Groundwater Quality into the Future: Workshop Summary

Environmental Change, Adaptation and Resilience Programme

Open Report OR/22/010

BRITISH GEOLOGICAL SURVEY

ENVIRONMENTAL CHANGE, ADAPTATION AND RESILIENCE PROGRAMME

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Summary

This report details the findings of a workshop held by the British Geological Survey and the Environment Agency on “Groundwater Quality into the Future” in February 2022. The workshop was attended by over 60 delegates, and was a part of a short scoping study aimed at improving understanding of the impacts of climate and land use change on groundwater quality. Four cross-cutting themes emerged from the workshop:

1. The high level of uncertainty associated with potential impacts of climate and land use change on groundwater quality over the next century
2. The need for holistic, systems approaches to the science and management of groundwater quality and resources in the terrestrial water cycle
3. Further education related to groundwater amongst the general public
4. The need for continued monitoring to characterise the impacts of environmental change on groundwater quality

A number of focus areas were also identified by the workshop delegates: nutrients, emerging substances, changing rainfall characteristics, changing temperature, groundwater rebound, urban development and construction, changing salinity and groundwater ecosystems. The cross-cutting themes and focus areas identified in the workshop will be used to feed in to future work to improve our scientific understanding and management of the impacts of climate and land use change on groundwater quality.

1 Introduction

1.1 BACKGROUND

In 2021 the Environment Agency (EA) commissioned the British Geological Survey (BGS) to undertake a short scoping study aimed at improving understanding of the impacts of climate and land use change on groundwater quality. As a part of this project, on Wednesday 9th February 2022, the BGS and EA held a workshop on "Groundwater Quality into the Future". The purpose of the workshop was to gather input from both Environment Agency and external stakeholders regarding what the key issues are related to future groundwater quality, and what are the priorities for adaptation, management and research.

The workshop was attended by over 60 delegates over Zoom. Delegates were asked to undertake three tasks in small breakout groups. The tasks were as follows:

1. Identify and prioritise 'Key Focus Areas' to ensure good groundwater quality in England in the medium and long term
2. Provide intelligence related to the prioritised Key Focus Areas
3. What else should we consider in taking this programme of enquiry forwards?

Each breakout group recorded notes relating to the three tasks above. In this report, we provide a brief overview of the workshop attendees, before synthesizing the notes made by each group to detail the cross cutting themes and key focus areas to be considered in future work. For each of the key focus areas we also identify a key message to be considered for future work.

It should be noted from the outset that the themes and focus areas discussed herein represent the opinions raised at the workshop, and do not necessarily reflect the positions of the author, BGS or the EA.

2 Workshop delegates

The workshop was attended by 63 delegates. Figure 1 details the breakdown of delegates by organisation type. Approximately half of the delegates were from the Environment Agency, which in turn were evenly divided between national and area staff. The remaining attendees were from water companies, other public bodies (e.g Drinking Water Inspectorate, Scottish Environment Protection Agency, Natural England), and academics and consultants. This broad community of interest is well placed to support the development of future work to improve our understanding of the impacts of climate and land use change on groundwater quality.

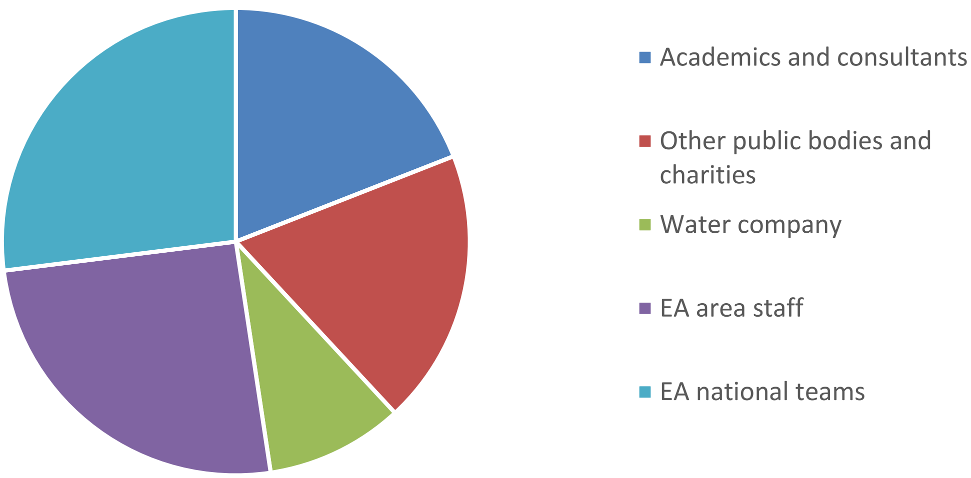

Figure 1 Breakdown of workshop delegates by organisation

3 Cross cutting themes

3.1 UNCERTAINTY

Uncertainty and lack of knowledge is a major limitation to adaptation, management and mitigation of the impacts of climate change on groundwater quality, particularly over longer timescales (> 50 years).

Over the course of this century there is uncertainty in both changes in drivers (e.g. climate change, population growth and socioeconomic change) and pressures (e.g. changes in recharge processes, land use, groundwater abstraction) controlling groundwater quality. This is compounded further by uncertainty in the hydrogeological system response to a given change in pressure (e.g. the groundwater quality impacts of groundwater level rebounds following reductions in abstraction), and because multiple competing drivers and pressures are likely to control groundwater quality in the future. Consequently, detection and attribution of changes in future groundwater quality associated with individual drivers and pressures is likely to be highly challenging.

There is a need for further research to build the evidence base to support decision making regarding appropriate mitigation and adaptation measures. Specific research needs are discussed further in section 4.

3.2 HOLISTIC, SYSTEMS APPROACHES

At present siloed approaches to both the science and management of the terrestrial water cycle are common. This includes divisions between both different components of the hydrological cycle (e.g. climate, soil water, groundwater, surface water) and how they are managed to address different issues (e.g. flooding, resources, quality).

The interconnectivity between groundwater resources and quality, and surface water and groundwater necessitates the development of integrated, systems based approaches to both the science and management of groundwater in the terrestrial water cycle.

Such joined up approaches should be founded on a vision of what, in the face of change, good groundwater management in the terrestrial water cycle looks like in 50-80 years. Approaches should build a culture of wider inclusion and interdisciplinarity with greater collaborative working and partnerships from the outset, including knowledge and data exchange.

3.3 EDUCATION

Despite decades of previous efforts (e.g. the UK Groundwater Forum) to raise awareness around groundwater, the level of public understanding remains poor. A new generation of funded engagement activities with the public and other stakeholders (e.g. Local Planning Authorities, developers, senior decisionmakers, parliamentarians) that “makes the invisible visible” is required. These activities should cut across political and financial agendas, and consider adopting new approaches (e.g. social media) to communicate the value of groundwater, using language that is simple to understand and engaging. Improved education of children about groundwater in the terrestrial water cycle in schools is required. A renewed UK Groundwater Forum is a possible approach for achieving this.

Numbers of undergraduate earth science students at universities are reported to have decreased substantially. These courses feed in to masters level training opportunities in hydrogeology; the graduates of which form a significant proportion of groundwater professionals in the UK. Further engagement to highlight the value of earth sciences to prospective undergraduate students is required to safeguard future generations of qualified groundwater professionals in the UK.

3.4 MONITORING

Environment Agency groundwater quality monitoring has decreased over the years associated with reductions in funding and resource availability. There is an ongoing requirement for long term monitoring to characterise groundwater quality before (baseline), during and after changes in pressures (e.g. changing land use, recharge, abstraction). If future financial constraints limit the extent of monitoring undertaken this may limit our ability to (1) characterise the impact of environmental change on groundwater quality and (2) predict future groundwater quality and assess the effectiveness of regulation and interventions.

Further, networks should be re-evaluated to ensure that the monitoring networks of the future are fit-for-purpose in a changing, uncertain world. This includes considerations related to:

1. Whether monitoring frequency is adequate given the changing nature of extreme events associated with climate change
2. How to monitor for the next generation of emerging substances, and a growing range of substances in the environment
3. Whether more monitoring should be focussed on urban sources, given increasing urbanisation and the need for representativeness of monitoring across different settings
4. Whether more innovative monitoring techniques can be used, such as citizen science and remote sensing
5. The carbon footprint of undertaking monitoring

4 Key focus areas

4.1 NUTRIENTS

Nutrients (nitrogen (N), phosphorus (P) and carbon (C)) remain an issue for groundwater quality, with significant costs associated with treatment and blending for public water supply as well as surface water eutrophication.

There is a relatively good understanding of a number of current sources of nutrients however some sources are poorly constrained such as fluxes from misconnections and septic tanks. For all sources there is uncertainty as to how these may change in the future as a function of climate and socioeconomic changes. Potential direct impacts of climate change on nutrient fluxes include changing rainfall patterns resulting in mobilisation from nutrient-saturated soils and changes in recharge pathways. Indirect changes in nutrient sources and pathways are likely to be significant, such as changes in population, dietary habits and energy demands resulting in growing of different crops.

Fate and transport of nutrients in groundwater is strongly controlled by aquifer characteristics. When considering nutrient concentrations at receptors, there is uncertainty regarding the relative contribution of legacy sources and current sources (e.g. fertilizer applications). Furthermore, legacy C and P are generally less well understood than N, and different management approaches are likely to be required for different nutrients. Nutrient inventories may be a useful tool to understand acceptable nutrient loadings to a catchment, and quantification of the economic value of nutrient excesses may improve usage on farms.

Key message: Further work to understand how nutrient sources and pathways may change in the future is required.

4.2 EMERGING SUBSTANCES

The emergence of new organic contaminants (e.g. Per- and polyfluoroalkyl substances (PFAS), pharmaceuticals) in groundwater is of concern, particularly where these are highly persistent and bioaccumulative.

There is considerable uncertainty regarding the sources, fate and transport of these contaminants both at present and over the next century. Changing rainfall patterns may result in increases in winter runoff and mobilisation of contaminants. Hotter temperatures may result in increased wildfires and associated use of foams and fire suppressants as well as use of PFAS-containing ground source cooling schemes. Further, our understanding of what concentrations constitute a significant risk in terms of ecotoxicology and human health is poor.

There is a need develop systematic approaches to characterising emerging substances in groundwater. This should include:

1. Continued baseline data collection for emerging substances
2. Identification of the next generation of emerging contaminants, with consideration of how climate change may affect use of chemicals (e.g the need for different medicines, pesticides)
3. Use of the source-pathway-receptor model to characterise transport in groundwater
4. Better understanding of the human and environmental toxicology of emerging substances and the impact of mixtures
5. Consideration of novel treatment solutions, where emerging substances pose a risk to human health

Key message: Understanding the human and environmental toxicology of emerging substances both individually and in mixtures is essential. This can help prioritise where to focus future work.

4.3 CHANGING RAINFALL CHARACTERISTICS

Changing rainfall patterns are predicted under climate change, resulting in wetter winters, drier summers and more extreme rainfall events. These changes are likely to affect groundwater quality. Whilst it is likely to be challenging to isolate the specific impact of changes in rainfall characteristics amongst other factors affecting groundwater quality, a number of changes may occur:

1. Increased leaching of contaminants and pathogens in winter
2. Increased soil capping and soil erosion, resulting in changes in the balance of recharge and runoff
3. Changes in the characteristics of recharge, with potentially increased rapid flow. This may result in changes in the contaminants entering an aquifer (for example, phosphorus may become more important)
4. Flushing of contaminants in the unsaturated zone

These possible changes are associated with increases in winter rainfall and increasing extreme rainfall events. Under drought scenarios, less water is available for dilution and so more extreme droughts may result in higher concentrations of contaminants in aquifers.

These possible changes may result in increased contaminant concentrations at public water supplies and other receptors. Whilst there are limited options to affect changes in driving meteorological conditions, changes can be made to alter recharge and groundwater abstraction. This could include land use changes to increase storage and slow runoff, and flexible abstraction regimes (e.g. increasing abstraction when groundwater levels are high).

Key message: Quality and quantity issues need to be integrated when considering the impacts of changing rainfall characteristics on groundwater.

4.4 CHANGING TEMPERATURE

Groundwater temperatures are likely to change over the next century as a function of two processes. In shallow groundwater systems, groundwater temperatures are anticipated to rise by c. 1-2 degrees associated with increases in air temperature due to anthropogenic warming. The development of ground source heating and cooling schemes associated with decarbonisation is also likely to be affecting groundwater temperatures, with potentially much greater changes in temperature than those associated with anthropogenic warming. In central London changes in groundwater temperature have been observed, which have been inferred to be due to the increasing number of ground source heat schemes present.

Biota and chemistry of groundwater systems are sensitive to changes in temperature. Changes in temperature may affect contaminant mobility through greater dissolution, and contaminant degradation through greater microbial activity. Small changes in groundwater temperature of the order of 1 - 2 degrees associated with anthropogenic warming may only have a limited impact on chemical and microbiological processes in groundwater. Larger changes in temperature associated with ground source heating schemes may have an impact but this is largely unknown at present. There is limited knowledge of the cumulative impact of both these processes. At present there is no national groundwater temperature monitoring network to assess changes in groundwater temperature. Both of these processes may affect the temperature of baseflow to rivers, although beyond the immediate area of groundwater discharge, river temperatures may be more affected by direct warming of surface water.

Key message: A national groundwater temperature monitoring network is required to support research to evaluate the impact of anthropogenic warming and ground source heating and cooling scheme development on groundwater temperatures.

4.5 GROUNDWATER REBOUND

Groundwater level rebound is likely to occur in some areas in the future associated with the requirement to reduce overabstraction. Groundwater level recoveries have the potential to affect groundwater quality. There is uncertainty associated with the extent to which groundwater levels will rebound in response to a given reduction in abstraction, particularly given the vertical heterogeneity in hydraulic properties of different strata, and potential interaction with boundary conditions such as the land surface and the sewer network. The impact of these changes on groundwater quality is a further source of uncertainty. Increasing groundwater levels will result in increased saturation of the unsaturated zone and mobilisation of contaminants. There is limited understanding of the vertical profile of contaminants in the unsaturated zone associated with historic loadings from the land surface. This means for any given change in abstraction there is limited predictive power in what changes in groundwater quality will be. This is highlighted by changes in abstraction in the Chalk where recent reductions in groundwater abstraction have caused inconsistent changes in groundwater quality. There may be similar implications if seasonal groundwater level fluctuations increase associated with greater winter recharge. Long term monitoring of groundwater levels and quality before and after changes in abstraction to evaluate the impacts of groundwater level rebound.

Key message: Understanding of how groundwater levels will recover due to abstraction reductions and associated water quality implications is poor. Long term monitoring is required.

4.6 URBAN DEVELOPMENT AND CONSTRUCTION

The need for housing for our growing population is exerting, and will continue to exert, a significant pressure on groundwater. There is increased development on both brownfield and greenfield sites which is resulting in increased nutrient loading associated with both direct discharges to ground and loadings to sewage treatment works. Increased loads at sewage treatment works may result in increased need for sludge spreading, on a decreasing area of agricultural land due to urbanisation. Targets are set for house building that do not consider groundwater protection, and if poor practices are used in attempts to reduce costs then there is a risk of contaminants leaching to groundwater. Whilst regulations are clearly set out and guidance is in place, there is a pressure to meet growth targets and limited resource for regulatory enforcement.

Large construction projects (e.g. HS2) are also anticipated to continue to exert pressure on groundwater. Development of deep piling can result in changes to groundwater flow paths with implications for pollutant transport (e.g. turbidity). New technologies used in such developments (e.g. ground freezing, additives in drilling fluids and cements) may have impacts on groundwater quality but this is unclear at present.

Key message: Effective planning and regulations of urban developments that consider groundwater are needed.

4.7 CHANGING SALINITY

Changes in salinity in groundwater are likely to occur due to minewater processes and saline intrusion in coastal aquifers. Both of these are likely to change in the future. Mobilisation of minewater contaminants (including increases in salinity) may occur due to groundwater level rebound following stopping pumping, and increases in groundwater levels due to climate-induced changes in recharge. Management of saline waters from legacy mineworkings in an environmentally sustainable manner remains an ongoing challenge. Desalination is very expensive and energy intensive, and creates a saline brine that needs disposal.

Increasing sea levels will change the extent of saline intrusion in coastal aquifers. This is likely to be exacerbated during drought periods when driving groundwater heads are lower. This may result in a need to reduce pumping rates to ensure that salinity at public water supply abstractions does not increase. Managed coastal retreat may also affect the extent to which saline intrusion occurs, but the extent to which groundwater quality is taken into consideration in coastal planning is unclear. There is a limited understanding of how increases in saline intrusion may affect groundwater ecology and terrestrial ecosystems.

Key message: There are substantial technical difficulties in the management of saline waters from treatment, waste, and regulatory perspectives. Innovative approaches are needed.

4.8 GROUNDWATER ECOSYSTEMS

At present there is a very limited understanding of the distribution, species composition and functioning of groundwater ecosystems. We do not know the current level of biodiversity in groundwater ecosystems and the ecosystem services that microbial communities provide.

To assess the impact of future changes in groundwater ecology we need a much better understanding of the current baseline functioning of these systems. A key risk is the potential loss of unique ecosystems and the ecosystem services they provide. These services may include breakdown of contaminants and dissolved organic matter.

Different species and microbial communities are likely to have different levels of sensitivities to changing conditions (e.g changes in temperature, water quality). Effects may be positive or negative, and there may be some conditions (in terms of temperature, redox, pH) under which some microbes may be unable to function.

Key message: There is currently insufficient knowledge to determine both the current and future form and function of groundwater ecosystems. We don’t know what conditions these ecosystems thrive under, as well as how changing temperature and groundwater quality will affect microbiology and species composition.

5 Conclusions

This report documents the findings of the BGS-Environment Agency workshop on “Groundwater Quality into the Future” held in February 2022.

Workshop delegates identified four cross-cutting themes: (1) the high level of uncertainty associated with potential impacts of climate and land use change on groundwater quality over the next century, (2) the need for holistic, systems approaches to the science and management of groundwater quality and resources in the terrestrial water cycle, (3) further education related to groundwater amongst the general public, (4) the need for continued monitoring to characterise the impacts of environmental change on groundwater quality.

A number of focus areas for further work were also identified: nutrients, emerging substances, changing rainfall characteristics, changing temperature, groundwater rebound, urban development and construction, changing salinity and groundwater ecosystems. The cross-cutting themes and focus areas identified in the workshop will be used to feed in to future work to improve our scientific understanding and management of the impacts of climate and land use change on groundwater quality.