Water Policy 23 (2021) 205–221

Public health without water? Emergency water supply and minimum supply standards of hospitals in high-income countries using the example of Germany and Austria

L. Bross IWA [a], J. Bäumer[b], I. Voggenreiter[c], I. Wienand[c] and A. Fekete[d]

[a]*Corresponding author. Institute of Hydro Science, Chair of Sanitary Engineering and Waste Management, Bundeswehr University Munich, Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany. E-mail: lisa.bross@unibw.de*
[b]*Federal Office of Civil Protection and Disaster Assistance, Provinzialstrasse 93, 53127 Bonn, Germany*
[c]*Technical University of Munich, Arcisstrasse 21, 80333 Munich, Germany*
[d]*Institute of Rescue Engineering and Civil Protection, TH Köln–University of Applied Sciences, Betzdorfer Straße 2, 50679 Köln, Germany*

Abstract

The drinking water supply is a core element of national regulations for normal and emergency supply as well as coping with crisis events. Particularly with regard to the interdependence of critical infrastructures means that water supply failures can have far-reaching consequences and endanger the safety of a society, e.g., by impairing hospital operations. In case of an emergency in the drinking water infrastructure, minimum supply standards, e.g., for patients in hospitals, become important for emergency management during crisis situations. However, wider recognition of this issue is still lacking, particularly in countries facing comparably minor water supply disruptions. Several international agencies provide guideline values for minimum water supply standards for hospitals in case of a disaster. Acknowledging these minimum standards were developed for humanitarian assistance or civil protection, it remains to be analyzed whether these standards apply to disaster management in countries with high water and healthcare supply standards. Based on a literature review of scientific publications and humanitarian guidelines, as well as policies from selected countries, current processes, contents, and shortcomings of emergency water supply planning are assessed. To close the identified gaps, this paper indicates potential improvements for emergency water supply planning in general as well as for supply of hospitals and identifies future fields of research.

Keywords: Disaster; Drinking water; Health care; Preparedness; Supply standards; Water supply

doi: 10.2166/wp.2021.012

Highlights

- Review of available and lacking minimum water supply standards of hospitals.
- Identification of future research needs in the field of emergency water supply of hospitals and health care facilities

Introduction

In March 2015, the UN World Conference on Disaster Risk Reduction (DRR) in Sendai highlighted the importance and relevance of critical infrastructure resilience (UNDRR, 2015). Critical infrastructures (CI) such as water supply and hospitals are, by definition, essential for society (BMI, 2009; DHS, 2015). Correspondingly, if CI suffer damage, destruction or disruption, this may have a significant negative impact on public health and the security of citizens (UNISDR, 2009; OECD, 2019; UNDRR, 2017). One of the seven core global targets defined in the Sendai Framework for Disaster Risk Reduction 2015–2030 is to

'*substantially reduce disaster damage to critical infrastructure and disruption of basic services'*

as well as

'*to promote the resilience of new and existing critical infrastructure, including water, transportation and telecommunications infrastructure, educational facilities, hospitals and other health facilities, to ensure that they remain safe, effective and operational during and after disasters in order to provide life-saving and essential services*'. (UNDRR, 2015)

This target is, worldwide, of particular relevance as the 21st century is characterized by major natural hazards (e.g., extreme weather events due to climate change) (Priscoli & Hiroki, 2015; Liu *et al*., 2016) and new security policy hazards (e.g., asymmetric conflicts, international terrorism, fundamentalism of various forms, and associated military conflicts) (Pescaroli & Alexander, 2016). Both types of hazards can potentially harm CI (BMI, 2009; Urlainis *et al*., 2014; Liu *et al*., 2016; Pescaroli & Alexander, 2016).

In this paper, the country examples of Germany and Austria have been selected to illustrate and clarify the aspects of unsuitable planning principles and shortcomings of emergency water supply planning. The water supply standard is considered very high in these two countries. This is proved by high consumer confidence in the reliability of the infrastructure, a high degree of connection to the central pipeline networks, and low downtimes (Lorenz, 2010). In Germany, drinking water supply is provided by approximately 6,000 water supply companies with a total pipeline length of 530,000 km, supplying nearly 81 million inhabitants every day (DVGW, 2015). Thus, 99% of the 82 million inhabitants of Germany are connected to the public drinking water supply network (DVGW, 2015). Every inhabitant in Germany consumes, on average, 121 liters per day (EurEau, 2017). Roughly 90% of Austria's eight million inhabitants are connected to the public drinking water supply. Less than 10% of the population supplies themselves via their own water supply system because the connection to the public water supply system is uneconomical and associated with hygienic challenges due to the decentralized settlement structure. Every day, around 5,500 water supply companies provide consumers drinking water through a pipeline grid of 78,000 km in length (BMNT, 2018). On average, every inhabitant of Austria consumes 130 liters per day (EurEau, 2017).

Water supply systems are confronted with an increasing number of technological risks as well as environmental factors in connection with a decentralized energy supply and increasing networking of IT systems (BSI, 2017). These burdens can lead to contamination or non-availability of drinking water. An impairment of a water supply system can have far-reaching consequences, particularly with regard to cascading impacts with adverse effects on other CI beyond the local level, which are often difficult to assess (Sitzenfrei *et al*., 2011). The effects on the water itself can be divided into an influence on the drinking water quality or the drinking water quantity (Bross & Krause, 2017). This applies to every country.

However, the characteristics of the existing supply system, such as the structure of water supply systems (e.g., redundancy, resilience of water supply system), local conditions, and dependency of other CI (e.g., hospitals) influences the diverse effects of outages and their countermeasures (Bross *et al*., 2019a). This paper focuses on emergencies caused by sudden, acute, and generally unexpected damage events that can lead to considerable impairments or even failure of the drinking water supply, taking into account that a regular supply can only be achieved with an appropriate response or reaction from the responsible institution. Nevertheless, the emergencies under consideration in this paper do not cause a displacement of the population or an irreversible loss of regular water supply. Therefore, emergencies are classified as temporary disturbances in the provision of safe drinking water. Consequently, this paper defines emergency water supply (EWS) as the provision of water to meet basic needs for a limited period when normal operations are disrupted and the water supply is insufficient.

International cases and the importance of the topic

One example of the potential vulnerability of hospitals in a high-income country to water supply disruptions was the water supply emergency in Heidelberg, Germany. On the morning of 7 February 2019, several citizens had reported a blue coloring of the water to the public health authority. Due to the unknown source and its effect on the water quality, it was suggested to the residents not to use the tap water for drinking, showering, and washing their hands anymore (Badische Zeitung, 2019). Only toilet flushing was allowed to continue (Focus online, 2019). As a result, the University Hospital of Heidelberg no longer had access to drinking water (RNZ, 2019). The failure of the water supply lasted about 6 hours. For the hospital, it was logistically a great effort to deal with this situation, because such an unusual water-related experience had never occurred before. In the clinic, the entire water supply was shut off after the colored water was reported. Thus, disposal of feces was not possible at this time. As well, there was no drinking water available for vital dialysis, cleaning work, sterilization processes, or for the kitchen. Since it was unknown how long the water failure would last, an emergency water supply structure with supply from other water utilities via tank trucks was initiated.

A community must be able to protect the lives and well-being of the emergency-affected population (WHO, 2015). This is particularly important in the minutes and hours immediately following the impact of exposure to the emergency. In these situations, the ability of public health services to function without limitation or interruption is a matter of life or death. However, the continued functioning of health services relies on various key factors: first, the need for housing structures of hospitals which can resist exposures and forces from all kinds of hazards (Adams *et al.*, 2015); second, medical equipment which is in good working order and protected from damage (WHO, 2015); third, health personnel can provide medical assistance in safe and secure settings (Adams *et al.*, 2015). Here, the COVID-19 pandemic shows that the protection of the mental health of medical staff (Chen *et al.*, 2020) and problematic care in psychiatric hospitals and gerontopsychiatric institutions (Yao *et al.*, 2020) are of particular importance; as well as, not lastly, the availability of critical infrastructures (such as water supply) to support the health services (CDCP & AWWA, 2012). According to Giovinazzi *et al.* (2016), the drinking water supply is the second most critical infrastructure element for the functioning of hospitals after electricity supply.

In emergencies, the provision of drinking water to CI represents a significant challenge for any water utility and authority. This applies even to high-income countries with high supply security. For instance, Welter *et al.* (2013) found the McAlester Regional Health Center to suffer from a loss of water supply for 2.5 days in the aftermath of an ice storm in Oklahoma, USA, in December 2000. In addition, Perrin (2006) illustrates the impact of the 2005 Hurricane Katrina on the Children's Hospital of New Orleans, which suffered from a lack of water supply that affected the hospital's air conditioning system. The University Hospital Neonatal Intensive Care Unit (NICU) in New Orleans, Louisiana, experienced a shortage of water, as running water and sewerage facilities were not available due to the flooding in the aftermath of Hurricane Katrina (Barkemeyer, 2006). The flood disaster in North Dakota and Minnesota, USA, in April 1997 triggered a loss of water supply which affected the Grand Forks' healthcare systems (Siders & Jacobson, 1998). Multiple hospitals were affected by a loss of water supply caused by the flooding in Des Moines, Iowa, USA, in 1993 (Peters, 1996).

Efficient hospital emergency management is considered as an essential way for hospitals to supply continuous health services during emergencies, even if the hospitals are directly affected (Barbera *et al.*, 2009; Sauer *et al.*, 2009). Welter *et al.* (2011) underline 'the volume of water required for hospital operations, even in curtailed mode, is more than what the hospitals could feasibly address through an on-site stockpiling approach.' Consequently, emergency water supply planning of the local municipality and water utility should consider the water demand of hospitals and other public health infrastructures. Due to the high needs placed on the water supply of hospitals concerning the high quality standards required and the large quantities of water, comprehensive emergency planning is needed. Emergency planning refers to the sum of all measures which are implemented at the time after an emergency has occurred but which are arranged beforehand (Bross *et al.*, 2019b). Accordingly, this must include both preventive and preparatory measures that are considered to avoid or reduce impairments and to cope with damage events, involving various CI operators as well as authorities and organizations with safety and security tasks. Thus, this paper is addressed to water suppliers, the hospital operators, health authorities and state health authorities as well as aid organizations, which are involved in ensuring the security of drinking water supply for such sensitive facilities and are directly participating in the development and elaboration of emergency preparedness planning. These include, in particular, the management, hygienists and safety officers of more extensive healthcare facilities, disaster control authorities, municipalities as well as the water supply companies themselves, which ensure the supply of drinking water during normal operation.

Bross *et al.* (2019a) have shown that the definition of the minimum supply standards of the population, especially in countries with a high level of security of supply, depends, in particular, on the existing characteristics of the infrastructure systems. An exemplary influencing factor is the system-dependent minimum amount of water which is needed to operate the grid system and to avoid hygienic problems. This factor can also be applied to hospitals. However, knowledge for the definition of minimum care standards of hospitals under consideration of their influencing factors is missing.

This paper provides recommendations for improved emergency water supply planning for hospitals and identifies gaps in the current practice by drawing on a literature review and analysis, as well as interviews as case study examples. The paper focuses on the supply standards of hospitals in high-income countries (e.g., Austria and Germany) and their water demand under normal conditions. The literature review of scientific publications and policies as well as humanitarian guidelines from selected countries shows the processes as well as the current state of emergency water supply planning of hospitals. In order to improve emergency water supply the necessity to go beyond existing policies of hospitals is demonstrated by using the two European Union (EU) member states Germany and Austria as country case studies.

Building on this, it is analyzed to what extent minimum supply standards can deviate from regular supply and how water demand can be derived from this for emergency situations. Research and knowledge gaps are identified as well as recommendations for action being derived from this and discussed in the paper.

Methods

Desktop researches were conducted to assess frameworks, guidelines, especially policy guidelines for emergency water supply as well as for legislation in the European, German and Austrian contexts.

Additionally, experts of four hospitals in southern Germany were interviewed with the aim of obtaining information on the hospitals' water requirements in order to finally compare them with the findings of this study. It was also of particular interest to find out how the surveyed hospitals would deal with a case of failure in the drinking water supply and whether the drinking water supply has already been included in the hospitals' alarm plan. The information from the hospital experts are presented anonymously. The questions were not sent in advance and all three experts were asked the same catalog of questions.

The country examples of Germany and Austria were chosen to compare the emergency management plans for a (partial) failure of water supply affecting hospitals and other healthcare facilities. According to the World Bank, the two neighboring countries are considered high-income countries due to their gross national income per capita (The World Bank, 2018). Germany and Austria have a very similar standard of living and comparable standards of drinking water supply. Additionally, the two countries have similar boundary conditions (climate, geography, population structure, demographic change, etc.) as well as challenges to the security of supply (including natural hazard-induced disasters, terrorism, and crime).

The water supply of hospitals under normal conditions and in emergencies in high-income countries

In general, policy documents and international guidelines propose values for the minimum water standards for the demand of different groups of consumers (e.g., general population, hospitals) to determine the overall quantity of emergency water supply of a community. Each type of consumer has a unique specific water demand. Several sources (e.g., DVGW W 410, 2008; WSDH, 2009; VDI 3807-2, 2016) suggest that the number of consumers within a hospital should be calculated on the basis of the number of maximum available hospital beds. The average of daily water demand does not indicate the variation in time as well as the daily peaks.

Differences in the hospital's equipment and the medical treatment methods offered lead to a variation in the water demand of hospitals in regular care. Table 1 shows the average daily water demand of a hospital bed in various countries and regions according to different sources.

Germany has 1,942 hospitals with a total of 497,182 beds (data for 2017) with more than 19.4 million treatment cases each year, treated by more than 1.2 million employees including 186,021 doctors (Destatis, 2018). Thus, 6.0 beds are available for every 1,000 inhabitants. On average, a German hospital has 256 beds. According to data from 2017, Austria has 271 hospitals with a total of 64,805 beds (BMGF, 2019). More than 140,500 employees including 22,800 doctors, treat approximately 2.8 million treatment cases each year (Statista, 2019). Consequently, 8.1 beds are available for every 1,000 Austrian inhabitants and an Austrian hospital has 239 beds on average.

Concerning the differentiation of the size of hospitals, it is primarily the number of beds that has to be considered, which in turn, is closely related to the individual care level. Although there is no uniform definition of care levels between the German federal states, the division into basic care (up to 200 beds) and standard care (up to 350 beds), central care (350–1,000 beds), and maximum care (over 1,000 beds) is the most widespread (Busse *et al.*, 2010).

Table 1. Daily water demand of a hospital bed under normal conditions and in emergencies.

	Water demand			
	Normal conditions		Emergencies	
Country/Region	l/(bed · day)	Source	l/(bed · day)	Source
Europe	500–1,000[a]	Ludwig, (2002)		
USA	300–1,514[b]	VDT, (2008); WSDH, (2009)	298	Welter *et al.*, (2013)
Japan			257	Murakawa, (2013)
Spain	534[c]	González *et al.*, (2016)		
Germany	120–830	Karger & Hoffmann, (2013)	75–150	BMI, (2016)
	283	González *et al.*, (2018)		
	370	VDI 3807-2, 2016		
	455[d]	Reller, (2000)		
	679[e]	Dettenkofer *et al.*, (2000)		
Austria	120–830	Neunteufel *et al.*, (2010)	40–60	ÖVGW, (2017)
World			40–60[f]; 100[g]	Sphere Association, (2018)
			220–300	UNHCR, (1992)

[a]Average annual water demand between 183 and 365 m^3 per bed.
[b]Average annual water demand between 110 and 553 m^3 per bed.
[c]Average annual water demand of 195 m^3 per bed.
[d]Average annual water demand of 166 m^3 per bed.
[e]Average annual water demand of 248 m^3 per bed.
[f]Inpatients.
[g]Per surgical intervention and delivery.

In addition to the number of beds, the type and quantity of specialist departments, the provision of specialized services, and technical equipment as well as the obligation to participate in emergency care (Heinrich, 2011) serve as differentiation criteria. Basic and standard hospitals, in general, have the task of ensuring universal care and in any case have the departments of surgery and internal medicine. Priority hospitals are usually responsible for supraregional care and are mostly located in medium-sized and larger cities. In their up to ten specialist departments, doctors and nursing staff are also frequently trained. Hospitals with maximum care include usually all hospital disciplines as well as a large number of specializations (Nagel & Braasch, 2007).

Table 2 shows the results of a study by the Association of German Engineers with a focus on specific values of water consumption of public health infrastructures. In this study, the reference value and the average value of hospitals regarded in the study are shown. The division into basic, standard, central, and maximum care hospitals conforms with Busse *et al.* (2010); however, the number of beds in each category varies. Although the hospital size indicates the extent of specialized services provided, there is no clear tendency of increasing patient-specific water demand apparent in the numbers shown in Table 2.

The areas of a hospital that are directly or indirectly dependent on drinking water are numerous (Exner *et al.*, 2007; CDCP & AWWA, 2012; Hsu *et al.*, 2017). According to CDCP and AWWA (2012) the critical medical-related water demands include:

- Diagnostic equipment (e.g., MRI cooling water)
- Dialysis
- Sterilization and equipment washing
- Water seal for medical gas pumping (air, oxygen, nitrous oxide, vacuum)

Additionally, the areas which are critical in the medical and technical sense, and therefore remain in service during a protracted water supply loss need to be considered. According to CDCP & AWWA (2012), these are, in particular:

- All laboratories
- Compo B (complicated labor and delivery)
- Critical Care/Intensive Care Unit (ICU)
- Critical Care Step Down Unit (SDU)
- Dental/oral maxifacial

Table 2. Specific values of water consumption of German public health infrastructures according to VDI 3807-2 (2016).

Type of hospital	Reference value l/(bed · d)	Mean value l/(bed · d)
Basic care, 0–250 beds	206	290
Standard care, 251–450 beds	266	361
Central care, 451–650 beds	325	430
Maximum care, 651–1,000 beds	224	370
Hospital with more than 1,000 beds	393	714

- Dining room
- Emergency room
- Gastroenterology clinic
- Nephrology/dialysis
- Neonatal Intensive Care Unit (NICU)
- Operating rooms
- Patient administrative computer services (PACS) computers
- Post Anesthesia Care Unit (PACU)
- Sterilization

For all of the above-mentioned sub-processes and areas, it is known that they cannot function without water. The exact water demand of the sub-processes or areas, or at least a gradation of the required water quantity, is currently unknown.

Frameworks and standards for emergency water supply

Universally used frameworks and standards for emergency water supply

Legal frameworks and guidelines have been developed at national and regional scales to ensure a secure water supply. However, only very few universally applicable standards were developed concerning emergency water supply in disaster situations. The small number of ISO standards, which directly address emergency water supply in general (Bross *et al.*, 2019a), indicate the lack of guidance for hospitals, health utilities, and authorities, who would typically use such standards to plan for and ensure a functioning hospital with minimum water supply in emergencies.

In the absence of internationally applied emergency water supply standards, the Sphere Project provides a manual covering minimum standards for the water supply of hospitals and other aspects of humanitarian response (The Sphere Project, 2011; Sphere Association, 2018). The manual includes a set of common principles and universal minimum standards for humanitarian response activities, which have been developed by a wide range of humanitarian actors. The manual is comparably unique as it provides hard numbers for minimum supply water needs that have to be met for basic survival in addition to qualitative descriptions.

According to the Sphere Project, minimum standards are 'conditions that must be achieved in any humanitarian response for disaster-affected populations to survive and recover in stable conditions and with dignity' (The Sphere Project, 2011: 5). The guidelines of the United Nations High Commissioner for Refugees (UNHCR, 1992), the World Health Organization (WHO, 2002), and the Sphere Project (The Sphere Project, 2011; Sphere Association, 2018) each addresses the minimum standards as conditions necessary for survival in humanitarian crises, for example, in the establishment of camps for displaced people after disasters.

A handbook providing guidance is the Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities of the Centers for Disease Control and Prevention (CDCP) in collaboration with the American Water Works Association (AWWA) (CDCP & AWWA, 2012). The handbook provides a four-step process for the development of an Emergency Water Supply Plan (EWSP) and gives recommendations on which aspects should be taken into account in emergency planning.

Quantities for minimum water supply needs per patient or hospital bed are covered in a few studies (Reed & Shaw, 1995; Adams, 1999; House & Reed, 2004; Reed, 2011; Welter *et al.*, 2010, 2011, 2013), which are applied compared to the Sphere Handbook. While Adams (1999), House & Reed (2004), Reed & Shaw (1995), and Reed (2011) provide numbers comparable to the Sphere handbooks, Welter *et al.* (2010, 2011, 2013) show numbers significantly higher.

The quantities for the water consumption per hospital bed can function as an appropriate basis for emergency planning. However, they need to be treated with caution as minimum water demands may vary significantly from average consumption between hospitals of different sizes and equipment. When comparing the number for minimum water needs of 40–60 liter per patient per day of the Sphere Handbook with the water consumption patterns under normal conditions around the world (as shown in Table 1), it becomes evident that the standards can only be applied in cases when it is not possible to fall back on existing infrastructure. Otherwise, the existing infrastructure cannot be used for supply, as it either is no longer functional or was never available (Bross *et al.*, 2019a).

Emergency water supply in European frameworks and guidelines

The European Commission has published several directives and guiding documents which are meant to ensure water supply security and quality under normal conditions. One of these directives is the European Drinking Water Directive (98/83/EC), which was developed and published in 1998 to secure the quality of drinking water in countries of the European Union. The directive states minimum requirements for the quality of water for human consumption. From a hygienic-medical point of view, the definition of 'water for human consumption' is of considerable importance, as the path of transmission of pathogens is no longer only recognized as the path of absorption by drinking, but also by inhalation (e.g., Legionella, atypical mycobacteria) or by contact (Exner & Kistemann, 2004).

In the European Drinking Water Directive, hospitals are assigned independent responsibility for the quality of the water in their building installation systems. This has far-reaching consequences for hospitals and other medical facilities (nursing homes, elderly homes), as the so-called 'house installations' in public facilities from which water is provided to the public are explicitly included in the scope of the European Drinking Water Directive. This may also result in liability consequences for the operator.

The directive also requests water providers including hospitals to develop water safety plans based on the WHO Framework for safe drinking water (WHO, 2017). A Water Safety Plan regulates the details of water use, ensuring proper quality, the measures to be taken in the event of reconstruction measures and restricted water use, as well as validation and verification by monitoring physical, technical, and microbiological parameters. These water safety plans include the assessment of hazards and risks that may threaten water supply and quality to consumers and the establishment of individual management plans to minimize those risks. Additionally, there are policy documents and legislation that focus on risk mitigation of water supply in general (e.g., DIN 15975-2, 2013; DIN 15975-1, 2016). Available documents do not, however, refer to minimum standards of hospitals or management procedures for cases of water supply disruptions or failures. This is neither regarding quantity nor quality of water.

The overall focus of the documents on the European level is put on risk management to secure water quality under normal supply conditions without consideration of the emergency supply of hospitals as well as minimum supply needs in emergencies.

Emergency water supply in German and Austrian frameworks and guidelines

In Austria, none of the federal legislation has a clear mandate for the emergency drinking water supply (ÖVGW, 2017). This is neither for emergency water supply of the population nor the supply of hospitals and other public health infrastructures. As services of general interest and a state competence, the emergency drinking water supply is in the power of the mayor and it is located at the intersection of water law and food law (ÖVGW, 2017).

The standard W 74 (ÖVGW, 2017) was updated by the Austrian Association for Gas and Water (ÖVGW) in 2017. It gives detailed information for water suppliers for crisis situations. The basis of the quantitative minimum supply standards for hospitals mentioned in the standard W 74 are the minimum supply standards published in the Sphere Project and in the WHO handbook.

The German Drinking Water Ordinance (TrinkwV, 2019) is the regulative framework for drinking water quality for normal conditions as well as in case of a drinking water emergency in Germany. Additionally, selected water-specific laws of the federal states oblige the water supplier and public authorities to protect the water supply system against emergencies, e.g., caused by an extreme event such as flooding. The Drinking Water Ordinance assigns the operators of domestic installations in public facilities, such as hospitals, autonomous responsibility for the quality of their water. Hospitals are obliged by the federal hospital-specific laws to prepare and update hospital alarm plans with corresponding hospital emergency plans (Cwojdzinski *et al*., 2008; Scholl & Wagner, 2010). These regulations are not uniform throughout Germany and their cascading interrelationships are not always easily accessible and understandable (Scholtes *et al*., 2018). In addition, there are predominantly no specifications with regard to the form and content of the action plans.

The Water Security Act (WasSiG) (Wassersicherstellungsgesetz, 1965) of 1965 is the legal basis for water security in Germany. It was drawn up during the Cold War and was initially provided for the case of defense. Since the middle of the 1960s, the Act has been modified only by a few small adjustments. More recently, the German Federal Ministry of the Interior published the so-called ‘Concept for Civil Defence’ in 2016 (BMI, 2016). It addresses aspects of drinking water supply in case of civil defense and other civil emergencies, such as quantitative minimum supply standards for patients of healthcare infrastructures. However, this document also refers to various aspects of the WasSiG (Wassersicherstellungsgesetz, 1965) and 1. WasSV (Erste Wassersicherstellungsverordnung, 1970), e.g., the minimum requirements per hospital patient as well as per patient in intensive medical care facilities. The Concept for Civil Defence has adopted the quantitative minimum supply standards from the 1. WasSV, because scientific findings for revising the standards are not available.

A comparison of the current legal framework concerning the determination of quantitative and qualitative minimum supply standards shows significant differences for emergency preparedness planning in the two countries. This is mainly caused by the need to adapt historical requirements as well as implementing existing international standards to local conditions.

Both countries have adopted minimum standards (Bundesministerium des Innern (BMI), 2016, ÖVGW, 2017) that should be maintained in case of an emergency. Minimum standards for water supply in hospitals are remarkably different. Whereas the guidelines in Austria (ÖVGW, 2017) are in line with the Sphere standards with 40–60 liters per in-patient per day (The Sphere Project, 2011; Sphere Association, 2018), the minimum supply standards in Germany require at least 75 liters per in-patient per day in hospitals and care facilities and up to 150 liters per in-patient per day in intensive medical care facilities (Erste Wassersicherstellungsverordnung, 1970; BMI, 2016). The reasons behind the German minimum standards for water supply in hospitals cannot be reproduced.

Discussion

Considering the results above, this paper has proved that hospitals, as well as water utilites, need to conduct preventive emergency planning. As one element of critical infrastructure, the loss of central water supply due to a power outage or natural disaster cannot be excluded entirely. Such an emergency can affect the water supply of hospitals, and it requires well-planned and a fast response including procurement and use of technical and human resources to reduce severe negative impacts on society.

Hospitals and other healthcare facilities play an essential role during emergencies as they provide 'lifeline' services to reduce the emergency-associated mortality and mobility, and thus minimize the impact of emergencies on the community (Braun *et al*., 2006; Albanese *et al*., 2008; Cimellaro *et al*., 2010; Paturas *et al*., 2010). In spite of this real threat and the potential effects of a drinking water failure in hospitals, there is, currently, hardly any consideration of this scenario in the hospital emergency plans (Fischer *et al*., 2013; Pfenninger & Adolph, 2017) in the guidelines or policy documents. There is a need for the development of emergency concepts for such a scenario on the part of hospitals, but also on the part of municipalities and water utilities. Many stakeholders are not aware that a failure of the drinking water supply is a problem for which preliminary planning is necessary (Hoyle, 2016). On the other hand, the awareness for the responsibility for carrying out such emergency planning is not existent (Jalba *et al*., 2010).

Throughout every phase of an emergency, municipalities should achieve an equitable supply of water for all parts of the society (WWAP 2012). As the general state of health influences the acceptable time without drinking water and the water amount required (Reed, 2011; The Sphere Project, 2011), hospitals and other healthcare infrastructures should receive a supply of water as a priority. Furthermore, communities affected by an emergency, expect the hospital to remain open and effectively operational throughout the emergency as hospitals have the overall task to help sick and suffering people (Milsten 2000; Barkemeyer, 2006; Kirsch *et al*., 2010; Welter *et al*., 2013).

It should be emphasized that there are barely any practical studies on the specific demand for drinking water in hospitals in emergencies. Although data are available on the total demand, which is quantified to the respective parameters, such as the number of beds, type, or extension of the hospital, only few actual measurements have taken place. This applies not only to normal conditions, but also to emergencies. For this reason, the reduced regular demand for emergency supply cannot be clearly verified.

Thus, a need for action in the field of planning and implementation of measures for the emergency water supply of hospitals can be identified, involving various stakeholders, especially water utilities, disaster and healthcare authorities. The necessary steps and processes for advanced emergency water supply planning to be addressed by hospitals as well as water utilities are recommended in the following paragraphs.

The water demand of a hospital should be analyzed and understood by a water audit, particularly the use of each unit or station should be determined in order to enable more precise planning. Furthermore, by analyzing the water demand, it is essential to consider which processes could be dispensed with in an emergency or can be temporarily replaced by waterless alternatives.

Alternatives to the regular water supply must be identified and planned. If the quality or quantity of the regular water supply is qualitatively or quantitatively impaired, alternative types of supply can be used. If the pipeline network is damaged, it is possible to bridge pipeline sections with mobile lines or to transport water through transport vehicles (Bross *et al*., 2019a). The alternatives to regular supply, however, depend on the nature of the damage. Therefore, the alternatives to the regular supply should be identified and planned for different scenarios, e.g., failure of the extraction plant and/or failure of the treatment.

A detailed emergency water supply plan should be developed, including all preventive and preparatory measures taken to obviate, reduce, and manage incidents (Bross *et al*., 2019b). In addition to the planning of emergency water supply in case of an interruption of regular operation, this also includes preventive measures as well as the determination of resources and responsibilities. Preventive measures serve the operational continuity of critical processes or reduce the functional susceptibility of risk elements to the effects of hazards. They, therefore, contribute to the reduction of risks for critical processes and plant components. The emergency water supply plan should be discussed and elaborated with all stakeholders.

Responsibilities must be clearly defined, coordinated, and communicated, which can be observed in the crisis management of the COVID-19 pandemic in 2020. Such responsibilities depend on governance and administrative structures. COVID-19, as well as many other previous crises such as major river floods have demonstrated the benefits as well as peculiarities of a distribution of responsibilities on various administrative levels. This enables a bottom-up approach on the one hand but requires more lateral as well as hierarchical risk communication and coordination. The example of Germany shows that the responsibilities with regard to an emergency water supply or the management of an impairment of the drinking water supply in hospitals can be different depending on the cause and extent of an event, but also at different times of a situation. A smaller impairment will involve the stakeholders of the hospital and the water utility while a larger impairment will include additionally the disaster management authories. Thus, there is a need for cooperative and inter-sectoral planning, i.e., involving all actors.

The planning for coping with emergency situations must be practiced and continuously improved. Exercises play a central role in crisis management and in maintaining the decision-making competence of the actors involved. They serve to check existing structures and processes, since weak points or opportunities for improvement can be identified through training. In addition, through the conscious interaction of different actors, exercises enable the best possible response to emergency situations.

Conclusion

The disruption of water supply is a significant challenge for every country, in particular, for countries that rarely experience such extraordinary events due to low-risk awareness. In addition, the high dependency of other CI leads to a higher vulnerability due to cascading effects in the case of a damaging event. The evaluation of existing scientific publications, policy frameworks, and guidelines on a global and European level, as well as for the selected countries Germany and Austria, shows that there is a need for comprehensive action.

The water demand of hospitals varies mainly due to different equipment, number of beds, the type and quantity of specialist departments, the provision of specialized services and technical equipment as well as the obligation to participate in emergency care. The existing planning and legal frameworks for emergency water supply of hospitals providing minimum supply standards are based on guidelines from humanitarian aid for disasters (WHO, 2002; The Sphere Project, 2011; Sphere Association, 2018) or for the establishment of refugee camps (UNHCR, 1992) with different framework conditions. A lack of methods for determining the parameters, especially the minimum water quantity of critical hospital processes, for planning the emergency water supply for water supply systems with a high degree of reliability in normal cases was identified.

Legal frameworks and standards are missing regulating emergency water supply of hospitals. To assess the complex water demands of hospitals and their patients further research is needed. Such research can represent a sound and valuable source for the development of a legal basis and/or standards for guidelines for emergency water supply of hospitals. Such standards need to define detailed quantity and quality requirements with regard to hospital characteristics, regular water supply structures, different scenarios and emergency supply requirements as well as different phases of emergencies. The standards need to be uniform, detailed, and transnational in order to be useful for water utilities, hospitals, and other stakeholders.

Acknowledgements

The authors thank Prof. Steffen Krause for his helpful suggestions for the preparation of the article. This work is based on the research conducted in the project 'Emergency water supply planning in Germany' on behalf of the German Federal Office of Civil Protection and Disaster Assistance (BBK). This work was also supported by the German Federal Ministry of Research and Education (BMBF) as part of the research project KIRMin (Critical Infrastructures – Resilience as a Minimum Supply Concept), carried out by BBK (grant number 13N13992) and THK (grant number 13N13989) as well as by the master thesis of Jan Bäumer and Ines Voggenreiter. It does not necessarily reflect the opinion of the funding institutions.

Data availability statement

All relevant data are included in the paper or its Supplementary Information.

References

Adams, J. (1999). *Managing Water Supply and Sanitation in Emergencies. An Oxfam Publication*. Oxfam Publishing, Oxford, UK.

Adams, H. A., Flemming, A., Krettek, C. & Koppert, W. (2015). Der Notfallplan des Krankenhauses. (The hospital emergency plan). *Medizinische Klinik, Intensivmedizin und Notfallmedizin 110*(1), 37–48. doi:10.1007/s00063-014-0414-8.

Albanese, J., Birnbaum, M., Cannon, C., Cappiello, J., Chapman, E., Paturas, J. & Smith, S. (2008). Fostering disaster resilient communities across the globe through the incorporation of safe and resilient hospitals for community-integrated disaster responses. *Prehospital and Disaster Medicine 23*(5), 385–390.

Badische Zeitung (2019). *Warnung vor blauem Trinkwasser in Heidelberg und Dossenheim. (Warning of Blue Drinking Water in Heidelberg and Dossenheim)*. Available at: https://www.badische-zeitung.de/suedwest-1/warnung-vor-blauem-trinkwasser-in-heidelberg-und-dossenheim–165847357.html

Barbera, J. A., Yeatts, D. J. & Macintyre, A. G. (2009). Challenge of hospital emergency preparedness: analysis and recommendations. *Disaster Medicine and Public Health Preparedness 3*(2 Suppl), S74–S82. doi:10.1097/DMP.0b013e31819f754c.

Barkemeyer, B. M. (2006). Practicing neonatology in a blackout: the University Hospital NICU in the midst of Hurricane Katrina: caring for children without power or water. *Pediatrics 117*(5), 369–374. doi:10.1542/peds.2006-0099F.

BMGF (Bundesministerium für Arbeit, Soziales, Gesundheit und Konsumentenschutz) (2019). *Krankenastalten in Zahlen*. (Hospitals in numbers) Federal Ministry for Social Affairs, Health, Care and Consumer Protection, Vienna, Austria. Available at: http://www.kaz.bmgf.gv.at/ressourcen-inanspruchnahme/krankenanstalten.html.

BMI (Bundesministerium des Innern) (2009). *Nationale Strategie zum Schutz Kritischer Infrastruktur (KRITIS-Strategie). (National Strategy for the Protection of Critical Infrastructures)*. Federal Ministry of the Interior.

BMI (Bundesministerium des Innern) (2016). *Konzeption Zivile Verteidigung (KZV). (Conception Civil Defense)*. Federal Ministry of the Interior.

BMNT (Bundesministerium für Nachhaltigkeit und Tourismus) (2018). *Wasserversorgung und -verwendung in Österreich. (Water Supply and Water use in Austria)*. Federal Ministry for Sustainability and Tourism. Available at: https://www.bmnt.gv.at/wasser/nutzung-wasser/versorgung.html (accessed 26.10.2018).

Braun, B. I., Wineman, N. V., Finn, N. L., Barbera, J. A., Schmaltz, S. P. & Loeb, J. M. (2006). Integrating hospitals into community emergency preparedness planning. *Annals of Internal Medicine 144*(11), 799–811. doi:10.7326/0003-4819-144-11-200606060-00006.

Bross, L. & Krause, S. (2017). Preventing secondary disasters through providing emergency water supply. In *World Environmental and Water Resources Congress 2017*, 21–25 May 2017, Sacramento, CA, USA.

Bross, L., Krause, S., Wannewitz, M., Stock, E., Sandholz, S. & Wienand, I. (2019a). Insecure security: emergency water supply and minimum standards in countries with a high supply reliability. *Water 11*(4), 732. doi:10.3390/w11040732.

Bross, L., Wienand, I. & Krause, S. (2019b). Sicherheit der Trinkwasserversorgung: Teil 2: Notfallvorsorgeplanung. Grundlagen und Handlungsempfehlungen für Aufgabenträger der Wasserversorgung in den Kommunen. Praxis im Bevölkerungsschutz. (Safety in drinking water supply: Part 2: Emergency preparedness planning. Basics and recommendations for action for authorities in the water supply in the municipalities with regard to exceptional risk situations) *Vol. 15 Practice in Civil Protection*.

BSI (Bundesamt für Sicherheit in der Informationstechnik) (2017). *Schutz Kritischer Infrastrukturen. (Critical Infrastructure Protection)*. Federal Office for Information Security.

Bundesregierung (1970). *Erste Wassersicherstellungsverordnung: 1. WasSV. (First Water Safety Ordinance) Antiphon Verlag*.

Bundestag (1965). *Gesetz über die Sicherstellung von Leistungen auf dem Gebiet der Wasserwirtschaft für Zwecke der Verteidigung (Wassersicherstellungsgesetz): WasSiG. (Law on the Provision of Services in the Field of Water Management for Defense Purposes (Water Security Act))*.

Busse, R., Schreyögg, J. & Tiemann, O. (2010). *Management im Gesundheitswesen (Healthcare Management)*, 2nd edn. Springer, Berlin, Germany.

CDCP (Centers for Disease Control and Prevention), AWWA (American Water Works Association) (2012). *Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities*, 1st edn. U.S. Department of Health and Human Service, Atlanta, GA, USA.

Chen, Q., Liang, M., Li, Y., Guo, J., Fei, D., Wang, L., He, L., Sheng, C., Cai, Y., Li, X., Wang, J. & Zhang, Z. (2020). Mental health care for medical staff in China during the COVID-19 outbreak. *Lancet Psychiatry 7*, e15–e16.

Cimellaro, G. P., Reinhorn, A. M. & Bruneau, M. (2010). Framework for analytical quantification of disaster resilience. *Engineering Structures 32*(11), 3639–3649. doi:10.1016/j.engstruct.2010.08.008.

Cwojdzinski, D., Kammel, P., Schneppenheim, U. W., Suckau, M. & Ulbrich, T. (2008). *Leitfaden Krankenhausalarmplanung. Edition Bevölkerungsschutz. (Guidelines for Hospital Alarm Planning. Volume 3 Training (Civil Protection Edition)*. Grimm, Berlin, Germany.

Destatis, Statistisches Bundesamt (2018). *Statistisches Jahrbuch. (Statistical Yearbook)*.

Dettenkofer, M., Kuemmerer, K., Mueller, W., Schuster, A., Muehlich, M., Scherrer, M. & Daschner, F. A. (2000). Environmental auditing in hospitals: first results in a university hospital. *Environmental Management 25*(1), 105–113. doi:10.1007/s002679910008.

DHS (Department of Homeland Security) (2015). *Homeland Security Presidential Directive 7: Critical Infrastructure Identification, Prioritization, and Protection*. Available at: https://www.dhs.gov/homeland-security-presidential-directive-7

DIN 15975-2 (Deutsches Institut für Normung e. V.) (2013). *Sicherheit der Trinkwasserversorgung – Leitlinien für das Risiko- und Krisenmanagement – Teil 2: Risikomanagement. (Safety of Drinking Water Supplies – Guidelines for Risk and Crisis Management – Part 2: Risk Management)*. p. 23.

DIN 15975-1 (Deutsches Institut für Normung e. V.) (2016). *Sicherheit der Trinkwasserversorgung – Leitlinien für das Risiko- und Krisenmanagement – Teil 1: Krisenmanagement. (Safety of Drinking Water Supplies – Guidelines for Risk and Crisis Management – Part 1: Crisis Management)*. p. 23.

DVGW (German Technical and Scientific Association for Gas and Water) (2015). Branchenbild der deutschen Wasserwirtschaft 2015. (Profile of the German Water Industry in 2015) ATT, BDEW, DBVW, DVGW, DWA, VKU. Wirtschafts-u. Verlagsges. Gas u. Wasser, Bonn, Germany.

DVGW W 410 (German Technical and Scientific Association for Gas and Water) (2008). *Wasserbedarf – Kennwerte und Einflussgrößen. (Water Demand – Parameters and Influencing Factors).*

EurEau (The European Federation of National Water Services) (2017). *Europe's Water in Figures: An Overview of the European Drinking Water and Waste Water Sectors*.

Exner, M. & Kistemann, T. (2004). Bedeutung der Verordnung über die Qualität von Wasser für den menschlichen Gebrauch (Trinkwasserverordnung 2001) für die Krankenhaushygiene. (*Significance of the ordinance on the quality of water for human consumption (Drinking water ordinance* 2001) for hospital hygiene). *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz 47*(4), 384–391. doi:10.1007/s00103-004-0806-7.

Exner, M., Kramer, A., Kistemann, T., Gebel, J. & Engelhart, S. (2007). Wasser als Infektionsquelle in medizinischen Einrichtungen, *Prävention und Kontrolle*. *(Water as a reservoir for nosocomial infections in health care facilities, prevention and control) Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz 50*(3), 302–311. doi:10.1007/s00103-007-0156-3.

Fischer, P., Wafaisade, A., Neugebauer, E. A. M., Kees, T., Bail, H., Weber, O., Burger, C. & Kabir, K. (2013). Wie gut sind Ärzte auf einen Massenanfall von Verletzten vorbereitet? *Ergebnisse einer bundesweiten Umfrage bei* 7700 Klinikärzten. (Preparedness of hospital physicians for a mass casualty incident. A German survey amongst 7,700 physicians). *Der Unfallchirurg 116*(1), 34–38. doi:10.1007/s00113-011-2035-5.

Focus online (2019). *Wasser in mehreren Geschäften in Heidelberg ausverkauft. (Water Sold out in Several Shops in Heidelberg)*. Available at: https://www.focus.de/gesundheit/news/nach-warnung-wasser-in-mehreren-geschaeften-in-heidelberg-ausverkauft_id_10292238.html.

Giovinazzi, S., Brown, C., Seville, E., Stevenson, J. R., Hatton, T. & Vargo, J. J. (2016). Criticality of infrastructures for organisations. *IJCIS 12*(4), 331. doi:10.1504/IJCIS.2016.081303.

González, A. G., García-Sanz-Calcedo, J., Salgado, D. R. & Mena, A. (2016). A quantitative analysis of cold water for human consumption in hospitals in Spain. *Journal of Healthcare Engineering 2016*. doi:10.1155/2016/6534823.

González, A., García-Sanz-Calcedo, J. & Salgado, D. (2018). Quantitative determination of potable cold water consumption in German hospitals. *Sustainability 10*(4), 932. doi:10.3390/su10040932.

Heinrich, D. (2011). Customer Relationship Management im Krankenhaus: Empirische Überprüfung eines Kundenwertmodells für niedergelassene Ärzte. (Customer relationship management in the hospital: Empirical review of a customer value model for general practitioners) Zugl.: Marburg University, dissertation, 2010, 1. Aufl. ed. Marktorientiertes Management. Gabler Verlag/Springer Fachmedien Wiesbaden GmbH Wiesbaden, Wiesbaden.

House, S. & Reed, B. (2004). *Emergency Water Sources: Guidelines for Selection and Treatment*, 3rd edn. Water, Engineering and Development Centre, Loughborough University, UK.

Hoyle, J. D. (2016). Healthcare facility disaster management. In *Koenig and Schultz's Disaster Medicine. Comprehensive Principles and Practice*, 2nd edn. Koenig, K. L. & Schultz, C. H. (eds). Cambridge University Press, Cambridge, UK, pp. 330–360.

Hsu, J., Del Rosario, M. C., Thomasson, E., Bixler, D., Haddy, L. & Duncan, M. A. (2017). Hospital impact after a chemical spill that compromised the potable water supply: West Virginia, *January* 2014. *Disaster Medicine and Public Health Preparedness 11*(5), 621–624. doi:10.1017/dmp.2016.193.

Jalba, D. I., Cromar, N. J., Pollard, S. J. T., Charrois, J. W., Bradshaw, R. & Hrudey, S. E. (2010). Safe drinking water: critical components of effective inter-agency relationships. *Environment International 36*(1), 51–59. doi:10.1016/j.envint.2009.09.007.

Karger, R. & Hoffmann, F. (2013). *Wasserversorgung*. (Water supply) Springer Fachmedien Wiesbaden, Wiesbaden.

Kirsch, T. D., Mitrani-Reiser, J., Bissell, R., Sauer, L. M., Mahoney, M., Holmes, W. T., Santa Cruz, N. & de La Maza, F. (2010). Impact on hospital functions following the 2010 Chilean earthquake. *Disaster Medicine and Public Health Preparedness 4*(2), 122–128.

Liu, H., Behr, J. G. & Diaz, R. (2016). Population vulnerability to storm surge flooding in coastal Virginia, USA. *Integrated Environmental Assessment and Management 12*(3), 500–509. doi:10.1002/ieam.1705.

Lorenz, D. F. (2010). Kritische Infrastrukturen aus Sicht der Bevölkerung. (Critical infrastructures from the point of view of the population) Schriftenreihe Forschungsforum Öffentliche Sicherheit 3. Freie University, Berlin, Germany.

Ludwig, A. (2002). *Substance-Flow Water/Waste Water Management in European Hospitals – Water Saving Strategies and Strategies for Reducing Waste Water Pollution; Project LIFE99 ENV/D/000455*. Available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE99_ENV_D_000455_LAYMAN.pdf

Milsten, A. (2000). Hospital responses to acute-onset disasters. *Prehospital and Disaster Medicine 15*(1), 40–53. doi:10.1017/S1049023X00024900.

Murakawa, M. (2013). Anesthesia department preparedness for a multiple-casualty incident: lessons learned from the Fukushima earthquake and the Japanese nuclear power disaster. *Anesthesiology Clinics 31*(1), 117–125. doi:10.1016/j.anclin.2012.11.007.

Nagel, E. & Braasch, P. (Eds.) (2007). *Das Gesundheitswesen in Deutschland: Struktur, Leistungen, Weiterentwicklung. (The Health System in Germany: Structure, Services, Further Development)*. Dt. Ärzte-Verl., Köln, Germany.

Neunteufel, R., Richard, L., Perfler, R., Tuschel, S., Mader, K. & Haas, E. (2010). *Studie Wasserverbrauch und Wasserbedarf: Teil 1: Literaturstudie zum Wasserverbrauch – Einflussfaktoren, Entwicklung und Prognosen. (Study of Water Consumption and Water Demand. Part 1: Literature Study on Water Consumption Influencing Factors, Development and forecasts)*.

OECD (Organisation for Economic Co-operation and Development) (2019). *Good Governance for Critical Infrastructure Resilience. OECD Reviews of Risk Management Policies*. OECD Publishing, Paris, France.

ÖVGW (Austrian Association for Gas and Water) (2017). *Trinkwassernotversorgung, Krisenvorsorgeplanung in der Trinkwasserversorgung: W 74. (Emergency Drinking Water Supply: Crisis Preparedness Plan in the Water Supply) Österreichische Vereinigung für das Gas- und Wasserfach.*

Paturas, J. L., Smith, D., Smith, S. & Albanese, J. (2010). Collective response to public health emergencies and large-scale disasters: putting hospitals at the core of community resilience. *Journal of Business Continuity & Emergency Planning 4*(3), 286–295.

Perrin, K. (2006). Closing and reopening of a children's hospital during a disaster. *Pediatrics 117*(5), 381–385. doi:10.1542/peds.2006-0099H.

Pescaroli, G. & Alexander, D. (2016). Critical infrastructure, panarchies and the vulnerability paths of cascading disasters. *Natural Hazards 82*(1), 175–192. doi:10.1007/s11069-016-2186-3.

Peters, M. (1996). Hospitals respond to water lost during the Midwest floods in 1993: preparedness and improvisation. *Journal of Emergency Management 14*, 345–350.

Pfenninger, E. & Adolph, O. (2017). Memorandum – Zur Vulnerabilität kritischer Infrastrukturen an Bundesdeutschen Kliniken. *(Memorandum – On the vulnerability of critical infrastructures at German clinics) Notfall Rettungsmed 20*(8), 673–681. doi:10.1007/s10049-017-0293-7.

Priscoli, J. D. & Hiroki, K. (2015). Water and disasters: cases from the high level experts and leaders panel on water and disasters. *Water Policy 17*(S1), 1–5. doi:10.2166/wp.2015.000.

Reed, B. (2011). *How Much Water is Needed in Emergencies: Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies*. World Health Organization, Geneva, Switzerland, pp. 45–48.

Reed, B. & Shaw, R. (1995). *Emergency water supply: technical brief* No. 44. *Waterlines 13*(4).

Reller, A. (2000). *Greener Hospitals: Improving Environmental Performance*. Wiss.-Zentrum Umwelt, Univ, Augsburg.

RNZ (Rhein-Neckar Zeitung) (2019). *Trinkwasser in Heidelberg und Dossenheim darf wieder verwendet werden (Drinking Water in Heidelberg and Dossenheim can be Reused)*. Available at: https://www.rnz.de/nachrichten/metropolregion_artikel,-entwarnung-trinkwasser-in-heidelberg-und-dossenheim-darf-wieder-verwendet-werden-plus-video-_arid,418828.html (accessed 22.07.2019).

Sauer, L. M., McCarthy, M. L., Knebel, A. & Brewster, P. (2009). Major influences on hospital emergency management and disaster preparedness. *Disaster Medicine and Public Health Preparedness 3*(2 Suppl), S68–S73. doi:10.1097/DMP.0b013e31819ef060.

Scholl, H. & Wagner, K. (2010). *Alarm- und Einsatzplanung: Risiko- und Krisenmanagement in Einrichtungen des Gesundheitswesens sowie in Alten- und Pflegeheimen. (Alarm and Deployment Planning: Risk and Crisis Management in Health Care Facilities as Well as Retirement and Nursing Homes)*. Stumpf + Kossendey, Edewecht.

Scholtes, K., Wurmb, T. & Rechenbach, P. (Eds.) (2018). Risiko- und Krisenmanagement im Krankenhaus: Alarm- und Einsatzplanung, 1. (Risk and crisis management in hospitals: alarm and deployment planning) Auflage ed. Verlag W. Kohlhammer, Stuttgart, Germany.

Siders, C. & Jacobson, R. (1998). Flood disaster preparedness: a retrospect from Grand Forks, North Dakota. *Journal of Healthcare Risk Management 18*(2), 33–40. doi:10.1002/jhrm.5600180206.

Sitzenfrei, R., Mair, M., Möderl, M. & Rauch, W. (2011). Cascade vulnerability for risk analysis of water infrastructure. *Water Science and Technology 64*(9), 1885–1891. doi:10.2166/wst.2011.813.

Sphere Association (2018). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*, 4th edn, Geneva, Switzerland. Available from: www.spherestandards.org/handbook

Statista (2019). *Statistiken zu Krankenhäusern in Österreich*. Available at: https://de.statista.com/themen/4978/krankenhaeuser-in-oesterreich/.

The Sphere Project (2011). *Humanitarian Charter and Minimum Standards in Disaster Response*. The Sphere Project, Geneva, Switzerland.

The World Bank (2018). *World Development Indicators*. The World Bank, Washington, DC, USA.

TrinkwV (2019). Verordnung über die Qualität von Wasser für den menschlichen Gebrauch: (Trinkwasserverordnung – TrinkwV).

UNDRR (United Nations Office for Disaster Risk Reduction) (2015). *Sendai Framework for Disaster Risk Reduction 2015–2030*. United Nations Office for Disaster Risk Reduction, Geneva, Switzerland.

UNDRR (United Nations Office for Disaster Risk Reduction) (2017). *Terminology on Disaster Risk Reduction*. United Nations, Geneva, Switzerland.

UNHCR (UN High Commissioner for Refugees) (1992). *Water Manual for Refugee Situations*. UNHCR, Geneva, Switzerland.

UNISDR (United Nations Office for Disaster Risk Reduction) (2009). *Terminology on Disaster Risk Reduction*. United Nations, Geneva, Switzerland.

Urlainis, A., Shohet, I. M., Levy, R., Ornai, D. & Vilnay, O. (2014). Damage in critical infrastructures due to natural and man-made extreme events – a critical review. *Procedia Engineering 85*, 529–535. doi:10.1016/j.proeng.2014.10.580.

VDI 3807-2 (2016). *Characteristic Consumption Values for Buildings: Characteristic Heating-Energy, Electrical-Energy and Water Consumption Values*.

VDT (Virginia Department of Transportation) (2008). *Smithfield Design and Construction Standards; Department of Transportation*. Available at: https://smithfield.municipalcodeonline.com/book?type=construction#name=PART_I_DESIGN_STANDARDS

Welter, G., Socher, M., Needham, P., Bieber, S. & Bonnaffon, H. (2010). Cross-sector emergency planning for water supply utilities and healthcare facilities. *Journal of the American Water Works Association 102*(1), 68–78.

Welter, G., Bieber, S., Bonnaffon, H. & Freundberg, S. (2011). Emergency water supply planning for the national capital region. *Journal of Emergency Management 9*(6), 17–28.

Welter, G., Socher, M., Needham, P., Bieber, S. & Bonnaffon, H. (2013). Cross-sector emergency planning for water supply utilities and healthcare facilities. *Journal of Healthcare Risk Management 32*(4), 5–14. doi:10.1002/jhrm.21105.

WHO (World Health Organization) (2002). *Environmental Health in Emergencies and Disasters: A Practical Guide*. WHO, Geneva, Switzerland.

WHO (World Health Organization) (2015). *Hospital Safety Index: Guide for Evaluators*, 2nd edn. Hospitals safe from disasters, World Health Organization, Geneva, Switzerland.

WHO (World Health Organization) (2017). *Drinking Water Parameter Cooperation Project: Support to the Revision of Annex I Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption (Drinking Water Directive)*. WHO, Geneva, Switzerland.

WSDH (Washington State Department of Health) (2009). *Water System Design Manual*. Division of Environmental Health, WSDH, Olympia, WA, USA.

WWAP (World Water Assessment Programme) (2012). The United Nations World Water Development Report 4. Managing Water under Uncertainty and Risk (Vol. 1) UNESCO, Paris, France.

Yao, H., Chen, J. H. & Xu, Y. F. (2020). Patients with mental health disorders in the COVID-19 epidemic. *Lancet Psychiatry 7*(4), e21. doi:10.1016/S2215-0366(20)30090-0.

Received 16 January 2020; accepted in revised form 6 December 2020. Available online 19 January 2021