Questionnaire survey on water consumption and preparedness for water outages at intensive care homes for the elderly in Japan

Masaki Sagehashi and Michihiro Akiba

ABSTRACT

The status of water consumption and preparedness for water outages at intensive care homes for the elderly (ICHE) in Japan was investigated by questionnaire. The ICHE is the nursing care facilities covered by public aid providing long-term care for the elderly in Japan. The daily water consumption per person admitted to the ICHE was estimated as 425 L (median) and the daily water consumption per admitted elderly person and the contributors (i.e., care staff and visitors) was estimated as 253 L (median). The question from the viewpoint of alternative water supply revealed a high rate of possessing water receiving tanks. In addition, the possession rate of personal wells was also clarified. High rates of drinking water storage and portable toilets were confirmed. From the viewpoint of action procedures, the rates of introduction of disaster training, disaster action manual, and mutual aid agreement in the event of a disaster with others, all of which took into consideration water outages, were also clarified. Furthermore, free written comments confirmed that many ICHE were concerned about toilet care in the event of an emergency.

Key words | emergency water supply, intensive care homes for the elderly, nationwide questionnaire in Japan, unit water consumption, water outage

Masaki Sagehashi (corresponding author)
Michihiro Akiba
National Institute of Public Health,
2-3-6 Minami, Wako, Saitama 351-0197
Japan
E-mail: *sagehashi.m.aa@niph.go.jp*

INTRODUCTION

A safe water supply plays an indispensable role in water, sanitation, and hygiene (WASH) health care activities. The aging of the population is an important consideration impinging on water supplies worldwide, and care of the elderly presents an increasingly urgent social challenge.

A number of studies have investigated water consumption in elderly care from various viewpoints, e.g., fluid consumption of the elderly (Chidester & Spangler 1997; Gaff *et al.* 2015), prevention of dehydration (Presse & Ferland 2010), and prevention of infectious diseases in bathing (Silk *et al.* 2013). In addition to the important findings of these analyses, data regarding routine water consumption – such as for daily toilet care, washing of clothes, and room cleaning – are also required for adequate planning. These data should account for lifestyle and other cultural differences among populations, as well as water consumption by the care workers themselves.

The Japanese population is classified as a super-aging society (Kido 2015). Thus, research in Japan can provide up-to-date data on water consumption in elderly care that would be useful in other countries with an aging society. Information regarding water consumption in daily life in Japan (Mae *et al.* 2003), as well as water consumption at specific facilities, such as hospitals (Mochizuki 1987), hotels (Tanaka *et al.* 2007), and schools (Nagano 2007), has been reported previously. However, there have been few studies regarding water consumption in elderly nursing care facilities, e.g., intensive care homes for the elderly

doi: 10.2166/aqua.2017.008

(ICHE), which is covered by Public Aid Providing Long-Term Care to the Elderly (Ogata *et al.* 2015). The Japan Sustainable Building Consortium has developed a Database for Energy Consumption of Commercial Buildings (Takaguchi *et al.* 2012; JSBC 2014). This database includes information regarding water consumption in various types of buildings. Several studies related to this database clarified the water consumption in welfare facilities (Takaguchi *et al.* 2009, 2010), and also in ICHE (Sugawara *et al.* 2009) per unit area of floor space was elucidated. In the case of ICHE, however, further detailed analyses will be needed to clarify the water consumption per admitted elderly subject. In a previous study, we clarified the water consumption in two types of elderly care facility in Tokyo (Sagehashi & Akiba 2014). To our knowledge, however, there have been no investigations into the water consumption per elderly admittee in ICHE throughout Japan. We should note that Sugawara *et al.* (2009) did report the water consumption per unit area of floor space for an ICHE in the Tohoku region of Japan.

The provision of an emergency water supply in the event of a disaster is another important factor in terms of WASH in health care facilities. Individuals in health care facilities are particularly vulnerable in the event of disasters or other emergency situations, such as contamination events, and lifeline outages can be fatal in such populations. The provision of safe drinking water in the event of a disaster is thus a top priority (Loo *et al.* 2012). In fact, the necessity for development of an emergency water supply plan (EWSP) at health care facilities has been pointed out (CDC & AWWA 2012). Finally, it is important to consider in this context that the elderly are vulnerable to waterborne diseases (Naumova *et al.* 2003). In this study, therefore, we focused on emergency water supply for the elderly, as well as on elucidation of the water consumption in elderly care facilities.

Among the world's nations, Japan has one of the highest levels of risk from natural hazard exposure (Welle *et al.* 2014). Various natural events have had a major impact on the elderly in Japan, including the Great East Japan Earthquake of March 11, 2011. Indeed, this earthquake highlighted the vulnerability of the elderly in temporary shelters (Nomura *et al.* 2013). As a result of this history, Japan is at the forefront of discussions regarding support for the elderly – including the provision of emergency water supplies – in the event of disasters, and the investigations being conducted in this area should be of use at the global level.

The adaptability for water outages can be measured by the level of preparation of alternative water sources and procedures for emergencies, including the provision of training and emergency manuals. Planning for nursing home evacuation is also critical (Castle 2008). Moreover, many facilities in Japan have been designated welfare refuges, and thus it is important to assess the level of preparation for water outages at these refuge facilities.

To help in elucidating these issues, and to ensure EWSP in elderly care, we herein performed a nationwide questionnaire survey of elderly care facilities in Japan with a focus on the following items:

1. The amount of water required for care of the elderly.
2. The adaptability for emergencies involving water outages from the viewpoints of materials and procedures.
3. The status of water supply for the elderly in the case of an emergency.

METHODS

Target facility

There are several types of care facilities for the elderly in Japan. This study focuses on ICHE, which are a type of health care facility designed for elderly individuals who require high-level, long-term nursing care. The ICHE targeted in the questionnaire survey were selected based on a database provided by the WELNESS Co. (WELNESS 2011). A total of 5,878 facilities were selected based on the data as of April 2011.

Questionnaire

The questionnaire survey was conducted by regular mail. A questionnaire entitled 'Questionnaire Survey on the Thermal Environment and Water Use/Countermeasures for Water Outages in Intensive Care Homes for the Elderly' was mailed to ICHE in November 2013. Note that this survey was conducted in combination with a survey about the thermal environment of ICHE (Bando *et al.* 2014). The present analysis was focused only on the items related to the water supply, which are summarized in Table 1.

We previously performed a similar questionnaire (Sagehashi & Akiba 2014) in the Tokyo metropolitan area, whereas the current questionnaire was sent to ICHE located in all 47 prefectures of Japan, including Tokyo. In addition, the questionnaire used in the present analysis included more detailed items, which permitted more accurate analyses of the water consumption and the preparedness for water outages.

The monthly water consumption in July 2013 was taken from the water meter. To avoid seasonal differences, the target month was limited to July. In Japan, many waterworks require payment every two months; in such cases the value per month was determined, and this adjustment was noted. To confirm the month of the consumption period, the total period was also clarified. Some of the ICHE reported having two or more water supply methods. To account for these multiple sources, data were gathered for all of the suppliers and the amounts of water from each. In addition, in the case of multipurpose facilities, the specific water consumption for the ICHE was required.

The numbers of elderly admittees, working staff and visitors were determined. The unit water consumption per admitted person was the most important value in this study, and this value was also determined in a previous study performed in Tokyo (Sagehashi & Akiba 2014). Meanwhile, we would like to clarify the unit water consumption per person in an ICHE. That is why we determined the numbers of these people.

The types of water supply equipment used in each ICHE are important for understanding the temporary water-storage capacity in the case of an emergency. For example, some facilities possessed an elevated water tank that could maintain the water supply under conditions of water outage and electric power failure. The survey also asked about the possession of a private power generator, which is needed to power a pump if the stored water cannot be fed by gravity alone.

After a disaster, water stockpiles are important for coping with water outages in the short term. The questionnaire therefore asked about drinking-water stockpiles and the availability of portable toilets. If the water supply is

Table 1 | Questionnaire items analyzed in this study

#	Question item	Detailed description
1	Basic information	Prefecture Types of buildings/rooming arrangements, etc. Types of food services/baths and toilets, etc.
2	Monthly water consumption with its reference period (the value in July 2013 was required)	Types of water suppliers (i.e., public water supply, private water supply, others) and amount of water consumption. Consumption specifically by the ICHE was required. For multipurpose facilities or facilities for which the discrete ICHE data were not clear, allocation was estimated by the number of users or the dedicated area
3	Numbers of admitted persons, working staff, and visitors per day	Data were required specifically for the ICHE or ICHE portion of the multipurpose facility in July 2013
4	Types of water supply equipment used in the ICHE	Select from the following options: Water receiving tank/Elevated water tank/Direct connection (Combinations of these systems were expected) Maintenance condition of the tank, and the possession of a private power generator
5	Possession of alternative water supply	Water well and its potability/An emergency water supply station nearby
6	Stockpiles for water outages	Storing drinking water/Portable toilets
7	Training, manuals, mutual aid agreements, etc.	Disaster training with consideration for potential water outages/Mutual aid agreement in the event of a disaster with water outages/Disaster action manual with consideration for water outages/Assignation of the facility as a welfare refuge
8	Comments, experiences, etc. (free-text box)	Difficulties encountered during past water outages (if any) Anticipated difficulties in the event of a water outage Special points of consideration regarding the water supply for the elderly in the case of a disaster Other particular points

disrupted for a longer period, possession of an alternative water supply becomes important. The respondents were thus asked about the availability of a personal well and the presence of an emergency water supply station nearby. Potability and distance are also important factors for the well and water supply station, respectively, and were included in the questionnaire.

The implementation of training, preparation of a training manual, and mutual aid agreement with other facilities in the event of a disaster are effective for rapid countermeasures in an emergency situation. Accordingly, the questionnaire also elicited responses regarding the status of these factors.

Finally, a free-text box was provided to solicit any other relevant comments and experiences with regard to water outages in elderly care facilities. All the collected data were then analyzed and summarized to clarify what resources might be lacking in each ICHE in the case of a water outage.

ANALYSES

Water consumption

For calculation of the unit water consumption, responses were considered to be valid if they met all of the following criteria:

1. The information on water consumption was clearly described.
2. The information was representative of the values in July 2013.
3. The numbers of admitted, working, and visiting persons were clearly described.
4. ICHEs depended only on the public (prefectural or municipal) water supply.

The unit water consumption was calculated by the following equations:

$$Q_a = \frac{(q/31)}{n_a} \quad (1)$$

$$Q_c = \frac{(q/31)}{n_a + n_w + n_v} \quad (2)$$

where Q_a [L/(day person-admitted)] and Q_c [L/(day person-concerned)] are the unit water consumptions in a month by an admitted person and concerned person (i.e., admitted + workers + visitors), respectively; q [L] is the monthly water consumption (#2 in Table 1); and n_a, n_w, and n_v are the numbers of persons admitted, working, and visiting, respectively [person] (#3 in Table 1).

Countermeasures asked in the questionnaire

Any reservoir tanks, stockpiles, or alternative water supplies, and any relevant training measures were summarized. Moreover, some of these variables were summarized for each region in Japan in order to examine their potential regional dependencies.

Statistical analysis

Statistical analysis of the results was performed with Microsoft Office Excel 2010 (Microsoft Japan Co., Ltd, Tokyo, Japan) with the Excel-Toukei Bell Curve (Social Survey Research Information Co., Ltd, Tokyo, Japan) for the Mann–Whitney U test and Smirnov–Grubbs test, IBM SPSS Statistics (IBM Japan, Ltd, Tokyo, Japan) for the Kruskal–Wallis test and the chi-square method, and the multiplatform open source statistical computing software R (R Development Core Team 2005) for the bootstrap method.

Ethical considerations

This questionnaire survey was performed with the approval of the Ethics Committee of the National Institute of Public Health (NIPH-IBRA#12055 and #12101).

RESULTS AND DISCUSSION

Questionnaire response ratio

The numbers of sent questionnaires and responses are summarized in Table 2. The questionnaire sheet was sent to 5,878 facilities and 767 response sheets were obtained. The bulk response rate was therefore 13.0%.

Table 2 | Summary of questionnaires sent and returned

Region	Prefecture	Number sent	Number returned	Response rate
Hokkaido	Hokkaido	280	43	15.4
Tohoku	Aomori, Iwate, Akita, Miyagi, Yamagata, Fukushima	586	113	19.3
Kanto	Ibaraki, Tochigi, Gunma, Chiba, Kanagawa, Yamanashi, Saitama, Tokyo	1,479	166	11.2
Shinetsu/Hokuriku	Nagano, Fukui, Toyama, Ishikawa, Niigata	464	86	18.5
Tokai	Shizuoka, Aichi, Gifu, Mie	563	63	11.2
Kinki	Wakayama, Nara, Kyoto, Osaka, Hyogo, Shiga	928	103	11.1
Chugoku	Okayama, Tottori, Hiroshima, Shimane, Yamaguchi	478	60	12.6
Shikoku	Tokushima, Ehime, Kagawa, Kochi	274	34	12.4
Kyushu/Okinawa	Fukuoka, Saga, Nagasaki, Oita, Kumamoto, Miyazaki, Kagoshima, Okinawa	826	99	12.0
Total		5,878	767	13.0

Types of water supply

A total of 86.9% of the responding ICHE used the public (prefectural or municipal) water supply. In addition, among those using public water supplies, 73.7% (64.0% of the total responding ICHE) were supplied by 'waterworks' (large-scale water supply utilities providing water to more than 5,000 people), while 10.0% were supplied by 'simplified waterworks' (small-scale water supply utilities providing water to between 101 and 5,000 people). Although the effective response rate was low, 12.2% of the responding ICHE were using a private water supply; approximately half and a quarter of the ICHE in this category used wells and a private water supply facility, respectively. These values were equivalent to 6.0% and 3.4% of the total responding ICHE.

Water consumption

After screening the responses according to the above-described criteria, the numbers of responses that permitted the calculation of water consumption were 302 and 228 for Q_a and Q_c, respectively. On the other hand, because the values were written by hand, in some cases there were unusual values caused by human error that had to be eliminated to avoid statistical error. In the present study, Q_a and Q_c did not follow the normal distribution as judged by the histograms. The outliers were then eliminated by the Smirnov–Grubbs method with reference to $\ln(Q_a)$ and $\ln(Q_c)$. As a result, 10 and 9 of the outliers were eliminated from Q_a and Q_c, respectively, and the ranges of 85.6–1,420.1 L/(day person admitted) ($n = 292$) for Q_a, and 33.1–704.2. L/(day person admitted) ($n = 219$) for Q_c were obtained.

A comparison of these values with those in the literature is shown in Table 3. Our previous study (Sagehashi & Akiba 2014) indicated that the median value of Q_a in ICHE in Tokyo was 411 [L/(day person)], which was comparable to the results obtained in this study. The water consumption in daily life was comparable to Q_c, indicating that the water consumption per person (admittee, staff, or visitor) in the ICHE was the same as that in daily life in an apartment. Moreover, the Q_a in ICHE was roughly half that in hospitals on a per bed basis.

The water consumption per unit area of floor was calculated for comparison with the values in the literature. The samples used for the calculation of Q_a ($n = 292$) were used. The annual value was obtained by multiplying the monthly value by 12. Considering the effective answers, the number of samples was 262. The results indicated a median of 4.1 $m^3/(m^2$ year) and average of 4.7 $m^3/(m^2$ year). This median value was comparable to the value of 4.5 $m^3/(m^2$ year) reported for ICHE in the Tohoku region (Sugawara *et al.* 2009), but slightly higher than the value of 3.73 $m^3/(m^2$ year) for welfare facilities (Takaguchi *et al.* 2010). Sugawara *et al.* (2009) reported that the water consumption in ICHE was higher than that in other welfare facilities. These comparisons show the validity of this study.

Table 3 | Comparison of water consumption in the present study and the literature

Facility	Value	Unit	Details	Reference
ICHE	425 (407–449[a])	L/(day person admitted)	Median, $n = 292$; July 2013, throughout Japan	This study
ICHE	253 (238–265[a])	L/(day person concerned[b])	Median, $n = 219$; July 2013, throughout Japan	This study
ICHE	411	L/(day person admitted)	Median, $n = 13$; October 2012, Tokyo	Sagehashi & Akiba (2014)
Elderly welfare facilities	431	L/(day person admitted)	Median, $n = 19$; October 2012, Tokyo	Sagehashi & Akiba (2014)
Apartment house	100–411	L/(day house)	Single life, $n = 7$; January and July in 1993, Tokyo	Mae *et al.* (2003)
Hotel	672.6[c]	L/(day room)	City hotel, June–September 2005, Kyoto	Tanaka *et al.* (2007)
Hotel	307.8	m^3/(year room)	$n = 137$; Investigation in FY2008, throughout Japan (=843.2 L/(day room))	Okano *et al.* (2015)
Hospital	890	L/(day bed)	National Hospital, $n = 98$; Investigation in March 1986	Mochizuki (1987)
Hospital	407.9	L/(day bed)	Average, $n = 404$; Investigation in FY2008, throughout Japan	Okano *et al.* (2015)
ICHE	4.11 (median), 4.73 (average)	$m^3/(m^2$ year)	July 2013, $n = 262$; throughout Japan	This study
ICHE	4.5	$m^3/(m^2$ year)	Investigation in FY2007, 2008; Tohoku Region	Sugawara *et al.* (2009)
Welfare facilities	3.29	$m^3/(m^2$ year)	April 2007–March 2008; throughout Japan	Takaguchi *et al.* (2009)
Welfare facilities	3.73	$m^3/(m^2$ year)	April 2008–March 2009; throughout Japan	Takaguchi *et al.* (2010)

[a]95% confidence interval.
[b]Person concerned = admitted person + working staffs + visitors.
[c]Average stay = 1.732 (persons/(day room)).

In addition, Q_a and Q_c were summarized according to the region, and regional differences were examined by the Kruskal–Wallis test. The results confirmed regional differences for Q_a ($p < 0.05$) but not for Q_c ($p = 0.06$). The median values of Q_a and Q_c with confidence intervals for each region calculated by the bootstrap method are shown in Figure 1. Here, the results for Japan as a whole are also shown. The results indicate that Q_a was lower in Hokkaido, Tohoku, and Shikoku, but higher in the Kinki and Tokai regions. However, no such tendencies were observed in Q_c except for the Kinki region. Due to the limitations of the data, the reason for this difference is not clear, and further studies will be needed to confirm these particular findings.

It is important to determine the factors that strongly affect water consumption in elderly care, and there is a possibility that these factors were responsible for the variety of water consumption levels, including regional differences, observed in this study. The average household in Japan uses 28% of its total water consumptions for toilets, 24% for bathing, 23% for cooking, 16% for laundry, and 9% for other (MLIT 2014). Additional investigations targeting individual ICHE are needed to clarify the rates of water usage, but this is outside the scope of this study. In the present study, we limited our analysis to the effects of the type of ICHE on water consumption. Water consumption may be affected by the scale of the ICHE, care style, bathing style, food serving method, and the degree of nursing requirements. Here, we examined the dependency of Q_a on each of these factors; as summarized in Table 4, the results indicated that there were no significant differences in Q_a related to any of these factors. There was a slight trend toward a correlation between water consumption and the scale and bathing styles of the ICHE, but this relation was not statistically significant.

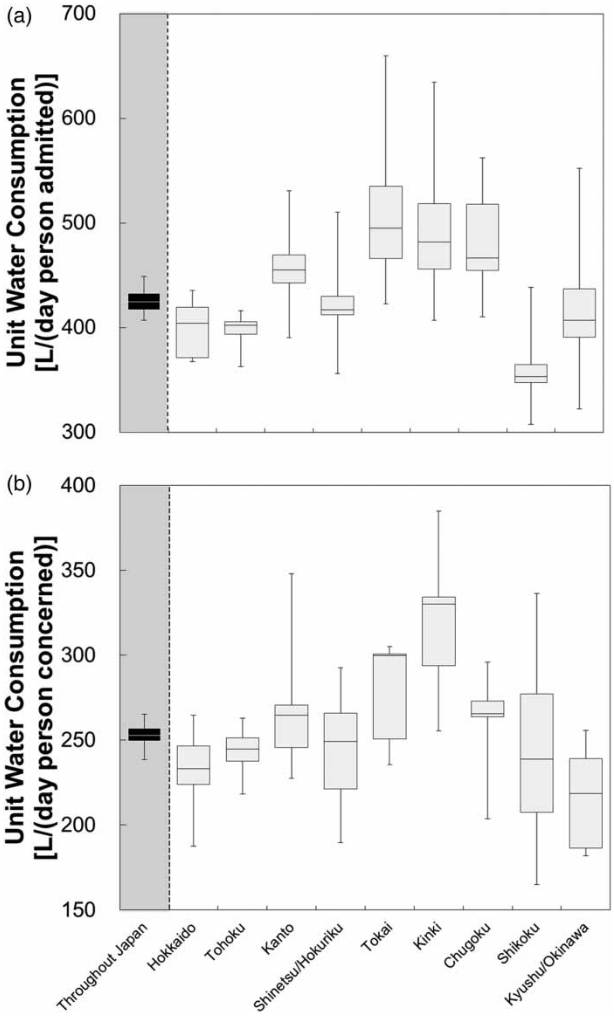

Figure 1 | Unit water consumption per person admitted (a) and concerned (b) in ICHE as estimated by the bootstrap method. Whiskers indicate the 2.5–97.5 percentile; boxes indicate the 25th–75th percentile; the line in each box indicates the median.

Potential water supply and sanitation in the case of an emergency

If an ICHE has a water receiving tank, a certain amount of water can be made available in the case of a water outage. In the case of elevated tanks, the water can be supplied by means of gravity alone. The effectiveness of a water receiving tank in the case of an earthquake has been reported (Suzuki *et al.* 2008).

The types of water supply equipment used in the ICHE are summarized in Figure 2(a). Although 22.2% of ICHE did not respond to this item, 70.7% responded that they possessed a water receiving and/or elevated water tank. This was comparable to the value of 74.8% obtained in Tokyo by Sagehashi & Akiba (2014), who concluded that the utilization of the tanks in an emergency was feasible.

The status of maintenance of these tanks is also shown in Figure 2(a). High implementation rates of maintenance activities were observed, although 1.7%, 5.3%, and 0.9% of ICHE did not measure the tank water quality, did not undergo tank inspections by an inspection institute, and did not clean their tanks, respectively. It is thus crucial that information be disseminated regarding the importance of tank maintenance, not only for daily use but also as a countermeasure for use in an emergency. In addition, careful attention must be paid to the quality of the water stocked in the receiving tank for long periods. The advantages of both direct connection and water receiving tanks according to the needs of each institute should also be discussed.

We also sought to clarify how many of the ICHE that had a water receiving tank had a private power generator, which would be needed to run an electrical pump in the case of a blackout. We found that 17.7% of the ICHE having a water receiving tank did not have a private power generator. Therefore, alternative methods for drawing water from the tank should also be considered.

A personal water well can also play an important role as an alternative water supply in the case of a water outage. The availability of a personal well in ICHE was analyzed only for those ICHE who clearly answered that they use the public water supply ($n = 568$), and the results are shown in Figure 2(b), along with the potability of the water. The results indicated that 9.3% of the ICHE possessed a personal well, and 83.5% of these ICHEs with a well possessed a private power generator. Although the number of respondents who left this item blank was not negligible, we conjecture that most of these respondents did not use their wells for drinking water. Similarly, a non-negligible number of ICHE did not have a private power generator (14.6%), and therefore it would be necessary to consider methods for drawing water from the well in the case of a power outage.

Analysis using the chi-square method indicated that there were regional differences in the rate of water well possession by ICHE. Simple regression analysis revealed a significant relationship between the dependency of the water supply utility on groundwater (JWWA 2015) and the

Table 4 | Statistical analysis of the relation between water consumption of ICHE characteristics

Item	Categorization	Analysis methods and resultant p value
Scale of institute	Number of admitted persons is <50, 50–59.9, 60–69.9, 70–79.9, 80–89.9, 90–99.9, or >100	Kruskal–Wallis test, $p = 0.221$
Care type	Unit care[a] or conventional multiple beds in a room	Mann–Whitney U test, $p = 0.949$; Kolmogorov–Smirnov test, $p = 0.681$
Bathing style	Possession of personal bath (individual bath, mechanical bath, and shower bath) or not[b]	Mann–Whitney U test, $p = 0.208$; Kolmogorov–Smirnov test, $p = 0.229$
Food service	Foods cooked in ICHE or not	Mann–Whitney U test, $p = 0.793$; Kolmogorov–Smirnov test, $p = 0.631$
Nursing care level	<4 or ≥4[c]	Mann–Whitney U test, $p = 0.401$; Kolmogorov–Smirnov test, $p = 0.713$

[a]Akiba & Park (2012).
[b]All of the targeted ICHE responded that they have communal baths.
[c]The degree of nursing care requirement in Japan. Judged from 1 (light) to 5 (heavy).

rate of water well possession in each region ($R^2 > 0.5$, $p < 0.01$). These observations indicated that this difference may be related to the regional hydrological characteristics.

Of course, much as for the water receiving tanks, it is also necessary to understand the quality of the water in the wells. The conditions of the surrounding groundwater may change following an earthquake, and thus there is a possibility of drastic changes in water quality between before and after an earthquake. The use of well water in the case of an emergency should be based on a guarantee of its safety.

The status of the presence of a nearby emergency water supply station, and the storage of drinking water and portable toilets in each ICHE are summarized. The number of ICHE answering 'yes' regarding the presence of an emergency water supply station was low (16.4% for all answers; 29.8% for answers excluding 'unknown'). A high percentage of ICHE responded 'unknown' to this item (42.4%). The average distance from an ICHE to a station was 2 km. Regional differences were confirmed only for 'yes' or 'no' responses by the chi-square method. The results indicated that there were no regional differences. The percentage of ICHE that had access to a nearby emergency water supply station was high in the Kanto area. The rate was especially high in the Tokyo area (61.9%), with an average distance of only 1.1 km. Much as in the regression analysis for water wells, a regression curve with high reliability ($R^2 > 0.5$, $p < 0.01$) was obtained between water supply coverage and the presence of a nearby water supply station, indicating that water supply coverage is one of the key factors for building an emergency water supply station near an ICHE. High storage rates of drinking water (83.7% for all answers; 86.3% for answers excluding 'unknown') and portable toilets (90.5% for all answers; 93.2% for answers excluding 'unknown') were indicated. The chi-square method revealed that there were regional differences in drinking water storage but no regional differences for the availability of portable toilets. The high and uniform rate of portable toilet availability may suggest that portable toilets were in everyday use at these facilities The median volume of drinking water stored was sufficient for 3.8 days of use, whereas the average numbers of portable toilets and excreta collecting bags per admitted person were 0.18 (median, $n = 421$) and 1.1 (median, $n = 47$), respectively.

Action planning

Disaster training, manuals, and mutual aid agreements are also essential as countermeasures for emergency situations. The status of training and manuals is summarized in Figure 3. With regard to disaster training, 95.6% of the ICHE answered that they had introduced disaster training and 31.1% of these (or 29.7% of the total ICHE) took water outages into consideration. A high implementation rate was found for training itself, and awareness of the importance of countermeasures for water outages was a key factor. The rate of disaster action manual preparation was 39.2%, and 49.5% of the ICHE that had prepared

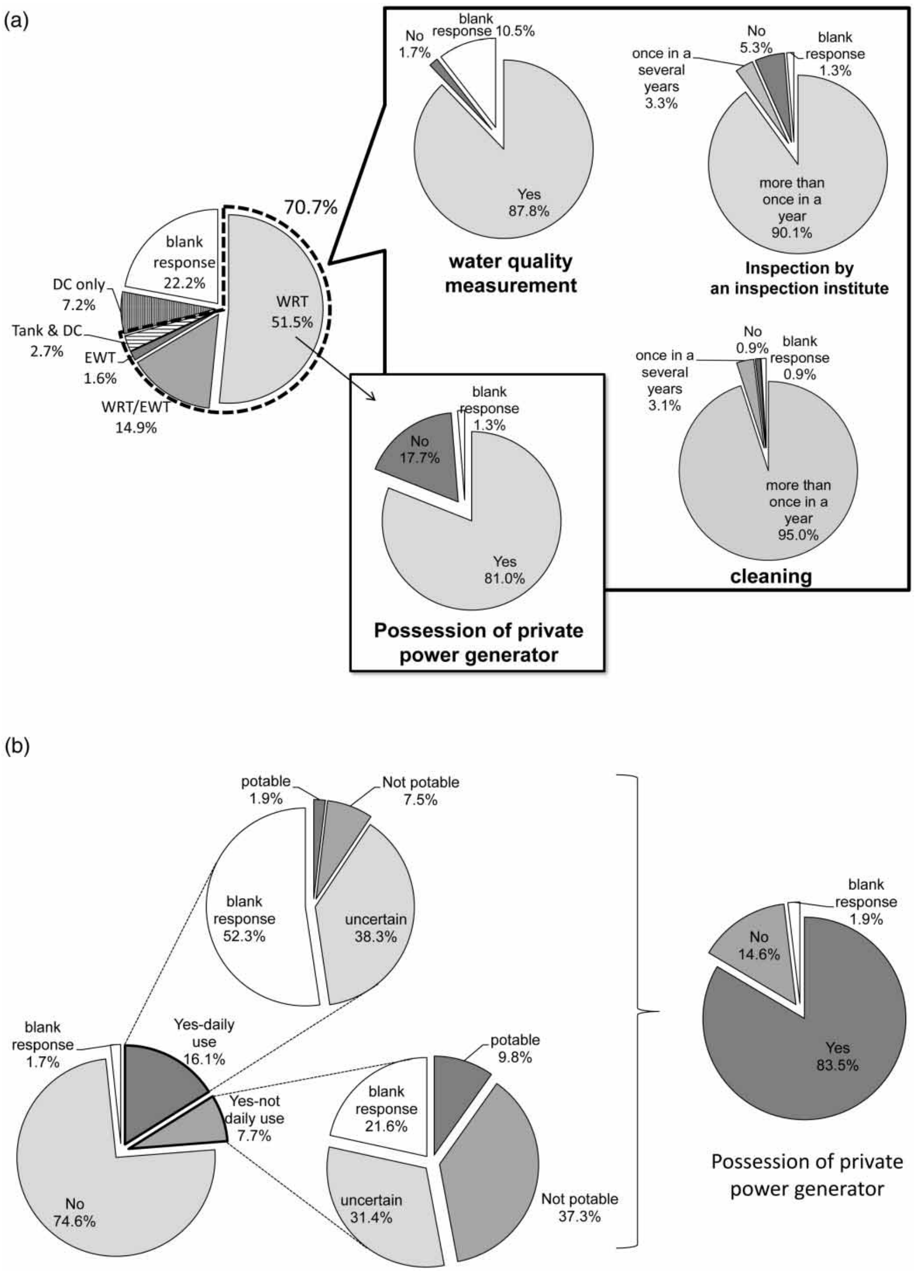

Figure 2 | Water receiving systems and water wells in ICHE. (a) Types of water receiving systems in ICHE. WRT: water receiving tank; EWT: elevated water tank; DC: direct connection. (b) Possession rate and potability of personal wells, and possession rate of private power generators in ICHE using the public water supply.

such manuals (or 29.7% for all responding ICHE) took water outages into consideration.

The status of mutual aid agreements in the event of a disaster involving water outages is also shown in Figure 3. Such agreements were introduced in 18.0% of the ICHE. In about half the cases, the counterpart in the agreement was the local municipality. The counterparts in the remaining cases included related facilities and local communities.

We also examined the differences in the above preparedness factors between the ICHE that were designated welfare refuges and the ICHE that were not. This can be thought of as a complete survey, because all of the ICHE listed in the

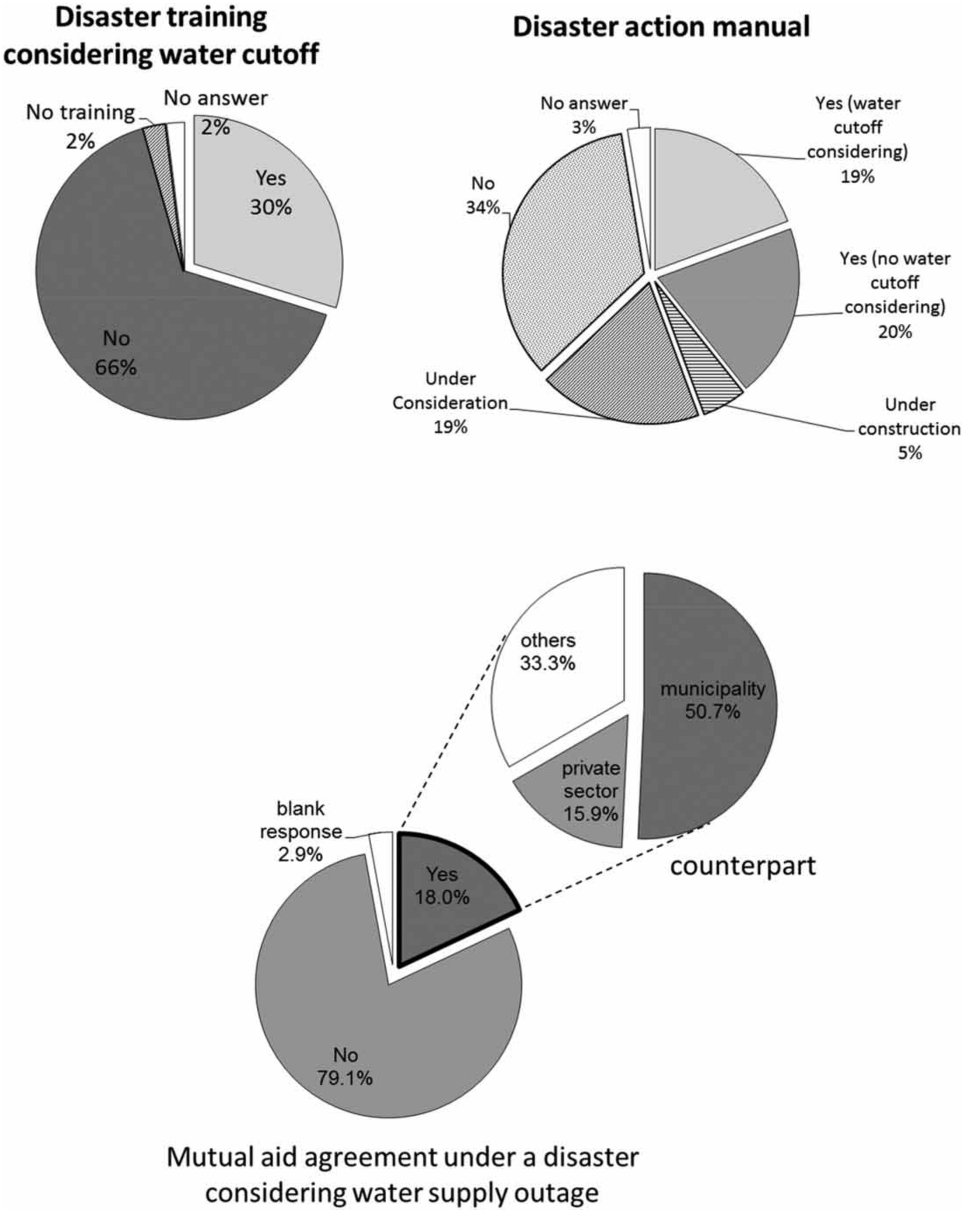

Figure 3 | Introduction status of disaster training, action manuals with consideration for water outage, and mutual aid agreements in the event of a disaster involving water outage.

referenced database (WELNESS 2011) were included. Thus, in the case of estimating proportion, an approximate 100 $(1-\alpha)$% two-side confidence interval for p, the rate of concerned answers could be calculated by Equation (3) (Barnett 2004) as follows:

$$p \pm z_a \times \sqrt{\frac{(1-f)pq}{n-1}} \quad (3)$$

where z_α is the two-tailed α point of the standard normal distribution, f is the sampling fraction ($= n/N$, where n is the sample size and N is the population), and $q = (1-p)$. The results are shown in Figure 4. The length of each bar indicates the 95% confidence interval calculated by Equation (3). The welfare refuges tended to exhibit a high degree of preparedness with respect to all three factors (training, mutual aid agreements and, to a lesser degree, disaster

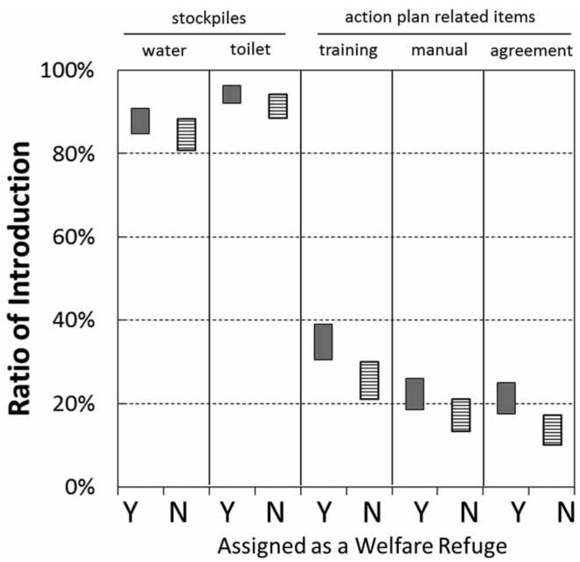

Figure 4 | Differences in the preparedness status of each water-outage countermeasure between welfare refuges and non-welfare refuges. Y: yes; N: no.

action manuals). Our results suggested that the combined experience of welfare refuges in making these preparations is an important resource that should be shared among other institutions.

Experience of water outage

The rates of water outage in each region and throughout Japan are shown in Figure 5. The results indicated that 13.0% of responding ICHE (13.5% when excluding ICHE that provided no response for this item) had experiences of water outage, and eight had experienced multiple water outages. Moreover, judging from the period of occurrence, the Great East Japan Earthquake caused water outages in 5.7% of the responding ICHE. The rate was high especially in the Tohoku (34.5%) and Kanto (10.2%) regions, where the effects of the Great East Japan Earthquake were critical. On the other hand, the rates of water outages with causes other than earthquakes were 4.3% throughout Japan and 0–12.7% in each region.

The durations of water outages were calculated both for the cases in March 2011, when the Great East Japan Earthquake occurred, and those classified as 'other than March 2011'. Among the cases classified as 'other than March 2011', four outliers with outages lasting more than 9 days were eliminated based on the results of Smirnov–Grubbs test. Outage events for which no duration was provided

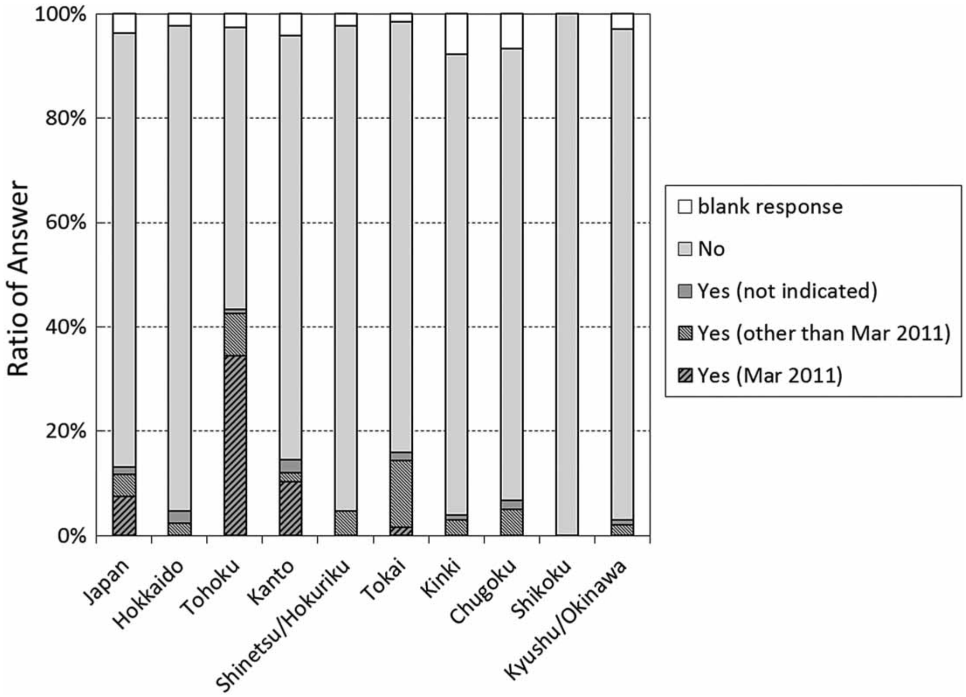

Figure 5 | Actual water-outage experiences. The period of occurrence is given in parentheses. Y: yes; N: no.

were not considered. The mean ± SD (standard deviation) duration of water outages that were attributable to the Great East Japan Earthquake was 4.5 ± 4.5 days, which was more than three times larger than the mean duration of outages not due to this major earthquake (i.e., cases not occurring in March 2011; the mean was 1.4 days, and the maximum was 4 days for these cases). The profound effects of large-scale disasters are evident in these values, and the countermeasures for large-scale disasters should be chosen with such potentially devastating effects in mind.

In addition, the emergency water supply-implementation status was also calculated both for the cases occurring in March 2011 and those occurring at other times. There was no clear difference in the rate of implementation between the March 2011 cases and the other cases. About 60% of the total water outages were supported by emergency water supplies, and roughly three-quarters of these were provided by water wagons.

Write-in comments on emergency water supplies for the elderly

Respondents were asked to write in the most important problems in regard to water outages, and their responses are summarized in Figure 6(a). Here, answers that can be considered as 'sanitation and hygiene' were categorized as toilet

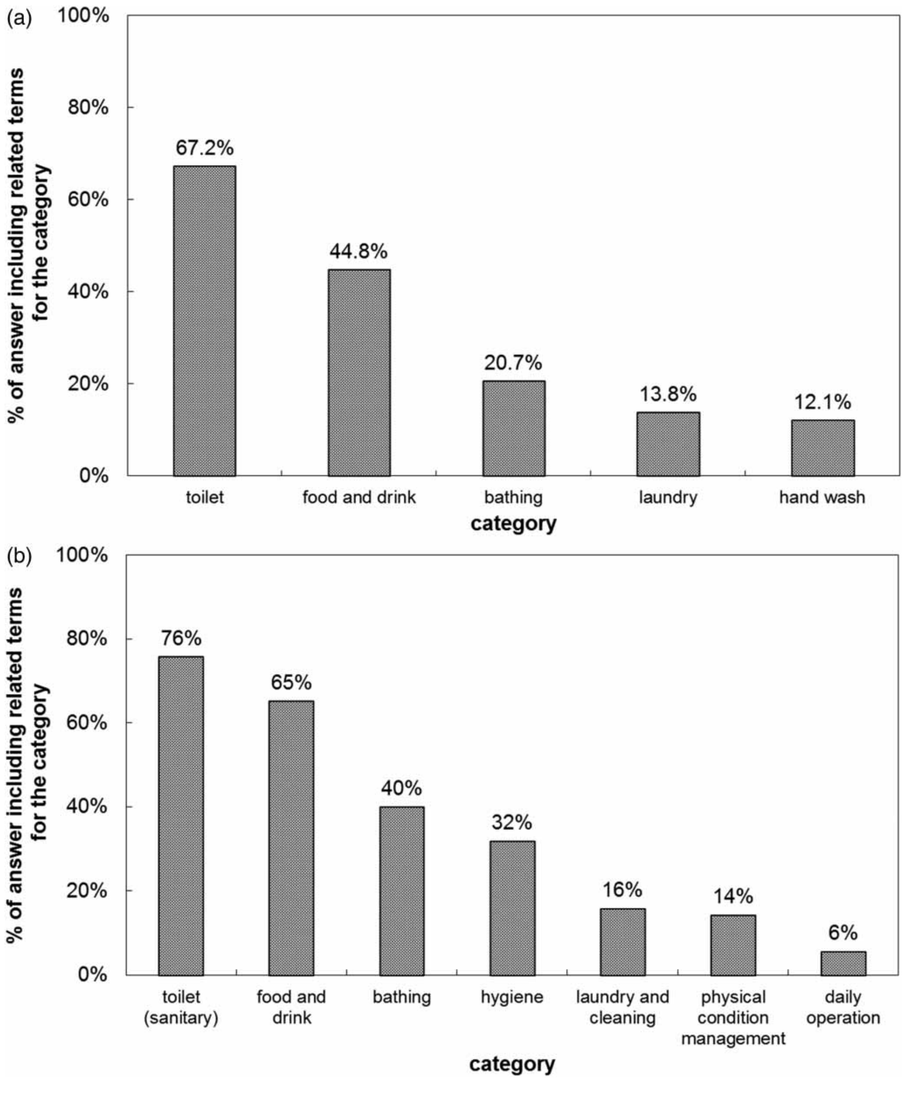

Figure 6 | Items that cause problems in the case of water outage (a) and anticipated difficulties under conditions of water outage (b).

and hand washing. Answers that said 'all things cause problems' were counted for all items. Most of the ICHE responded that toilets were the primary problem, followed by food and drink. The preparation of a stockyard for the emergency water supply was also noted as a problem. As mentioned above, 60% of ICHE that suffered water outages had emergency water supplies, and tapped into them. Thus the method of storage for emergency water supplies is quite important.

Keyword extraction was performed for the write-in item about 'anticipated difficulties in the event of a water outage.' The following words were extracted: food and drink, toilet (sanitary), hygiene (e.g., cleanliness, hand washing, etc.), laundry and cleaning, physical condition management (e.g., communicable diseases, oral care, etc.), bathing, and daily operation (e.g., lack of manpower for extra transportation of water, air conditioning, etc.). The total number of effective answers for this question was 471, and the percentages of this total that included words related to the respective categories were calculated as shown in Figure 6(b). Toilet (sanitary) was the factor of greatest concern (76%), followed by food and drink (65%). There was also concern about bathing (40%) and hygiene (32%).

The top three items in Figure 6(a) and 6(b) are the same, with the problem of toilets eliciting the greatest concern in both cases. Other notable answers were concerns regarding the disposal of waste from portable toilets. The preparation rate of portable toilets was high, although this concern should be kept in mind, and rational countermeasures for toilet care, including waste disposal, should always be considered.

In addition, 20.8% of effective answers to the question 'particular points that should be considered regarding water supply for the elderly in the case of a disaster' ($n = 342$), and 17.6% of 'other particular points' ($n = 108$) indicated concern about dehydration and other health effects caused by the shortage of water intake. In the Niigata Chuetsu Earthquake that occurred in 2004, there were reports of dehydration-derived thromboses caused by victims forgoing fluid intake in order to avoid having to use the inconvenient toilets (i.e., narrow, large step, and squat toilet) in the refuge (Kato & Nagahara 2010). This problem would thus be indirectly related to the importance of preparing sufficient and convenient toilets. Other answers included the lack of a stockyard, the freezing of stored water in cold weather, and the difficulty of transporting large water tanks.

When respondents were asked to provide 'particular points that should be considered regarding water supply for the elderly in the case of a disaster,' they raised concerns about health maintenance, such as avoiding the development and spread of infectious diseases, and dehydration. In addition, the use of thickening agents and the importance of maintaining a comfortable temperature were also mentioned as points to be noted for hydration among the elderly.

Future perspectives

The daily water consumption in elderly care in ICHE in Japan was clarified in this study. This is the most significant outcome of this study, and will be useful for elderly care planning from the viewpoint of the water supply. At the same time, the data on the critical volume of water needed for an emergency should also be helpful. In fact, many disaster manuals have indicated the amount of drinking water to be prepared (e.g., CDC 2016; Tokyo Metropolitan Government 2017). On the other hand, data will be needed about the consumption of water not only for drinking but also for sanitary and hygiene managements, since many of the elderly in ICHE will require nursing care during a disaster. To improve the practicality of disaster-preparedness measures, more detailed information on water consumption, including a breakdown of the different uses of water, will be needed in the future. It will be particularly important to clarify the amount of consumption related to toilet care. Water for hand washing must also be considered, due to its importance in preventing communicable diseases.

In addition, the possibility of using a water receiving tank as an alternative water source was noted. The importance of water quality management and monitoring, as well as a safe method to obtain water from the tank under conditions of a power outage should be considered. The same can be said with regard to personal water wells. Concurrent with the promotion of emergency water supply stations, it is important to increase the awareness of such stations. In addition, the distance to a water supply station is also an important factor. What constitutes a reasonable distance should be clarified in future studies.

The advantages of providing disaster training, preparing disaster manuals, and making mutual aid agreements in the event of a disaster were also clarified. These advanced preparedness measures taken in welfare refuges should be described to other ICHE as case studies, and examples of training, manuals, and mutual aid agreements should be provided.

Information on the water consumption and the preparedness for water outages in ICHE should be shared with stakeholders, including water suppliers, disaster and welfare administrative departments in municipalities, and staffs of ICHE, in order to achieve a sustainable water supply for our increasingly aging society.

CONCLUSIONS

A questionnaire survey about the water consumption and preparedness for water outages in ICHE in Japan was conducted, and the amount of water consumption was estimated. From the viewpoint of alternative water sources, we clarified that a large percentage of ICHE possess water receiving tanks. On the other hand, the low awareness of nearby emergency water supply stations indicated the importance of disseminating information regarding such stations. The high storage rates of drinking water and portable toilets were also elucidated.

We also determined the rates of introduction of disaster training, disaster action manuals, and mutual disaster-aid agreements (all with respect to water outages), and showed that the ICHE designated as welfare refuges had higher rates of introduction of these preparedness measures. Concern about toilets in the case of an emergency indicated the importance of the emergency water supply with consideration for toilet care in ICHE.

ACKNOWLEDGMENTS

The authors are grateful to all of the participating ICHE. The authors would also like to thank the Japanese Council of Senior Citizens Welfare Service and Division of the Support for the Elderly, Health and Welfare Bureau for the Elderly, MHLW Japan for their assistance with the questionnaire survey. The authors are also grateful to Dr Haruki Osawa, Dr Michiko Bando, and Dr Hoon Kim for their help with the questionnaire.

REFERENCES

Akiba, M. & Park, S. 2012 A Study on the Actual Conditions of Unit - Type Nursing Homes. *Journal of Architecture and Planning, Architectural Institute of Japan* **77**, 1–8. (In Japanese with English Abstract)

Bando, M., Kim, H. & Osawa, H. 2014 Survey on indoor environment in nursing homes for the elderly. *Journal of the National Institute of Public Health* **63** (4), 359–367. https://www.niph.go.jp/journal/data/63-4/201463040005.pdf (accessed 28 June 2017). (In Japanese with English Abstract)

Barnett, V. 2004 *Environmental Statistics Methods and Applications*, John Wiley & Sons, Chichester, UK, pp. 77–104.

Castle, N. G. 2008 Nursing home evacuation plans. *American Journal of Public Health* **98** (7), 1235–1240. DOI: 10.2105/AJPH.2006.107532.

CDC 2016 *Water, Sanitation, & Hygiene (WASH)-Related Emergencies & Outbreaks*. Centers for Disease Control and Prevention. https://www.cdc.gov/healthywater/emergency/drinking/creating-storing-emergency-water-supply.html (accessed 28 June 2017).

CDC & AWWA 2012 *Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities.* Centers for Disease Control and Prevention and American Water Works Association, Atlanta, GA, USA.

Chidester, J. C. & Spangler, A. A. 1997 Fluid intake in the institutionalized elderly. *Journal of the American Dietetic Association* **97** (1), 23–28; quiz 29–30. DOI: 10.1016/s0002-8223(97)00011-4.

Gaff, L., Jones, J., Davidson, I. H. & Bannerman, E. 2015 A study of fluid provision and consumption in elderly patients in a long-stay rehabilitation hospital. *Journal of Human Nutrition and Dietetics* **28** (4), 384–389. DOI: 10.1111/jhn.12294.

JSBC 2014 Data-base for Energy Consumption of Commercial Buildings, Japan Sustainable Building Consortium http://www.jsbc.or.jp/decc_english/index.html (accessed 19 July 2016).

JWWA 2015 *Heisei 25 Nendo Suido Tokei – Shisetu Gyomu Hen (2013 Waterworks Statistics – Facilities and Operations)*. Japan Water Works Association, Tokyo, Japan. (In Japanese)

Kato, A. & Nagahara, R. 2010 Toilet and hygiene measures for refuges following an earthquake. *Journal of the National Institute of Public Health* **59** (2), 116–124. https://www.niph.go.jp/journal/data/59-2/201059020005.pdf (accessed 28 June 2017). (In Japanese with English Abstract)

Kido, Y. 2015 The issue of nutrition in an aging society. *Journal of Nutritional Science and Vitaminology* **61** (Supplement), S176–S177. DOI: 10.3177/jnsv.61.S176.

Loo, S. L., Fane, A. G., Krantz, W. B. & Lim, T. T. 2012 Emergency water supply: A review of potential technologies and selection criteria. *Water Research* **46**, 3125–3151.

Mae, M., Funo, Y., Ishiwatari, H., Ichikawa, N. & Kamata, M. 2003 The analysis and evaluation on usage of hot and cold water on urban apartment house (part 1). *Journal of Environmental Engineering, Architectural Institute of Japan* **566**, 73–80. DOI: http://doi.org/10.3130/aije.68.73_1. (In Japanese with English Abstract)

MLIT 2014 H26 Nihon No Mizushigen (Japanese Water Resource 2014), Ministry of Land, Infrastructure, and Transportation. http://www.mlit.go.jp/mizukokudo/mizsei/mizukokudo_mizsei_fr2_000012.html (accessed 16 July 2016). (In Japanese)

Mochizuki, M. 1987 Byoin No Mizisiyouryou Oyobi Yushiyouryou No Jittai (Enquête Chosa Wo Chushin Toshite) (Actual conditions of water and hot water consumption in hospitals (focusing on questionnaire)). *Journal of Hospital Engineering Association of Japan* **29** (2), 178–180. (In Japanese)

Nagano, T. 2007 Investigation of actual conditions in water supply of school. In: *Technical Papers of Annual Meeting, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan*, Miyagi, Japan, 12–14 September 2007, pp. 13–16. (In Japanese with English Abstract)

Naumova, E. N., Egorov, A. I., Morris, R. D. & Griffiths, J. K. 2003 The elderly and waterborne Cryptosporidium infection: gastroenteritis hospitalizations before and during the 1993 Milwaukee outbreak. *Emerging Infectious Diseases* **9** (4), 418–425. DOI: 10.3201/eid0904.020260.

Nomura, S., Gilmour, S., Tsubokura, M., Yoneoka, D., Sugimoto, A., Oikawa, T., Kami, M. & Shibuya, K. 2013 Mortality risk amongst nursing home residents evacuated after the Fukushima nuclear accident: a retrospective cohort study. *PLoS ONE* **8** (3), e60192. DOI: 10.1371/journal.pone.0060192.

Ogata, A., Aida, N. & Nagaya, Y. 2015 Preventing turnover among care workers and nurses in facilities covered by public aid providing long-term care to the elderly. *Journal of Japan Academy of Nursing Science* **35**, 90–100. DOI: 10.5630/jans.35.90. (In Japanese with English Abstract)

Okano, S., Murakawa, S., Nishina, D., Kindaichi, S., Ikeda, D., Murakami, S., Bogaki, K., Kameya, S., Takaguchi, H., Hanzawa, H., Yoshino, H., Okumiya, M., Asano, Y., Shimoda, Y. & Yoda, H. 2015 Hijyutakukenchiku (Minseigyomubumon) Kenchikubutsu No Kankyokanren Database Kouchiku Ni Kansuru Kenkyu Sono 132 Hotel Ryokanshisetsu To Byoinshisetu Niokeru Mizusyohi Jittai (Study on the Environmental Load Database (DECC) for Buildings: Part 132 Water consumption in hotels and hospitals). In: *Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan*. 4–6 September, 2015, Kanagawa, Japan. pp. 1165–1166. (In Japanese)

Presse, N. & Ferland, G. 2010 Risk factors associated with insufficient water supply among elderly people living in nursing homes: a literature review. *Canadian Journal of Dietetic Practice and Research* **71** (4), e94–e99. DOI: 10.3148/71.3.2010.e94.

R Development Core Team 2005 *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Sagehashi, M. & Akiba, M. 2014 Analyses of the amount of water use and preparedness for the cutoff of water supply at elderly facilities in Tokyo. *Journal of Water and Environment Technology* **12** (3), 211–220. DOI: http://doi.org/10.2965/jwet.2014.211.

Silk, B. J., Foltz, J. L., Ngamsnga, K., Brown, E., Muñoz, M. G., Hampton, L. M., Jacobs-Slifka, K., Kozak, N. A., Underwood, J. M., Krick, J., Travis, T., Farrow, O., Fields, B. S., Blythe, D. & Hicks, L. A. 2013 Legionnaires' disease case-finding algorithm, attack rates, and risk factors during a residential outbreak among older adults: an environmental and cohort study. *BMC Infectious Diseases* **13** (1). DOI:10.1186/1471-2334-13-291.

Sugawara, Y., Sudo, S., Yoshino, H., Miura, S., Watanabe, H., Xu, L., Iki, Y. & Kawada, S. 2009 Study on the environmental load database (DECC) for buildings: part 28, energy and water consumption of buildings for the elder people in Tohoku (investigation in 2007 & 2008). In: *Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan 2009*, pp. 1147–1148. (In Japanese)

Suzuki, K., Hayakawa, T. & Okumura, A. 2008 Niigataken Chuetsuoki Jishin No Kyusui Taiou To Kanisenyousuidou No Genjyou (*The water supply at the Niigata Chuetsu earthquake and the actual conditions of small private water supplies*). In: *Proceedings of the 59th Annual Meeting of Japan Waterworks Association*, 28–30 May 2008, Miyagi, Japan, pp. 628–629. (In Japanese)

Takaguchi, H., Murakami, S., Bogaki, K., Kametani, S., Ikaga, T., Sakamoto, Y., Matsunawa, K., Hanazawa, H., Yoshino, H., Okumiya, M., Shimoda, Y., Murakawa, S. & Watanabe, T. 2009 Study on the database for energy consumption of commercial building (DECC). Part 3 outline and nationwide analysis of the database. In: *Technical Papers of Annual Meeting, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan*, Kumamoto, Japan, pp. 1131–1134. (In Japanese with English Abstract)

Takaguchi, H., Kametani, S., Hanzawa, H., Yoshino, H., Asano, Y., Okumiya, M., Shimoda, Y., Murakawa, S., Yoda, H., Bogaki, K., Matsunawa, K. & Murakami, S. 2010 Study on the database for energy consumption of commercial building (DECC). Part 4 outline and nationwide Analysis of the survey in 2009. In: *Technical Papers of Annual Meeting, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan*, Yamaguchi, Japan. (In Japanese with English Abstract)

Takaguchi, H., Izutsu, S., Washiya, S., Kametani, S., Hanzawa, H., Yoshino, H., Asano, Y., Okumiya, M., Shimoda, Y., Murakawa, S., Yoda, H., Sakamoto, Y., Bogaki, K. & Murakami, S. 2012 Development and analysis of DECC (Data-base for energy consumption of commercial building). Part 1 development on basic database of DECC. *Journal of Environmental Engineering, Architectural Institute of Japan* **77** (678), 699–705. (In Japanese with English Abstract)

Tanaka, A., Murakawa, S. & Takata, H. 2007 An analysis on the hot and cold water usage of the guest rooms in a city hotel.

Journal of Environmental Engineering, Architectural Institute of Japan **611**, 53–58. (In Japanese with English Abstract)

Tokyo Metropolitan Government 2017 Disaster Prevention Website – Before a disaster occurs. http://www.bousai.metro.tokyo.jp/foreign/english/bousai/2000170/2000053.html (accessed 28 June 2017).

Welle, T., Birkmann, J. & Rhyner, J. 2014 The World Risk Index 2014. In: *World Risk Report 2014* (L. Jeschonnek, M. Aberle, J. Kandel, W.-C. Ramm & B. Wiegard, eds). United Nations University – Institute for Environment and Human Security (UNU-EHS) and Bündnis Entwicklung Hilft (Alliance Development Works), Bonn, Germany.

WELNESS 2011 Niji Iryoken Database System: Zenkoku Tokubetsu Yougo Roujin Home Ichiran Data (*Database system of the second medical area: All Japan Intensive Care Homes for Elderly List*), Ver. 2.0.0. xls, http://www.wellness.co.jp/siteoperation/msd/ (accessed 8 November 2013). (In Japanese)

First received 18 December 2016; accepted in revised form 23 November 2017. Available online 18 December 2017