja tube)
10	Industrial waste
11	Sampling point (Andja road bridge)
12	Waste deposit
13	Mereäärne clay pit
14	Toolse sand pit
15	Sampling point (Kunda-Vainupea road bridge)
16	River inflow into the sea
17	Abandoned Toolse sand pit
18	Sampling point (upstream Ubja surface mine)

Fig. 3. Areal view of Ubja oil shale surface mine [3].

The Ubja oil shale surface mine influences the Keila-Kukruse aquifer (aggregated Silurian Ordovician groundwater body group). The water layer is fed by inflow from the Pandivere Upland [2]. Oil shale in Ubja and limestone in Aru-Lõuna are extracted under groundwater table. Water pumped out from the Aru-Lõuna (Fig. 5) and Ubja surface mines is led to sedimentation ponds, after sedimentation water pumped from the Ubja oil shale strip mine as well as from the Aru-Lõuna limestone quarry is led to the Toolse River.

Fig. 4. Areal view of Aru-Lõuna limestone quarry.

Fig. 5. Outflow from Aru-Lõuna limestone quarry.

Flow and water chemical analyses

Every season samples for chemical analyses of the Toolse River water were taken from the critical riverpoints, sedimentation ponds of the Ubja surface mine and the Aru-Lõuna quarry, outflow of the abandoned Ubja oil shale underground mine, Andja tube, Andja road bridge and Kunda-Vainupea road bridge (Fig. 2 points 2, 3, 8, 9, 11, 15). Sulphate content was measured in all previously mentioned points using chemical water laboratory Hach DREL2800 [2]. Ca, Mg, N, Fe, Cl, P, NO_3-N, NO_2-N, dry residue, solid suspension, pH, Chemical Oxygen Demand (COD_{Mn}), biological oxygen demand (BOD_7), ammonium (NH_4-N), sulphate ($SO^{2-}{}_4$) and phosphate (PO_4-P) were measured to determine the quality of river water and the components of suspended solid (Table 2).

The portion of the channel cross section in which the flow occurs is called active portion, and the cross section with no flow is called off-channel storage or dead storage. A velocity meter is used for determining water velocity at equally distributed points across and in depth of the stream channel [5].

Water velocity in the gauging sections was measured by using a calibrated universal current meter allowing to measure stream flow velocity from 0.025 m/s up to 10 m/s in water depth down to three meters (Fig. 6) [6, 7]. For each propeller turning one impulse is given. The area of the river has to be divided into shares according to the profile of channel width. Firstly, the distance from the shore and water depth at various points across the stream flow was measured to construct the channel profile. The current velocity meter was used for determining the vertical axis of water velocity at several points across the stream channel.

As a result of surveying the distance from the bank, water depth, current meter depth to water table and number of propeller rotations were measured

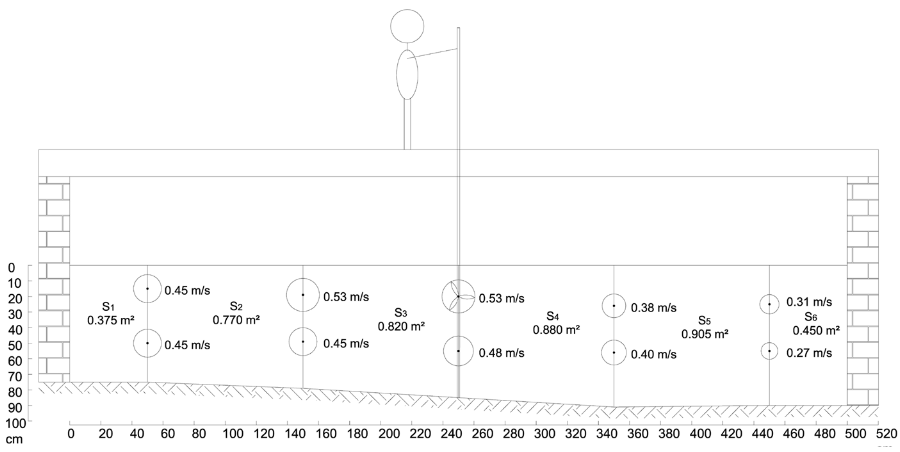

Fig. 6. Water flow and water velocity measurement in river-bed.

and the scheme of the flow was constructed. The stream flow for the profile is a weighted average of each subsection of the stream flow [5]. As a result, the flow in every measuring point as well as level, temperature and quality indicators were determined.

Results

Comparing the data of pumping rates and flow in different river parts gives the share of mine water, amount of water and its possible influence on water quality. Water amount in the Toolse River depends directly on pumping in locations 2 and 9 due to the fact that the stream bed is highly permeable and practically dry without pumping from the Ubja oil shale surface mine.

The river collects water mainly from pumping but also from precipitation, surface water, soil water, and groundwater (Figures 7 and 8). Measurements show that the amount of pumped water is almost half of the total amount or exceeds the actual flow in the river (Table 2).

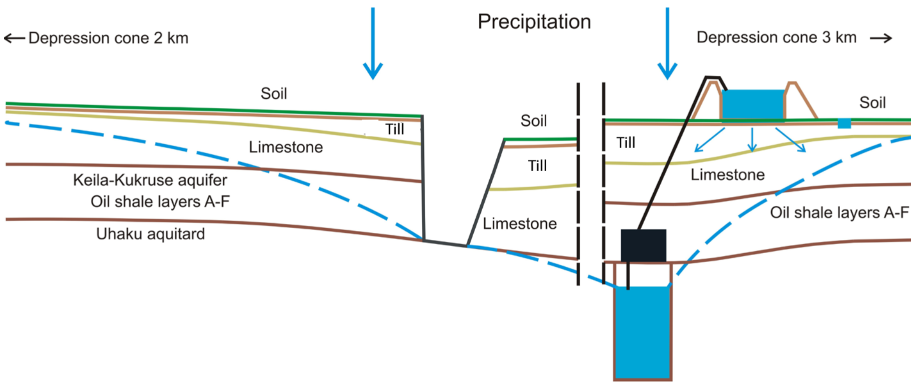

Fig. 7. Layout of dewatering Ubja oil shale surface mine.

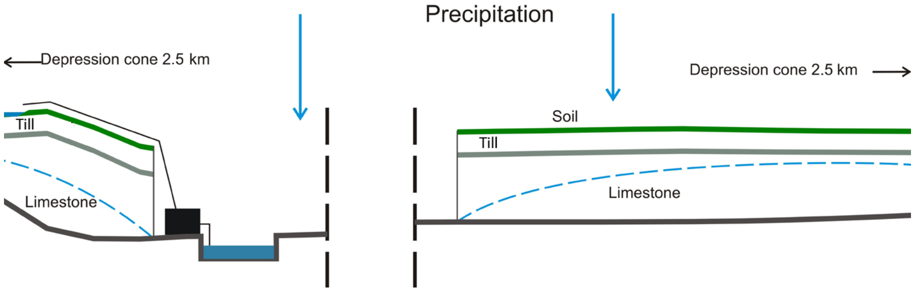

Fig. 8. Layout of dewatering Ubja oil shale surface mine.

Table 2. **Pumping rates and shares of surface mine waters in riwer waterflow in the Ubja region**

Location in map	Year	Water amount in river point, Mm^3/year	Amount of water pumped out from Ubja oil shale surface mine, Mm^3/year	Amount of water pumped out from Aru-Lõuna limestone quarry, Mm^3/year	Share, %
2	2009	11	5	–	41
3	2007	4	5	–	113
	2009	9	5	–	50
9	2005	17	2	9	63
	2006	10	5	9	141
	2007	25	5	10	58
	2008	47	6	12	38
	2009	32	5	8	39
15	2005	19	2	9	57
	2006	13	5	9	102
	2007	50	5	10	29
	2008	63	6	12	29
	2009	58	5	8	21

Analyses and previous research data in Table 2 show that after the outflow from the Ubja oil shale surface mine the quantity of river water exceeds about three times the amount of pumped out water, however, 500 m downstream the water quantity diminishes approximately by one third (Table 2). Further the amount of river water increases until the Andja tube on account of tributaries and water form the Ubja abandoned undeground mine and the Aru-Lõuna limestone quarry. At the Andja road bridge the water quantity decreases because some water infiltrates back to the Aru-Lõuna limestone quarry [2]. Downstream the Andja bridge the quantity of water increases again on account of tributaries.

The permitted level of solid suspension in river water is 15 mg/l but it may be higher during high water. Figure 9 shows that the average content of solid suspension exceeds the permitted level after the outflow from the Aru-Lõuna limestone quarry. Downstream the Toolse River the content of solid suspension is under the permitted level until the Kunda-Vainupea road bridge and flows further to Kunda Bay. Measurements show that during high water the content of solid suspension exceeds the limit 15 mg/l, and the river water is more turbid because of fast water flow and a large amount of water (Table 3).

The permitted level of total P that corresponds to the first water quality class in river water is 0.05 mg/l [8]. Figure 11 shows that the average content of total P is lower than the permitted level until the outflow from the Aru-Lõuna limestone quarry. After this riverpoint the content of total P increases.

The limit of sulphate content in river water is 100 mg/l. Figure 10 shows that the average content of sulphate is under the limit value before the mine water outflow to the Toolse River upstream of the Ubja oil shale surface mine.

Table 3. **Chemical analyses of water from the Toolse River**

(in brackets sampling point numbers from Fig. 2)

Date	Water amount in river points, l/s	BOD_7, mgO/l	Solid suspension, mg/l	Dry residual, mg/l	pH	COD_{Mn} mg O/l	NH4-N mg/l	NO2-N mg/l	NO3-N mg/l	PO4-P mg/l	Total P, mg/l	Cl mg/l	SO4 mg/l	Total Fe, mg/l	Ca mg/l	Total N, mg/l	Mg mg/l
Outflow from Ubja abandoned underground mine (5)																	
24/05/2005	565	1	8	624	7.6	3.1	0.02	0.001	1.3	0.004	0.013	10	120	0.16		88	32
16/11/2005	70.1	1	2	560	7.6	1.2	0.01	0.001	0.41	0.002	0.008	11	130	0.22		114	29
14/06/2006	65.9	1	2	622	7.51	1.3	0.01	0.002	0.76	0.002	0.007	13	145	0.19		120	30
28/09/2006	17.5	1.9	2	582	8	2.1	0.05	0.001	0.11	0.002	0.004	16	141	0.16		132	23
15/12/2009	139.4	1.3	4	706	7.58	2.9	<0.01	0.014	3.7	<0.02	<0.02	13	161	0.04	160	4	29
Upstream Ubja oil shale surface mine (18)																	
15/12/2009		1.9	2	550	7.89	3.2		0.015	4.2	<0.02	<0.02	17	89	0.06	126	4.6	24
Outflow of Ubja oil shale surface mine (2)																	
15/12/2009	352.5	1.5	10	556	7.51	3.4	<0.01	<0.005	1.2	<0.02	<0.02	10	123	0.33	148	1.2	18
Aresi bridge (3)																	
20/09/2007	138.1	1	9	644	7.89	4.9	0.04	0.01	0.16	0.002	0.016	12	212	0.31	144	0.26	13
16/01/2009	261.9	1.8	17	532	8.1	2.7	<0.01	<0.005	0.59	<0.02	<0.02	10	118	0.45	134	0.59	17
15/12/2009	319.8																
Andja mõisataguse tube (9)																	
24/05/2005	691.5	1	18	572	8.0	5	0.02	0.006	0.52	0.012	0.067	9	119	0.17	58		46
16/11/2005	392.1	1.7	24	474	8.0	3.1	0.03	0.004	0.17	0.2	0.32	10	122	0.65	84		34
14/06/2006	340.6	1	6	560	8.1	5.4	0.01	0.001	0.14	0.02	0.038	12	125	0.22	84		29
28/09/2006	276.3	1.2	11	546	8.1	5	0.01	0.001	0.04	0.007	0.019	13	129	0.16	122		18
16/08/2007	258.2	<1	16	632	8.02	4.3	0.02	0.000	0.14	0.010	0.024	14	137	0.180	144	0.43	28
20/09/2007	1290.9	1.2	8	542	7.61	3.2	0.04	0.020	0.29	0.010	0.074	11	137	0.360	100	0.4	19
24/10/2007	771.3	1.4	<2	686	7.79	4.1	0.10	<0.002	0.16	0.004	0.020	13	157	0.120	122	0.74	7
27/11/2007	834.3	1.3	14	572	7.87	3.8	0.05	0.004	0.27	0.069	0.092	12	190	0.300	122	0.62	22
03/04/2008	1875.5	1.1	10	348	8.49	5.4	0.01	0.005	1.66	0.011	0.029	11	176	0.210	124	1.85	22
19/06/2008	917.3	1.1	59	314	7.74	3.6	0.02	<0.005	0.42	<0.02	0.051	7	30	1.000	58	0.72	15
09/10/2008	1673.8	1.7	19	658	7.99	4.9	<0.01	<0.005	0.78	<0.02	<0.02	12	141	0.050	120	0.99	24
16/01/2009	958.9	2.3	11	512	8.31	4.1	0.030	0.012	0.93	<0.02	0.080	11	103	0.290	124	0.96	12
15/12/2009	1091.2	1.4	16	578	7.73	4.8	0.020	0.010	1.400	0.020	0.070	12	131	0.370	136	1.5	18
Andja tube (11)																	
16/08/2007	-	<1	11	596	7.93	4.2	0.01	0.010	0.10	0.013	0.025	13	137	0.200	142	0.6	28
20/09/2007	883.1	1.6	8	406	7.72	4.1	0.03	0.010	0.27	0.013	0.076	12	121	0.380	88	0.3	19
24/10/2007	558.3	1.5	1	588	7.59	3.6	0.02	<0.002	0.16	0.002	0.015	13	158	0.100	118	0.2	16
09/10/2008	1266.6	1.2	20	666	7.94	4.2	0.010	<0.005	0.62	<0.02	<0.02	12	139	0.040	122	0.81	23
Kunda-Vainupea road bridge (16)																	
24/05/2005	699.300	1.000	19	494	8.500	11.0	0.010	0.007	0.300	0.036	0.110	6	76	0.340	92		29
16/11/2005	509.400	2.400	7	454	8.500	5.5	0.040	0.004	0.220	0.082	0.150	10	103	0.570	76		35
14/06/2006	520.300	1.000	7	484	8.180	6.6	0.010	0.001	0.070	0.025	0.057	12	114	0.200	82		27
28/09/2006	332.100	1.700	6	484	8.230	5.8	0.020	0.001	0.070	0.007	0.027	12	124	0.170	100		23
27/11/2007	1595.4	1.7	23	480	8.19	4.4	0.05	0.006	0.38	0.087	0.170	11	126	0.880	120	0.98	17
03/04/2008	3200.6	2.1	29	408	8.69	9.9	0.01	0.005	1.23	0.032	0.120	9	110	0.640	104	1.73	22
19/06/2008	2115.4	1.8	35	282	7.97	13.0	<0.01	<0.005	0.33	0.05	0.180	6.7	25	0.580	78	0.97	12
09/10/2008	657.5	1.3	21	510	8.21	7.0	0.01	<0.005	0.46	0.030	0.050	11	108	0.180	120	0.9	19
16/01/2009	2711.4	<1	13	432	8.59	7	0.04	0.022	0.68	0.03	0.12	8.7	71	0.45	106	0.84	18
15/12/2009	996.9	1.9	4	498	7.98	5.8	0.02	0.047	0.96	0.04	0.05	10	99	0.16	126	1.1	19
Outflow from Aru-Lõuna limestone quarry (8)																	
16/01/2009		2.1	13	492	8.22	3.3	0.02	0.0058	0.43	<0.02	0.08	10	106	0.2	112	0.43	26
15/12/2009		1.3	10	532	7.61	4.6	0.01	0.027	0.67	0.02	0.03	10	122	0.17	130	0.79	26

After the Aru-Lõuna outflow the content of sulphates increases until the outflow from the Aru-Lõuna limestone quarry. After the outflow in the Andja bridge the content of sulphates decreases but before the inflow into Kunda Bay the content is under the limit. In total 16 quality parameters were determined. The results of the analyses are presented in Table 3.

The main purpose of the water flow analysis is to find the sources and reasons for changes in water quality in the Toolse River catchment area. Water analysis together with flow measurements in 2007–2009 taken from main inflows to the Toolse River gave quality indicators along the river – solid suspension, SO_4^{2-} and total P (Figures 9–11).

Analyses show that the outflow from the Ubja oil shale surface mine increases the amount of river water by about three times; however, 500 m downstream the water amount is decreased approximately by one third (Table 2). Further the amount of river water increases until the Andja road bridge on account of tributaries and water from the abandoned Ubja underground mine and Aru-Lõuna limestone quarry. At the Andja tube the amount of river water decreases due to water infiltrations back to the Aru-Lõuna limestone quarry (Fig. 2). Downstream the Andja tube the amount of river water increases on account of tributaries.

There is some evidence that the decreasing amount of pumped-out mine water has a negative influence on the quality of water of some rivers due to decreasing amount of water in them as shown by previous investigations [9, 10, 2, 1]. The current measurements in 2008 and 2009 have not proved any dependence of quality and quantity on different amounts, seasons or locations.

Discussion

Due to the fact that water is pumped out from the Ubja oil shale surface mine, the water level of the Toolse River is at the required level for the biota. The Toolse River would be dry for most of the time during summer if there would be no drainage water pumping from the mines (Table 2) [1, 2].

The water quality is in accordance with normative except total P that exceeded the first quality class of drinking water normative (Table 3) [8]. Measurements show that total P content is not related to mining activity because the amount of total P starts increasing after the stream inflow from the region of households away from mines (river section between points 11 and 12 Fig. 2).

Changes in water regime are related to the deepening of the aeration zone due to lowering of the water table by pumping that causes oxidation of pyrite (FeS_2) in alluvial sediments releasing sulphate ion (SO_4) into the water [9, 10]. The content of sulphates in water pumped out from the Ubja oil shale surface mine is several times lower than in water pumped out from underground mines because the area that is exposed to the air is much more

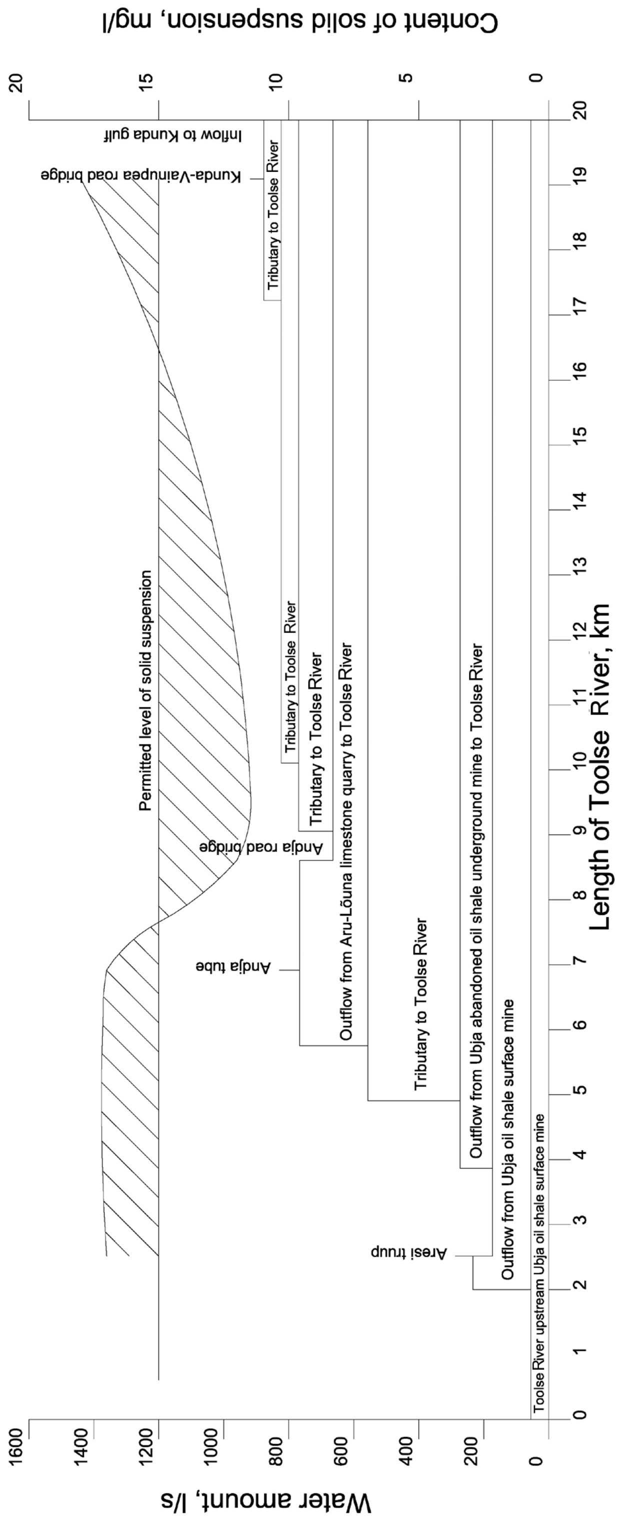

Fig. 9. Distribution of solid suspension in the Toolse River in 2008.

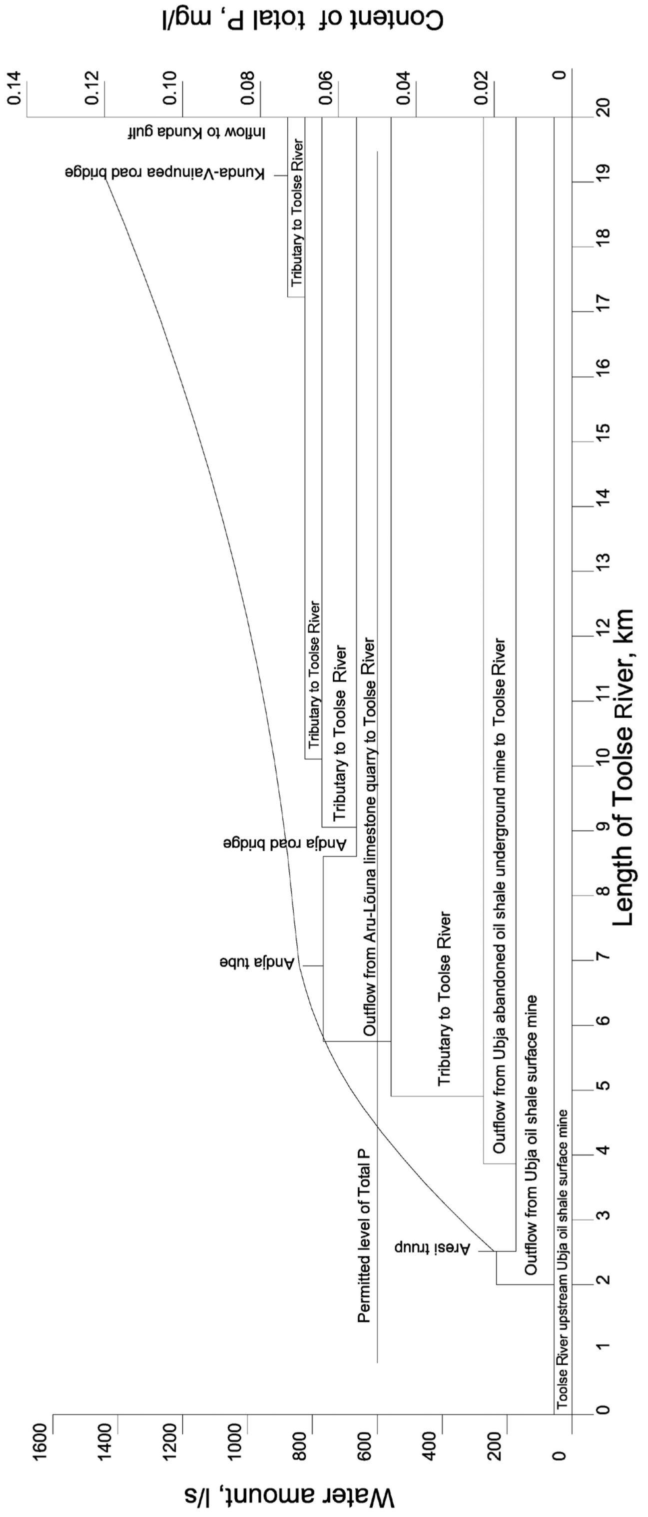

Fig. 10. Content of SO^{2-}_4 along the Toolse River in 2008.

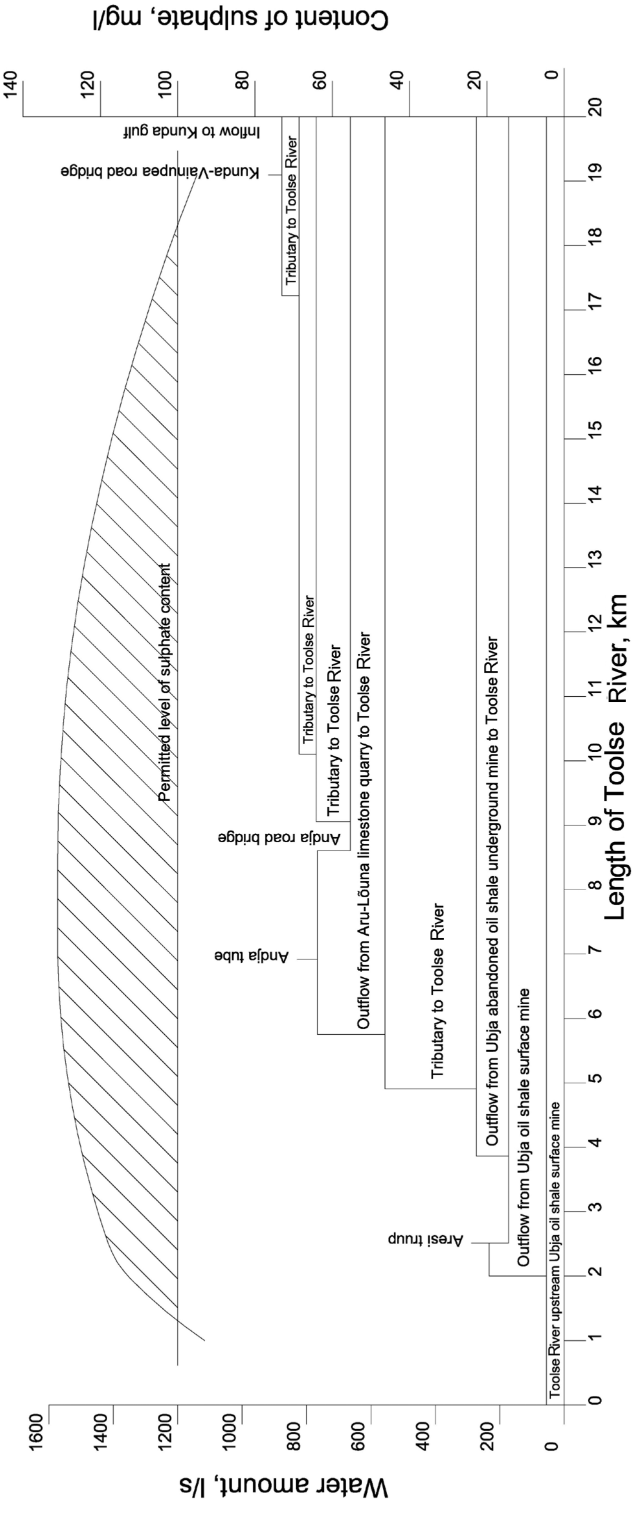

Fig. 11. Content of total P along the Toolse River in 2008.

smaller and no large-scale oxidation of pyrite takes place. Basing on the half-life data and graphs we may presume that in about five years after the closure of a mine the content of sulphates and iron decreases below the maximum level permitted for drinking water [8]. The highest permitted content of iron in the first-class drinking water is 0.2 mg/l and that of sulphates 250 mg/l. As sulphate ion is mobile, it may be used as an indicator to investigate changes in sulphate content of post-mining groundwater of the Keila-Kukruse and Lasnamäe-Kunda aquifers of the Ordovician system in the area of closed and working mines [11].

Upstream the Ubja oil shale surface mine the permitted level of SO_4^{2-} content in the Toolse River water is 89 mg/l. After the Ubja oil shale surface mine at outflow to the river the content increases and reaches the value of 148 mg/l (point no. 2 in Fig. 2 and 10, Table 3). In the section from the Ubja surface mine to the Aru-Lõuna quarry there is the inflow from the abandoned Ubja oil shale mine where average sulphate content is about 161 mg/l (Table 3, Fig. 10) that increases sulphate content of river water. Average sulphate content in water pumped out from the Aru-Lõuna limestone quarry is 114 mg/l (Table 3, Fig. 10). In the section from the Aru-Lõuna outflow to the Kunda-Vainupea road bridge the content of sulphates decreases on account of tributaries, and before the inflow into Kunda Bay the average content of sulphate 96 mg/l is under the permitted level (Table 3, Fig. 10).

An important problem in the Toolse River is turbidity of the water from the Ubja oil shale mine that is caused by solid suspension in drainage water. The permitted level of solid suspension in river water is 15 mg/l (Fig. 9). Analyses have shown that the average content of solid suspension is under the permitted level before the outflow from the Ubja oil shale mine to the Toolse River (about 2mg/l) (Table 3, Fig. 9). After the outflow from the Ubja oil shale surface mine the average content of solid suspension in drainage water increases to 17 mg/l (Table 3, Fig. 9). Drainage water from the Aru-Lõuna limestone quarry contains about 12 mg/l solid suspension. Downstream the Toolse River the solid suspension content of river water increases, and before inflows into Kunda Bay at the Kunda-Vainupea road bridge the content of solid suspension is 18 mg/l (Table 3, Fig. 9). The amount of solid suspension increases in this section because water amount and flow increase on account of tributaries and mine water. Solid suspension originates primarily from the Ubja oil shale surface mine. Solid suspension represents small solid particles in water, which are not settled on the bottom of the Toolse River because of large amount and high flow of drainage water. Therefore it may be floating for a long time, often from the surface mine to the sea [1].

The limit of total P that corresponds to the first water quality class in river water is 0.05 mg/l (Fig. 11). Before the outflow from the Aru-Lõuna limestone quarry the content of total P corresponds to the first class of water quality [8]. In the Andja tube the content of phosphorus is 0.074 mg/l and the amount that came from the Aru-Lõuna mine is 0.055 mg/l (Table 3, Fig. 11). It shows that phosphorus is not coming from the mining activity. It may originate from tributaries that are closely related with agricultural activity. After this riverpoint the content of total P is increasing, and before inflow into the Kunda Bay the amount of total P in river water is 0.12 mg/l (Table 3).

Conclusions

Operating surface mines in the Ubja region act as water reservoirs. Collected water is directed to the Toolse River increasing its flow about 50–100% after the Ubja mine and 40 to 100% after the Aru mine (Table 2). Due to the fact that water is pumped out from the Ubja oil shale surface mine the waterlevel in the Toolse River is at the level required for the biota. According to the observations in the Ubja region the Toolse River is seasonally dry in summer and winter and water amount depends on precipitation. The Toolse River would be dry for most of the time during summer if there would be no pumping of drainage water from the surface mines.

Quality indicators are in accordance with drinking water normatives except total P downstream the Toolse River but this is not originated from the mining activity. It may originate from tributaries draining agricultural activity. Water quality is in accordance with normative, except total P that exceed the 1st quality class normative for drinking water. For evaluating probability and range of constant P pollution a longer and more intensive sampling has to be performed.

Solid suspension represents small solid particles in the water which are not settled on the bottom during high water. Therefore the Toolse River water is turbid and suspension may be floating for a long time, often from mines to the sea.

The future developments of the current research are related to the new surface mines planned in neighbouring areas, both limestone quarries and oil shale open casts. Current and earlier data on water balance help to prognose and plan water inflow and to reduce measures of infiltration. A dynamic model of groundwater, surface water and soil water with water quality indicators will be developed and used as an analysing tool for improving the study in the near future.

Acknowledgments

This study is financed by Estonian Science Foundation Grant No. 7499 – Conditions of Sustainable Mining. KNT of Heidelberg Cement and Department of Mining of Tallinn University of Technology have provided the support to this study.

REFERENCES

1. Monitoring of Kunda mining region and the Toolse River water in 2008. Report Department of Mining of TUT. Tallinn, 2009, 63 p. [in Estonian].
2. Monitoring of Kunda mining region, water and bottom sediments of the Toolse River in 2007. Report Department of Mining of TUT. Tallinn, 2008, 72 p. [in Estonian].
3. Iskül, R., Kaeval, E., Robam, K., Sõstra, Ü., Valgma, I. The origin and amount of removal water in the Ubja oil shale opencast mine and its influence to the Toolse River. – In: Book of abstracts: International Oil Shale Symposium, Tallinn, Estonia, 8–11 June, 2009. Tallinn, 2009, 83.
4. Environmental Review No. 18. – Kunda Nordic Heidelberg Cement Group, Kunda, 2008, 34 p.
5. Robam, K., Väizene, V., Anepaio, A., Kolats, M., Valgma, I. Measuring mining influence in the form of students practice in opposition to the emotional environmental impact assessment. – In: 5th International Symposium "Topical problems in the field of electrical and power engineering". Doctoral school of energy and geotechnology / (Ed.) Lahtmets, R. – Tallinn University of Technology, 2008. P 62–65.
6. *Maastik, A*. Hydrology and Hydrometry. – Tartu: Estonian University of Life Sciences, 2006. P. 62–71 [in Estonian].
7. Equipment for water pumping Eijkelkamp. Available at: http://www.eijkelkamp.com/ [30.10.2007].
8. Drinking Water Normative. Available at: https://www.riigiteataja.ee.
9. *Erg, K.* Groundwater Sulphate Content Changes in Estonian Underground Oil Shale Mines. – Tallinn: Tallinn University of Technology Press, 2005.
10. *Perens, R., Punning, J.-M., Reinsalu, E.* Water problems connected with oil shale mining in North-East Estonia // Oil Shale. 2006. Vol. 23, No. 3. P. 228–235.
11. *Erg, K*. Changes in groundwater sulphate content in Estonian oil shale mining area // Oil Shale. 2005. Vol. 22, No. 3. P. 275–289.

Received April 5, 2010