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Effects of inequality of supply hours on consumers' coping strategies and perceptions of intermittent water supply in Kathmandu Valley, Nepal

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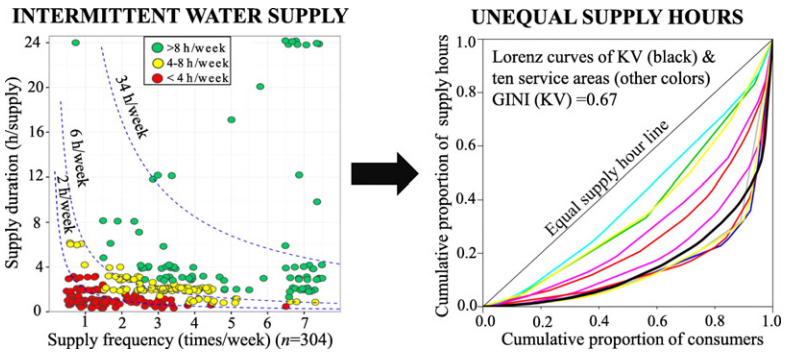
HIGHLIGHTS

- Lorenz curves and Gini coefficients were used to measure inequality of piped supply.
- Inequality was found both between and within service areas.
- Coping strategies for reduced supply hours vary between home owners and tenants.
- Expectations for improved water quality are higher than those for supply volume.
- Consumers' perceptions of piped water services worsen as supply hours shorten.

GRAPHICAL ABSTRACT



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ABSTRACT

To investigate the effects of unequal supply hours on consumers' coping strategies and perceptions of the intermittent water supply (IWS) in the Kathmandu Valley (KV), Nepal we conducted a randomized household survey ($n = 369$) and on-site water quality tests. Half of the households received piped water for 6 or fewer hours per week. To augment or cope with the inadequate supply, 28% of the households used highly contaminated and expensive tanker-delivered water. Half of the piped water samples ($n = 13$) were contaminated with *Escherichia coli*. Free chlorine concentration in all piped water samples was below the national standards (0.1–0.2 mg/L), but combined chlorine was detected at an average of 0.24 mg/L, indicating ingression of contaminants in the network. Point-of-use devices could increase access to safe water in the KV from 42% to 80%. The use of Lorenz curves and Gini coefficients revealed inequality of piped water supply hours per week both between and within service areas in the KV, due mainly to a small percentage of households who receive longer supply hours. To cope with reduced supply hours, home owners pay more to get water from alternative sources, while tenants compromise their water consumption. Under IWS, expectations for improvements in piped water quality and supply regularity are higher than those for supply volume. Consumers' perceptions of the piped water services worsen with the reduction in supply hours, but perceptions of piped water tariff are independent of supply hours.

1. Introduction

The supply of piped water on premises, considered the most improved water source (WHO and UNICEF, 2015), does not always take

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into consideration the core values of improved water sources: safety, adequacy, and reliability (Godfrey et al., 2011; Heitzinger et al., 2015; Shaheed et al., 2014). Globally, at least 300 million people receive piped water under the condition of intermittent water supply (IWS), a form of water apportioning (Kumpel and Nelson, 2016). Prior studies have identified several causes of IWS that can be broadly grouped into two categories: (1) purposely reduced supply hours due to water shortages caused by urban population growth, inefficient water supply systems, and shrinkage of water resources, and (2) an effect of power rationing and financial constraints (Galaitsi et al., 2016; Klingel, 2012; Kumpel and Nelson, 2016; Rosenberg et al., 2008; Totsuka et al., 2004).

Access to improved water sources among the urban population in Nepal is decreasing (from 97% in 1990 to 91% in 2015), unlike in most developing countries (WHO and UNICEF, 2015). The Kathmandu Valley (KV) is the biggest urban concentration in Nepal, with a population of 2.5 million (CBS, 2011). Its water supply company, Kathmandu Upatyaka Khanepani Limited (KUKL), is continually struggling to provide safe, reliable, and adequate piped water to its consumers. Piped water was supplied for 6 h a day in the 1970s (World Bank, 1974). Since then, because of the widening gap between KUKL's supply volume and the water demand of the increasing population, KUKL has regularly reduced the supply hours. Currently, intermittency prevails throughout the KV (KUKL, 2016), and the supply–demand gap stands in excess of 200 MLD (million liters per day) (KUKL, 2015). IWS in the KV will continue at least until 2028, when an additional 510 MLD from the Melamchi Water Supply Project will eventually become available (Hazama Ando, 2015). Water utilities, including KUKL, consider physical water scarcity as the primary cause of IWS and tend to disregard improving other operations, because little is known about how service levels can be improved under source water volume constraints (Galaitsi et al., 2016). Consumers are therefore forced to rely on alternative water sources to meet their water demands and to use various coping strategies such as storing water in large tanks and using household water treatment systems to improve water quality (Katuwal and Bohara, 2011; Pattanayak et al., 2005).

KUKL receives an average of 60 complaints a week, most of them related to inadequate supply, leaks, contamination, and inequity in distribution (KUKL, 2008). A continued water supply–demand gap will exacerbate the intermittency and thus the number of complaints will increase. Delays or inaction in addressing complaints devalue consumer trust in utilities (Celik and Muhammetoglu, 2008; García-Valiñas and Miquel-Florensa, 2013; Jain et al., 2014; Roche et al., 2013; Vásquez et al., 2011). Dietrich et al. (2014) consider consumers real-time sensors, whose perceptions are useful in assessing the service levels of piped water supply. It was reported that consumers' perceptions are influenced by the comparative levels of piped water services, system reliability, and water quality among nearby houses (Vásquez et al., 2011), and by their concerns for piped water quality (Celik and Muhammetoglu, 2008; García-Valiñas and Miquel-Florensa, 2013; Jain et al., 2014; Vásquez et al., 2011). Moreover, previous investigations revealed that consumers' subjective perceptions (Doria, 2010; Vásquez, 2012), as well as their socioeconomic characteristics (such as income, education level, and household size), influence the selection of coping strategies (García-Rubio et al., 2016; García-Valiñas and Miquel-Florensa, 2013; Roche et al., 2013; Vásquez, 2012; Vásquez et al., 2011). Therefore, we hypothesized that the inequality of supply hours under IWS, as well as supply frequency per week, can influence consumers' coping strategies and their perceptions. However, despite its prevalence, studies of the effects of IWS on consumers' coping strategies and perception of piped water are sparse. Existing studies considered only the average supply duration as a measure of IWS and did not elaborate on the inequality of water supply among consumers (Andey and Kelkar, 2009; Fan et al., 2014; Zérah, 2000). This study is the first to our knowledge to visualize the inequality in supply hours caused by IWS and to reveal the effects of such supply inequality on consumers' coping strategies and perceptions of piped water services.

The objectives of this study were to assess the prevalence of IWS in the KV using supply hours and supply frequency as measures of IWS, and to graphically express and quantify the supply inequality of piped water in the KV. The supply inequality was visualized by Lorenz curve and quantified by the Gini coefficient in each service area and in the whole KV. Another objective was to evaluate the effects of supply hours and supply inequality under IWS on consumers' coping strategies and their perceptions of the piped water services.

2. Methodology

2.1. Questionnaire survey

A questionnaire survey (Approval No. 28-182, the Ethical Review Board of the University of Tokyo) was conducted in all ten service areas of KUKL in November and December 2015. The sample size was determined by Eq. (1) (Daniel, 1999):

$$\text{Sample size} = \frac{Z^2 P(1-P)}{d^2} = \frac{1.96^2 * 0.5(1-0.5)}{0.05^2} = 384 \quad (1)$$

where, Z is the Z statistic for the confidence level (1.96 for 95% confidence level); P is the expected prevalence (for maximum sample size, $P = 50\% = 0.5$); and d is the precision, taken as 5% (Naing et al., 2006). These values gave a sample size of 384, but unforeseeable constraints in the survey meant that only 369 samples could be taken. We assumed that this number was close enough to 384. Proportional stratified random sampling (Nardi, 2013) was used to select samples on the basis of the number of pipe connections in each service area (Table 1). The surveyed households were spread widely over the KUKL service areas (Fig. 1), and are assumed to be representative of the total population.

The questionnaire included both open and closed questions which probed respondents' demographic information, water sources, water storage and treatment, and perception of the water services. Table 2 shows the specific information collected. A 5-point (Likert-type) scale was used to assess perceptions of the service level (quality of piped water services: very good, good, neutral, poor, and very poor) and the piped water tariff (too high, high, normal, low, and too low). All questionnaire sheets were coded to maintain anonymity before data analysis.

2.2. Statistical analyses

We investigated five strategies used by the consumers to cope with IWS: (1) purchasing tanker-delivered water from vendors, (2) storing water in large tanks, (3) treating piped water with household water treatment systems, (4) pumping low-pressure piped water, and (5) spending money on all sorts of water (Katuwal and Bohara, 2011; Pattanayak et al., 2005). We also investigated the effects of IWS on consumers' perceptions of four aspects of the piped water services:

Table 1
Service areas and numbers of households surveyed (Hazama Ando, 2015).

Service area	Number of pipe connections	Population served	Households surveyed
Kamaladi	5940	37,677	9
Kirtipur	7629	89,180	19
Madhyapur Thimi	7962	83,036	28
Bhaktapur	10,496	100,308	25
Chhetrapati	13,894	115,458	28
Tripureshwor	20,766	196,612	52
Baneshwar	25,796	281,621	50
Maharajgunj	31,204	343,191	42
Mahankalchaur	31,339	424,228	53
Lalitpur	39,692	316,403	63
Total households surveyed			369