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ScienceDirect

Procedia Engineering 209 (2017) 83–91

Procedia Engineering

www.elsevier.com/locate/procedia

Urban Subsurface Planning and Management Week, SUB-URBAN 2017, 13-16 March 2017, Bucharest, Romania

Thermal management of urban subsurface resources - Delineation of boundary conditions

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Abstract

Shallow subsurface resources are progressively used for the production of geothermal energy, i.e. for the installation and operation of a broad variety of Geothermal Energy Systems (GES). Additionally, in many urban areas there is a surplus of heat from large buildings and constructions reaching into the groundwater saturated zone. Likewise, groundwater is more often used as a cheap cooling medium. As a result, significantly increased subsurface temperatures have been observed in many urban areas.
Several studies investigated how the so-called "Subsurface Urban Heat Island" (SUHI) effect and how current thermal subsurface regimes developed. However, a sustainable management of subsurface resources requires a general understanding on how "current thermal states" of subsurface and thermal regimes developed in context of different urban settings and boundary conditions. These aspects yet are mostly unexplored. In practice mitigation measures are generally taken for individual projects. Thereby, a consideration of the broader context of hydrogeological and thermal processes and boundaries and the interacting thermal activities could lead to a more sustainable use of subsurface energy resources.
Besides providing an overview of subjects related to the thermal management of urban subsurface resources this review paper summarizes the results from different research projects that have been realized in the densely urbanised area of Basel in north-western Switzerland.

Peer-review under responsibility of the scientific committee of the Urban Subsurface Planning and Management Week.

Keywords: Shallow subsurface resources; Geothermal energy; Building structures; Subsurface Urban Heat Island; Boundary conditions

1. Introduction

1.1. Current thermal state of shallow urban subsurface resources

Recently, several studies investigated the SUHI effect [1-4]. However, a general understanding of how the ***"current thermal state"*** of the subsurface and thermal regimes developed in the context of different urban settings

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1877-7058 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the Urban Subsurface Planning and Management Week.
10.1016/j.proeng.2017.11.133

and boundary conditions is mostly unexplored. Some studies indicate that increased temperatures of subsurface resources and the associated stored geothermal energy in urban areas mainly originate from local and regional anthropogenic factors, while climate change is secondary [4, 5].

Why is SUHI relevant? Heating and cooling using groundwater (resp. the subsurface in general) is often performed without considering potential effects on subsurface resources as well as the multiple interactions of different subsurface utilizations. Uncoordinated use can lead to conflicts among different subsurface users, and specifically thermal pollution of subsurface resources may lead to large-scale thermal impacts and impairments of groundwater quality. As SUHI strongly influences thermal regimes of soil and groundwater systems [6], the effects are, and increasingly will be, a global groundwater quality issue. So far, little is known about influences of increased temperatures on groundwater quality, including biological, chemical and physical aspects [7-12].

1.2. Concepts and legal framework for thermal management

For most urban areas, concepts for the thermal management of groundwater resources are missing. So far, the attitude ***"first come, first served"*** dominates. For some cities, first fundamentals for a more targeted thermal management of the subsurface are being developed and the essential thermal factors and causes of groundwater heating were evaluated. In [13] we could present chances for, and limitations of, the intensive thermal use of the shallow subsurface in urban areas in the context of the current energy debate in Germany.

In general, it is accepted that in urban areas subsurface infrastructure development should not lead to further thermal pollution of groundwater resources. It is obvious, however, that the current unregulated approach of managing energy resources, especially in urban areas, will not be able to sustain future demands. Therefore, more actively managed approaches are needed to meet energy demands [14]. Whereas some guidelines for new GES exist, regulations concerning the requirements for, e.g. building isolation, subsurface structures are scarce [15, 16].

A sustainable use of subsurface resources requires compulsory regulations as to which requirements are to be met for the approval of GES. In general, these requirements concern authorization procedures for individual installations. However, in most urban areas, the usage pressure on subsurface resources is high and today individual exploits are already competing. New usage requests can therefore not be assessed without taking into account the overall context and the current state of the situation and existing subsurface uses.

Although legal frameworks for water protection as well as water policy have continuously been adjusted in the last decades, considerable damage to subsurface resources still occurs. Previous studies only concentrated on potential mitigation[1] [17] of various impacts. There are several reasons for this: (1) More attention is paid to purely technological problems concerning water management rather than to issues dealing with sustainable water use; (2) Water protection and engineering projects were planned under outdated legal frameworks and would not be approved today. Nowadays more restrictive laws, as well as changed perceptions and policy concerning water resources apply; (3) Realization of water protection is still orientated mainly towards documentation of changes in the flow regime[2] and water quality, whereas less attention is paid to the prediction of future demands and to the management of water resources in general; (4) Until now, the impacts of engineering measures on water systems were only regarded as solitary and limited events. However, examinations of the interactions between the impacts and other activities as well as changing boundary conditions were not attempted; and (5) Existing legal frameworks for water protection usually focus on the local monitoring of a set of given parameters rather than on the understanding of the fundamental processes and long-term changes.

1.3. Thermal potentials and resource management

Generally, thermal waste energy today is often dealt with in the same unconcerned way as garbage was treated decades ago [4, 15]. Heat-input of subsurface structures and GES can develop large heat plumes (Thermally Affected Zones TAZ) in the aquifer. In principle, the aquifer could be directly 'mined' to exploit and store thermal waste energy, whereas technologies would be particularly suitable in new buildings and infrastructures in centers of economic

[1]The term "mitigation" encompasses a broad range of measures that might reduce or compensate the effects of environmental damage.
[2]The term "flow regime" includes all flow patterns, velocities and budgets for a defined region in a temporal context.