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INTRODUCTION

The use of energy from alternative sources both in Poland and in the European Union is hampered by high investment costs, which are largely front-loaded (the cost of drilling the injection well, among other things), and are much higher than the financial outlay required in the case of conventional energy sources. Taking into account Poland's obligations to increase the share of energy from renewable sources, it is essential to intensify efforts aimed at reducing the aforementioned costs.

The specific nature of the problem and wide variation in the physico-chemical properties of geothermal waters (whose mineralisation ranges from a few to more than 120 g/dm^3) has given rise to a research programme designed to promote the comprehensive utilisation of geothermal waters in order to improve the water balance, stimulate the balneological sector and improve the operating conditions of existing systems.

Reducing the high investment expenditure, which is, inter alia, related to the need to drill the injection well, the cost of improving absorption capacity, etc., may be of key importance for the initiation of new investment and as a consequence for increasing the share of renewable energy in the domestic market.

This paper presents preliminary observations concerning the feasibility of desalinating geothermal waters, which would contribute to their utilisation in many areas, including:

- An improvement in the management of fresh water resources through the use of desalinated geothermal waters;
- Limiting corrosion processes and the precipitation of minerals that clog geothermal systems through an attempt to mix raw geothermal water cooled in heat exchangers with "pure water" in appropriate proportions following the treatment process;
- The development of the balneotherapy, tourism and leisure sectors;
- The recovery of mineral compounds with balneological and economic importance (the production of mineral resources).

In Poland, geothermal water resources are associated with the presence of large regional underground reservoirs. The proper examination and determination of the operating conditions in relevant facilities will not negatively affect the amount of resources, the possibility of sourcing renewable energy or the opportunities for sustainable operation.

THE SALINITY OF GEOTHERMAL WATERS EXTRACTED IN POLAND

The chemical composition of groundwater depends on several factors, including the lithology of the aquifer rocks, the circulation of groundwaters and the water-rock thermodynamic equilibrium. The geothermal water reservoirs that have been made available and are currently exploited in Poland exhibit varied physico-chemical properties. Fresh and weakly mineralised waters with an increased content of specific components are present here as well as brines.

In central Poland, in Mszczonów, weakly mineralised water (below 0.5 g/dm^3) with a temperature of 40.5^{o}C is being extracted from the Mszczonów IG-1 well, from a Lower Cretaceous horizon composed of sandstones interbedded with mudstone and claystone. This is high quality Cl-HCO_3-Na-Ca water. After the extraction of heat using an absorption pump and treatment, the water is used for consumption purposes in the municipal water supply system. Groundwater sourced from a Cenomanian reservoir in Słomniki (south-eastern Poland) is used for similar purposes. This is weakly mineralised (ca. 0.35 g/dm^3) HCO_3-Ca-Na-Mg water with a temperature of 16.5^{o}C at the well outlet.

In south-eastern Poland, in Podhale region, geothermal waters are extracted from carbonate formations of the Middle Eocene and from Middle Triassic limestones and dolomites. These exhibit relatively low mineralisation — from 2.358 g/dm^3 (Na-Ca-SO_4-Cl hydrogeochemical type) in the Bańska IG-1 well to 3.150 g/dm^3 (SO_4-Cl-Na-Ca) type in the Bańska PGP-1 well (Kępińska, 2006). Their temperature at the well outlet ranges from 69 to 86°C.

Geothermal water extracted from Mesozoic formations in the Polish Lowlands (e.g. in Pyrzyce, north-western Poland) has a different composition. Very hard (8,653 mg $CaCO_3$/dm^3) Cl-Na brines with a mineralisation of ca.123 g/dm^3 (Pyrzyce GT-1 well) and a temperature of 61°C are present here. The water has a high content of sulphates (1115 mg/dm^3), iron (16.4 mg/dm^3), manganese (1.5 mg/dm^3) and fluorides (1.2 mg/dm^3) (Kania, 2003).

WATER DESALINATION METHODS

Desalination processes can be classified as follows on the basis of changes in the phase, the type of energy used and the separation technique applied (Sadhukhan et al. 1999; El-Dessouky and Ettouney 2000; Bodzek et al. 1997):

1. On the basis of changes in the phase:

- without changing phase — reverse osmosis (RO) and electrodialysis (ED);
- involving changes in phase — distillation and freezing out.

2. On the basis of the type of energy used:

- heat-based processes — distillation processes;
- processes based on mechanical energy — reverse osmosis;
- processes based on electrical energy — electrodialysis.

3. On the basis of the separation technique applied:

- processes separating water from the solution: distillation processes and reverse osmosis;
- processes separating salt from the solution: electrodialysis and ion exchange.

The choice of the most appropriate water desalination process is dependent on the physicochemical properties of the water, its temperature, gas content and technical aspects related to the energy requirements of individual methods. The following factors are also significant: process efficiency (water recovery level), installation life (mechanical, thermal and chemical resistance of the membrane), the possibility of cleaning modules (membranes) and the need to implement extensive water pre-treatment processes as a result of, inter alia, raw water containing organic substances (macromolecular compounds, biological substances), inorganic compounds (metal hydroxides, calcium salts, silica), suspended particles, colloids (organic and inorganic) that may cause membrane efficiency problems — fouling and scaling.

Desalination processes based on thermal and membrane separation are the most important ones for drinking and domestic water production (Tsiourtrtis, 2001; El-Dessouky, Ettouney, 2000). Currently, membrane-based water desalination processes predominate due to their lower energy consumption compared to distillation techniques (Bodzek et al., 1997). Reverse osmosis (RO) enables pollutants to be separated at the molecular or ion level. In this process, pressure is applied to a water (solution) to force it through a semipermeable membrane, which separates two solutions with different concentrations. Under pressure, pure (permeate) water molecules pass through the membrane, while molecules of salts and other pollutants (e.g. colloids) and bacteria remain on the raw water side.

Hybrid installations combining thermal and membrane-based technologies are increasingly frequently used to treat salty water. These processes are, among others, the multi-stage flash process (MSF) and multi-effect distillation (MED). Their efficiency does not depend on the quality of the water supplied, which is the case with reverse osmosis (RO).

GEOTHERMAL WATER DESALINATION PROJECT

Water physico-chemical properties have to be determined in detail in order to assess whether it is possible to use geothermal water and to determine the most efficient treatment method. To this end, water has to be tested in situ at two locations: at the wellhead in order to determine the water parameters at the well outlet and in the geothermal installation, after it has been cooled in heat exchangers. During the geothermal water cooling process, several physico-chemical reactions take place, as a result of which the thermodynamic state of the water changes. This may cause the precipitation of the minerals dissolved in the water, which leads to many operational problems in the installation (Kępińska, 2006; Kania, 2003; Górecki (ed.) 2006). The analysis of the information obtained regarding the specific features of the heating system in question is a precondition for assessing the possibility of treating geothermal water by one of the methods available and using it in various applications other than the most common one.

In-situ studies at selected geothermal facilities in Poland that use water with varying salt content will make it possible to test the process on a semi-industrial scale (with a water desalination installation capacity of around 1 m^3/h). The study is to be implemented in two stages. In the first stage, the aim will be to obtain water that meets the requirements for safe drinking water, while at the same time recovering minerals that can be used in balneology or industry. In the second stage, attempts will be made to mix raw geothermal water cooled in heat exchangers with "pure water" following the treatment process in appropriate proportions. The final objective is to achieve a chemical composition of water that will reduce the mineral precipitation processes leading to the clogging of geothermal systems.

The results of studies on the treatment of geothermal waters following the heat recovery process, which often exhibit high salt content and do not constitute drinking water resources, will be used to assess the possibility of improving the local fresh water balance.

PILOT INSTALLATION

A pilot geothermal water desalination installation in Poland was commissioned at the Geothermal Laboratory of the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (PAS MEERI). Laboratory is localised in Podhale region, in south-eastern Poland. Geothermal waters are extracted from carbonate formations of the Middle Eocene and from Middle

Triassic limestones and dolomites. These exhibit relatively low mineralisation — from 2.358 g/dm^3 to 3.150 g/dm^3. Their temperature at the well outlet ranges from 69 to 86°C. After the cooling, in heat exchangers, water are used in the cascading system using geothermal energy. The first step of cascade is heating objects of PAS MEERI. In the next geothermal energy is used for drying wood, plant breeding greenhouses, thermophilic fish farming and heating of the land in plastic tunnels (Tomaszewska, 2009). The next step will be to research to the production of drinking water which is needed in the vicinity of the well. Installation is supplied with water at a temperature of about 35°C. The pilot installation must include typical industrial plant components because the pilot research must yield representative results which will constitute guidelines for industrial facilities (Fig. 1). For this reason, the minimum installation capacity has been set at 1 m^3/hour of desalinated water, which meets the above condition and will enable the extrapolation of results from the pilot installation to an industrial one. The study will take six to twelve months. The use of membrane-based methods is envisaged. The objective of geothermal water desalination will be to obtain water that meets the requirements stipulated in the Regulation of the Minister of Health of 29 March 2007 (Official Journal [Dz. U.] No. 61/2007 item 417) concerning the quality of water intended for human consumption.

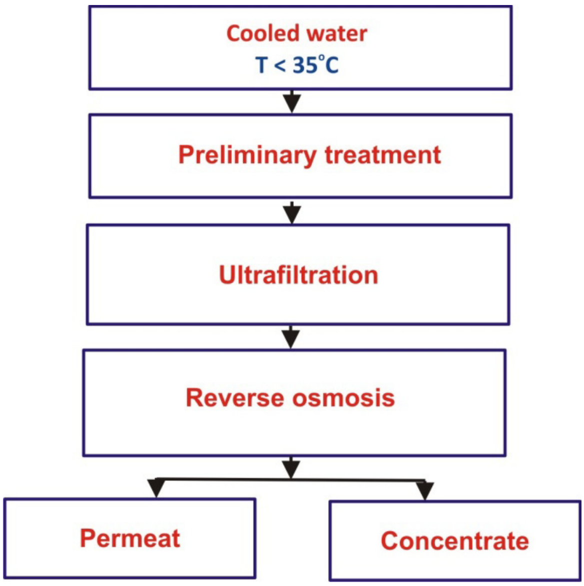

Figure 1. The concept design of the installation geothermal water desalination from the Bańska IG-1 well.

Primary criterion in selection of water desalination technology was <u>reliability</u> of installation in the presence of: silica — 62,5 mg/dm^3, hydrogen sulfide — 0,085 mg/dm^3, boron — 9,95 mg/dm^3, barium — 0,142 mg/dm^3, strontium — 7,19mg/dm^3, ammonium ion — 1,3 mg/dm^3, fluoride — 1,3 mg/dm^3, bromide — 1,75 mg/dm^3, sulfate — 872 mg/dm^3, mineralisation — 2482,59 mg/dm^3. After preliminary calculated there was selected the technology for the pilot installation, inclusive: preliminary filtration 1000 μm, ultrafiltration UF (for SDI < 4), activated carbon AC filtration double reverse osmosis (RO).

The successful implementation of the water desalination research programme presented in this paper would ultimately enable the development of best practices for geothermal water treatment in newly constructed installations and initiate proposals for improving the operation of existing facilities.

In particular, the application of water desalination methods at facilities which operate an open drain system (without reinjection) where the cooled water is released into a surface reservoir, would contribute to more effective use of the water released, including an improvement in the water balance of the area in question. Improvement of the economic parameters may be of key importance in the stimulation of new investment and as a consequence for increasing the share of renewable energy in the domestic market.

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