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Micro-components survey of residential indoor water consumption in Chiang Mai

Y. Otaki[1], M. Otaki[2], P. Pengchai[3], Y. Ohta[2], and T. Aramaki[4]

[1]Center for Research and Development Higher Education, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 133-0033, Japan
[2]Graduate School of Humanities and Science, Ochanomizu University, 2-2-1 Otsuka, Bunkyo-ku, Tokyo 112-8610, Japan
[3]Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand
[4]Department of Urban Engineering, The University of Tokyo, 7-3-1, Hongo, Bunkyo, Tokyo 113-8656, Japan

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Correspondence to: Y. Otaki (yurina00@nifty.com)

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Abstract

The direct measurement of the micro-components of water consumption (i.e., consumption by each residential activity, such as toilet, laundry, bath, and kitchen) both in the dry season and in the rainy season was conducted in Chiang Mai, Thailand. It was expected that rainfall differences between the dry and rainy season could influence awareness for water resources so that water consumption in the dry season may be smaller than that in the rainy season. It was also examined that whether the differences in water resources such as public waterworks or non-public waterworks like community waterworks, mountainous water and groundwater, affect the water use amount. A small-sized accumulative water meter was developed for measurement. This survey can provide the important information for water demand estimation and water supply planning in middle-developed countries where their water consumption should be expected to increase from here on.

1 Introduction

Generally, water consumption increases per capita proportional to GDP growth. It stops increasing or begins decreasing when it reaches the plateau according to historical data in developed countries (Bengtsson, 2005). Most of the developed countries have already reached such a level. In the case of middle-developed countries, such as Thailand, economic growth is remarkable now and their water consumption level may increase to a large extent in the near future. For water demand estimation and water supply planning of such countries, it is important to know not only total water consumption per capita, but the micro-components of water consumption (i.e., consumption by each residential activity, such as toilet, laundry, bath, and kitchen). For example, toilet use depends on equipment to a considerable extent, but kitchen use does not. Thus, such detailed knowledge regarding water consumption leads to more practical and accurate demand estimation.

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Many kinds of research have been conducted to know the micro-components of water consumption in developed countries. For example, Fig. 1 shows the results of residential indoor use (Otaki, 2003). Water use patterns differ city by city, however, and the city with a larger consumption level is not always the larger user for every component. For example, although total consumption in Singapore is relatively small, its consumption for baths is the second largest amount.

As there have not been enough studies about micro-components in countries other than developed ones, this paper is trying to study and to measure micro-components of indoor use in middle-developed countries like Thailand. Economic growth within Thailand has been significant in the past several years, and its water consumption also should be expected to increase from here on. Therefore, Thailand is one of the important countries where we have to consider the water demand and supply plan.

2 Methodology

2.1 Development of the device for measuring water consumption

In the case of developed countries, their methodologies are classified into three groups. The first one is the direct measurement of the water use amount. For example, Tokyo's municipality in Japan adopted this method and set meters to each tap of seventy-six households for one year. This limited number of samples is a shortcoming because of the necessity for numerous meters (4–6 m per household) and for deep cooperation from each household. Despite this, however, the Tokyo's method was able to retain real and accurate data. The second method made estimations through interviews. Each micro-component was determined by ownership of appliances, frequency of use, and the volume of water per use. The Environmental Agency (UK) used this method and estimated data were used for water demand forecasting. Fukuoka (Japan) and Bangkok (Thailand) also used this method and collected 100 and 814 interviews (MWA, 1996). Although the data is an "estimated" value, it is easy to obtain many samples. The third method is to collect the time-series data of total residential water consumption and to calculate it to each component by water flow pattern. The American Water Works Association (AWWA), Osaka (Japan), and East Anglian Region (UK) adopted this method (AWWA, 1999; Yamanishi, 2002; Edwards, 1995). This method is convenient for both the user and the experimenter, because there is no need to set meters to each tap. The only real problem is the cost.

In some developing countries such as Thailand, people usually collect water in large containers to cope with the lack of water pressure, the intermittent water supply and the impurities within the water. Thus, the time-series data method (third one) is not suitable. For surveys in such countries, we have to choose from the direct measurement method (first one) or the interview method (second one). In the case of interview surveys in developing countries, the reliability of the estimated water consumption may not seem high because people are apt to exaggerate their water use abilities. Therefore, we decided to collect the data by direct measurement.

To measure the water consumption of each tap, we developed a small-sized accumulative water meter of 5.5cm in length and a diameter of 1.7 cm (Fig. 2). The small water flow meter (Turbine meter Vision 2000-4F22, GRAZ Co., Ltd.) was set to the tap end, and its pulse (1000 pulse/L) was monitored by pulse counter (OMRON). This meter is so small that tap users do not feel any inconvenience. Four D size alkaline batteries supplied power to the sensor. This device can monitor water flow continuously for two months.

2.2 Selection of Chiang Mai

A list of provinces with the top ten populations in Thailand, Table 1, indicates a higher concentration of people in the province of Bangkok. Although Bangkok is the largest and most represented city in Thailand, we considered it unsuitable for our research. The reasons are as follows. First, Bangkok is already a developed city to some extent, so it does not fit our aim to collect data for regions of economically, middle-developed conditions. Secondly, the Metropolitan Waterworks Association (MWA) had already finished the questionnaire survey in Bangkok in 1996 (MWA, 1996). This result is shown in Table 2. Thus, from the list of top ten cities in Thailand, we choose Chiang Mai, the central city of the country's northern area, as our study area.

Chiang Mai is located about 70 km north of Bangkok. Approximately 1.6 million people live in Chiang Mai province and 0.25 million people live in the city area known as Muang Chiang Mai. Its climate is classified as tropical monsoon and can be divided into three seasons, rainy season (May to November), dry season (November to March), and the hot season (March to May). This survey was conducted during the rainy season and the dry season. Although there are many reports that indicate how temperature differences affect water consumption, there has been no research which compares the consumption between the rainy season and the dry season. Most households in Chiang Mai have enough water resources other than rainfall, thus a total amount of water is not lacking even during the dry season. However, it is expected that the lack of rainfall during the dry season will arouse water awareness and thus, people will try to avoid wasting water consciously.

2.3 Survey procedure

At first, we delivered the questionnaire sheet to approximately 160 households based on household income levels. Then, we visited these households and checked the availability of meter settings. Finally, we selected 63 households for the dry season and 55 households for the rainy season. Then, we set the meters to each tap of each household. In cases when one tap was used for various activities, we used the equipment for divarication to divide activities. In cases where it was impossible to divide activities, we exempted that particular tap from the survey. The consumption for flush toilets was calculated from the flush tank volume multiplied by the number of times counted by a pedometer.

3 Results and discussion

3.1 Brief overview of current water supply in Chiang Mai

Public waterworks operated by the Provincial Waterworks Association (PWA), supplied water to 18% of the central area of Chiang Mai in 2002. A water resource for public waterworks is the Pin River. The monthly water bill averages 132.39 baht compared to the average monthly power bill of 488.83 baht (Mathurasa, 2005). This was not because of cheap water fare only, but because of parallel usage of public waterworks and other water resources, such as rainfall or mountainous water, which make up a part of the small community's water system and whose resource is directly from the mountain, etc. People who lived in other areas used community waterworks, mountainous water and groundwater. In the dry season survey, 45 households used public waterworks mainly, and 18 households used other resources. Similarly, the rainy season survey revealed that 39 households used public waterworks mainly, and 16 households used other resources.

3.2 Water consumption for toilets

The typical toilet in Thailand consists of a pail and a squat toilet. People flush water down the toilet by using the pail (Fig. 3). 87% of households in this research study used the pail and squat toilet and 13% used flush toilets. Normally, the water consumption of the pail and squat toilet was smaller than that of the flush toilet (White, 2003). Thus, water consumption for toilets may be smaller than that of developed countries. In the case of the pail toilet, where the water required is done by hand, it can be supposed that there might be no difference between the rainy and the dry season. Furthermore, it can also be supposed that water use in the dry season is smaller because of psychological factors based on the lack of water available.

Figure 4 indicates the histogram of water consumption for toilet use in the dry and the rainy seasons. Most households used under 30 L/p/d. According to the Kolmogorov-

Smirnov test (KS-test), there was no significant differences (significant level >0.05) between the dry and rainy season. The median of the dry season, 15 L/p/d, is rather larger than that of the rainy season, 11 L/p/d which is opposite to the estimation. More than 60% of observed data distributed under 20 L/p/d, and more than 80% distributed under 30 L/p/d. In the case of developed countries, the least amount was 25 L/p/d in Fukuoka and 31 L/p/d in Singapore. Compared to these data, consumption in Chiang Mai was small to a considerable extent, because of mainstream usage via the pail toilet. Compared to Bangkok, 27 L/p/d, consumption in Chiang Mai was smaller, too. In 1996, when the survey was carried out in Bangkok, 80% people used the pail toilet. The ratio of people using pail toilets in Bangkok was 80% and 87% in Chiang Mai. Since these ratios are similar, toilet consumption differences in Bangkok and Chiang Mai are not because of type of toilet, that is pail toilet or flush toilet.

According to Fig. 5, water consumption per capita for toilets appears distributed through log-normal distribution. It means that the distribution of the values before conversion for logarithm is considered normal distribution. Gentle slope means large dispersion, and the intersection with x-axis is the central value of distribution. R2 values of linier regression are 0.996 for the dry season and 0.991 for the rainy season. This is verified by the Shapiro-Wilk W-test (significant level >0.05). This tendency could be found in previous studies on water consumption (Krewski and Thomas, 1991). Therefore, it should support the reliability of our methodology and collected data.

Judging from the KS-test, the difference of water resources and public waterworks does not result in consumption differences.

3.3 Water consumption for laundry

In Chiang Mai, not all households use washing machines since some households still wash clothing by hand. The most popular type of washing machine is the twin-tub washing machine, thus, there is a possibility that people have reduced water use in the dry season because of psychological factors influenced by less water around them.

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Figure 6 indicates the histogram of water consumption for laundry use in the dry and rainy seasons. Most households use under 30 L/p/d. According to the KS-test between these two histograms, there are no significant differences (significant level >0.05) between the dry season and rainy season. An intermediate value also reveals no differences between the dry season, 18L/p/d, and the rainy season, 19 L/p/d. Therefore, it can be said that psychological factors do not affect water consumption for laundry. More than 55% of observed data distributed under 20 L/p/d, and more than 80% distributed under 30 L/p/d. This amount was similar to the European cities which used drum-type washing machines. Generally speaking, water consumption for semi-automatic washing machines is 1.5 times as much of that for drum-type washers. The reason for smaller water consumption in Chiang Mai stems from household occupancy. As the average household occupancy of this survey (4.4) is larger than that of developed countries, (between 2.3 and 3.5) clothes washing in Chiang Mai is so efficient that water consumption per capita has resulted in a smaller number. Compared with average water consumption in Bangkok, 45 L/p/d, consumption in Chiang Mai is relatively small. The average household occupancy of surveyed households in Bangkok was 2.37, which is smaller than that in Chiang Mai (4.4). This causes the difference of water consumption in Bangkok and Chiang Mai. The difference of water resources, such as public waterworks or not, does not result in the consumption difference as shown from the KS-test.

According to Fig. 7, water consumption per capita for laundry appeared to be distributed via log-normal distribution. R2 values of linier regression are 0.989 for the dry season and 0.983 for the rainy season. This can be verified by the Shapiro-Wilk W-test (significant level >0.05).

3.4 Water consumption for bath water

Because of the hot climate in Thailand, the typical bath room has a bath basin (Fig. 8). The bath basin is always filled with cold water, and people bathe themselves in it in order to cool down several times a day according to the questionnaire. In the bath

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room, some households have only a bath basin, whereas others have both a bath basin and a shower, which is used if people want hot water. In this study, 72% households have both a bath basin and a shower. Therefore, the water consumption for baths is expected to depend on temperature, and not just the season. As temperatures in the dry and rainy season remain almost the same, there is supposed to be no significant difference in water consumption.

Figure 9 indicates the histogram of water consumption for bath use in the dry and rainy seasons. According to the KS-test between these two histograms, there is no significant differences (significant level >0.05) between the dry season and the rainy season as we supposed. Most households used 20–30 L/p/d, which was similar to the European cities. People in Singapore, where the climate is similar to Thailand, used much more water (about 80 L/p/d) because they showered several times a day. In Chiang Mai, people also used the bath room several times a day. However, they did not shower, but used stored water in bath basin instead. Thus, water consumption did not have a higher level there. Consumption in Chiang Mai was half as much as that in Bangkok (68 L/p/d). Although both climate and culture in Bangkok are the same as that in Chiang Mai, the difference in the progress of its water system construction may have resulted in the difference of consumption. The difference of water resources does not result in the consumption difference, judging from the KS-test.

According to Fig. 10, water consumption per capita for bath water appeared log-normally distributed. The regressions have R2=0.983 for the dry season and R2=0.984 for the rainy season. This was verified by the Shapiro-Wilk W-test (significant level >0.05)

3.5 Water consumption for the kitchen

In Thailand, typically, there is a huge water jar in the kitchen that is used to store water for cooking and bottled water that is used for drinking, according to the questionnaire. Used dishes are soaked in the washing-up bowl in the meantime, and then washed. Figure 11 indicates the histogram of water consumption for kitchen use in both the dry and rainy seasons. According to the KS-test between these two histograms, there is no significant differences (significant level >0.05) between the dry season and the rainy season. 80% households used under 30 L/p/d, which is similar to European cities and to Singapore. The average consumption in Bangkok (4 L/p/d) was very small, and was the same as consumption for dishwashers in US cities. This might be because people in Bangkok usually do not cook at home. On the other hand, 95% of surveyed households in Chiang Mai usually have dinner at home, so consumption in Chiang Mai was larger than that in Bangkok. Same as other purpose described above, the consumption difference arise from the difference of water resources, public waterworks or not, can not be recognized judging from the KS-test.

According to Fig. 12, water consumption per capita for kitchen appears distributed via log-normal distribution. R2 values of linier regression are 0.996 for the dry season and 0.995 for the rainy season. This can be verified by the Shapiro-Wilk W-test (significant level >0.05)

4 Conclusions

It was expected that rainfall differences between the dry and rainy season could influence awareness for water resources so that water consumption in the dry season may be smaller than that in the rainy season. However, the result was opposite to our expectations in that there was no significant difference in water consumption for all activities between the dry and the rainy season. Although some households still used rainfall in Chiang Mai, people did not think of rainfall as a water resource because it was not the main water resource. In contrast, we could have concluded that consumption did not increase in the rainy season just because it did not decrease in the dry season. People did not waste water because rainfall increased.

Furthermore, the differences in water resources such as public waterworks, which can be used easily by just running a faucet, or non-public waterworks like community waterworks, mountainous water and groundwater, did not factor much in the consumption difference.

The consumption in Bangkok was much larger than that in Chiang Mai for every residential activity. For laundry use, household occupancy might cause the consumption difference. Differences other than laundry may be because of progressed construction of water systems and the development of the city as a whole in Bangkok. Thus, this development could have caused the disappearance of classical water usage and customs.

Water consumption per capita for every usage appeared to be distributed with log-normal distribution, and was verified by the Shapiro-Wilk W-test (significant level >0.05). This tendency could be found in previous studies about water consumption, so it should support the reliability of our methodology and collected data.

Acknowledgement. This work has been supported by CREST (Core Research for Evolutional Science and Technology) of Japan Science and Technology Corporation.

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Table 1. Top 10 population by province.

Province	Population 2003
Bangkok	5 844 607
Nakhon Ratchasima	2 591 050
Ubon Ratchathani	1 805 322
Khon Kaen	1 770 605
Chiang Mai	1 603 220
Buri Ra	1 554 009
Udon Thani	1 542 071
Nakhon Si Thammarat	1 531 072
Si Sa Ket	1 465 538
Surin	1 406 612

Statistical Yearbook Thailand 2004

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Table 2. Micro-components of residential use in Bangkok.

Total	L/p/d
Toilet	31
Bath & Shower	78
Laundry	52
Kitchen	4
Loss	24
Others	28

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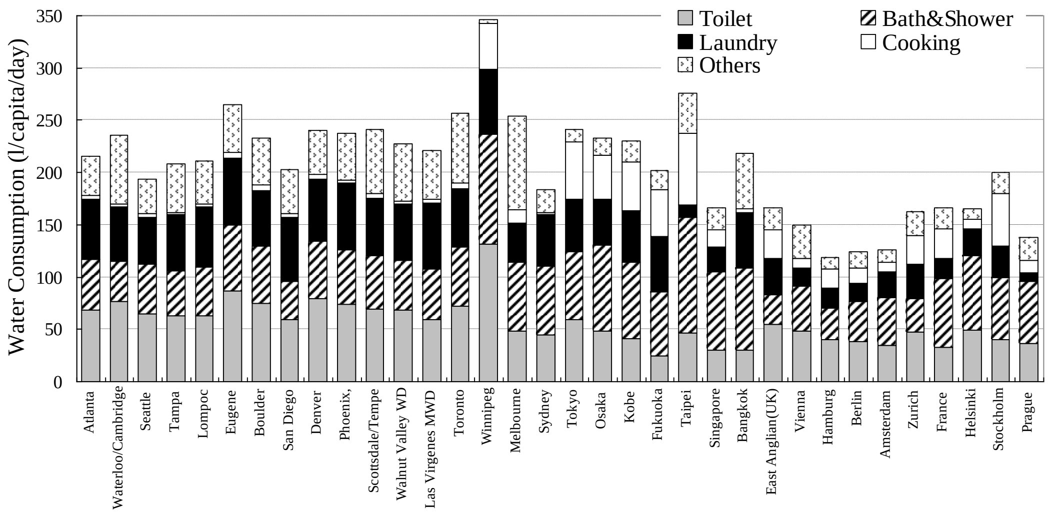

Fig. 1. Micro-components of residential indoor use.

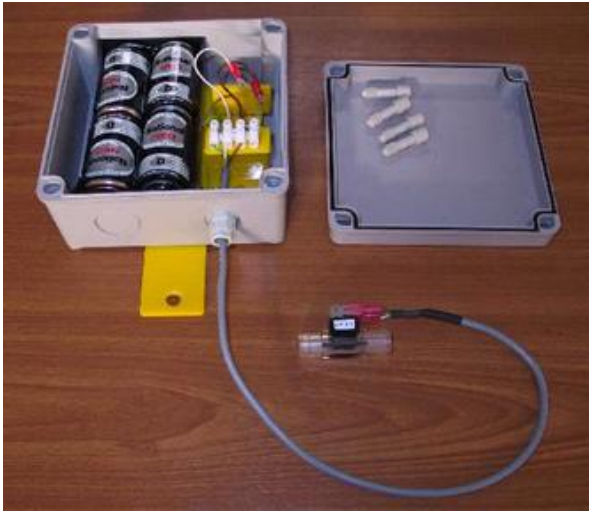

Fig. 2. Small-sized accumulative water meter.

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Fig. 3. Pail toilet.

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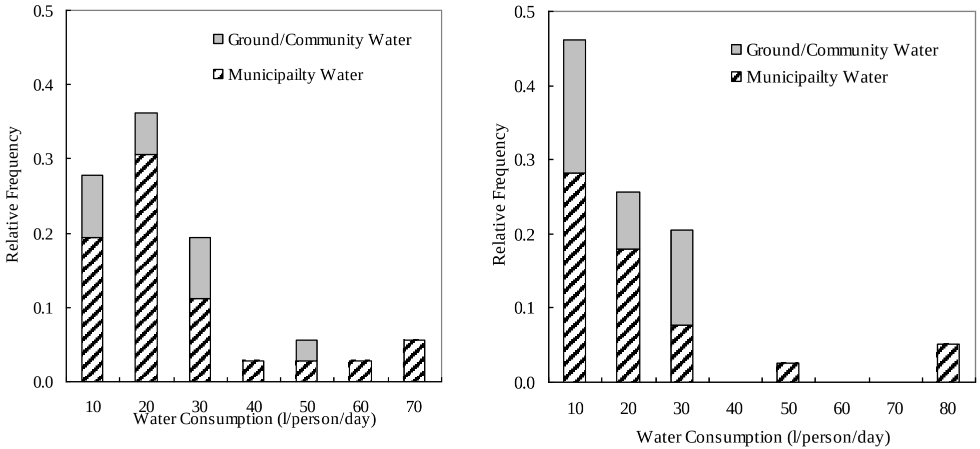

i) Dry season

ii) Rainy season

Fig. 4. Histogram of per capita consumption for toilet.

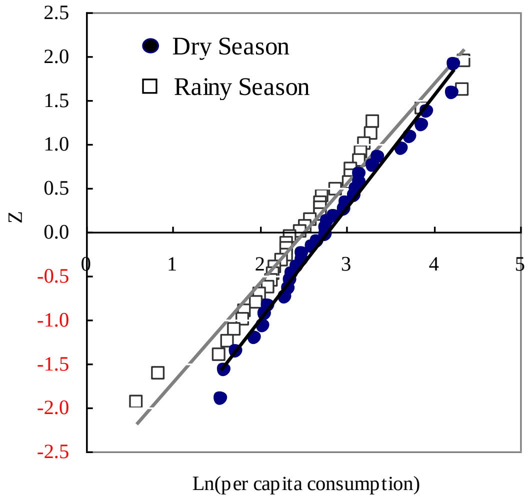

Fig. 5. Distribution of water consumption for toilet.

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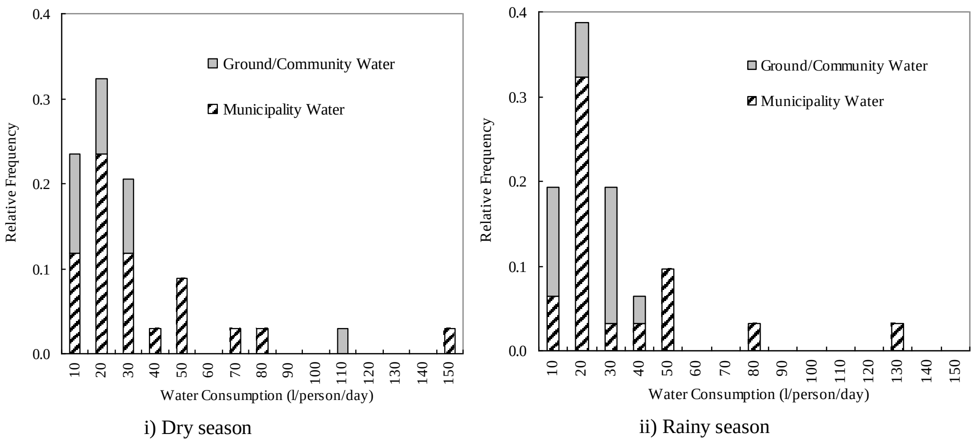

Fig. 6. Histogram of consumption per capita for laundry.

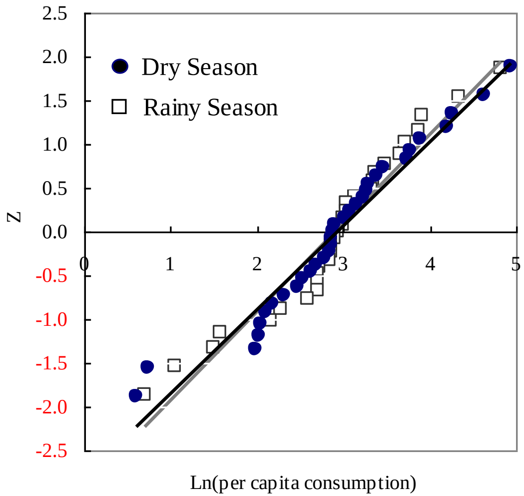

Fig. 7. Distribution of water consumption for laundry.

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Fig. 8. Typical bath room in Thailand.

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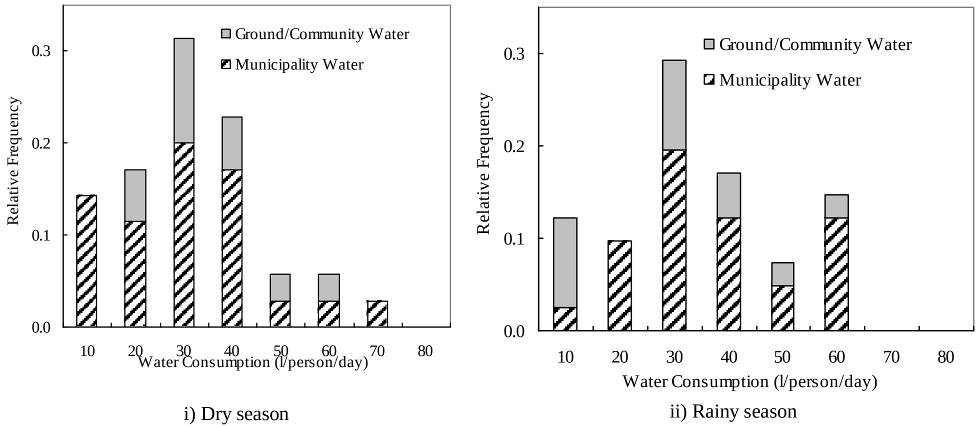

Fig. 9. Histogram of consumption per capita for bath.

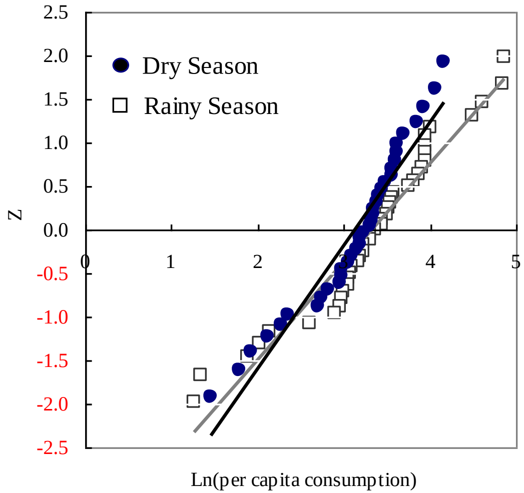

Fig. 10. Distribution of water consumption for bath.

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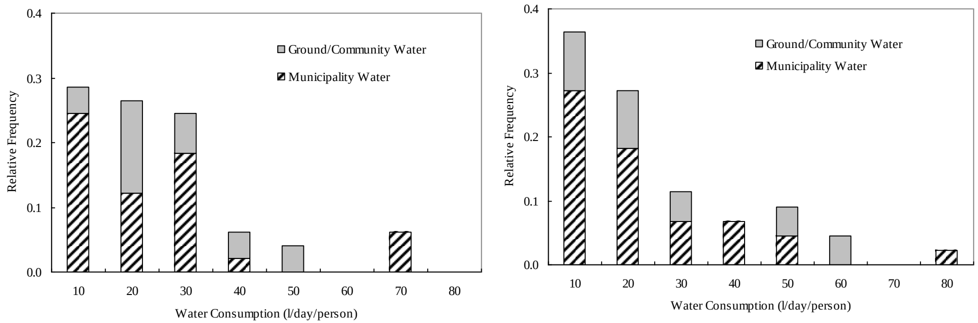

i) Dry season

ii) Rainy season

Fig. 11. Histogram of consumption per capita for kitchen.

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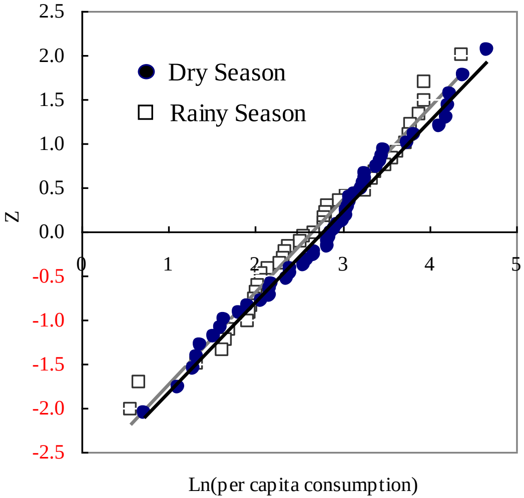

Fig. 12. Distribution of water consumption for kitchen.

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