Center for Applied Geoscience (ZAG)
Hydrogeothermics

Sustainable Management of Urban Heat Islands

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Introduction

In recent years, urban heat islands, defined as built up areas that are hotter than nearby rural areas[1], have received much attention. Of interest is not only the regional surface temperature increase (e.g. Figure 1), but also the significant rise of subsurface temperatures in such urban areas (e.g. Table1). Meanwhile, geothermal energy use has become popular, because it offers a number of advantages over traditional energy sources based on fossil fuels. Therefore, there is great chance for future growth of geothermal energy use, particularly in densely populated urban regions with higher underground temperature.

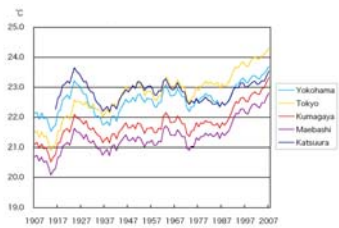

Figure 1: Development of average surface air temperature of several cities in Japan [2]

Table 1: The average subsurface temperature differences (ΔT) between wells in the urban area and rural area in several cities all over the world.

City	ΔT (°C)	Measurement depth (m)	Number of observation points (-)
Tokyo[3] [4]	~ 2	~ 20	29
Osaka[3]	~ 2	~ 20	37
Nagoya[3]	~ 2	~ 20	36
Bangkok[5]	~ 2	~ 30	18
Winnipeg[6]	~ 5	20	50
Cologne[7]	~ 3	~15	45

Previous studies so far have been more concerned about the causes of subsurface temperature increase, which might be micro-climatic changes in the urban environment and the heating effect of sewage effluents and large buildings[5,6]. The focus of this project is set on the specific features of sustainable geothermal use in such large and densely populated areas. Our example case is Frankfurt/Main.

Methodology

The main procedure of this project is as follows:

1. Data survey
2. Field measurements
3. Modelling
4. Assessment of sustainability

After the data survey on geological and hydrogeological conditions, we did the first field measurements in Frankfurt/Main (see Figure 2 and 3); the Hessian Agency for the Environment and Geology (HLUG) provides access to ongoing, highly spatially resolved field measurement locations. A comprehensive field investigation gives insight into the spatial temperature variations in the underlying aquifers of the city.

Figure : Satellite photo of the research area in the city of Frankfurt/Main (*Google Earth*).

Figure : Field measurement sites in the city of Frankfurt/Main.

Results and Discussion

Groundwater levels and temperatures in each borehole depth were logged every two seconds. The following temperature profile (measured in April, 2009) shows the results from two monitoring wells in different locations in Frankfurt/Main (Figure. 4).

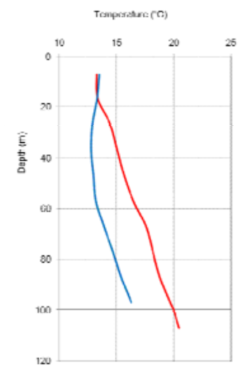

Figure 4: Temperature measurement in the city of Frankfurt/Main. The red line is from the measurement of an observation well in the city center and the blue line is 4 km away from it.

The temperature profile from this measurement shows that below 20 m the observation wells in the city center has much higher groundwater temperature than the one 4 km away from it. However, more measurements are needed in order to obtain a generally valid interpretation. The geology in Frankfurt is complex, a mixture of clay and silt with thin layers of limestone up to 200 m. Hot groundwater was found in some deep observation wells, which might originate from special natural reservoirs.

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Conclusions and future work

Previous studies and recent measurements in Frankfurt/Main have shown that there exist substantial temperature differences between the subsurface of the city and the rural area around it. Particularly in the center we find elevated temperatures, a fact which makes this area attractive for geothermal heating.
Due to the common anomalies, there is the need to estimate and quantify the potential energy below urban areas. Of particular interest is how to sustainably manage such heat islands. Compared with less disturbed regimes, more emphasis has to be placed on heat extraction rather than on the growing use of aquifers for cooling of buildings.

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