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Rozprawa doktorska

**Evaluation of prospective areas for low-temperature geothermal water utilization in
Małopolska Voivodship, Poland**

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Abstract: The dissertation presents potential opportunities for using groundwater in low-temperature geothermal systems assisted by water/water heat pumps in Małopolska Voivodship.

The analysis includes groundwater occurring at a depth up to approximately 500 m below the surface (the water temperature at this depth usually does not exceed 20°C) and refers water from Quaternary, Quaternary-Tertiary, Tertiary, Tertiary-Cretaceous, Cretaceous, Jurassic, Triassic formations.

The geological and hydrogeological conditions demonstrates that the Małopolska region has potential to use groundwater from shallow aquifers in low-temperature systems. The characteristics of these conditions are presented. The study focuses on the analysis of physical and chemical properties of water and thermal power potential of water intake as the lower source for the heat pump.

Data for this study were obtained from the Central Hydrogeological Database (so-called Bank Hydro). The collected results of 241 531 analyses were verified and limited to the years 2000–2014. Data from 1 583 groundwater intakes were obtained and used for further calculations and evaluations.

In order to verify whether there are installations assisted by water/water heat pumps within the analyzed region, a query to 22 District Governor's Offices of the Małopolska Province, The Marshal's Office of the Małopolska Voivodship in Kraków and The Regional Water Management Authority in Kraków, was sent. Water used in water/water heat pumps systems usually require the water-legal permits (permit required by Water Law Act (Water Management Act)). The question concerned the number of permits issued for such installations (in the years 2003–2013).

Based on water yield and temperature data, the thermal power potential of water intakes as the lower source for the heat pump, was estimated. The calculated values of thermal power of the shots allowed for determination of prospective areas in terms of energetic use of water in Małopolska.

Evaluation of the possibility of using the analyzed water in low-temperature systems assisted by water/water heat pumps was carried out by referring the results of physicochemical analyzes to the parameters indicated by manufacturers of heat pumps as important for the proper operation of installations: pH, electrical conductivity (EC) and concentrations of chlorides (Cl⁻), sulphates (SO₄²⁻), nitrates (NO₃⁻), bicarbonates (HCO₃⁻), iron (Fe), manganese (Mn), ammonium (NH₄⁺), oxygen (O₂), free (aggressive) carbonic acid (CO₂ agg.), nitrites (NO₂⁻), hydrogen sulphide (H₂S) and aluminium (Al). This assessment allowed for determination of prospective areas in terms of the chemical composition of groundwater in Małopolska.

Using the empirical formula method, the assessment of groundwater quality with reference to its potential of scale formation and corrosivity was made. The assessment of stability of the physical and chemical parameters indicated by manufacturers of heat pumps as important for the proper operation of installations, was presented.

Taking into account all the results and local conditions resulting from the spatial development plans (local zoning plan), the prospective areas for the use of groundwater in low-temperature installations within the Małopolska Voivodship were indicated.

The possibilities of using groundwater from shallow aquifers in low-temperature systems has been verified on the examples of existing wells located in Biała Nizna, Rudniki, Gaj, Porąbka Iwkowska and Stanisław Dolny.

The rules of conduct for this type of installation were proposed and presented on the example of the I/828/3 Zawoja-3 (located in the south-western part of the Małopolska Province).

The development of the use of groundwater in heat pump systems depends on the legal regulations. An assessment of the legal status of low-temperature geothermal in Poland and the European

Union has been carried out and financial support for these installations has been presented.

The assessment conducted demonstrates that in the Małopolska Province groundwater could be used in low-temperature systems assisted by water/water heat pumps in terms of depth of water occurrence (up to approximately 500 m below the ground level), potential water flow rates (approx. 1,2–1,5 m³/h per each 5 kW of heating power), water temperatures (below +20°C) and suitable physical and chemical composition of water, practically throughout the whole region.

