Applied Geochemistry xxx (2015) 1–5

Contents lists available at ScienceDirect

Applied Geochemistry

journal homepage: www.elsevier.com/locate/apgeochem

The Geogenic Contamination Handbook: Addressing arsenic and fluoride in drinking water

Anja Bretzler*, C. Annette Johnson

Department of Water Resources and Drinking Water, Eawag: Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, 8600 Dübendorf, Switzerland

ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form
27 August 2015
Accepted 28 August 2015
Available online xxx

Keywords:
Arsenic
Fluoride
Groundwater
Geogenic contamination
Mitigation
Guidelines

ABSTRACT

In some groundwaters, arsenic and fluoride can reach concentrations that are hazardous to human health if geological and geochemical conditions favour the release of these contaminants. This can especially pose a problem in developing countries where water service providers already struggle with the provision of clean water. The Geogenic Contamination Handbook, released in January 2015, aims to provide concise guidelines for practitioners faced with the problem of geogenically contaminated drinking water in low- and middle-income countries. The handbook is a digital resource, with the reader benefitting from numerous weblinks and embedded documents giving additional information where relevant. The necessary steps needed for sustainable mitigation of arsenic or fluoride-contaminated drinking water are outlined. This includes information on water quality testing (e.g. how to plan a field survey), different water treatment options as well as practical guidelines on the integration of technical, institutional and sociological aspects of arsenic and fluoride mitigation.

1. Introduction

Groundwater is the major source of drinking water for over half of the global population (Margat and Van der Gun, 2013) and is generally considered to have better water quality than surface water, often being consumed untreated. Even though groundwater generally does not contain high levels of microbial contamination, its quality may be compromised by naturally occurring (geogenic) contaminants such as arsenic and fluoride. Even though microbial contamination is usually prioritised due to its immense burden of disease and associated childhood mortality (Pruess-Ustuen et al., 2014), geogenic contamination is also responsible for causing significant health impacts. In Bangladesh, for example, an estimated 45 million people are drinking water with arsenic concentrations above 10 μg/L and an estimated 24,000 adult deaths are attributed to arsenic exposure each year (Flanagan et al., 2012). Prolonged ingestion of drinking water containing arsenic above the WHO guideline value of 10 μg/L can cause a range of maladies, including skin disorders, respiratory problems and cancer (Smith and Steinmaus, 2009). Excess fluoride concentrations (>1.5 mg/L) can cause dental fluorosis (tooth discolouration, enamel pitting, early tooth loss) and skeletal fluorosis (joint stiffening and deformation) as well as a range of non-skeletal effects (Ozsvath, 2009). In high- and middle-income countries, these contaminants are removed in municipal treatment plants to match national drinking water guidelines before water is distributed to consumers. Low-income countries that are already struggling with clean water provision often lack the know-how, infrastructure and financial means to handle the additional problem of geogenic contamination.

Rural communities with non-centralised water supplies (e.g. communal village pumps) are especially vulnerable to being exposed to geogenic contamination over long periods, often because the water has not been tested for chemical contamination, or there is a lack in capacity and means to deal with the problem on both local and national governmental levels. Since 1998, researchers at Eawag, the Swiss Federal Institute of Aquatic Science and Technology, have worked on various projects concerning geogenic contamination of drinking water in low-income communities in Africa and Asia, looking at technical, institutional and sociological aspects of the problem. Collaborations with local universities, non-government organisations (NGOs) and community groups helped to highlight issues that are overlooked in many research projects, such as consumer preferences for certain technological solutions and cultural taboos or inhibitions. The resulting insights

* Corresponding author.
E-mail address: anja.bretzler@eawag.ch (A. Bretzler).

http://dx.doi.org/10.1016/j.apgeochem.2015.08.016
0883-2927/

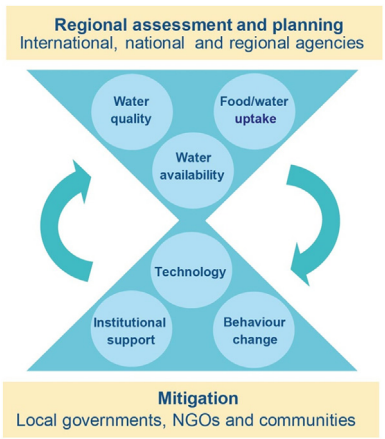

Fig. 1. The mitigation framework presented and discussed in the Geogenic Contamination Handbook highlights the main elements that need to be taken into account when planning strategies to mitigate geogenic contamination.

and outcomes of this work have been compiled in a practical guide (freely available for download at www.wrq.eawag.ch), aimed at practitioners in developing countries faced with problems around arsenic and fluoride contamination. The "Geogenic Contamination Handbook" serves as a step-by-step guidance manual, highlighting the main points needing consideration when aiming for successful mitigation of geogenically contaminated drinking water. In the following sections we are presenting the main points discussed in the handbook, from identifying contaminated regions to water treatment solutions and financing options. Even though the focus of the handbook is on arsenic and fluoride, many points are also relevant when handling other chemical or microbiological contamination.

2. A framework for the successful mitigation of geogenic contamination in drinking water

Projects in the water sector may fail or only be partially successful due to the disregard or neglect of a diverse number of issues, ranging from weak financing, unsuitable technologies, unreliable operation and maintenance, to failing to involve community stakeholders and disrespect for local culture and beliefs. In the "Geogenic Contamination Handbook" we have presented a framework composed of six elements that, from our experiences, should be taken into account when planning and carrying out projects related to the mitigation of arsenic and fluoride contamination, in order to have a greater chance of project success and sustainability (Fig. 1). Mitigation strategies and measures addressed either from a regional or national perspective (presented in the top triangle of the framework) need careful assessment and planning to identify i.) priority regions affected by geogenic contamination ("Water Quality"), ii.) the presence of alternative water resources ("Water Availability") and iii.) whether contaminants may also be ingested via other pathways, for example food ("Food/water uptake"). The three points presented in the bottom triangle of Fig. 1 are more concerned with the implementation of mitigation options (e.g. water treatment filters). Such options need to be assessed not only technically – i.e., in terms of cost, efficiency, simplicity, electricity requirements, availability of materials and know-how, but also in terms of institutional support and user acceptance.

2.1. Identifying contamination

Both arsenic and fluoride are still often not included in routine water quality surveys, whether due to costs and time issues or lack of suitable equipment for analysis. Initial indications that there is a contamination problem in local groundwater may be given by health-related symptoms in the local population, for example skin lesions and unusual pigmentation pointing to arsenic poisoning, or brown marks on teeth (dental fluorosis). As such symptoms may also occur due to other ailments, it is essential that investigations are carried out with medical staff trained in recognising arsenicosis and/or fluorosis.

Further identification of priority areas may be possible by the collection of existing maps and data. Often water quality studies are carried out by different bodies, be it universities and research institutes, consultants or governments. The resulting data may not be

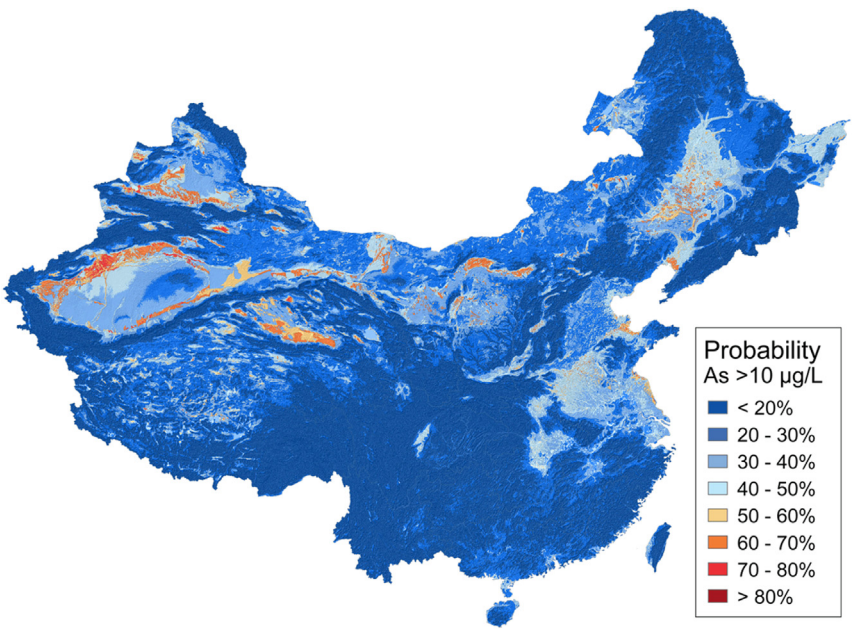

Fig. 2. Map of China showing the modelled probability of groundwater arsenic exceeding the WHO guideline of 10 µg/L (Rodríguez-Lado et al., 2013).

Please cite this article in press as: Bretzler, A., Johnson, C.A., The Geogenic Contamination Handbook: Addressing arsenic and fluoride in drinking water, Applied Geochemistry (2015), http://dx.doi.org/10.1016/j.apgeochem.2015.08.016