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ADVERSE ENVIRONMENTAL IMPACTS OF THERMAL WATER UTILISATION

INTRODUCTION

The excellent geothermal conditions in Hungary, the geothermal water reservoirs and their natural pressure conditions, the quality of thermal waters and the need for their medicinal effects make it reasonable to product thermal waters in Hungary in high extent. They are used for at least seven kind of purposes and the energy production is going to be a significant thermal water utilisation in the future. All the advantages of using thermal waters must not let us forget to control its sustainability concerning the quality and quantity of our natural resources involving the thermal water resources themselves and surface waters, soils and the ecosystems. The endangering factors of the current practice of thermal utilisation are introduced as well as its aspect of regional range of changes. As an answer to the expectable adverse processes a few possibilities of solutions are also drafted in the article.

1. THE REASONS FOR THERMAL WATER PRODUCTION AND UTILISATION IN HUNGARY

Waters coming from wells and springs of higher than 30 ° C wellhead water are thermal waters. They are usually mineral waters at the same time, containing at least 1000mg/l of dissolved substances or certain components above specified concentrations. Qualified medicinal waters are mostly thermal waters. Qualification is based on medicinal aspects.

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The excellent geothermal conditions means that the geothermal gradient in Hungary is

5 °C/100 m and the value of heat flux is 90,4 mW/m^2 both values being one and a half times as high as the worldwide average .

The geothermal water reservoirs provide waters of higher than 30 °C temperature can on 70 % of the area of the country. They either come to the surface as a spring or we product them by wells operated by pumps. Near half of the wells are of the temperature below 40 °C.

The quality of thermal waters have a significant difference depending on whether they derive from carbonate rocks or porous reservoirs. Karstic thermal waters are usually of calcium-magnesium character and contain CO_2, clay minerals, sulphate, sulphide, NaCl. dissolved salts usually not more than 1g/l.

Porous geothermal waters are usually of alkali-hydrogen character and contain dissolved salt (1-3 [it can be even 10]g/l), chlorides (like in seawater), clay minerals, lime, methane, oil, phenol.

The need for the utilisation is reflected by the distribution of the wells based on their utilisation. In the year 2000. it was as follows:

243 wells (22,27 % of total 1091 operating wells) – baths, or spas as called in Great Britain

232 wells (21,27 % of total 1091 operating wells) – drinking water supply(mixed with the water of other wells) and domestic hot water supply for example in Szeged, like in Iceland.

210 wells (19,25 % of total 1091 operating wells) – agricultural utilisation (heating of green houses)

70 wells (6,42 % of total 1091 operating wells) – industrial utilisation

85 wells (7,8 % of total 1091 operating wells) – multipurpose (complex utilisation)

13 wells are used also for reinjection.

Still there is no mention of geothermal energy production but it is evident that in the foreseeable future this will play a significant role in this chapter of the issue.

The simplest way to exploit geothermal energy is the direct use of hot springs (e.g. in Iceland hot water circulates in the heating system of houses). Another possibility is the utilization of geo-pressured systems harnessing the internal pressure of the crust. In this case hot water, which is located in a sedimentary basin that has descended relatively quickly, can only be mined at a high temperature and under high pressure. In general, the fluid is excavated from the reservoir through one drilling and re-injected into it through another. Level of utilization of geothermal energy in the world has been increased in the last few years. Geothermal energy was the leading producer with 70% among the renewable energy sources (wind, solar, geothermal and tidal) followed by wind energy with 28% of the electricity production. In Hungary the geothermal energy has been utilized in direct use, that is, no electricity has been generated so far. The proportion of geothermal energy utilization in the energy balance of Hungary, despite the significance proven has remained very low (0,25%).

Many benefits and ways of utilisation exist, but besides the benefits of utilisation of thermal waters it has got also several side effects, at least as many as benefits.

2. PRODUCTION AND UTILISATION OF THERMAL WATERS IN HUNGARY AND MAINLY IN THE LOWLAND

The county regional Plan contains detailed data concerning production and utilisation of thermal waters in Hajdú- Bihar County. 2 660 000 m3 of thermal water is brought to the surface from 81 wells. A part of this, about 8-12 000 m3 / year is dicharged directly into the recipients which are mainly channels in the Lowland. Nearly half of this amount is of temperature below 40 °C, and abot 30 % of it is above 60 °C. In Debrecen the utilised thermal water is driven into a reservoir before discharged into the surface water.

3. THE PRIMARY AND SECONDARY ADVERSE EFFECTS OF THE PRODUCTION OF THERMAL WATERS

3.1. Proved decrease in the pressure and water level of the thermal waters

Their natural pressure conditions are changing with production. In the beginning the wells were operated by their own pressure and their static level above the ground surface was 10 m. By today pressure has fallen 8 m-s as an average during the period 1982.-1999. in the Lowland according to the measurements of the National Geological Survey but 50 m-s of decrease can also be experienced at several places. Today less than half of the wells are positive since 1985.

3.2. Decrease in thermal water resources

Production in Hungary exceeds the extent of recharge significantly, so the quantity of thermal water that can be brought to the surface level is decreasing continuously→ impact on other utilisations of the thermal water resources in the region.

3.3. Decline of shallow groundwater table

Decline of shallow groundwater table because of the vertical hydraulic connection with the thermal water level and due to overexploitation

It can be a limit to the production of thermal waters, like in the region between the rivers Danube and Tisza → impact on other utilisations of the shallow groundwater resources in the region → impact on natural terrestrial ecosystems

4. THE ROUTE OF THERMAL WATERS AFTER UTILISATION AND THEIR PRIMARY AND SECONDARY ADVERSE EFFECTS

Thermal waters are usually discharged indirectly into surface waters after utilisation, effecting them in various ways.

They can be discharged through :

- public sewer systems,
- storage reservoirs or
- drainage channels.

Here are the adverse effects in short:

4.1. Public sewer systems

When they are discharged through a *public sewer system*, the salt content may have adverse effects on the built-in materials of the sewage system and on the biological treatment process in the sewage treatment plant. It will depend on the level of salt content. High concentrations of salt in wastewater typically result in biological treatment processes achieving lower than usual removal of Biochemical Oxygen Demand (BOD) due to the adverse effects of the salt on microbial flora. Above about 1 % (10 g/l) of salt in the wastewater, plasmolysis of the bacteria cells and loss of activity occurs. In the case of a small settlement this effect can be significant as the ratio of the thermal water discharge and the communal sewage is smaller than in bigger cities.

This observation of effects on microbial flora can be extended to natural freshwater ecosystems as well.

Rapid changes in salt concentration cause more adverse effects than gradual changes which may make it necessary to establish a balancing reservoir preceding the treatment plant. There are certain differences in expected effects of salt content in the cases of different biological methods used in the sewage treatment plant:

In cases of using activated sludge process, at salt concentrations above about 8 g/l progressively reduced BOD removal efficiency and flocculation of the bacteria is expected. Nitrification is also inhibited. The possibility to maintain a high bacteria population in the aeration tank by re-cycling sludge from the clarifier may be also limited in case the salinity inhibited bacterial activity [9.].

In cases of using extended aeration (oxidation ditch) temporary reductions in BOD removal efficiency can be expected with changes in salinity when the organic or hydraulic loads are high [8.].

No significant effects of salt concentrations up to 2 % (20 g/l) on the fixed-film Rotating Biological Contactor process can be expected [9.].

4.2. Storage reservoirs

Storage reservoirs serve to let the water getting cool before entering the living water bodies. This is the most general method in Hungary currently.

4.3. Drainage channels

Drainage channels may provide some dilution but we should not disregard the quality of these channels either. Due to continuous saline water inflow the water of the channels become more and more salty.

On the one hand they receive and carry large amount of communal wastewater deriving from sewage treatment plants of settlements on the Great Plain lacking enough watercourses. This means a BOI load the mineralization of which needs oxygen. The thermal water inlet increases the water temperature that results in less oxygen diffunding into the water body. Higher temperature at the same time accelerates the biological activity and the metabolism of the living beings. It may lead to the silting of the channels due to the dead biomass gathering on the bottom.

On the other hand the water of these channels are partly used for irrigation. Using salty water for irrigation causes salinity of soils causing unproductiveness. The salinity of the water in the channels is determined by the amount of inflows (and their salt content), runoff and the amount of evaporation. When there is a lot of inflow and overland runoff, the salinity of the water decreases. When there is less inflow or the evaporation rate is high, the water becomes saltier. Irrigation is usually needed when there is little precipitation, runoff and inflow – so when the channels receive little freshwater inflow – and, on the contrary, the evaporation is insignificant, consequently, when the salt concentration must be high. Practically there is no regular measurement of salt concentration in these channels .

These channels are also considerable as water bodies providing habitat for living beings, so they can have an ecologic role as well. The global climate change should also make us precautious as to improve or at least protect the quality of all of our existing water bodies because their role in the supply of different water demands – including irrigation water as well – possibly increases significantly in the future.

5. ENVIRONMENTAL ADVERSE IMPACTS OF THERMAL WATER DISPOSAL INTO THE SURFACE WATERS

5.1. Increasing the quantity and level of the surface waters.

In the case of Lowland channels it can cause problems in the periods of big runoffs when the capacity of the channels of driving excess waters away from the lands is already exhausted

5.2.Polluting the surface waters with salt

Polluting the shallow and deep ground waters with salt through infiltration from the surface waters. It causes damages in the agricultural production because it makes the soils saline as the salt deposits in the upper layer when the salt content of the soil is so high that it does not all remove towards the deeper layers with infiltration.

It can be caused also by the high salt content of the irrigation water as well in the process of increasing in the water table level and makes the salt deposit there.

Total Salt content in the discharged waste water must be under 5 g/l from medicinal utilisation and 2 g/l from baths according to KöM-KöViM Ordinance no. 9/2002. (III. 22.) [5.].

5.3. Destroying the existing ecosystems in the surface waters

Biodiversity conservation helps to preserve the good quality of environmental elements. Simplification of ecosystems may disrupt food chains and cause declines in many species. Ecosystems are endangered by the salt-, phenol- and the ammonia content. Limit for phenol content in waste waters is 0,1-3 mg/l, for ammonia it is 2-10 mg/l according to KöM-KöViM Ordinance no. 9/2002. (III. 22.) [5.] . These substances are toxic to nearly all the species of the water ecosystem. There exist special flora and fauna that can adjust to saline conditions.

5.4.Polluting the surface waters with high temperature

Loss of O_2 → loss of species needing O_2 and decrease in the pollution assimilation capacity of the surface waters. According to the so-called van't Hoff rule increase of 10°C in the fresh waters makes biochemical reactions two times more rapid. Permitted highest temperature is not given generally in KöM-KöViM Ordinance no. 9/2002. (III. 22.) [5.], it is defined each time by the local Water Authority.

5.6. Polluting the soils with salt, particularly with irrigation

Stalinisation (soil preservation is a strategic issue in sustainable agriculture and environment management). Saline soils are among the so-called less-favoured areas (LFA-s) which are areas of the EU where natural physical conditions cause lower agricultural productivity [4]. Some 56 % of the EU's agricultural land is defined as LFA (data from 1998). A major objective of this measure is to preserve scenic landscapes as well as environmentally valuable habitats.

Drainage and irrigation can also cause habitat degradation in arable lands in itself and using saline water for irrigation is a aggravating factor.

It is evident that we must not let these areas grow in the future due to bad practises.

6. IMPACTS ON THE METABOLISM OF THE REGION OF THERMAL WATER UTILISATION

Water supply of people independently from thermal water utilisation as well generates the biggest anthropogenic material flux. Our environment serves as a reactor for bio-chemical changes in the waters. The flux of water masses is increased by us by one fifth of the natural rate. There are no significant stocks of water formed.

The residual times of substances in the elements of the environment differ by orders of magnitude [12.]. In fresh water systems (rivers, lakes, ground waters) the residence time of dissolved and particulate substances ranges from days to years if they are not subject of any biological or chemical transformation. In soils, that is, the surface layer of about 1-2 m, substances may stay from weeks to thousands of years. That is why soils and waters with long residence times like lakes and ground waters within the region can become main sinks for anthropogenic residual substances, either wastes or not. By changing the chemical composition of the environmental elements and their physical properties the biocenoses may change adversely and irreversibly for all forms of life in the region. The possibilities of ecosystems to shape and control their environment for their purposes are limited.

The anthropogenic material fluxes change the natural ones more and more and we can not be successful by controlling the discharges of pollutions or wastes solely by limits of discharge. Activities, processes and products must be evaluated with respect to the resulting residual fluxes into the environment [12]. In the case of thermal water utilisation the natural flux of materials are changed in the biggest rate with respect to water and salts. The recharging rote of the water is very long in time. It causes decrease in available quantities of resources in the exploited ones. The change of salts fluxes causes pollution by developing stocks of this substances in the waters and soils. The changes can not be reversed in the same rate so we must expect that their adverse effects will be long - lasting.

The process can be made slower by extracting the salt content of the utilised thermal waters and using this medicinally valuable substance once more. If we use it once more, the flux of this substance would be decreased to half of the current rate. It is technically realizable. If we use it more times the flux will decrease more times but it is technically nor reasonable.

7. POSSIBLE SOLUTIONS FOR PREVENTION AND MITIGATION OF ADVERSE IMPACTS OF THERMAL WATER UTILISATION

7.1. Technological solutions

Removing the salt content of the utilised thermal waters and reusing this medicinally valuable substance is a solution for avoiding surface water-, groundwater and soil pollution, for protecting all forms of lives which are endangered by high salt contents, by phenol and ammonia. It is technically realizable.

For desalination the term for salt water is introduced. The general term for all water over 1g/l total dissolved solids is salt water. In Hungary thermal waters are salt waters. They can be characterised with a salt content of 1-3 g/l TDS.

Within salt waters we distinct the following kind of salt waters:

fresh water : <1 TDS

brackish : 1-5 TDS

highly brackish : 5-15 TDS

saline : 15-30 TDS

sea water : 30-4 TDS

brine : 40-300 and more TDS

7.1.1. Reinjection of utilised thermal water

Reinjection of utilised thermal water is a considerable solution for avoiding the following adverse effects:

- avoiding surface water-, groundwater and soil pollution
- for protecting all forms of lives which are endangered by high salt contents, by phenol and ammonia
- for the increasing the quantity and level of the surface waters
- for the minimising of the adverse effects on the biological process in the communal sewage treatment plants
- for the decrease in the pressure and water level of the thermal waters but only if utilised water is recharged into the same aquifer.

It is technically realizable but to protect the water quality only waters deriving from closed energy production systems may be reinjected.

7.1.2. Membrane-technology, or membrane distillation process

Membranes seem to be an optimal technology for thermal water treatment. They are adequate for water filtration, mikro- and nano filtration, ultra filtration of biomolecules. There are many phenol removal methods in the literature, among them the membrane separation is used to minimise or rather to remove the phenol contain of thermal waters. In Szeged ultra filtration was applied to reduce the phenol contain of the thermal water samples produced in Szentmihálytelek below the admitted value. It was very successful concerning phenol content but the ion concentration did nor change significantly[2].

7.1.3. Reverse osmosis desalination method

Seawater may become a reliable source of drinking water, this technology provides such a great efficiency in desalination. In the course of the measurements carried out in Szeged on the samples deriving from the

Szentmihálytelek thermal water reverse osmosis was also made to remove phenol from the water. It was found that no phenol remained in the samples after the experiment. The ion concentration was also decreased successfully [2.] Satisfying results are shown in the figure 1. below:

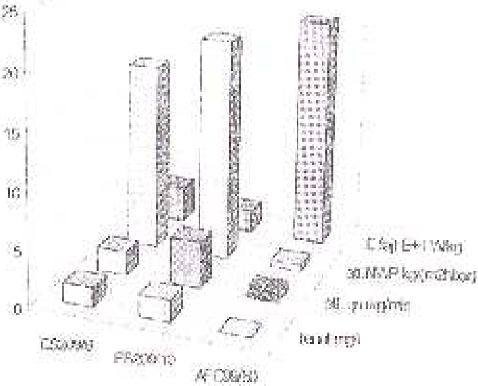

Figure 1.: Results of ultra filtration and reverse osmosis in thermal water treatment: ES209/6, ES209/10 were used for ultra filtering and AFC99/60 membrane was used for reverse osmosis [2.]

7.2. Not technical solutions:

Influence of utilisers by water resource charges, pollution fees Now it is regulated by Gov. Decree no. 43/1999.(XII.26.)

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