Drinking-Water Access and Health in Refugee Camps

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Abstract
Drinking-water deprivation in terms of access, quantity, and quality poses serious health hazards both in the short and long term. This is especially critical in refugee chronic situations that last for decades, such as the Saharawi refugee camps (>40 years). Water access and water quantity improves health, as water is not only needed for direct consumption or cooking but also for hygiene, directly related to health. On the other hand, water quality avoids not only gastrointestinal diseases in the short term, but also other health issues that appear under a long-term exposure. This chapter reviews the history of drinking water and health at the Saharawi refugee camps, showing how water access has improved over the years but still does not guarantee the minimum quantity of 20 l/person/day established by the United Nations High Commissioner for the Refugees (UNHCR). It also shows how water treatment using chlorination has reduced dramatically the diseases associated to microbiological contamination, and how the poor raw water quality that a percentage of the population is still consuming has produced long-term health effects, such as the prevalence of fluorosis and goiter.

Keywords
Refugee camps · Protracted · Drinking water · Access · Quantity · Quality · Health risk · Microbiology · Diarrhea · Nitrate · Blue-baby syndrome · Fluoride · Dental fluorosis · Iodine · Goiter

List of Abbreviations

NGO	Nongovernmental organization
SPHERE	Sphere Humanitarian Charter and Minimum Standards in Disaster Response
UNHCR	United Nations High Commissioner for the Refugees
UNRWA	United Nations Relief and Works Agency
WFP	World Food Programme
WHO	World Health Organization

Introduction: Water and Health

Why drinking water when talking on starvation or nutrient deprivation? Although discussing on nutrition issues is often directly related to food income, water should be always considered as one of the main sources of nutrients in any nutritional study. As the United Nations High Commissioner for the Refugees (UNHCR) states, “Water is one of the main nutrients, along with fat, protein, carbohydrates, and micronutrients, that the human body needs on daily basis” (UNHCR 2016a). Water is needed for food preparation; therefore, safe drinking water is essential as otherwise it can cause diarrhea, producing loss of nutrients that results in malnutrition. This is especially dangerous for children under five as malnutrition contributes to almost 60% of deaths of this fragile population (UNHCR 1992).

But not only microbial safety is one of the main required characteristics of drinking water, there are also physicochemical requirements to guarantee water safety. Water quality includes also a series of micronutrients that can affect health, by absence or excess, and both are equally risky. Some examples are nitrate presence, fluoride, or iodine, which will be explained further in the next sections. And while microbiological contamination produces short-term health effects, causing diarrhea almost immediately, most of physicochemical components will only show their effects after several years of exposure (long-term effect), which is especially risky in some refugee situations that last for long periods of time (decades).

Finally, the other main challenge is to provide sufficient water quantity to the population, which is not only related to the amount of safe water available for drinking and/or cooking, but to other uses such as hygiene (personal washing, household cleaning) and sanitation, which are directly associated to health benefits. How to decide how much water is needed? In the past, organizations and relief agencies used to have different criteria till the development of the SPHERE Project (The Sphere Project 2011), which defines the minimum requirements for water quality and quantity, along with water access, for emergencies situations. In this line, UNHCR adapted these standards for refugee situations (UNHCR 2017), considering that refugees might stay longer in a camp that an "emergency situation" (Table 1). A minimum of 20 l/person/day of water is established, along with no microbiological contamination and a minimum of 0.2 mg/l of free residual chlorine to ensure water safety.

Guaranteeing drinking-water access at refugee camps is actually a worldwide challenge, especially in situations where the resources are scarce, and also in cases of

Table 1 Water guidelines for refugee situations. Guidelines on water minimum standards for refugee populations defined by the United Nations High Commissioner for the Refugees (UNHCR) (and comparison with the Sphere Humanitarian Charter and Minimum Standards in Disaster Response (SPHERE) Project for emergencies), including water quantity, quality, and access

Parameters	Standard	UNHCR (refugee camps)	SPHERE (emergencies)
Water quantity – basic needs for health and well-being	Average quantity of water available per person/day	>20 l	>15 l
	Water containers per household (average of 5 members)	1×20 l, 2 × 10 l, 2 × 5 l	2 of 10–20 l
Water quality – prevention of health risk	Number of fecal coliform organisms at distribution point (microbiological content)	0 per 100 ml of treated water	0 per 100 ml of treated water
	Free chlorine residual concentration in disinfected water	0.2–0.5 mg/l	0.5 mg/l
Water access	Distance from farthest dwelling to water point	<200 m	<500 m
	Number of persons in each water point	80 to 100/tap 200 to 300/hand pump/well	250/ tap500/hand pump 400/ well

chronic crisis, the "protracted refugee" situations (Loescher et al. 2008; UNHCR 2009). According to UNHCR, "6.7 million refugees were in a protracted situation by the end of 2015," plus 5.2 million Palestinian registered with the UNRWA, about 12 million in total (UNHCR 2016b). Among the longest refugee camps, there are the Palestinian population in Gaza, Jordan, Lebanon, and the West Bank (1948, >65 years), the Sudanese in Ethiopia (since 1950), the Burundians in Tanzania (1971) and the Saharawi camps in Algeria (1975, >40 years). In these long-term cases, the effects on health from an inadequate nutritional intake, including an appropriate drinking-water source, are always more serious, not only because of the long-term effects of malnutrition, but also because the population keeps depending on international external assistance for fulfilling their basic needs, for an indefinite period of time, staying in a "limbo" situation.

This chapter reviews the case of the Saharawi refugee camps in Algeria, describing their challenges for a clean drinking water source, and the health effects that the deprivation of safe drinking water has produced in the refugee population since the early days of the camps.

Drinking-Water Access at the Saharawi Refugee Camps

Saharawi refugee population from Western Sahara is one of the "forgotten" international conflicts that remain in a protracted situation. After 40 years, there are still about 165,000 refugees – according to local authorities and the estimations of the Government of Algeria – that live under the harsh conditions of the Sahara desert, with very limited access to basic needs, including those related to health, energy, and water. Meanwhile, there has not been any significant advance in the peaceful political conflict resolution and most of the refugee population still live in very precarious conditions.

The refugee camps were established in 1975 in the initial stages of the international conflict in Western Sahara. At present, they are composed by one institutional center (Rabouni) that comprises the administrations, and five refugee camps located near Tindouf (Algeria). These refugee camps are divided into five "wilayas" (Fig. 1): El Aiun, Awserd, Smara, Dahkla, and Boujador (Boujador is near Rabouni, not shown in the Figure). Each wilaya is organized in smaller communities called "dairas." Most of the population live in tents ("jaimas") or rudimentary houses made of adobe, made with a mixture of sand and water ("mud-houses"), with no direct access to water neither electricity (Fig. 2).

Drinking-water access has been one of the main concerns since early days of the refugee situation, starting with "survival" emergency shallow handmade wells, then building deep groundwater wells, and finally incorporating water treatment using reverse osmosis and/or chlorination; 100% water supply in terms of quantity and quality has not yet been achieved. This evolution corresponds to the natural change from an initial "temporary" settlement (emergency) to a more permanent one (prolonged crisis). Three stages on the water supply access can be differentiated (Fig. 3):

Fig. 1 Situation of the Saharawi refugee camps. Map of Western Sahara (UNHCR 2006) and detail of the Saharawi camps area, showing the different wilayas. Data are from UNHCR (2006), with permission from Publishers

Fig. 2 Overview of Saharawi refugee camps. Overview of the Saharawi refugee camps. Tents and adobe houses constitute the dwellings of most of the population. Picture is from the authors

Stage I (1975–1993) – Shallow Groundwater Wells

In 1975, the drinking-water supply was set up as an "emergency" solution to the Saharawi population that fled the Western Sahara region to Algeria. It consisted of traditional handmade shallow groundwater wells and superficial ponds dug at El Aiun and Dakhla. They supply 75% of the population, up to 20 l/person/day, which is above the minimum standard given by the Sphere Project (15 l/person/day) (The Sphere Project 2011) or the WHO (WHO 2011a) for emergency situations. Water quality was originally good, although contamination was a main risk and water quantity was seriously limited.

Stage II (1994–1999) – Deeper Groundwater Wells

In 1994, after already almost 20 years of settlement without any significant evolution in the water supply access, unusual strong rains caused devastating floods that contaminated the shallow wells mainly due to the lack of a sanitation system in the camps, originating a cholera epidemic at El Aiun. This led to a considerable change in the water supply as the shallow wells were no longer a safe solution.

Deeper groundwater wells of about 100 m with automatic pumping were created followed by a chlorination stage (only microbiological treatment). Water supply was centralized in these new wells rather than in the immediate vicinity of the households as for the previous traditional wells, and then water distribution was operated by tanker trucks to the different camps. Another important aspect was the introduction of the first water microbiological analysis from that moment onwards (*E.coli* and total coliforms analysis). These improvements guaranteed safer drinking-water access, but the available water quantity per person decreased dramatically to

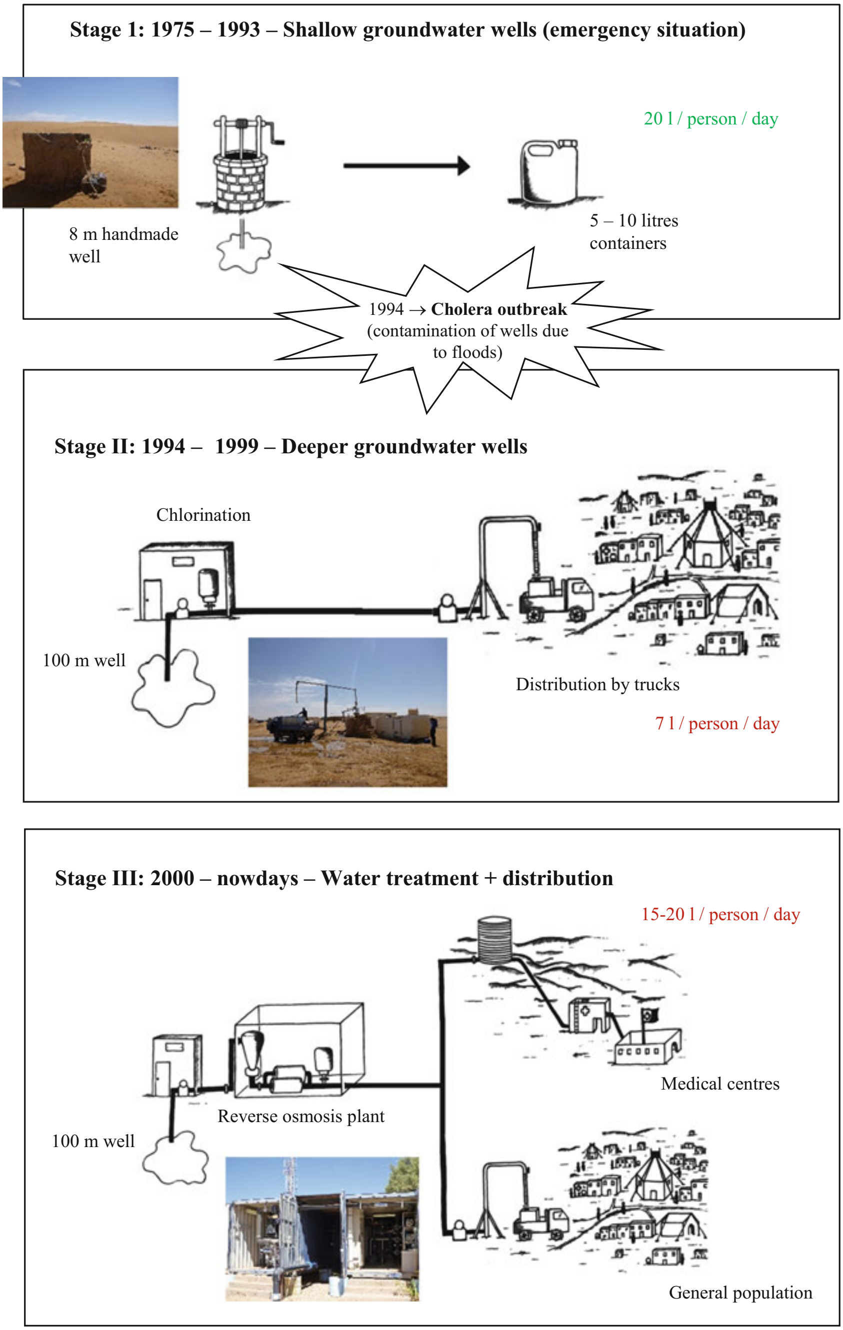

Fig. 3 Water access at the Saharawi camps over time (1975–2016). Different stages and the water supply access characteristics of each of them: a) Stage I (1975–1993): shallow 5–8 m deep hand-made wells, b) Stage II: 1994–1999: deeper groundwater wells (~100 m) plus chlorination and

7 l/person/day, below the minimum standards of 15 l/person/day given by the Sphere Project. Simultaneously, the associated costs increased notably.

Stage III (2000–Currently) – Water Treatment and Distribution

After a more than 25 years in the camps, and with no significant advances in the resolution of the political conflict, the Saharawi authorities and UNHCR decided to further improve the current water supply facilities. The main improvements included: (a) raw water treatment using reverse osmosis, (b) water quality control (physicochemical and microbiological analyses), and (c) expansion of water distribution networks. Now, general drinking-water supply at the camps is organized in three zones that include one or several wilayas:

- *Zone 1: El Aiun, Awserd*. Water supply consists of groundwater wells and a reverse osmosis plant for both wilayas. The treated water quantity in the plant is not currently sufficient to supply continuously the population in these two wilayas so each wilaya receives treated water in turns of 20 days.
- *Zone 2*: *Smara, Rabouni, Boujador*. Groundwater wells and two reverse osmosis plants working alternately provide continuous treated water to the zone.
- *Zone 3*: *Dakhla*. This wilaya is located about 140 km far from the rest of the refugee camps, so it has a dedicated water supply which consists of a groundwater well followed only by a chlorination stage due to the good quality of the raw water.

Water Quantity and Health

The different uses of safe drinking water are directly linked to health effects on the population. First, the main use of water is for human consumption, which includes drinking and cooking. As stated by WHO and Kleiner (Kleiner 1999; WHO 2003a), "Water is a basic nutrient of the human body and is critical to human life. It supports the digestion of food, adsorption, transportation and use of nutrients, and the elimination of toxins and wastes from the body." The immediate consequence of not having access to an adequate quantity of safe drinking water is dehydration, which can cause diarrheas. As an indication established by WHO, the volumes of water required for maintaining hydration are of 2.2–2.9 l/day for adults and 1.0 l/day for children.

Regarding cooking, water is needed for the preparation of foodstuffs, and quantities can vary significantly depending on the diet, although a minimum water quantity must be always included to be able to prepare the basic food basket of a

Fig. 3 (continued) water distribution by trucks, c) Stage III: 2000 - nowadays: groundwater wells followed by reverse osmosis, wider water distribution including also medical centers. Data, drawings and pictures are from the authors

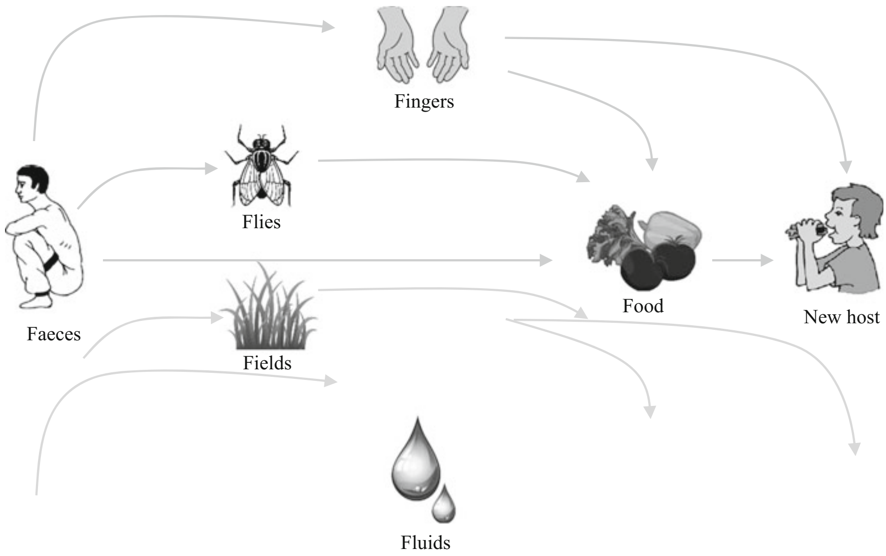

Fig. 4 Fecal-oral route for transmission of diseases, showing the importance of personal hygiene (requiring a sufficient quantity of safe water). Scheme from the authors

family. Additionally, it is important if the milk is provided as powder or not, as this would increase the required quantities of water.

The other important use of water that is related directly to the health status of a population is hygiene, including personal washing and domestic cleaning. Within personal washing, one critical aspect is handwashing, as an inadequate habit of handwashing can accelerate cases of diseases transmitted through the fecal-oral route (it is necessary to hand wash before eating and cooking and after defecation), such as diarrhea and skin and eye diseases (Fig. 4). In many developing regions, the main reason behind an inadequate personal hygiene is the lack of an appropriate quantity of water (WHO 2003a).

As defined by UNHCR, the minimum water quantity in a refugee situation should be at least 20 l/person/day. Recent data on the quantity of water supplied to the Saharawi people report that it is currently of about 15–17 l/person/day in all the settlements (below the UNHCR standard) excepting Dakhla that reaches 20–25 l/person/day (Vivar et al. 2016), although other sources (AECID 2015) report even lower quantities: 15–20 l/person/day in Dakhla, Smara, and Boujador and only 9–11 l/person/day in El Aiun and Awserd camps. UNHCR also reported in 2015 an average quantity of potable water distribution for the Saharawi refugees around 18 l/person/day (UNHCR 2015). In conclusion, the quantity of water provided to the population is currently insufficient and improvements on the service should be implemented to guarantee the minimum amount of water established by UNHCR.

Another important consideration regarding water quantity is the reliability of the service, or in other words, the water supply continuity. One of the problems of the

Fig. 5 Water distribution at the Saharawi camps . Example of water distribution network at the Saharawi camps: a) main water supply point in Dakhla using trucks for distribution to households; b) typical tent in the camps, with a water tank in the vicinity (in this case it is adequate for human consumption, vs. other tanks made of metal or other non-food grade materials). Photos from the authors

Saharawi water distribution system is that is based on trucks that transport the water to the different wilayas (Fig. 5). According to the latest reports, the condition of the fleet is not adequate and the trucks are in very poor condition, which often results in the fact that they are not able to adhere to the distribution calendar, producing shortcomings of water in the population (WFP and UNHCR 2013). Although in some cases the amount of water might reach the minimum requirements, often these quantities are not provided continuously, with periods of time with insufficient water to cover the basic needs.

Finally, the other important issue in the Saharawi camps is the variations of demand of water over the year. WFP and UNHCR conducted a survey in 2012 and found that the quantity of the water distributed during the winter (December–February) was considered sufficient to meet the needs of households, while in the summer months (June–August) the demands for water increased due to the high temperatures in the desert (>50 °C) and it was not sufficient (WFP and UNCHR 2013).

Water Quality and Health

Water quality is essential to guarantee a healthy status of any human being. An inadequate water quality has not only immediate effects on health (usually associated to gastrointestinal diseases), but the continuous consumption of water with inappropriate chemical content can origin other diseases in the long-term.

Short-Term Health Risks: Microbiological Content and Nitrates

In general, the effects of short-term ingestion of contaminated water are more widely known, as they produce rapid and acute effects on health such as watery diarrheas that often lead to death in developing countries (mainly due to the lack of safe water to prevent dehydration during diarrhea), especially in children under five. These gastrointestinal diseases transmitted by water might have their origin in the microbiological content of water: microorganisms that are pathogen for the human, such as bacteria, viruses, and protozoa. These microorganisms have their optimum growth temperature about 37 °C, which is the average normal human body temperature, so when they are in the human organism they can proliferate rapidly.

The most common bacteria related to fecal microbiological contamination of water (Fig. 4) are *Escherichia coli*, *Intestinal enterococci*, and *Clostridium perfringens*, which are used as indicators of water contamination. These bacteria are present in the normal intestinal flora of humans and animals, where they can live with no harm for the host. The problem arises when they enter in other parts of the body via ingestion of water where they can cause infections.

Another group of bacteria that is used as an indicator of water contamination after it has been disinfected is total coliform bacteria, which should be absent immediately after disinfection, so their presence indicates inadequate treatment or contamination problems in the distribution network.

Finally, one of the most common groups of bacteria in epidemics in developing countries associated with water contamination is *Vibrio*, with pathogenic species such as *V. cholerae*, producing cholera, with symptoms that include fulminating and severe watery diarrhea. To guarantee microbiological safety of water, WHO standards (WHO 2011a) indicate that the content in water of any of the *microbial indicators* must be *0 in 100 ml of water.*

There are also a number of chemical components that at high concentrations can produce immediate effects on the human body posing serious hazards. Despite the general understanding that inadequate physicochemical properties of water show their effects in the long term, there are chemicals such as nitrates (NO_3^-) that are especially dangerous for the infant population, for those being fed with artificial milk ("bottle-fed").The hazard appears when water from ground wells containing high concentration of nitrates is used for the preparation of milk. When the water is ingested by the infant, large quantities of nitrates are converted into nitrites (NO_2^-) that react with hemoglobin in the red blood cells and forms methaemoglobin, blocking the oxygen transport. It is commonly called the "blue baby syndrome" because of the blue-gray skin color. The disease can evolve rapidly causing coma and death if not treated adequately (WHO 2011b).

As today, the standard limit given by WHO is 50 mg/l of nitrates in drinking water.

Long-Term Health Risks: Fluoride and Iodine

Other chemical compounds that might be present in the water will show their health effects only after several years of exposure. These are long-term health risks and are especially relevant for the case of chronic humanitarian crisis. For the case of the Saharawi camps, the main chemical contaminants naturally present in water are fluoride and iodine:

- Fluoride

Fluoride (F^-) in high concentrations can appear in groundwater, usually in areas with naturally fluoride salts. While at low concentrations fluoride is used as protection against dental caries and it is added to toothpastes, gels, or even drinking-water, higher concentrations than >1.5 mg/l if ingested during years can lead to important diseases as dental fluorosis and skeletal fluorosis. Fluoride is absorbed by the bones, and with time it can increase the possibilities of bone fractures and produce chronic pain. Fluorosis in teeth in children usually produces a characteristic "mottled enamel" aspect that in some cases can cause physical damage to the teeth (WHO 2003b).

WHO standards for fluoride in water is 1.5 mg/l.

- Iodine

Although WHO does not establish a direct relationship between iodine in drinking water and associated health effects due to either deficiency or excess of iodine, it does give an indication of the total dietary requirement for adult humans, ranging from 80 to 150 μg/day. This number includes all the nutritional sources that compose the dietary intake, not only the drinking water, but in many parts of the world, the water is an important source of deficiency or excess of iodine, and it affects directly the total iodine daily ingestion. Iodine is an essential element for the synthesis of thyroid hormones and, in inadequate quantities, can lead to severe adverse effects on health, including hypo and hyperthyroidism, goiter, and neurological development.

Only the Chinese legislation establishes standard values to evaluate the iodine concentration in water: adequate (10–150 μg/l), inadequate (high iodine zone >150 μg/l), and iodine excess goiter zone (>300 μg/l) (Pichel and Vivar 2017).

Water Quality and Health at the Saharawi Camps (1991–2016)

The relationship between water quality and health at the Saharawi camps can only be understood following the evolution of water quality along the years and the water supply infrastructure improvements (section Drinking-Water Access at the Saharawi Refugee Camps). This is especially important when studying diseases with origin in long-term exposures to certain substances.

- Microbiological content

The main epidemic related to microbiological contamination of drinking water at the Saharawi camps is the cholera outbreak in 1994 after unexpected floods contaminated all the shallow groundwater wells. These wells were closed and water from deeper groundwater wells followed by a chlorination step was used from then onwards. Although there has not been any other report on problems associated to gastrointestinal diseases from unsafe water, recent data from 2016 (Fig. 6) show that

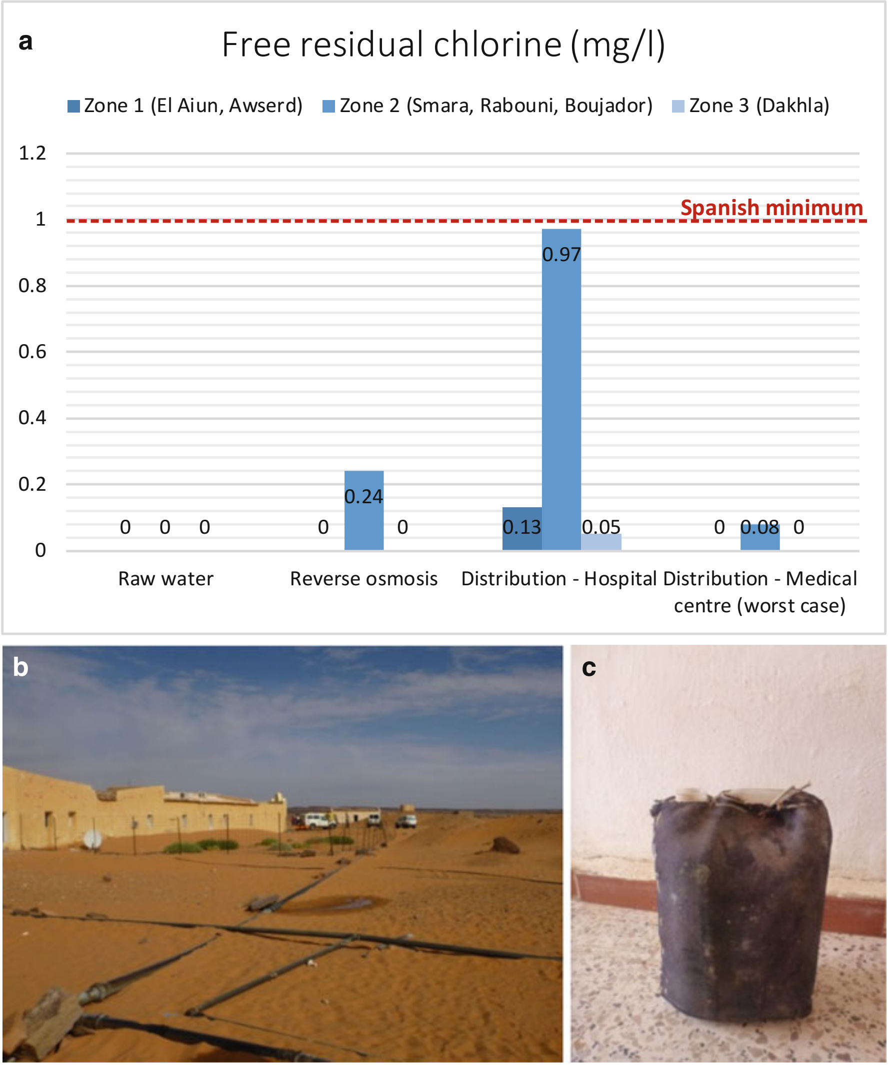

Fig. 6 Sources of microbiological contamination. (a) Free residual chlorine (mg/l) from sampling at different water supply and distribution points at the Saharawi refugee camps in 2015, (b) points of potential contamination due to failures in the distribution network; and (c) 10 l containers showing total coliforms contamination. Data and photos from the authors

the free residual chlorine levels in distribution points (tanks and taps sampled) do not reach the minimum values established by the Spanish legislation (Spanish RD140/2003 2003) neither by WHO guidelines, detecting total coliforms, especially in 10 l containers. Some distribution points also presented turbidities above 5 NTU, probably due to contamination in the distribution network, indicating potential microbiological contamination (Vivar et al. 2016).

- Nitrates

As of today, no published study has reported cases of blue-baby syndrome within the population of the Saharawi camps, but the reality is that nitrate levels have been high in the past, posing a health risk until the water started to be treated. On the other hand, maternal breastfeeding has been always promoted as the main lactation method for infants, thus reducing the use of water to prepare baby milk.

High levels of nitrates in water at the camps were first reported 2001 by Docampo (2006), and 3 years later, in 2004, another Spanish team (Docampo 2006) reported once again the same high levels of nitrates affecting the drinking water quality at El Aiun and Smara.

In 2007 two reverse osmosis plants were built in Smara, and several years later, in 2010, another reverse osmosis plant was commissioned to provide water to El Aiun and Awserd. As the raw water quality in Dakhla was adequate, only a chlorination stage was included as water treatment. These reverse osmosis plants reduced the high levels of nitrates. As of 2015, current nitrate levels (Fig. 7) in raw water in Smara were of 125.5 mg/l, decreasing to 15.9 mg/l after the osmosis. Smara water supply is the best regarding quality in distribution within the refugee camps, as it is always treated water from one of the two available reverse osmosis plants, vs. El

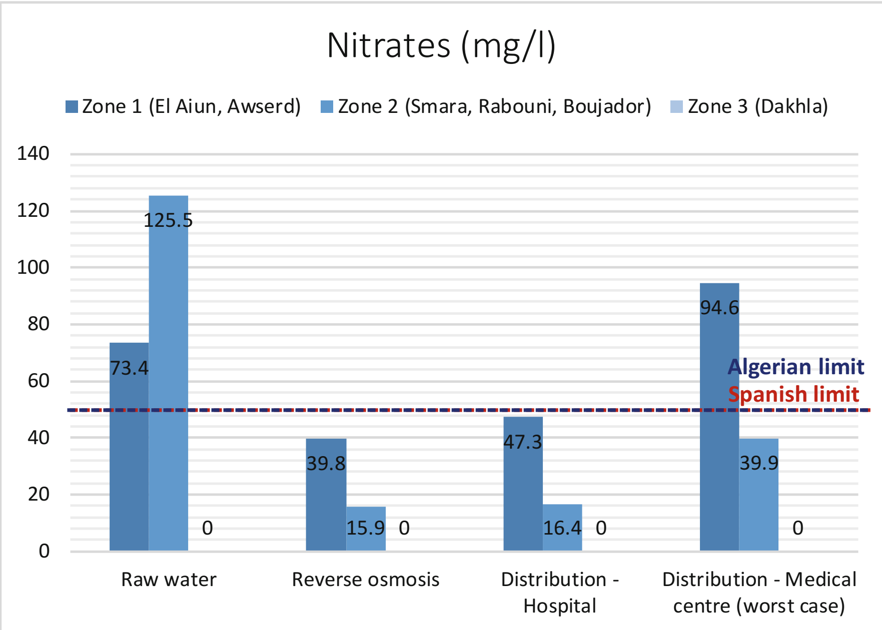

Fig. 7 Current levels of nitrates in Saharawi drinking water. Nitrate levels in water (mg/l) from sampling at different water supply and distribution points at the Saharawi refugee camps in 2015. Spanish and Algerian (Algeria 11–125 (2011)) legislation limits are shown as reference. Data are from the authors

Aiun and Awserd, which receive treated water only in turns of 20 days, receiving treated water and raw water directly alternatively. In this case, latest levels of nitrates in raw water are of 73.4 mg/l, well above the recommended limit of 50 mg/l given by WHO, posing a health risk for the infant population if bottle feeding is used. Finally, levels of nitrates in Dakhla are low, 8.88 mg/l, so there is no health risk associated (Vivar et al. 2016).

- Fluoride

Dental fluorosis can be directly observed nowadays in the population of El Aiun and Awserd in their brown spotted enamel, especially in those who have already been born in the refugee camps (young population) and have been exposed to fluoride since birth. The most detailed study on the dental status of the refugee children at the Saharawi camps is the conducted by Almerich-Silla et al. in 2008 (Almerich-Silla et al. 2008). They already associated the unbalanced diet, poor oral hygiene habits, and high concentration of fluoride in drinking water (~2 mg/l) to the current dental status. They worked with the refugee camps of Smara, El Aiun, and Awserd, and they observed that among the 6- to 7-year-old children, 36.9% were free of fluorosis, 15.6% presented moderate fluorosis, and 7.8% presented severe fluorosis. Among the 11- to 13-year-old children, only 4.2% were free of fluorosis, 30.2% exhibited moderate fluorosis, and 27.4% presented severe fluorosis. They also studied decayed permanent teeth and caries prevalence, and they concluded that these were higher on children affected with severe fluorosis, suggesting that it could increase the susceptibility to dental caries (Fig. 8).

Regarding fluoride content in water at the refugee camps over time, in 1991, Díaz-Cadórniga et al. (2003) reported already values of fluoride in water exceeding the recommended standard limit (1.5 mg/l) of 1.6 mg/l, which were reported again in 2000, ranging from 0.7 to 1.5 mg/l in the camps. In 2001, "Aguas de Sevilla" (Docampo 2006) conducted a more detailed water analysis at the camps, obtaining also high fluoride values at El Aiun and Smara (1.4 and 1.8 mg/l, respectively). Three years later, in 2003, another Spanish team (Docampo 2006) analyzed the water, reporting once again the same high values for fluorides in water at El Aiun and Smara.

Another study from the Norwegian College (Akershus University College 2008) in 2008 conducted a series of water analysis after the reverse osmosis at Smara was designed and set-up and their results reflected this improvement. While El Aiun continued to present high fluorides values, Smara water supply dramatically reduced them, from 1.8 mg/l to 0.16 mg/l.

Latest available data correspond to 2015, with the reverse osmosis plant of El Aiun and Awserd already in function. In this case, raw water quality still presents high values of fluorides (1.95 mg/l) that although are reduced to 0.23 mg/l after osmosis, still critical because the population uses this source of raw water as drinking water in turns of 20 days. On the other hand, despite the high values of raw water in Smara (1.8 mg/l), all the population in this camp receives treated water (0.12 mg/l), so no posing any health risk. Once again, Dakhla presents low values of fluorides (0.6 mg/l), not requiring any water treatment in this regard (Vivar et al. 2016).

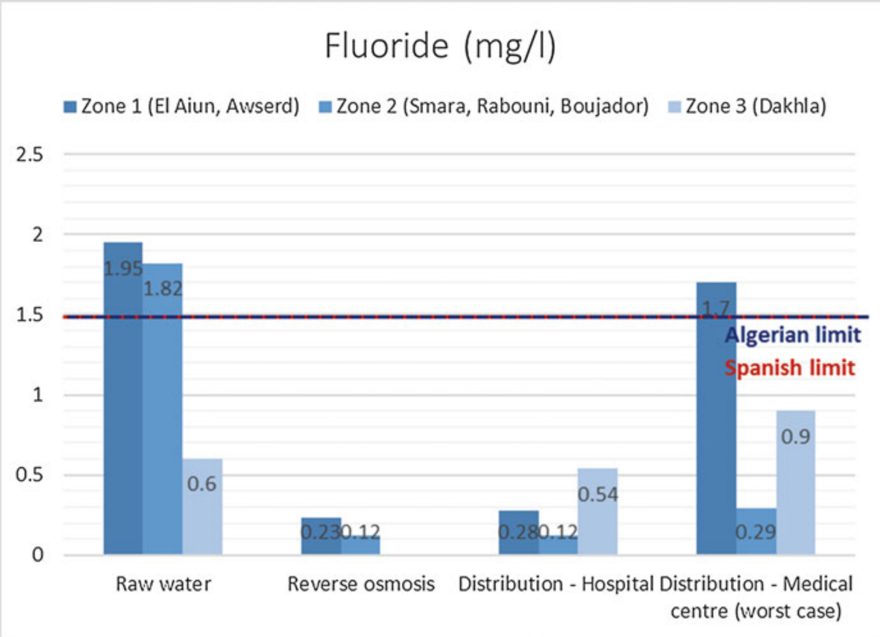

Fig. 8 Current levels of fluorides in Saharawi drinking water. Fluoride levels (mg/l) from sampling at different water supply and distribution points at the Saharawi refugee camps in 2015. Data are from the authors

- Iodine

The Saharawi refugee camps have been considered as an endemic goiter region (more than 5% of the individuals presenting goiter) since the first studies in the 1990s reported significative percentages of the population presenting goiter. For example, Prezzino et al. (1998) results showed 28% of a school children population with palpable goiter prevalence, and in the year 2000, Díaz-Cardóniga et al. (2003) reported even a higher value for goiter prevalence in the same age range population, 58%. Both studies associated prevalence of goiter with excess iodine in drinking water, with values up to 934 µg/l in El Aiun.

Another group of studies in 2007 by Henjum et al. (2010, 2011) and Barikmo et al. (2011) showed again high prevalence of goiter among school children (6- to 14-year-old) and women (15- to 45-year-old), with values of 11% and 18%, respectively. These studies also attributed excess iodine in the daily intake to drinking water, but also showed that iodine content in milk was very high (70–13,071 µg/l), so not only drinking water could be the cause of the excess iodine in the diet. Later studies by the same research group in 2007 and 2010 (Aakre et al. 2015a, b) on iodine and goiter at the camps reported also high prevalence of goiter and continued to associate it to drinking water, although iodine concentrations in water decreased to values of 80–254 μg/l on average in 2007, vs. iodine content in animal milk of 1175–2049 μg/l, much higher, up to 20 times. Water iodine concentration continued to decrease in 2010, with an average of only 58 μg/l, but the thyroid dysfunction diseases continued to be as high as 34.1% in the surveyed population.

Overall, the iodine concentration in drinking water was strongly reduced from the high average values of 638 μg/l in 1998 (corresponding to an endemic goiter region according to the Chinese legislation, >300 μg/l), to adequate levels of iodine in water in 2010, with values of only 58 μg/l.

Latest analysis conducted by Pichel and Vivar in 2015 and 2016 (Pichel and Vivar 2017) show only high iodine concentrations in raw water before the reverse osmosis plants at El Aiun and Smara, with concentrations of 193 μg/l and 357 μg/l, down to 81 μg/l and 95 μg/l after the water treatment. On the other hand, iodine content in drinking water in Dakhla was of 108 μg/l. Average iodine in drinking water in the camps ranged from 81 μg/l to 139 μg/l, considering that the values are higher for El Aiun and Awserd that receive treated water each 20 days. According to Chinese legislation, water iodine concentration below 150 μg/l would be adequate for human consumption. As a reference, this study also shows the iodine concentration in Madrid (Spain), in an area of adequate levels, reporting values of 66 μg/l for mineral water and 57 μg/l for tap water. Finally, the study concludes that although iodine excess seems to be the cause of prevalence of goiter in the Saharawi refugee camps and drinking water has been associated directly to this goiter since the first studies on the matter, it would be convenient to analyze the entire dietary intake of the population to detect other potential sources of iodine, especially after iodine content in water has been dramatically reduced in the last years and after animal milk has shown high values of iodine in the latter literature studies (Fig. 9).

Policies and Protocols

Water Guidelines on Access, Quality, and Quantity for Refugee Situations

In this chapter, the importance of water in refugee situations has been described along with the effect of unsafe water in the Saharawi population, both under short- and long-term exposure. Guidelines on water access have followed the recommendations given by UNHCR, guidelines and policies on water quantity (>20 l/person/day) have also followed UNHCR and WHO standards, and water quality in terms of microbiological (0 CFU/100 ml), nitrates (<50 mg/l), fluorides (<1.5 mg/l), and iodine content (<300 μg/l) have followed the WHO guidelines for drinking water as well as the Algerian and Spanish legislation. For the case of iodine, the Chinese legislation has been also considered.

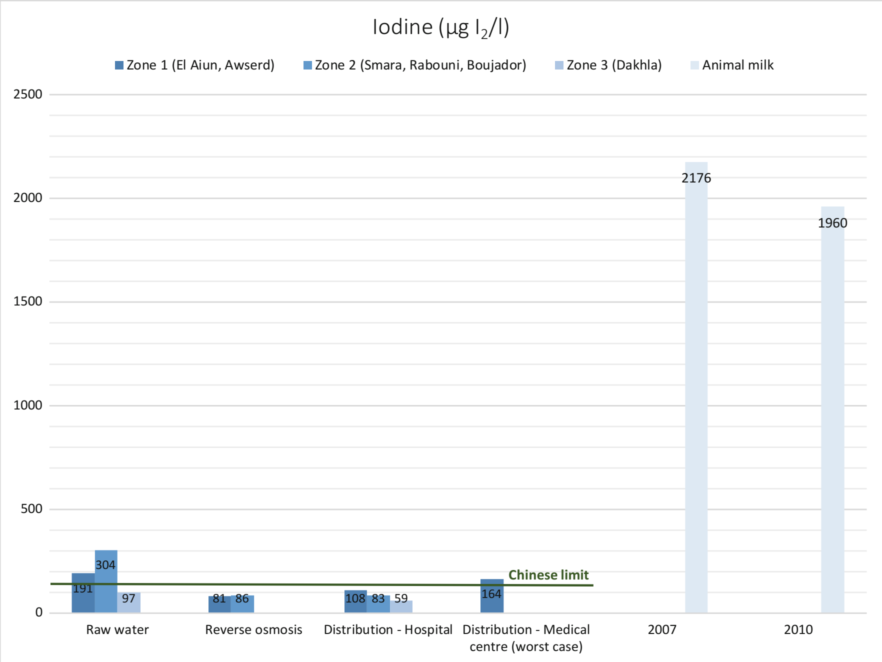

Fig. 9 Current levels of iodine in Saharawi drinking water and animal milk. Iodine levels (mg/l) from sampling at different water supply and distribution points at the Saharawi refugee camps in 2015. Iodine concentration in animal milk from the studies of 2007 and 2010 is shown as comparison and potential source of excess iodine. Data on water are from the authors, data on milk from referenced studies

Water Quality Analysis

Field-measured parameters included temperature and dissolved oxygen, pH, conductivity, and turbidity. Residual-free chlorine, total iodine, and fluoride were measured daily after sampling. Microbiological analyses were conducted using 3M Petrifilm plates with chromogenic *E.coli* and total coliforms culture medium, incubated 24 h at 37 °C. Quantification limit was of 1 CFU/ml.

At central laboratories in Spain, water samples were analyzed for different parameters according to the “Standard Methods for the Examination of Water and Wastewater” (APHA 2005): pH, conductivity and redox potential, alkalinity, total phosphorous, total nitrogen, organic content, major ions including chloride, nitrate, nitrite, phosphate, sulfate, fluoride, sodium, ammonium and potassium; and single elements such as iodine, chrome, manganese, iron, nickel, copper, arsenic, cadmium, lead, mercury, antimony, boron, aluminum, and selenium using ICP-MS (inductively coupled plasma mass spectrometer).

Dictionary of Terms

- **Blue-baby syndrome** – Disease that is common in babies under 3 months that have been ingesting water with high levels of nitrates, which react with the hemoglobin in the red blood cells and blocks the oxygen transport. It is called "blue baby syndrome" because of the blue-gray skin color.
- **Daira** – A smaller urban administrative area similar to a district or suburb. A wilaya can be composed of several dairas.
- **Fluorosis** – Fluoride that is present in drinking water is absorbed by the bones, and with time it can increase the possibilities of bone fractures and produce chronic pain.
- **Goiter** – Disease caused by a thyroid dysfunction, which causes the enlargement of the thyroid gland.
- **Protracted refugee situation** – Populations of at least 25,000 refugees who have lived in exile for at least 5 years in developing countries.
- **Wilaya** – An administrative region within the Saharawi urban organization, similar to a town.

Summary Points

- This chapter focuses on the relationship between deprivation of drinking water and health issues at the Saharawi refugee camps.
- The Saharawi refugee camps were established in 1975 and are one of the oldest chronic refugee crisis.
- Drinking-water deprivation in terms of access, quantity, and quality poses serious health hazards both in the short and long term.
- Water access at the camps has improved from the first emergency handmade wells to deep groundwater wells combined with water treatment via reverse osmosis.
- Water quantity is still insufficient in the camps, 18 l/person/day, below the minimum standard of 20 l/person/day established by the United Nations High Commissioner for the Refugees (UHNCR).
- Raw water quality has been an issue since early days at El Aiun, Awserd, and Smara, with high values of nitrates, fluorides, and iodine that pose a health risk.
- Currently, water treatment via reverse osmosis has reduced the hazards of raw drinking water, although El Aiun and Awserd still consume raw drinking-water in 20 days turns.
- These parameters have affected the population that after a long exposures how dental and skeletal fluorosis and goiter problems.
- Microbiological water content has been reduced since the cholera outbreak in 1994 when handmade wells were closed and chlorination water treatment was introduced.

- But the levels of residual-free chlorine at the distribution point and maintenance problems of the distribution networks still pose a health risk.
- It is necessary to extend the distribution of treated water with adequate quality for all the population and to increase the available water quantity in order to improve the refugees' health status.

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