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The Developmental Trends of Groundwater Horizon Surface Depression and Sea Water Intrusion Impact in Liepaja City

Juris Burlakovs and Dzintars Lacis

Oy Space Technology and Science Group Ltd,
Paper by Collaborative Partner, University of Latvia, Latvia

Abstract: Quaternary groundwater in former times was used as the source for water, later first water supply wells were drilled in the bedrock. Different horizons are used for this purpose in Latvia. Liepaja City uses drinking water mostly of the Famena Stage horizons. Laboratory tests have shown presence of chlorides in the drinking water, but level measurements in wells with intense exploitation history have shown the development of groundwater surface depression in city and surroundings. The intensive and long-time exploitation of the Upper Devonian groundwater horizon has caused the origin and further development of complicated hydrodynamic and hydrochemical situation: intrusion of sea water enriched with chlorides and migration into lower situated water horizons. Problematic question is that the sea water intrusion according some evaluations frontally is shifting with the speed 50 m/yr. Possible solution for this problem can be more intense pumping in Liepaja City area in order to generate artificially bigger surface depression for the groundwater surface in order to stop the migration of the sea water intrusion further inland.

Key words: Hydrogeological research · Saltwater intrusion · Piezometric surface depression · Devonian

INTRODUCTION

Liepaja City is situated in the western part of Latvia nearby the coast of the Baltic Sea. Crystalline basement is more than 1 km deep in this western part of Latvia and several groundwater horizons can be found in a way down to this depth. Deeper horizons located deeper in sedimentary bedrock older than Devonian are strongly mineralized, therefore not acceptable for drinking water supply needs [2, 3]. Ancient times Quaternary groundwater was used as the source for water supply in Liepaja City, only in the middle of the 19th century first water supply wells were drilled deeper - in older sedimentary bedrock layers. Mostly the _agare horizon of Upper Devonian (D_3 _g) was exploited and the more extensive use of it has started in 30-ties and 40-ties of the 20th century. At this time the industrial development of Liepaja was on the wave, the amount of exploited water resources was growing and first reports appeared on development of the sea water intrusion, which percolated horizons of artesian groundwater (Fig. 1). Laboratory tests have shown that water quality thus diminished and didn't meet the standard for drinking water.

Hydrogeological mapping in scale 1:100 000 for Liepaja City and surroundings was done in 1947 and authors insisted that as the only useful source of the drinking water Naujoji Akmene-Middle Ketleri and Mûru-_agare artesian horizons of the Upper Devonian can be used. The system of drinking water extraction wells was recommended to be developed to the east from the Liepaja Lake between Grobiòa and Otaòíi [4, 5].

First two experimental research-exploitation wells were drilled in this area in 1953, the depth of these wells were 102,8 m and 117,0 m respectively. For water supply the research for artesian horizons of Lower Carboniferous and Upper Devonian (_agare Formation) was carried out. The further analysis has shown that the capacity of these horizons was great enough to use for the water supply of the Liepaja City. Two additional drinking water wells were drilled in 1959 in Otaòíi, the construction of it was the same as for previous two. Water quality results in 1960 already have shown that the content of dry matter and chlorides in water horizons of Lower Carboniferous and Upper Devonian _agare Formation in the center of Liepaja City were 2-3 g/l and 1,6 g/l respectively [6].

Corresponding Author: Juris Burlakovs, Oy Space Technology and Science Group Ltd,
Paper by Collaborative Partner, University of Latvia, Latvia.

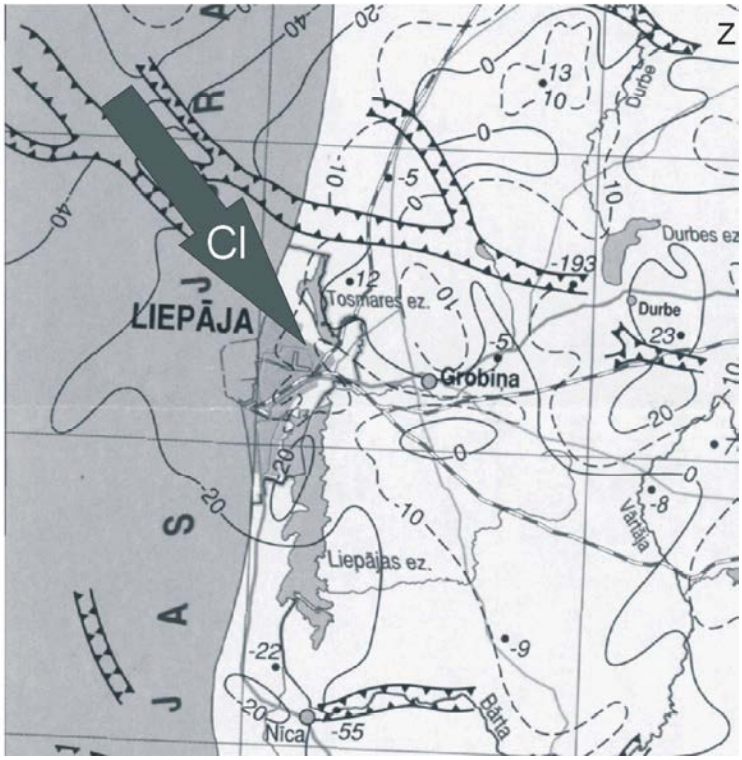

Fig. 1: Sub-Quaternary surface map [1] and the direction of chloride intrusion into Upper Devonian Famena complex groundwater horizons in Liepaja.

There had been no significant changes of static Upper Devonian Jonišíi-Kursas (D_3 jn-krs) horizon groundwater level in prospect "Aistere" in period from 1990-2011, thus considerable negative impacts from water extraction are not expected. Also laboratory testing has shown that in period from 2007-2011 concentration of chlorides in drinking water from this horizon is averagely 10-15 mg/l and there are no signs that that could change in nearest future [6].

RESULTS AND DISCUSSION

In the period from 1960-1970 the growing of the size of groundwater horizon surface depression in the centre of Liepaja City took place because of the increasing of water extraction intensity, thus already during that time this surface depression has started to fulfil particular protective functions from the intensive sea water intrusion in Otaòíi water supply prospect. In order to improve the situation in Liepaja City water supply, several research-exploitation wells were drilled in Liepaja (Fig. 3) and the Aistere prospect. During the research of 1983-1985 in Liepaja City it was observed that piezometric surfaces of Upper Devonian Mûru-_agares and Jonišíi-Kursas groundwater horizons are almost the same (around -7 m). Both these horizons are separated by up to 20 m thick sedimentary rocks of Akmene Formation with low filtration properties [4-6].

The intensive and long-time exploitation of the Upper Devonian Mûru-_agare groundwater horizon in Liepaja City and surroundings has caused the origin and further development of complicated hydrodynamic and hydrochemical situation: sea water (enriched with chlorides) intrusion and shifting of lower situated Eleja-Pïaviòas water horizons (with sulfates). As the result of mentioned obstacles, already in 1944 the concentration of chlorides in groundwater of Mûru-_agare horizon rose from 10-20 mg/l to 245 mg/l, but the concentration of sulphates averagely from 100 mg/l to 200 mg/l (Fig. 4). Piezometric surface of this horizon in 1944 was 2-3 m, ten years later 3-4 m below the sea level, but the concentration of chlorides in wells rose up to 600 mg/l. From 1976 it was observed that the eastern part of sea water (and chloride) intrusion zone started to move in direction of the groundwater prospect Otaòíi, where the main reason for this process was the intensive exploitation of wells in this prospect [6].

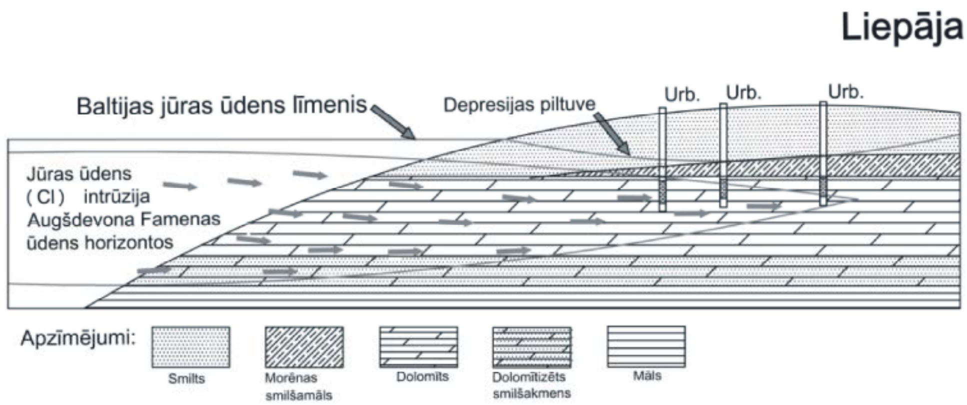

Fig. 2: The principal development scheme of chloride intrusion and groundwater surface depression formation in dolomites, dolomitized sandstones and sandstones of Famena stage in Liepaja and surroundings.

Fig. 3: One of groundwater monitoring wells Nr. 8849 near the dam in Liepaja City.

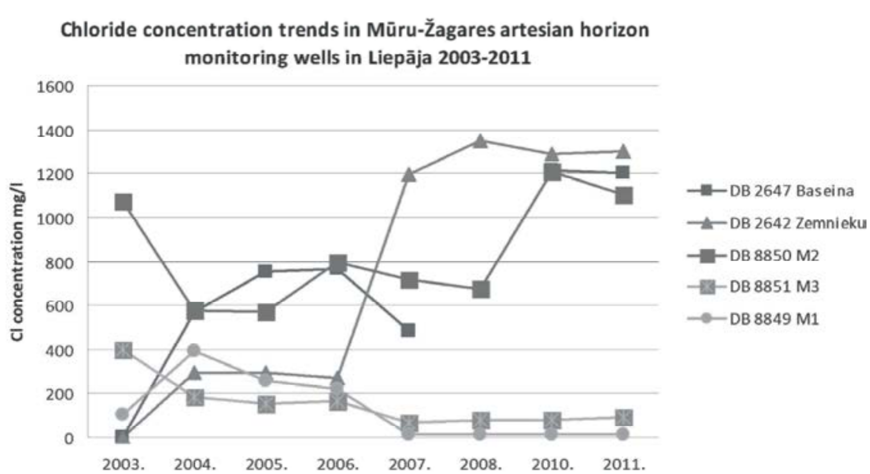

Fig. 4: Groundwater chloride concentration trends in samples taken from monitoring wells in Famena Stage groundwater horison 2003-2011 [4-6], sampling by authors.

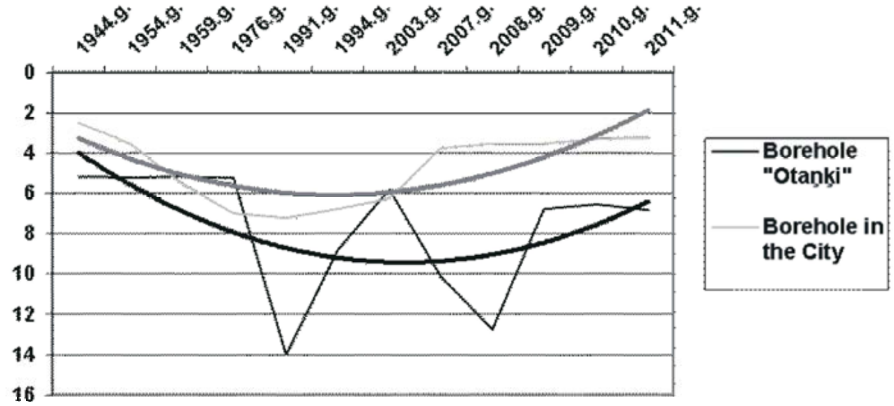

Fig. 5: Static level of D3 Mûru-_agares groundwater horizon in City and further inland (Otanki) [4-6], measurements by authors.

The lowest levels of piezometric surface in Liepaja City were observed from 1985-1990 (-14 m), when the exploitation of the Mûru-_agare horizon was the most intense. If to compare trends of development of surface depression in Liepaja City territory and Otaòíi groundwater prospect, according data from last years from "Liepaja Water" Ltd., static groundwater level in Otaòíi prospect for Mûru-_agares horizon surface is systematically lowering and in 2008 reached -9,0 to -16,5 m. At the beginning of the exploitation of Otaòíi prospect from 1961-1976 piezometric surface of Mûru-_agares horizon was fixed at the level -5,0 to -5,5 m (Fig. 5) [4-6].

Sea water intrusions have been described in research articles and applied solutions found around the globe, where surface depression and thus saltwater intrusion problems arise with water supply in cities of coastal areas [7; 8]. After careful research according results gained from experimental hydrogeological pumping testing artificial surface depressions can be generated in order to diminish impact to water prospects [9].

Results of "Liepaja Water" Ltd. central testing laboratory of period 2007-2011 from Otaòíi groundwater prospect are showing chloride concentrations, which are not exceeding water quality norms (250 mg/l). Problematic question is that the sea water intrusion according some evaluations frontally is shifting with the speed 50 m/yr. The first stage of the research must include additional analysis and interpretation of hydrogeological and hydrochemical data. Groundwater and artesian levels must be determined and hydrochemical parameters fixed, after what it is possible to predict future trends. Hydrogeological parameters of groundwater horizons may be determined by implementation of experimental pumping from monitoring wells and following analysis of data. Possible solution for this problem can be more intense pumping in Liepaja City area in order to generate artificially bigger surface depression for the groundwater surface in order to stop the migration of the sea water intrusion further inland, f. ex., to Otaòíi prospect.

CONCLUSIONS

The lowering of the piezometric surface of Mûru-_agares groundwater horizon is the reason for the increasing of concentration of chlorides in water. Maximum concentration (up to 2000 mg/l) is observed in wells of Liepaja City, which is the depression center, but results of groundwater chemical analysis from observation wells in Liepaja City show chloride concentration up to 1200 mg/l. There had been no significant changes of static Upper Devonian Jonišíi-Kursas (D_3 jn-krs) horizon groundwater level and chloride content in prospect "Aistere".

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