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# Insecure Security: Emergency Water Supply and Minimum Standards in Countries with a High Supply Reliability

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**Abstract:** Drinking water supply is at the core of both, humanitarian action in times of crisis, as well as national policies for regular and emergency supply. In countries with a continuous water supply, the population mostly relies ingenuously on the permanent availability of tap water due to high supply standards. In case of a disruption in the drinking water infrastructure, minimum supply standards become important for emergency management during disasters. However, wider recognition of this issue is still lacking, particularly in countries facing comparably fewer disruptions. Several international agencies provide guideline values for minimum water provision standards in case of a disaster. Acknowledging that these minimum standards were developed for humanitarian assistance, it remains to be analyzed whether these standards apply to disaster management in countries with high supply standards. Based on a comprehensive 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 flags potential improvements for emergency water supply planning and identifies future fields of research.

**Keywords:** disaster; drinking water; high-income country; preparedness; supply standards; water supply

## 1. Introduction

In March 2015, the UN World Conference on Disaster Risk Reduction (DRR) in Sendai highlighted the importance and relevance of critical infrastructure resilience. Critical Infrastructures (CI) such as water supply are, those by definition, essential for society. Correspondingly, if CI suffer damage, destruction or disruption, this may have a significant negative impact on public health and the security of citizens [1]. 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" [2]. This target is globally valid and of particular relevance as the 21st century is characterized by new security policy risks (e.g., asymmetric conflicts, international terrorism, fundamentalism of various forms, and associated military conflicts) and major natural risks (e.g., extreme weather conditions due to climate change) that can potentially harm CI.

The standard of water supply in Germany and Austria is considered very high. This is shown by a high degree of connection to the central pipeline networks, low downtimes and high consumer confidence in the reliability of the infrastructure. More than 99% of Germany's 82 million inhabitants are connected to the public drinking water supply and less than one percent of the population supplies themselves via their own water supply systems. Every day, around 6000 water supply companies supply consumers through a pipeline grid of 530,000 km in length [3]. On average, every inhabitant of Germany consumes 121 L per day [4]. In Austria drinking water supply is provided by approximately 5500 water supply companies, supplying 7 million inhabitants every day with a total pipeline length of 78,000 km [5]. Thus, 90% of the 8 million inhabitants are connected to the public drinking water supply network [5]. Every inhabitant in Austria consumes on average 130 L per day [4].

An increase in both environmental determinants [6], as well as technological hazards [7] related to a more decentralized energy supply, puts a strain on the water supply systems and can lead to pollution or the unavailability of drinking water. This applies to any country. However, potential impacts of outages and countermeasures will depend to a large extent on what type of supply systems exist. Yet, the impact on the water itself can be categorized into an influence on the quality of drinking water or on the quantity of drinking water. The disruption of water supply systems can have extensive consequences and cascading effects with adverse impacts beyond the local level, which are often difficult to assess [8]. The cause of an impairment of infrastructure and its extent depends on numerous factors such as the development of the water supply or local framework conditions. This paper focuses on emergency situations caused by a sudden, acute, and generally unexpected damaging events, which can lead to considerable impairment or even failure of drinking water supply. However, with a proper response from the responsible institution, normal supply can be resumed. Emergency management, including preparatory planning and preparation for emergency response, is of utmost importance to mitigate the extent of damage [9]. The emergencies considered do not involve dislocation of the population nor an irretrievable loss of the normal water supply. Therefore, emergencies are categorized as temporary disruptions in the provision of safe drinking water. Consequently, emergency water supply (EWS) is defined in this paper as the provision of water to meet vital needs for a limited time, if normal operations are interrupted and cannot provide an adequate water supply.

One example of the potential vulnerability of infrastructure systems to natural hazards was the heavy rainfall event in Simbach am Inn at the German-Austrian border. Heavy rainfall in combination with a clogged pipe and the bursting of a dam led to a flood wave, which inundated large parts of Simbach on 1 June 2016 [10]. The electricity for around 8000 households was cut off as a result of the flood disaster [11]. In addition, the regular drinking water supply was interrupted as extraction facilities were under water. In the days following the onset of the flood, an ad-hoc emergency water supply response was conducted. More than 5.5 million liters of drinking water [12] were fed into the local drinking water network in places where it was still functional as an emergency water supply measure [13]. Due to the high dependency of the population on the central water supply, failures such as those as in Simbach quickly lead to supply bottlenecks and restrictions. This can be prevented by appropriate precautionary planning instead of ad hoc reactions. Precautionary planning includes the preparation and activation of measures to ensure the functional capability of the water supply, ensure operational or business continuity and a rapid return to normal operation. One of the most important tasks of precautionary planning is to create the conceptual, organizational and procedural prerequisites and to establish structures for reaction in the event of a crisis [14].

Such events exemplify the necessity of foresight and precautionary planning in the sense of risk and crisis management and the associated availability of technical and personnel resources for emergency water supply in the event of an emergency, crisis or catastrophe [15]. To be able to react appropriately to impairments, emergency measures must be planned and prepared in advance. Smadi et al. have shown, that for disaster relief the last mile of distribution takes the most effort [16]. This can be transferred to emergency water supply measures. The logistical effort for emergency water supply, especially grid-independent EWS, is higher than for normal supply. Water has to be transported with tanker trucks or as bottled water if the grid cannot be used. In addition, the available resources such as mobile treatment plants, water transport vehicles and mobile pipelines are available only in limited quantities. Consequently, comprehensive planning is necessary to cope with increased effort. The central questions to be answered for emergency water supply is: (i) How much water do we need? (ii) Where do we need how much? (iii) When do we need it? (iv) For whom do we need how much water? (v) Where do we get the water from? (vi) How can it be distributed?

In an emergency, the provision of drinking water to the population represents significant challenges for any water utility and authority even in high-income countries with a high supply security. For instance, Banks et al. found rural communities in Central Appalachia, USA, to suffer from flooding and related infrastructure damages, including water supply [17]. In addition, Cutter describes the impact of 2016 Hurricane Matthew on local communities in South Carolina, USA, which suffered from power outages that affected access to water, food, and health infrastructure [18]. The 2002 floods in the Czech Republic that triggered prolonged failures of drinking water supplies urged the Czech Republic to request vaccines [19]. A flood and storm in New South Wales, Australia in 2007 interrupted power, water, and gas supplies, impacting on household winter heating and hot water supplies of more than 200,000 homes and businesses. One council utility had to draw river water and issued precautionary advice to consumers to boil water until treated water met Australian Drinking Water Guidelines [20]. The 2011 Tohoku earthquake, tsunami, and Fukushima meltdown in Japan left 1.5 million households without water supply, consequently much of the international relief was linked to bottled water and water tanks [7,21–23].

If, in the event of an emergency, the utilities or municipalities can no longer avoid a limitation or a failure of the public water supply, emergency response needs to consider alternative supply measures. Therefore, various additional resources are required, such as water transport vehicles, packaged bottled water, and mobile treatment plants. Since these capacities are available only in limited quantities, thorough planning in advance is necessary. In high-income countries, such as Germany and Austria, a range of resources for emergency planning in the drinking water supply is available. However, it has become apparent in the past that many local communities could have been better prepared for a large and longer-term failure of the public water supply. Hence, technical and organizational emergency water supply measures are missing [24].

The purpose of this paper is to discuss the elementary aspects of emergency water supply planning while addressing decisive stakeholders such as private and public water utilities, as well as public authorities for both disaster management, homeland security and civil protection. While not routinely involved in the core of multi-agency emergency response and recovery work, these stakeholders will have an essential role in the response to, and recovery from, emergencies affecting their nation or region. Therefore, the planning process should include all involved stakeholders.

This paper highlights recommendations for improved emergency water supply planning and identifies gaps in the current practice by drawing on a solid literature review and analysis, as well as case study examples. In the first step, the paper focuses on the need for emergency water supply planning in countries with a high level of water supply security by comparing existing supply standards in low- and high-income countries. In a second step, a comprehensive literature review of scientific publications and humanitarian guidelines as well as policies from selected countries shows the current state and processes of emergency water supply planning according to various standards and guidelines. Third, using the two European Union (EU) member states Austria and Germany as country case studies, the necessity to go beyond existing policies in order to secure emergency water supply is demonstrated. Finally, the paper sheds light on potentials for improved emergency water supply planning to be carried out by water utilities, as well as authorities. Furthermore, it identifies future fields of research.

## 2. Materials and Methods

A multi-method approach is employed in this paper, rooted in literature and policy analyses on different geographic scales. Desktop researches were done to assess policy guidelines, standards, and frameworks for emergency water supply as well as for legislation in the European, Austrian, and German contexts. Another structured document search with different keyword searches regarding the linkages between critical infrastructure (CI) failure, social vulnerability, and minimum supply [25] done in SCOPUS database in July 2017 served to identify past disasters and their impacts on water infrastructure and supply.

The country examples of Austria and Germany were chosen to compare the emergency management plans for a (partial) failure of water supply. The two neighboring countries, are considered high-income countries according to the World Bank (WB) due to their gross national income per capita [26]. Both countries have a very similar standard of living and comparable standards of drinking water supply. Overall, the countries have similar boundary conditions (climate, geography, population structure, demographic change, etc.) and challenges to the security of supply (including natural hazard-induced disasters, terrorism, and crime).

## 3. Water Supply and Supply Failure in Different Groups of Countries

Water is a human right. Everyone has the right to safe and clean drinking water and sanitation [27], which is essential for the full enjoyment of life and all other human rights. According to the World Bank Group, the number of people living without access to a safe water source is the highest in low-income countries [28], often also referred to as developing countries. The right to water is a right to subsistence: its consideration is critical for people to survive within a state's sphere of influence. The minimum subsistence level of water and sanitation is, therefore, non-negotiable to any state. If states are unable to fulfill their obligations, they are entitled to international assistance and to humanitarian aid for the whole country or particular regions albeit with certain restrictions.

Acknowledging that boundary conditions for countries and regions are different, administrative arrangements and governance of a region or a country can favor international aid processes [29] and can lead to a strong increase in access to drinking water within a few years through international aid [30]. However, existing structures, especially in public administration, may prevent international institutions from granting or freezing financial aid until conditions change [30].

The availability of a permanent water supply contributes to enhancing the standard of living, both in urban and rural environments. Permanent availability (coverage, quantity, quality, and continuity) of drinking water is of high societal relevance [14]. However, the availability of and access to water supply and supply systems differs significantly between different groups of countries. To demonstrate the variation in water supply systems and the service levels between high-income countries, the differences in context and shape as well as the different expectations among the different sets of countries are highlighted.

In high-income countries, drinking water is supplied by a centralized grid system. While a large majority of inhabitants of high-income countries have a high supply security and overall access to grid-based water supply of high quality, this share is much smaller in middle-income countries and lowest in low-income countries where only 37% of the population has access to grid-based water and 23% can supply themselves from safely managed drinking water located on their premises (see Table 1).

**Table 1.** Drinking water access and supply in different world regions (sources: [31], country list according to [26]).

| | | High-Income Countries (%) | Upper-Middle Income Countries (%) | Lower-Middle Income Countries (%) | Low-Income Countries (%) |
|---|---|---|---|---|---|
| **Facility type** | Grid-bound water | 96 | 82 | 52 | 37 |
| | Grid-independent water | 3 | 14 | 33 | 37 |
| **Source** | Safely managed drinking water from an improved water source which is located on premises | 96 | 77 | 53 | 23 |
| | Limited access (collection time exceeds 30 min) | 2 | 3 | 6 | 13 |
| | Unimproved (unprotected dug or spring) | 1 | 2 | 9 | 18 |
| | Surface water | 0 | 1 | 6 | 7 |
| **Access** | At least basic access | 99 | 94 | 79 | 61 |
| | Accessible at premises | 97 | 87 | 59 | 28 |
| | Available when needed | 95 | 76 | 71 | 54 |
| | Free from contamination | 98 | 85 | 62 | 37 |

The quantity of water consumed per capita is higher in countries with grid-bound water supply from a safely managed water source. One reason for this is that grid-independent water needs to be carried or transported somehow. Cairncross and Feachem have shown that water consumption decreases significantly with increasing travel time to collect the water [32]. Another reason for the difference in the quantity of water consumed is that the price per cubic meter is higher if the water is delivered independent of the grid, for example by water vendors, than if it is delivered grid-bound by public utilities [33–35]. It becomes evident that the permanent availability of water leads to the situation that people in high-income countries treat it as an infinite good and consume more water, while people in lower-income countries treat water as a finite good, since they need to go and fetch water once it runs out due to the unreliability of the water supply to their premises.

If the amount of water available for the general supply or the hydraulic capacity of the system is insufficient to meet the needs of the population, one of the most common methods of controlling water consumption is an intermittent water supply [36]. An intermittent water supply does not supply consumers with water continuously, but only temporarily. Such supply is common in many lower- and upper-middle-income countries [36]. Households with limited, discontinuous, or no access to the formal network are likely to get their water from several sources and multiple providers [37]. This is in contrast to countries with a continuous and reliable grid-bound supply as these countries get water from a single provider [37].

## 4. Standards and Frameworks for Emergency Water Supply

### *4.1. Universally Used Standards and Frameworks for Emergency Water Supply*

By declaring access to clean drinking water, a human right on 28 July 2010 (Resolution 64/292) [27], the United Nations General Assembly established the formal foundation for acknowledging the universally important role of a clean water supply for human livelihoods and development. However, even before this milestone, the international community considered water supply important. This can be exemplified by the total of 51 standards that have been developed and published by the International Organization for Standardization (ISO) between 1977 and 2010 for standardizing water supply systems around the world [38]. Up to 2018, this number rose to 83. In addition, a multitude of standards in related fields such as “Pipelines and its parts for external water conveyance systems” or “External water conveyance systems” were published. Additionally, 11 standards for drinking water quality have been established between 1992 and 2018 [39]. While not legally binding, these internationally applicable standards showcase awareness for the high relevance of clean water supply and build a basis for utilities to ensure a permanent and safe water supply.

Strikingly, only very few universally applicable standards were developed with regard to emergency water supply during and after disasters. The little number of ISO standards directly addressing emergency water supply is an indication for a lack of guidance for utilities and authorities, who would normally use such standards to plan for and ensure a functioning minimum water supply in emergency situations.

In the absence of international emergency water supply standards, a handbook developed in the frame of the Sphere Project represents one of the most renowned and applied guidelines, providing minimum standards for water supply and other aspects in humanitarian response. Developed by a wide range of humanitarian actors, the handbook composes of a set of common principles and universal minimum standards for humanitarian response activities.

The United Nations High Commissioner for Refugees (UNHCR) [40], the World Health Organisation (WHO) [14] and the Sphere Project [36,41] guidelines each address the conditions necessary for survival in humanitarian crises. Minimum standards as defined in the Sphere Project "describe conditions that must be achieved in any humanitarian response in order for disaster-affected populations to survive and recover in stable conditions and with dignity" [41] (p. 6). Further, it is stated, that "each standard is derived from the principle that disaster-affected populations have the right to life with dignity. They are qualitative in nature and specify the minimum levels to be attained in humanitarian response." [41] (p. 7).

These minimum supply standards focus on essential humanitarian aid that is necessary, for example, in the establishment of camps for displaced people after disasters. The need for humanitarian aid is highest when a disaster hits a low-income country due to higher levels of vulnerability (e.g., poorly constructed buildings, poor medical facilities, poor infrastructure and poor governance). In these cases, it is often not possible to fall back on existing infrastructure; or existing infrastructure cannot be used for supply, as it was either never available or is no longer functional.

While humanitarian aid primarily relies on emergency water supply that is grid-independent, from a hygienic point of view grid-bound is the type of supply in high-income countries to be prioritized [42].

The Sphere Standards are supposed to function as a tool that "guides practitioners in their reflections around reaching a universally applicable standard in a concrete situation or context, with particular focus on specific vulnerabilities and capacities." [41] Water supply in emergency situations is directly addressed in the chapter "Minimum Standards in Water Supply, Sanitation and Hygiene Promotion". It lists three standards for minimum water supply that have to be met in humanitarian action in response to disasters, which refer to: 1. access and water quantity; 2. water quality; and 3. water facilities. The handbook is comparably unique in the sense that it provides not only qualitative descriptions but also hard numbers for minimum supply water needs that have to be met for basic survival. Another universally applicable document referring to water supply minimum standards in emergency situations is the UNHCR Water Manual for Refugee Situations [40]. It outlines quantitative minimum supply standards independent of specific country settings. Both handbooks define similar quantities for minimum water needs for individuals, as well as institutions in case of emergencies, which is illustrated in Table 2.

**Table 2.** Water demands according to Sphere [36,41], UNHCR [40] Handbooks and German [43,44] as well as Austrian [45] legal frameworks.

| | Sphere Handbook [36,41] | UNHCR Water Manual for Refugee Situations [40] | Germany Legal Framework [43,44] | Austria Legal Framework [45] |
|---|---|---|---|---|
| **Minimum Supply in Case of Water Shortages** [a] | 15 | / | 50 [d] | / |
| **Drinking Water Need** [a] | 2.5–3 | 7 survival allocation | / | 2.5–3 (short term) |
| **Domestic Water Need** [a] | 5–12 | 15–20 camp allocation | / | 7.5–15 (mid-term) |
| **Total** [a] | 7.5–15 | / | 15 | / |
| **Hospitals and Health Centers** [b] | 40–60 (inpatients) 100 (per surgical intervention and delivery) | 220–300 [e] | 75 (hospitals and care facilities) 150 (in intensive medical care facilities) | 40–60 |
| **Feeding Centers** [a] | 30 | 20–30 | / | 20–30 |
| **Schools** [c] | 3 | 2 | / | / |
| **Mosques** [a] | 2–5 | 2–5 | / | / |

[a] liters per capita per day; [b] liters per patient per day; [c] without toilet flushing; [d] grid-bound supply; [e] with laundry facilities.

The minimum standards for water quality found in the Sphere Standards [36,41] are shown in Table 3. These quality requirements apply for grid-bound water supplies, or "all water supplies at times of risk of diarrhea" [41] (p. 100). The UNHCR Water Manual does not quantify the quality requirements specified for emergency situations as the manual focuses on refugee situations. The manual provides guidelines on water quality, "which have been prepared based on WHO's Guideline for Drinking Water Quality (as published in 1984) and on UNHCR's experience" [40] (p. 7). It is explicitly mentioned that for the definition of water standards, geographical, socio-economic, dietary, and environmental conditions need to be considered [40].

**Table 3.** Minimum standards for water quality in emergencies (adapted from [36,41]).

| Parameter | Minimum Standard |
|---|---|
| Faecal coliforms | None per 100 mL of water |
| Turbidity | <5 NTU |
| Chlorine residual | $\approx$ 0.5 mg/L |

To the knowledge of the authors, there are only very few other documents providing quantities for minimum water supply needs per person [16,46–50], which are less popular and applied than the Sphere Handbook. They provide numbers comparable to the Sphere and UNHCR handbooks. Other internationally used guidelines such as the WHO's Practical Guide on "Environmental health in emergencies and disasters" [14] refer to the Sphere Handbook when it comes to minimum water supply quantities. Regarding water quality, in emergencies, the available publications focus on the technical systems to purify water in emergencies (e.g., [51,52]) rather than stating a minimum quality which must be met.

While the quantities for individual consumption and for institutions can function as a sound basis for emergency planning, they need to be treated with caution as minimum water demands may vary largely from average consumption between countries of different income levels. When comparing the number for minimum domestic water needs of 7.5–20 L per capita per day of the Sphere Handbook with water consumption patterns under normal conditions around the world, it becomes evident that the standards can hardly be applied in high-income countries. In Germany, for instance, the daily domestic water consumption per capita amounts to 121 L [53]. This figure is well in line with the European average for residential water consumption per day, which is estimated to be 128 L per inhabitant [4]. In contrast to this, low-income countries such as Burkina Faso, Niger, and Haiti as well as lower-middle income countries like Kenya and Cambodia consume less than 50 L of water per person daily [37]. It has to be mentioned, however, that the daily water consumption is increasing up to levels comparable to high-income countries even in these countries, as soon enough water is available and affordable. While these numbers only represent national averages, they are still valuable for indicating a large divergence in water consumption patterns and water supply system characteristics in relation to the income level—a fact that is not and most likely can hardly be considered in standards and frameworks.

### *4.2. Emergency Water Supply in European Guidelines and Frameworks*

To ensure a secure water supply, guidelines and legal frameworks have been developed at regional and national scales. In the European case, which will serve as an example, the European Commission has published several directives and guiding documents which are meant to ensure water supply security and quality.

The European Drinking Water Directive (98/83/EC) developed and published in 1998 is meant to secure the quality of drinking water in countries of the European Union. It states minimum requirements for the quality of water for human consumption. The directive also instructs water providers to develop water safety plans based on the WHO Framework for safe drinking water [54]. These include the assessment of risks and hazards that may threaten water quality and supply to consumers and the establishment of respective management plans to minimize those risks. Additionally, there are legislation and policy documents that focus on risk mitigation (e.g., [55,56]) Available documents however, do not refer to minimum standards or management procedures in case of water supply disruptions or failures, neither regarding quantity nor quality of water.

In the beginning of 2018, the European Commission published a proposal for a revised drinking water directive to "improve the quality of drinking water and provide greater access and information to citizens." [40]. Among others, the revised directive will use a risk-based approach, enabling authorities to improve their water risk management according to the WHO water safety plan concept. Additionally, the distribution of timely and adequate information to the public is stressed as a new component of the revised version.

Overall, the focus of the documents on the European level is on risk management to secure water quality under normal operation supply conditions rather than on emergency supply, let alone minimum supply needs in emergency situations.

### *4.3. Emergency Water Supply in Austrian and German Guidelines and Frameworks*

In the following, the legal requirements for emergency water supply in Germany and Austria are compared in order to show what effects non-standardized requirements can have.

In Germany, the regulative framework for drinking water quality for normal conditions and also in the case of a drinking water emergency is the German Drinking Water Ordinance (TrinkwV) [57]. Additionally, selected water-specific laws of the federal states oblige the water supplier and public authorities to protect the water supply system against crisis situations, e.g., caused by an extreme event such as flooding.

The legal basis for water security originally provided for the case of defense in Germany is the Water Security Act (WasSG) [58] of 1965, which was drawn up during the Cold War and has since been modified only by a few adjustments. In 2016, the German Federal Ministry of the Interior published the so-called "Concept for Civil Defence" [44], which addresses aspects of drinking water supply in case of civil defense and other civil emergency situations. However, this document also referred to various aspects of the WasSG [58] and 1. WasSV [43], e.g., the minimum requirements per inhabitant, per hospital patient. and per livestock unit. The rationale behind the quantitative minimum supply standards, which the Concept for Civil Defence has adopted from the 1. WasSV, cannot be reproduced.

In Austria, the emergency drinking water supply is located at the intersection of water law and food law as a federal competence, disaster control as a state competence and services of general interest in the competence of the mayor [45]. None of the federal legislation has a clear mandate for the emergency supply of drinking water [45].

In 2017, the Austrian Association for Gas and Water (ÖVGW) updated the standard w 74 [45], which gives detailed recommendations for water suppliers for crisis situations and specifies consumption values for drinking water quality in case of a drinking water emergency. The quantitative minimum supply standards mentioned in the standard w 74 are based on the minimum supply standards published in the Sphere Project and in the WHO.

A comparison of the current legal framework with regard to the determination of quantitative and qualitative minimum supply standards shows significant differences for emergency preparedness planning in the two countries 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 [44,45] that should be maintained in case of an emergency situation (see Table 2). They are meant to meet quantities of clean water for basic survival and include not only drinking water but also water for cooking and hygiene. With 7.5–15 L [36,41,53], the Sphere Standards and the Austrian standards are lower but still on a similar level as German standards with 15 L per capita per day [43]. In both countries, inhabitants are expected to complement the emergency water supplies with their own stored drinking water. According to the German Concept for Civil Defence [44] and Austrian standard w 74 [45], people should store 10 L per capita at home as a permanent self-supply of drinking water. However, doubts remain to what extent the population stockpiles drinking water in reality.

Minimum standards for water supply in hospitals are strikingly different. Whereas the guidelines in Austria [45] are in line with the Sphere standards with 40–60 L per in-patient per day [36,41], the minimum supply standards in Germany require at least 75 L per in-patient per day in hospitals and care facilities and up to 150 L per in-patient per day in intensive medical care facilities [43,44]. The German Concept for Civil Defence [44] adapts the minimum supply standards of the 1. WasSV [43], which were defined almost 50 years ago, with different boundary conditions and different technical equipment available. Consequently, the rationale behind the German minimum standards for water supply in hospitals cannot be retraced.

For Germany, specifications on the minimum water quantities for grid-bound emergency water supply can be found in the "Civil Defence Concept" [44] published in 2016. Here (see Table 2) a minimum water quantity of 50 L per person and day is specified. In Austria are no specifications in the revised document of the w 74 for a grid-bound-emergency supply.

In 2015, the qualitative minimum supply standards for emergency supply in Germany were specified and revised, assuming a consumption of water for 30 days and two liters per capita per day [59]. A maximum consumption of 30 days are the basis for the minimum water quality requirements in Austria as well [45]. Requirements for the quality to be provided for the emergency supply can be found in Table 4. For comparison, the requirements from Germany and Austria are listed for the supply during normal operation. Under normal operation, the specifications are identical for most of the parameters (e.g., chrome) and different for other parameters (e.g., nitrite). The minimum quality supply standards for emergency water supply vary for all of the shown parameters in both countries depending on the examined parameter. Hence, no clear trend referring to strictness or tolerance can be observed, although both countries have to fulfill the European standards. The differing standards reflect the status of the risk assessment regarding emergency water supply in both countries.

The results of this paper are summarized in Figure 1. Global frameworks show the need for water supply under all conditions as the Post-2015-Agenda focuses both on normal supply and resilience of the engineered infrastructure. Normal and emergency supply are addressed superficially in international and national guidance. However, the emergency water supply standards are mostly rooted in humanitarian literature (e.g., [36,40,41]). An adaptation of standards to local conditions rarely occurs. Consequently, transboundary emergency preparedness is complicated due to different minimum standards in neighboring countries.

**Table 4.** Extract of differences in relevant qualitative minimum supply standards in Germany and Austria under normal and emergency conditions.

| | **Germany** | | **Austria** | |
|---|---|---|---|---|
| **Source** | [57] | [59] | [57] | [45] |
| **Applies to** | normal supply | emergency situations | normal supply | emergency situations |
| **Chemical parameter** | mg/L | mg/L | mg/L | mg/L |
| **Cadmium** | 0.003 | 0.38 | 0.005 | 0.005 |
| **Chrome** | 0.05 | 2.3 | 0.05 | 0.05 |
| **Cyanide** | 0.05 | 1.9 | 0.05 | 0.1 |
| **Manganese** | 0.05 | 0.2 | 0.05 | 0.5 |
| **Nitrate** | 50 | 50 | 50 | 100 |
| **Nitrite** | 0.50 | 3 | 0.1 | 0.5 |
| **Mercury** | 0.001 | 0.06 | 0.001 | 0.004 |
| **Sulfate** | 250 | 500 | 250 | 250 |

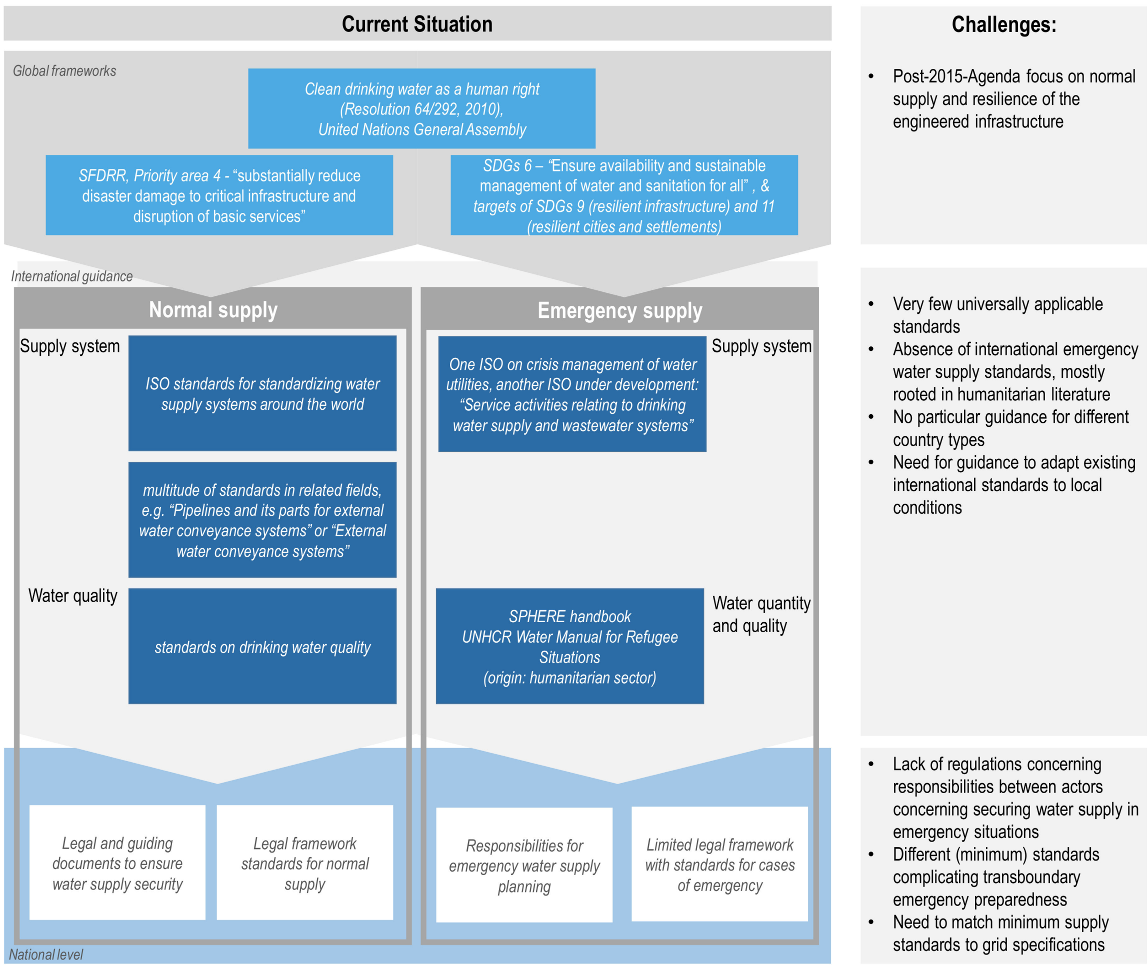


**Figure 1.** Summary of the findings of this paper.

## 5. Discussion

Considering the results of the previous chapters (summarized in Figure 1), this paper argues that countries with a high water supply reliability need to conduct extensive precautionary emergency planning. As one element of critical infrastructure, the loss of central water supply due to a power outage or natural disaster cannot be completely excluded. It requires a fast and well-planned response including procurement and use of technical and human resources in order to reduce severe negative impacts on society. The high water supply standard leads to a low risk awareness regarding disruptions or failures and a high dependency on a permanent water supply.

In countries or areas where the water supply reliability is high under normal conditions, both population and industry are highly dependent on the supply via the central supply system. This holds true for many high-income countries such as Germany, where inhabitants, as well as industry, are characterized by a strong dependency on a permanent water supply through existing infrastructures. A comparably low risk awareness regarding disruptions of water supply, leading to ad hoc reactions instead of planned emergency water supply measures if emergency situations with water supply disruptions or failures occur [60]. In addition, the high complexity and connectivity of the existing water supply systems with other infrastructures increases the risk for cascading impacts in case of water supply disruptions. Overall it can be stated that the permanent availability of water supply represents a paradox of vulnerability, which highlights the necessity for targeted emergency preparedness planning. Only through precautionary planning and the subsequent availability of technical equipment, can the chaotic conditions within a disaster-affected area be controlled [17,19,61].

The dependency on water supply reliability becomes even more relevant in the face of newly developing hazards, such as extreme climate events or terrorism. Hence, there is a need for well-guided risk management and emergency water supply planning, which, according to the review results, is currently not adequately established. According to the proposal of the EU drinking water directive [40] a comprehensive risk-based approach should be adopted which should also imply the consideration of extreme events, e.g., natural disasters like flooding or draught, and the consequential preventive planning of emergency water supply measures [42,62]. To support water supply in risk and crisis management planning, in some countries, for example Germany and Austria, codes of conduct based on EN 15975-1 [55] and EN 15975-2 [56] have been developed and implemented.

Furthermore, the comparison of minimum supply standards in Germany and Austria exemplifies the diversity of water requirements in high-income countries. Despite similar context conditions, both countries show differences in emergency preparedness planning. This means that cross-border events may raise additional challenges. In a crisis event in a border region between Germany and Austria (similar to the described flood in Simbach am Inn) the difference in quantitative and qualitative minimum supply standards could cause difficulties in the emergency planning process and crisis management. As an example, hospitals in Austria have to supply their patients with approximately 50% of the water volume of hospitals in Germany under specific consideration of differing quality requirements. Consequently, there is a need for uniform minimum supply standards for comparable systems. Since most of the publications worldwide on emergency water supply were published a long time ago (1981–1994) or focus on a different aspect, minimum standards have to be adapted to country categories or even more detailed to critical infrastructure sectors in countries. This gap remains unaddressed today, probably due to a lack of research and risk awareness, as well as risk management.

Thus, a need for action in the area of planning and implementation of measures for emergency water supply can be identified involving different stakeholders. Necessary steps and processes for improved emergency water supply planning to be addressed by water utilities, as well as national and public authorities, are recommended in the following paragraphs.

The responsible institutions, therefore, need uniform, detailed, transnational standards, guidelines and recommendations for planning the preparation and implementation of emergency water supply measures. The minimum standards defined by the Sphere Handbook seem to be well applicable in emergency situations in low and lower-middle income countries. For high-income countries, they should, however, be further analyzed as the given minimum water amounts would only ensure the supply of around 1/6 of normal daily water consumption in for instance European countries. Grid-based emergency water supply can only be operated with a system-dependent minimum amount of water. Since the determination of the water demand is the basis for emergency supply, the boundary conditions of the respective countries and regions should be taken into account. It is, therefore, necessary to comply with the proposed minimum supply standards [40,41] with regard to demographics (age, gender), socio-cultural aspects, as well as the type and phase of an emergency (acute vs. post emergency) [41] to the existing framework conditions. Standards can, or must, be country-specific and considering the different legal requirements. However, standards should be communicated among neighboring countries to ensure effective measures for cross-border emergencies.

In high-income countries, grid-based supply must be the prioritized option. The grid-bound supply is hygienically safer than the grid-independent water supply. Currently available standards and documents are mainly concerned with the grid-independent supply (e.g., supply with emergency wells in Germany). If possible, the grid-based water supply should be maintained, even if the water is not of drinking water quality. In this way, wastewater disposal can be maintained and the safe disposal of faeces can be guaranteed. A combination of grid-bound and grid-independent supply can be applied if the grid-bound supply cannot be maintained for all consumers. The logistical effort for both grid-based and grid-independent water supply needs to be considered. To optimize the costs and efforts for emergency water supply, further research in the field of emergency logistics is needed. However, in order to protect the existing infrastructure, grid-bound supply types must be prioritized.

Validated methods to determine the grid-bound, as well as grid-independent emergency water demand, are currently missing. Differentiated consumer specific water demand must be determined for the total water demand in an emergency. This applies to grid-bound and grid-independent supply. The current assessment of water demand in emergencies is predominately based on rough estimates, which diverge regarding the mentioned quantities of drinking water as well as for other water needs [46]. Water demand assessment under normal conditions is based on average supply needs calculated as means from the water consumption of numerous consumer groups. Using the example of Germany, water consumption per capita can be disaggregated by types of usage such as water used for drinking and cooking, hygiene and house cleaning. Additionally, it is differentiated regarding different user groups or peak times. In order to facilitate the planning of needed grid-bound emergency water supply, assessments should be carried out with more detail. There is a need for research in the area of the consumer-specific determination of the water demand for grid-bound and grid-independent supply in emergencies.

A system-dependent minimum water volume is necessary for the operation of the grid-bound supply in order to avoid hygienic problems, occurring due to the entry of impurities, negative pressure, as well as a difference between the water demand and the amount of water fed into the system. This volume depends on various factors such as the structure of the supply network, the supply pressure or the possibility of temporary separation of partial areas. In order to determine the quantity of water depending on which disturbances occur (e.g., air in pipes, negative pressure), hydraulic pipe network modeling needs to be carried out for the supply network under consideration. There is a need for research in the area of the system-dependent water demand for grid-bound supply in emergencies.

Emergency planning must take into account the quantity and quality requirements. The abstraction, treatment, transport, storage and distribution of drinking water is subject to strict regulations to protect health and prevent the occurrence and spread of communicable diseases. The legal framework for the supply of water focuses primarily on the quality of the water to be maintained. Minimum quantities for the normal case are rarely shown. In contrast, the few existing framework conditions for emergency water supply provide minimum quantities but they rarely define quality criteria for the emergency water supply. However, especially the supply of vulnerable consumers (e.g., public health infrastructure) must meet certain minimum quality criteria. According to Clarke et al. [63], Adams [64], Dorea [52], and Smith and Reed [65], the quality and quantity requirements should be prioritized as follows. The supply of water in the shortest possible time is the first priority [66], followed by the provision of the minimum daily quantity of water required. Additionally, the durability and reliability of the water supply should be aimed at. If these criteria are fulfilled, the quality and cost of water supply should be considered [63]. Therefore, in general, the provision of a larger quantity of water with relatively good (safe) quality is better than to provide a small quantity of water of very high quality [66]. Consequently, the emergency water supply planning needs to consider minimum supply standards regarding the quantity and quality of the water.

## 6. Conclusions

The disruption of water supply is a major challenge for all countries and especially those that rarely experience failures face a high risk of disastrous consequences due to their low-risk awareness and high dependency. However, since the effects of hazards depend, among other things, on the existing infrastructure, the way in which facilities in high-income countries (which tend to have a reliable, centralized supply) prepare for and manage incidents differs from countries with a more decentralized water supply system. The evaluation of existing policy frameworks, guidelines and scientific publications on a global and European level, as well as for the selected countries Austria and Germany, shows that there is a need for comprehensive action.

Existing planning and legal frameworks are based on guidelines for the establishment of refugee camps [8] or from humanitarian aid for disasters [9–11] with different framework conditions. There is a lack of methods for determining the parameters, especially the minimum water quantity, for planning the emergency water supply for water supply systems with a high degree of reliability in normal cases.

Legal frameworks and standards regulating emergency water supply are largely lacking in high-income countries where global minimum standards are hardly applicable. Further research is needed to assess the heterogeneous water needs of populations and institutions. In addition, a method to determine the emergency water demand and an assessment of realistic technical options to guarantee a minimum water supply in emergency situations have to be established. Such research can represent a valuable and sound source for the development of standards and/or a legal basis for emergency water supply guidelines. Such standards need to include quantity and quality requirements with regard to demographics, socio-cultural aspects and different phases of emergencies, as well as consideration of grid-based and grid-independent emergency supply requirements. In order to be useful for water utilities and other stakeholders, the standards need to be uniform, detailed, and transnational.

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