Domestic Water Availability in Vientiane, Lao PDR —The Water Quality Variation in the Rainy Season—

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Abstract

Many of the water sources in Lao PDR are used for drinking and other domestic purposes. There are few reports on the domestic water availability in Lao PDR, which is composed of quality and quantity. The aim of this study was set to determine actual domestic water use and quality conditions during the rainy season in Vientiane, Laos to reveal seasonal variations in domestic water quality. In the target region, the supplied water and the deep and shallow well water were used for the domestic water sources. The different sources were taken depending on the purpose. On the whole, the quality of the supplied water was much better than that of the deep well water, which contrasted with the residents’ understanding. The quality of the shallow well water varied in the rainy season due to a dilution effect on many items except NH4+, TP, PO4−3 and coliform bacteria. Some shallow well with a very high NH4+ concentration implied contamination from a leaking sewer through the groundwater. The shallow well water used in the kitchens of some households may have bad health effects because of coliform contamination.

Key words: Domestic water, Groundwater, Laos, Seasonal variation, Water quality.

1. Introduction

Southeast Asia has abundant water resources, such as groundwater for domestic use and marshes that naturally purify water. About one-third of the Asian population (1,000–2,000 million) uses groundwater for drinking (United Nations Environment Programme [UNEP], 2003). However, due to rapid economic growth, environmental water problems and degradation have become serious issues. In particular, urbanization has resulted in excess pumping and contamination of groundwater because of population growth (Hadipuro, 2010; Nyenje et al., 2013) and surface water is polluted due to inadequate water treatment (Karn and Harada, 2001).

The Millennium Development Goals (MDGs) are aimed at eradicating poverty and tackling these problems. The target of halving the proportion of people with no access to a healthy drinking water source has been achieved worldwide and in Southeast Asia (United Nations [UN], 2014). World Health Organization and United Nations Children’s Fund Joint Monitoring Programme [WHO/UNICEF JMP] defines drinking water as the water used for normal domestic purposes, including consumption and hygiene (WHO/UNICEF JMP, 2004); this definition is applied for the documents related to developments such as MDGs. Hereafter in this paper, we use the term “domestic water” for representing the whole domestic use and “drinking water” only for drinking. On the other hand, measures have been implemented in Indonesia to prevent excess pumping of groundwater in urban areas but the lack of infrastructure prevents access to water by all people, and many poor people cannot afford to connect to the system (Hadipuro, 2010). One of the Sustainable Development Goals (SDGs), which were adopted in September 2015 as a post-2015 agenda item, was set out to “ensure availability and sustainable management of water and sanitation for all.” To achieve this goal, solutions considering the financial limitations in developing countries and comprehensive strategies utilizing local knowledge should be designed to assess the capacity, limitations, and sustainability of ecosystem services.

Many of the water sources in Lao PDR are used for drinking and other domestic purposes (Ministry of Health and Lao Statistics Bureau, 2012). The ratio of people connected to an adequate water supply has been increasing but it was only 28% of the total and 64% of the urban population in 2015 (WHO/UNICEF JMP, 2015). Groundwater is a main domestic source and is generally preferred for drinking because of its purity (Schmoll et al., 2006). Some studies have assessed groundwater quality for domestic use. Fengthong et al. (2002) reviewed the test program conducted by the Ministry of Health in 1999 to survey groundwater drinking quality. They pointed out the contamination risk from surrounding wastewater and latrines caused by the absence of fencing or cover. Although that report was based on a one-time-only survey, seasonal variations in groundwater quality are assumed, as reported for Taiwan (Kuo et al., 2004). Taiwan and Lao PDR experience the Asian monsoon climate with distinct rainy and dry seasons.

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However, no study has revealed seasonal variations in groundwater quality or availability in Lao PDR. Thus, the aim of this study was set to determine actual domestic water use and quality conditions during the rainy season in Vientiane, Lao PDR to reveal seasonal variations in domestic water quality.

2. Methodology

2.1 Field Measurements

The sampling targets were four villages located near the That Luang marsh in the eastern part of the capital Vientiane (Fig. 1), where water resource availability, such as ground and surface water, is high but rapid land development has been progressing due to foreign investments. Five target households in each village were selected to sample shallow and deep groundwater as well as the water supplied to residents, which originated from the Mekong River, and is purified, pressurized, and delivered to each household. Shallow groundwater is pumped by electric pump except one household from an unconfined aquifer several meters underground through an open well with a heavy cap. Deep groundwater is pumped from a confined aquifer ten to several tens of meters underground through a closed pipe. The number of target domestic water resources in each village is listed in Table 1. Water samples were taken through tube well or tap directly after rinsed in the same water twice in order to measure the water quality residents usually used for domestic purposes. For one shallow well without electric pump, we drew the water by bucket and took sample after rinsed in the same water twice.

Three water samples were collected in July, August, and October 2015, which represent the beginning, middle, and end of the rainy season, respectively. The sampling dates and cumulative precipitation are shown in Fig. 2. The Hourly Gauge-calibrated Rain Rate data in the Global Satellite Mapping of Precipitation product ver. 6 (Okamoto et al., 2005; JAXA/EORC, 2009) was used for the precipitation data. Total precipitation from January 1 to November 20 was 1,029 mm, and the cumulative precipitation quantities on the field sampling dates were 272 mm (July 8), 597 mm (August 14), and 965 mm (October 9). The domestic use for each water source was investigated in each household during the first survey in July.

2.2 Water Quality Analysis

The analytical methods and equipment used are listed in Table 2. All factors analyzed, except coliform bacteria, were analyzed at the University of Tokyo. Coliform bacteria were analyzed in August samples by the Natural Resources and Environment Institute, the Ministry of Natural Environment and Resources, and the October samples were analyzed by the Ministry of Health. The number and water source of the samples for the coliform analysis are listed in Table 3. Turbidity and chromaticity were measured in the July and October samples, and then all samples were filtered and analyzed for suspended sediment (SS). Filtered samples were analyzed for total nitrogen (TN), nitrate/nitrite-nitrogen (NO₃⁻/NO₂⁻), ammonium nitrogen (NH₄⁺), total phosphorus (TP), phosphate phosphorus (PO₄³⁻), and total organic carbon (TOC). Turbidity, Chromaticity and SS which were easily perceived by

![Fig. 1. The location of target villages in suburban Vientiane.](image-url)
residents were measured in order to compare with the residents' recognition of water quality. TN, NO$_3^-$/NO$_2^-$, NH$_4^+$ were measured to detect contaminations by human excrement and fertilizer, whereas TP and PO$_4^{3-}$ were to detect contaminations by detergent and fertilizer. TOC was measured to detect contaminations by excrement and other domestic waste water. Coliform bacteria were measured to assess a possibility of health hazard.

3. Results and Discussion

3.1 Domestic Water Uses for Each Source

The domestic water uses for each source are listed in Table 4. None of the water from the three sources was used for drinking, as the villagers usually drank bottled water. Xayyavong and Babel (2010) reported the quality of the bottled water met the most standards except pH in a few sample for drinking water set by Lao PDR.

Small portions of the supplied water and shallow well water were used for cooking. The main purposes of the shallow and deep well water were washing cars, dishes, and vegetables. Most of the villagers assumed that the quality of the deep well water was much better than that of the shallow well water and used the supplied water as an alternative to the deep well (Makino et al., 2016). Availability of the supplied water was unpredictable, particularly on the terrace, and one household terminated their connection to the pipe in August because of a long-term supply interruption.

3.2 Water Quality of Each Source

The results of the turbidity, chromaticity, TN, NO$_3^-$/NO$_2^-$, NH$_4^+$, TP, PO$_4^{3-}$, TOC, and SS analyses are shown in Fig. 3. The drinking water quality standard values for turbidity, chromaticity, and NO$_3^-$/NO$_2^-$ in Lao PDR (Water Resource and Environment Administration Department of Environment, 2010) were added to Fig. 3 because standards for these parameters have been defined. Turbidity and chromaticity showed similar low concentrations in the supplied water and the deep water well, whereas those values in the shallow water well were higher. This trend was consistent with the villagers’ understanding of the water quality of each source (Makino et al., 2016), although nitrogen, phosphorus, and organic matter concentrations were different from their understanding. The concentrations in the shallow water well decreased from the beginning to the end of the rainy season. Four shallow well water samples exceeded the turbidity standard in July and two exceeded the standard in October. Seven samples exceeded the chromaticity standard in July, whereas five exceeded the standard in October, suggesting a dilution effect due to rising groundwater level.

The main TN component in all of the water sources was NO$_3^-$/NO$_2^-$, and NH$_4^+$ concentrations were very low except in two shallow wells. Little nitrogen was detected in the supplied water during the rainy season. TN and NO$_3^-$/NO$_2^-$ concentrations in the deep well were 3.0–5.0 mg L$^{-1}$, and the maximum value did not exceed the water quality standard. Three shallow well samples
exceeded the nitrogen standard in July, five exceeded the standard in August, and three exceeded the standard in October. This trend was similar to the quartiles for the shallow well water samples. The slope of the cumulative precipitation curve was very steep, which allowed contamination to occur. The shallow well with a very high NH₄⁺ concentration was located near the sewer mainline where the groundwater level was high (1 m). These conditions may have be lead to contamination of the shallow well water from a leaking sewer. The other shallow well with a high NH₄⁺ concentration was located next to the latrine in the same household. The well itself was covered on the top and sides with concrete but the water may have become contaminated through the groundwater.

TP and PO₄³⁻ concentrations showed a similar trend, in which deep well water had the highest concentrations, followed by the shallow well water, but neither was detected in the supplied water. A high phosphorus concentration was reported in a deep well. The change in phosphorus concentration in the shallow well water was opposite to that observed for turbidity and chromaticity and may have been caused by annual variations during the dry season because deep well water is assumed not to be affected immediately by precipitation falling on the ground.

TOC and SS showed a similar trend, except for the quartiles of the deep well in August. When we filtered the deep well samples in August, we found some white solid on the filter. We could not identify this solid but iron ion was not detected in water samples. The supplied water and deep well water should have low TOC and SS concentrations and higher concentrations could be caused by insufficient management of the plumbing or other equipment. Changes in the concentrations in the shallow well water were likely due to a dilution effect from rising groundwater.

### Table 2. Items and methods for water quality analysis.

<table>
<thead>
<tr>
<th>Items</th>
<th>Method</th>
<th>Equipment</th>
<th>Japanese Industrial Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN / NO₃⁻ / NO₂⁻</td>
<td>Continuous flow analysis</td>
<td>STAT-2000, BL TEC K.K.</td>
<td>JIS K0170-3</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>Indophenol blue absorptiometry</td>
<td>V-630, JASCO</td>
<td>JIS K0102 42.2</td>
</tr>
<tr>
<td>TP</td>
<td>Potassium peroxodisulfate decomposition method¹</td>
<td>JIS K0102 46.3.1</td>
<td></td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>Molybdenum blue absorptiometry</td>
<td>WA-PT-4DG, KYORITSU CHEMICAL-CHECK Lab.</td>
<td>JIS K0102 46.1.1</td>
</tr>
</tbody>
</table>

¹ We applied the pretreatment to remove the effect of arsenic when we analyzed TP concentration in all the samples taken in December, but there were no difference between pretreated and no-pretreated results.

### Table 3. The number and source of analyzed samples for coliform items.

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>Entrusted organization</th>
<th>Item</th>
<th>The number of samples from each water source</th>
</tr>
</thead>
<tbody>
<tr>
<td>14, August</td>
<td>Natural Resources and Environment Institute</td>
<td>Fecal coliform</td>
<td>Supplied water: 2, Deep well: 3, Shallow well: 4</td>
</tr>
<tr>
<td>9-11, October</td>
<td>Ministry of Health</td>
<td>Total coliform</td>
<td>Shallow well: 7</td>
</tr>
</tbody>
</table>

### Table 4. The purpose of water use for each domestic water source (multiple answers were allowed).

<table>
<thead>
<tr>
<th>Source of water</th>
<th>The number of samples</th>
<th>Drinking</th>
<th>Cooking</th>
<th>Washing dishes</th>
<th>Washing ingredients</th>
<th>Shower</th>
<th>Washing car</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplied water</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Deep well</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Shallow well</td>
<td>15</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>12</td>
<td>11</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>
MNP 100 ml⁻¹; Fecal coliform was detected in all August samples taken from the shallow water wells but was not detected in any supplied water or deep well samples. The shallow well water samples collected in October exceeded the total coliform standard. Bottled water is usually used for drinking, whereas the supplied water, deep well water, and shallow well water are used in the kitchens of these households. A household with only a shallow well as their domestic water resource should watch their health because many people eat raw (washed) vegetables with other dishes.

4. Conclusion

In this study, we investigated the actual conditions of domestic water use and quality during the rainy season in the capital city of Lao PDR. In the target region, the supplied water and the deep and shallow well water were used for the domestic water sources. The different sources were taken depending on the purpose. On the whole, the quality of the supplied water was much better than that of the deep well water, which contrasted with the residents’ understanding. The quality of the shallow well water varied in the rainy season due to a dilution effect on many items except NH₄⁺, TP, PO₄³⁻ and coliform bacteria. Some shallow well with a very high NH₄⁺ concentration implied contamination from a leaking sewer through the groundwater. The shallow well water used in the kitchens of some households may have bad health effects because of coliform contamination. The data collected in this study will be useful to reveal annual and seasonal variations in domestic water quality in Vientiane and may contribute to achievement of the water target of the SDGs in Asia, where many people are dependent on groundwater for domestic use. Additional data will be collected during the dry season, as the volume of water available during the dry season is an important issue.

Acknowledgement

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