Hydrogeol J (2016) 24:273–276
DOI 10.1007/s10040-015-1355-x

ESSAY

Overview of groundwater for emergency use and human security

Jaroslav Vrba[1] **· Fabrice G. Renaud**[2]

Received: 10 November 2015 / Accepted: 9 December 2015 / Published online: 13 January 2016

Keywords Emergency groundwater resources · Disaster

Introduction

Water resources and their management are critical to human security and are essential for achieving sustainable development (UN-Water 2013). According to UNDP (1994), human security is a people-centered concept and implies safety from both chronic and sudden threats or disruptions. Human security is composed of seven pillars: economic, food, health, environmental, personal, political, and community security (UNDP 1994), but other dimensions have since been suggested such as livelihood or energy security (O'Brian and Leichenko 2007), and further developments of the human security concept have been proposed (e.g., Barnett et al. 2010; O'Brian and Leichenko 2007; these two papers also include references to groundwater resources, although these are not a central discussion point). Most of the preceding dimensions depend on having access to sufficient freshwater of adequate quality. In many arid and semi-arid regions, groundwater resources represent the main source or an essential supplement to other sources of available freshwater and thus play an important role for everyday livelihoods and human security (e.g., Burke and Moench 2000; UNESCO 1999; UNESCO-WWAP 2003). Groundwater can play an equally important role in environmental disaster-related emergencies (Vrba and Verhagen 2011).

This article belongs to a group of articles that consider groundwater resources for risk reduction in emergencies

✉ Jaroslav Vrba
javr@mymail.cz

Fabrice G. Renaud
renaud@ehs.unu.edu

1 Korandova str.32, 14700 Prague 4, Czech Republic

2 United Nations University Institute for Environment and Human Security, UN Campus, Platz der Vereinten Nationen 1, Bonn 53113, Germany

However, groundwater resources are not always managed optimally and are often overused or becoming increasingly polluted (e.g., Van der Gun 2012; UNESCO-WWAP 2012; Musolff 2009; Konikow and Kendy 2005). This poses a threat to the health and livelihoods of many people on a daily basis but is also a problem in the context of environmental and anthropogenic disasters when the supply of freshwater is essential during an emergency phase. Briefly discussed in the following is the role of groundwater for human security and in the context of emergency situations, and an introduction to three companion articles which are published in this volume of *Hydrogeology Journal*.

Groundwater for human security and emergency situations

Environmental hazards become disasters when they impact vulnerable people and infrastructure. The probability of their occurrence and temporal and spatial distribution is related to (1) meteorological conditions and geographical locations such as for floods along rivers and droughts in arid lands, (2) geological setting of the regions in unstable zones along the contact of tectonic plates (volcanism, earthquakes) and tsunamis, along coastlines, or (3) to the joint effect of geological and meteorological conditions (landslides). With improvements in early warning systems (among other factors), the number of reported disasters have declined globally since the beginning of this century (compared to previous decades which had seen rapid increases in reported disasters) and the number of casualties, although highly variable from year to year, is much lower than those recorded in the first half of the 1900s (EM-DAT 2015). However, disasters continue to affect very large number of people and generate increasing economic losses. About 90 % of all natural hazards are water-related (UNESCO-WWAP 2003; UNESCO-WWAP 2012). Floods impact most populations and account for 15 % of total global casualties. Droughts affected more than 2 billion people from 1990 until 2010 (UNISDR 2011). Drylands cover 41.3 % of the global terrestrial areas and 34.7 % of the global population living in drylands is facing drinking-water scarcity, which has direct implications for livelihoods and human security on a daily basis (ICRISAT 2008). Finally, hazard events increasingly impact infrastructures, including water supply facilities, polluting drinking-water supplies and damaging drinking water distribution systems.

Securing water supplies during and in the immediate aftermath of disasters is critical and there is a potential to use groundwater resources in both rapid onset and prolonged hazard events. However, groundwater depletion is projected to become an important challenge in the future (UNISDR 2015).

In emergencies, substitution of affected drinking-water facilities for the time necessary for renewal of their operation could be found in less vulnerable groundwater resources in deeper, often confined aquifers with groundwater characterized by long residence time or in non-renewable (fossil) groundwater resources. Both exhibit low vulnerability to hazards events and can serve as a safe source of freshwater in the aftermath of a disaster. It is therefore important to identify, investigate and protect these groundwater resources.

Methods of hydrogeological investigation of such resources require thinking beyond conventional appraisal. Investigation of deep-seated aquifers can include remote sensing applications, geophysical measurements, isotope–hydrology techniques, and groundwater monitoring. These data can be analyzed to construct groundwater vulnerability and other maps (e.g., inundation, recharge, risk maps) and develop disaster stress and vulnerability indicators. For example, groundwater stress indicators can be based on the number of affected people in disaster-prone areas and the available groundwater resources resistant to environmental disasters. These methods have been applied e.g. in arid lands in the Republic of South Africa (Verhagen 2006, 2011), floodplain areas in the Czech Republic (Šilar 2011), and a storm-prone coastal areas in India (Sukhija and Rao 2011).

On the policy front, despite its importance, groundwater is not explicitly mentioned in two important agreements that were reached in 2015, namely the Sustainable Development Goals (SDG; UN 2015a), and the Sendai Framework for Disaster Risk Reduction (SFDRR; UN 2015b). In the SFDRR, water as a resource is only noted under Priority 4 entitled "Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction", which emphasizes the promotion of the resilience of critical infrastructure which includes water supply systems. However, the SFDRR mentions the importance of updating preparedness policies and plans for all sectors, including the water sector.

Although water has a dedicated goal in the SDG entitled "Ensure availability and sustainable management of water and sanitation for all", groundwater is not referred to in the targets under this goal, despite the fact that groundwater will be instrumental in achieving development goals. Groundwater will also be essential for many of the dimensions of human security addressed in the SDG such as improved health or food production, and climate change adaptation (e.g., UN-Water 2010).

Groundwater emergency projects

Recognizing the critical role of groundwater in emergencies and human security, two projects were implemented in the period 2002–2013.

Groundwater for emergency situations

The UNESCO project "Identification and management of strategic groundwater bodies to be used in emergency situations as a result of extreme events" known as "Groundwater for Emergency Situations" (GWES), was implemented during the sixth (2002–2007) and seventh (2008–2013) phases of UNESCO's International Hydrologic Programme (IHP). This project focused on: (1) identification of potential safe, low-vulnerability groundwater resources that can replace damaged or polluted water supplies during emergencies; (2) evaluation of risks to groundwater resources and water supplies in disaster-prone areas in emergencies, (3) addressing emergency groundwater governance; and (4) incorporation of emergency water plans into country water-master plans and land-use planning policies.

Activities under the GWES project included: (1) development of methodological guidelines for the identification, development and management of emergency groundwater resources; (2) development of a global groundwater vulnerability map; (3) organization of international workshops; and (4) presentation of case studies addressing the role of groundwater in emergency situations (Vrba and Verhagen 2011).

The global groundwater vulnerability map (Vrba and Richts 2015) covers droughts and floods, which are the most frequent hydro-climatic hazards, and is based on weighting and rating systems applied to globally available groundwater vulnerability parameters (e.g., type of aquifers and mean annual groundwater recharge). The map highlights areas of highest groundwater vulnerability worldwide as well as areas with groundwater resources of low vulnerability which are resistant to flood and drought impacts.

Ten case studies developed in the GWES Methodological Guide address types of disasters and their potential impact on drinking-water supplies. The studies demonstrate the ability of governmental authorities to cope with disaster impact. In India, the destruction of water supplies, mostly shallow wells, by Orissa super cyclone (in 1999) led to rapidly implemented relief measures: damaged water-supply services were restored within 4 months by drilling deep wells supplying 100 L/person/day of drinking water to one million people (Sukhija and Rao 2011).

By way of example, this volume of *Hydrogeology Journal* contains an article that examines emergency water management arising from major earthquakes in Japan (Tanaka 2015). Water supply for hospitals was secured by drilling hundreds of deep wells located in hospital areas equipped with treatment and filtration plants that allow producing water of high quality. In addition, domestic shallow wells were equipped with hand or diesel/petrol-driven pumps, and citizen-owned and company-owned wells were registered and handled as a cooperative. Groundwater quality and quantity are regularly monitored. Stored rainwater on the roof of households provides additional water in an earthquake emergency. Such simple, financially low-demanding techniques can be applicable in developing countries.

This volume of *Hydrogeology Journal* also includes a paper (Vrba 2015) that addresses the role of emergency groundwater governance in specific phases of disaster and activities and actions applied in particular disaster sequences associated with identification, development and management of emergency groundwater resources. The role of institutional and technical capacities to build (1) effective groundwater governance policy, (2) drinking-water risk and demand management in emergencies, (3) disaster-risk-mitigation plans, and (4) relief measures and post-disaster rehabilitation of drinking-water facilities for gradual renewal of regular drinking-water services, is discussed in detail.

Groundwater for human security

The Groundwater for Human Security - Case Studies project (GWAHS-CS), was coordinated by the United Nations University in partnership with UNESCO-IHP and the UN Water Decade Programme on Capacity Development from 2008 to 2010. The project addressed the threats to human security and well-being posed by groundwater scarcity and groundwater quality degradation in developing countries and the role of groundwater management and protection in alleviating such threats (Renaud et al. 2010). Human security in this project closely followed the dimensions of the Human Development Report (UNDP 1994). The project adapted existing approaches to determine the vulnerability of communities that face freshwater supply problems, with an emphasis on groundwater. GWAHS-CS also recognized that groundwater is critical to livelihoods of communities in water-scarce areas or in areas where other freshwater systems are polluted and that groundwater can become a threat to health and livelihoods when it is polluted (through natural and anthropogenic factors). Social and ecological indicators characterizing the hazards (in this context groundwater quantity and quality) and the vulnerability of social-ecological systems with respect to groundwater were developed (vulnerability indicators encompassed exposure, sensitivity and resilience dimensions). To characterize the vulnerability of selected communities facing groundwater degradation processes or the opposite, four case-study areas were selected for research: one in Egypt (Wadi El Natroun), one in Iran (Gareh Bygone Plain, in the same location as the one reported by Mesbah et al. (2015) in this issue of *Hydrogeology Journal*), and two in Vietnam (Tra Vinh Province in the Mekong Delta and Binh Thuan Province; Dun et al. 2010). Results were used to investigate the impacts of groundwater degradation on local communities (e.g. King and Salem 2012) and showed the critical role of groundwater in sustaining livelihoods.

Mesbah et al. (2015) provide a good case study of how human security can be improved through well-designed artificial recharge of groundwater. The study, in the Gareh Bygone Plain in Iran, shows that floodwater spreading and artificial recharge in dry environments do not only allow sustaining groundwater levels and quality for the long run (when combined with sustainable withdrawal), but also allow for irrigated area expansion, increased forage production, and reduced flood impacts, all contributing to improving livelihoods of local communities. One major outcome has been the reversal of migration trends with people returning to rural areas they had previously left partly because of the insecurity of water supplies.

Conclusions

Raising awareness of governmental authorities on the need to support the development and the management of emergency groundwater resources resistant to the impact of disasters is an urgent task, particularly in areas affected by recurrent floods, droughts, earthquakes and other disaster events.

Implementation of disaster risk preparedness and warning provisions based on the principle "prevention is better than cure", together with building effective emergency groundwater governance, are important measures of disaster-risk-reduction policies. Enhancement of knowledge of hydrogeological conditions in disaster-prone regions, establishment and operation of groundwater monitoring networks and early warning systems, construction of groundwater vulnerability and disaster risk maps and analysis of historical data of past extreme events are the key activities. Strengthening of such groundwater governance policy (1) makes populations living in disaster-prone areas less vulnerable and more resilient against drinking-water scarcity in emergencies, (2) reduces human exposure and raises adaptation capacity to future disasters, and (3) creates better conditions for rehabilitation of affected water infrastructure and renewal of drinking-water services in emergencies.

Special attention should be given to low-income developing countries, which need international cooperation and support in (1) development of emergency groundwater governance structures to combat extreme events, (2) education and training of experts in emergency drinking-water services and (3) financial backing for identification, investigation and development of deep, low-vulnerability groundwater resources which can be used in emergencies.

Ethical considerations and equity and solidarity between all participants of groundwater governance in emergencies should have emphasis in both developed and developing countries. The role of groundwater in water security need to be given further attention in both academic and policy fora.

Acknowledgments Great appreciation to Dr. Alice Aureli, Chief of the Groundwater Systems and Settlements Section, UNESCO – Division of Water Sciences, for the professional assistance and support of the UNESCO -IHP project Groundwater for Emergency Situations.

References

Barnett J, Matthew RA, O'Brian KL (2010) Global environmental change and human security: an introduction. In: Matthew RA, Barnett J, McDonal B, O'Brian KL (eds) Global environmental change and human security. The MIT Press, Cambridge, MA, pp 3–32

Burke JJ, Moench MH (2000) Groundwater and society resources, tensions and opportunities. United Nations Publication ST/ESA/205, UN, New York

Dun O, Martin-Bordes JL, Thomas R, Renaud F (2010) Groundwater and human security: case studies. Report of the 4th Workshop. http://www.unwater.unu.edu/file/get/325. Accessed November 2015

EM-DAT (2015) Natural disaster trends. The International Disaster Database, Centre for Research on the Epidemiology of Disasters, http://www.emdat.be/natural-disasters-trends. Accessed November 2015

ICRISAT (2008) Climate change and desertification put one billion poor people at risk. Hyderabad, India. International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). http://www.icrisat.org/newsroom/news-releases/icrisat-pr-2007-media14.htm. Accessed November 2015

King C, Salem BB (2012) A socio-ecological investigation of options to manage groundwater degradation in the Western Desert, Egypt. Ambio 41:490–503

Konikow L, Kendy L (2005) Groundwater depletion: a global problem. Hydrogeol J 13:317–320

Mesbah SH, Mohammadnia M, Kowsar SA (2015) Long-term improvement of agricultural vegetation by floodwater spreading in the Gareh Bygone Plain, Iran. In the pursuit of human security, is artificial recharge of groundwater more lucrative than selling oil? Hydrogeol J 10.1007/s10040-015-1354-y

Musolff A (2009) Micropollutants: challenges in hydrogeology. Hydrogeol J 17(4):763–806

O'Brian K, Leichenko R (2007) Human Security, vulnerability and sustainable adaptation. Human Development Report 2007/2008, Human Development Report Office occasional paper, UN Development Programme, New York

Renaud FG, Martin-Bordes JL, Schuster B (2010) Quo Vadis Aquifer? A joint programme addressing the links between groundwater and human security. In: Managing shared aquifer resources in Africa. Proceedings. IHP-VII, Series on Groundwater no. 1. UNESCO, Paris, pp 281–286

Silar J (2011) Groundwater for emergency situations: Labe (ELBE) River flood in the Czech Republic, August 2002. In: Groundwater for emergency situations: a methodological guide. IHP-VIII, Series on Groundwater no. 3, UNESCO, Paris, pp 249–257

Sukhija B, Rao N (2011) Impact of the October 1999 super cyclone on the groundwater system and identification of groundwater resources for providing safe drinking water in coastal Orissa, India. In: Vrba J, Verhagen B (eds) (2011) Groundwater for emergency situations: a methodological guide. IHP-VIII, Series on Groundwater no. 3, UNESCO, Paris

Tanaka T (2015) Measures for groundwater security during and after the Hanshin-Awaji Earthquake (1995) and the Great East Japan Earthquake (2011), Japan. Hydrogeol J 10.1007/s10040-015-1352-0

UN (2015a) Sustainable development goals. UN, New York. https://sustainabledevelopment.un.org/topics. Accessed November 2015

UN (2015b) Sendai Framework for Disaster Risk Reduction 2015–2030. UN, New York. http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf. Accessed November 2015

UNDP (1994) Human development report: new dimensions of human security. UN Development Programme, New York

UNESCO (1999) Integrated drought management: lessons for sub-Saharian Africa. UNESCO-IHP publication, UNESCO, Paris

UNESCO - WWAP (2003) Water for people – water for life. The United Nations World Water Development report 1 (WWDR1). Part of the UN World Water Assessment Programme (WWAP), UNESCO, Paris and Berghahn, New York

UNESCO - WWAP (2012) Managing water under uncertainty and risk, vol 1. The United Nations World Water Development report 4 (WWDR4). Part of the UN World Water Assessment Programme (WWAP), UNESCO, Paris

UNISDR (2011) Global assessment report on disaster risk reduction. UNISIDR, Geneva

UNISDR (2015) Making development sustainable: the future of disaster risk management. Global assessment report on disaster risk reduction. United Nations Office for Disaster Risk Reduction, Geneva

UN-Water (2010) Climate change adaptation: the pivotal role of water—a UN-Water policy brief. Available at http://www.unwater.org/downloads/unw_ccpol_web.pdf. Accessed November 2015

UN-Water (2013) Water security and the global water agenda: a UN-Water analytical brief. Available at http://www.unwater.org/downloads/watersecurity_analyticalbrief.pdf. Accessed November 2015

Van der Gun J (2012) Groundwater and global change: trends, opportunity and challenges. UNESCO-WWAP, SIDE publications series 01, UNESCO, Paris

Verhagen B TH (2006) Isotope hydrology assist in identifying a safe groundwater resource in South Africa. In: Groundwater for emergency situations: a framework document. IHP-VI, Series on Groundwater no. 12, UNESCO, Paris, pp 65–68

Verhagen B TH (2011) Identifying a potential emergency groundwater supply in a fractured rock quartzitic aquifer with environmental isotopes. In: Groundwater for emergency situations: a methodological guide. IHP-VIII, Series on Groundwater no. 3, UNESCO, Paris, pp 233–241

Vrba J (2015) The role of groundwater governance in emergencies during different phases of natural disasters. Hydrogeol J 10.1007/s10040-015-1353-z

Vrba J, Richts A (eds) (2015) The global map of groundwater vulnerability to floods and droughts. Explanatory notes, UNESCO IHP, Paris and German Federal Institute for Geosciences and Natural Resources (BGR), Hanover, Germany

Vrba J, Verhagen B (eds) (2011) Groundwater for emergency situations: a methodological guide. IHP-VIII, Series on Groundwater no. 3, UNESCO, Paris