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A technical investigation on tools and concepts for sustainable management of the subsurface in The Netherlands

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HIGHLIGHTS

- Case studies illustrate pressure points for sustainable management
- Technical concepts behind physical, social, legal and ethical issues identified
- Technical elements behind management considerations pinpointed

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ABSTRACT

In response to increasing use of the subsurface, there is a need to modernise policies on sustainable use of the subsurface. This holds in particular for the densely populated Netherlands. We aimed to analyse current practice of subsurface management and the associated pressure points and to establish a conceptual overview of the technical issues related to sustainable management of the subsurface. Case studies on the exploitation of subsurface resources (including spatial use of the subsurface) were analysed, examining social relevance, environmental impact, pressure points and management solutions. The case studies ranged from constructing underground garages to geothermal exploitation. The following issues were identified for the technological/scientific aspects: site investigation, suitability, risk assessment, monitoring and measures in the event of failure. Additionally, the following general issues were identified for the administrative aspects: spatial planning, option assessment, precaution, transparency, responsibility and liability. These issues were explored on their technological implications within the framework of sustainable management of the subsurface. This resulted into the following key aspects: (1) sustainability assessment, (2) dealing with uncertainty and (3) policy instruments and governance. For all three aspects, different options were identified which might have a legal, economic or ethical background. The technological implications of these backgrounds have been identified. A set of recommendations for sustainable management of the subsurface resources (incl. space) was established: (1) management should be driven by scarcity, (2) always implement closed loop monitoring when the subsurface activities are high-risk, (3) when dealing with unknown features and heterogeneity, apply the precautionary principle, (4) responsibility and liability for damage must be set out in legislation and (5) sustainability should be incorporated in all relevant legislation and not only in environmental legislation. Other aspects to be considered are the reversibility of the impacts from subsurface activities and the abandonment of installations.

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1. Introduction

In April 2010 the Dutch Cabinet approved the policy concept 'sustainable use of the subsurface' (VROM, 2010), which elaborates on how a leading and integrating role is assigned to the subsurface (including groundwater and soil) in policy. In the policy vision, the approach opted for to assess sustainable use of the subsurface is function-oriented rather than protection-oriented, and a central position is given to socio-economic development and government aims. Furthermore, it is stated that central government is aware that for a proper assessment, it is necessary to have sufficient knowledge of and insight into the consequences of interventions in the subsurface for the functions of this subsurface. It is also stated that the government will develop the essential elements of sustainable use of the subsurface together with provincial and local governments.

In the development of Dutch policy on soil, the accent is now on the use of the subsurface and on seeking a balance between protection and exploitation. In addition to uses of the subsurface that should contribute to 'new' social themes such as quality of the environment, sustainable energy and the efficient use of space, there are existing uses such as provision of drinking water, using space for cables and pipelines and using the soil for agriculture and nature. If the new opportunities become exploited, it will be busier underground and therefore it will be necessary to plan, direct and guide, and take account of uncertainties. Sustainable use of the subsurface has to do with being able to continue using the subsurface for existing uses, and with accommodating new uses. To do so, account must be taken of the interrelationships between soil, groundwater, organisms and all the chemical, physical and biological properties and processes.

There is no assessment methodology that can be applied as an instrument for the sustainable use of the subsurface. A need, however, exists to evaluate the sustainability of different uses of the subsurface. This is useful to prioritise the potential uses among themselves and also to compare the individual uses with aboveground alternatives. To develop such an assessment methodology, insight into the ingredients that should be included is necessary.

This study aims to present an inventory of the elements and methods that contribute most to sustainable use of the subsurface within the context of the geoscientific setting of The Netherlands. To reach this aim, first, practical examples of exploitation of the subsurface are analysed on their opportunities and pressure points and, second, an investigation is made on the technical concepts behind different options for sustainable management of the subsurface. This contributes to the inventory of elements that are essential for using the subsurface sustainably. Recommendations are given from the conceptual analysis to reach sustainable management of the subsurface. This study is based on an investigation of the "Duurzaam Gebruik Ondergrond" (sustainable use of the subsurface) working group (TCB, 2012) of the Dutch Soil Protection Technical Committee (TCB). The TCB gives technological and scientific advice to the Dutch government on soil policy, and its recommendations provide support for developments in such policy.

2. Geoscientific settings

The Netherlands can be divided into a Holocene area and a Pleistocene area (De Mulder et al., 2003; De Gans, 2007). The shallow subsurface of the low-lying western and northern parts of the country is predominantly composed of shallow Holocene marine, peri-marine and fluvial deposits and peat. The soft deposits act as an impermeable to semi-permeable top layer with Pleistocene sediments below, which are predominantly composed of permeable, fluvial sands. Most of the Holocene area consists of polders that are discharged through a system of drains and ditches, half of which lie below sea level. Holocene dunes and barriers occur along the coastline, where aeolian deposits lie on top. The maximum altitude of these dunes is several tens of metres above mean sea level. No Holocene marine deposits are found in the central riverine plain of the Rhine and Meuse rivers, or in the Meuse valley in the southeast of the country and the IJssel valley in the east. Here, a thin semi-permeable top layer is found that predominantly consists of Holocene fluvial and peat deposits with Pleistocene, sandy, permeable sediments below. The Pleistocene area of The Netherlands comprises older fluvial deposits and glacial or peri-glacial deposits near the surface. Permeable sands are predominantly found here. The shallow subsurface of the southernmost part of The Netherlands has an entirely different geology. Here, Pleistocene loess deposits lie at the surface, covering Cretaceous carbonate rocks or Tertiary clastic sediments.

The Netherlands is a densely populated country with an average 450 inhabitants/km^2. Except when referenced, the following general information can be found in a series of specialised atlases on The Netherlands (www.bosatlas.nl). The western part of The Netherlands is the most urbanised including the cities of Amsterdam, Rotterdam (with their harbours) and The Hague. Almost all buildings in the Holocene part with clay and peat soils have pile foundations, including many old listed buildings. Traffic tunnels have been build since the Second World War, and their construction has intensified since the 1990s. Subsurface construction of garages and other buildings has also intensified since the 1990s. About 65% of the land is in agricultural use, which is among the most intensive world-wide. Soil and groundwater contaminations by industrial, military and agricultural activities, petroleum hydrocarbon production, landfills, etc. are frequently found and anthropogenic groundwater contamination down to about 25 m is common with exceptions down to about 100 m (Vanden Brink et al., 2007; Van Wezel et al., 2008). The Netherlands was among the first countries world-wide where soil and groundwater remediations started in the 1980s. Drinking water is for about 65% produced from groundwater and these winnings are found in the Pleistocene area, the coastal dunes and along the rivers Rhine and Meuse. The winnings are found in both phreatic aquifers down to several tens of metres and confined aquifers down to several hundreds of metres. Winning of sand, gravel and clay happens at the surface, where the focus for sand winning has been shifted to the North Sea during the last tens of years. Crude oil, natural gas and salt are exploited from layers that lie below 500 m depth. The Netherlands has exported natural gas since the end of the 1960s. Many hundreds of open aquifer thermal energy sites and closed borehole thermal energy sites are found in the urbanised areas (Bonte et al., 2011). The first geothermal energy winnings have been installed a few years ago and this kind of energy production receives increasing attention. Exploitation of shale gas is under study by the government and a few exploration licences have been granted.

3. Using the subsurface: lessons learned from practice

Exploitation of the subsurface influences the properties of the subsurface itself. In general, these impacts are desired (temperature changes resulting from aquifer thermal energy storage (ATES), for example) but sometimes the impacts are unwelcome, such as interference with another use, the spread of contaminants, groundwater layers disturbed by the mixing of groundwaters of different qualities, induced subsidence and salinisation. Problems, solutions and lessons learned were distilled from real examples of subsurface exploitation in The Netherlands. Several of these examples are typical for the geological and geographic settings of The Netherlands: land subsidence of in particular peatlands, soil contamination and remediation in a densely populated, highly industrialised and rich country, and exploitation of natural resources from or storage in sedimentary rocks (Fig. 1). The examples investigated were classified according to the type of subsurface use and are listed below with increasing depth at which the use occurs: