Reduction of residual chlorine in the Drinking water in Yokohama City

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1. Overview of the waterworks facility in Yokohama

The City of Yokohama is the second largest city in Japan with an area of approximately 435 km\(^2\) and a population of about 3.65 million. The city’s waterworks system dates back to 1887, celebrating 122 years in operation in October 2009. With four water filtration plants and pipelines stretching to about 9,000 km in length, the city supplies an average of around 1.2 million m\(^3\) of water per day. Providing services in the city’s hilly landscapes with elevations ranging from zero to 150 meters, the Yokohama Waterworks Bureau divides its water distribution areas into twenty-six large blocks, each of which has one distribution reservoir. They are designed to easily control water pressure and the amount of water supplied during normal operations, as well as to minimize the impact of water outage caused by water leakage accidents or renovation work.

The distribution area of each reservoir is also divided by water supply system into two blocks: pressure distribution using pumps and gravity flow distribution. Furthermore, these middle-sized blocks are divided into smaller segments to provide equalized water pressure in mains, thereby avoiding excessive water pressure and reducing the amount of water caused by leakage. The small block system also aims to equalize the time the water stays in the distribution system, so that residual chlorine can be kept at an optimal level.

2. For a supply of safe and high-quality drinking water

The Yokohama Waterworks set the goal of achieving "Supply of safe and highest quality drinking water" in its “Long-term Vision,” a future vision for Yokohama’s water utility management due to be implemented twenty years from now. It proposes measures necessary to attain this goal, including the improvement of filtration facilities by incorporating advanced filtration technologies and the removal of the odor of chlorine from drinking water (Figure 1).
3. Efforts for eliminating the chlorine odour (reduction in residual chlorine)

According to the poll conducted among the citizens, about 40% of the respondents were cautious when drinking water directly from the tap, and out of them, 60% said that they had noticed the odour of chlorine.

The odour of chlorine can be effectively alleviated by reducing the amount of the disinfectant sodium hypochlorite, fed in at water treatment works. However, the Water Supply Law in Japan specifies that a minimum residual chlorine of 0.1mg/ℓ should be maintained in the tap water to ensure the safety of water for public health.

In response to the citizens’ request for water with a less noticeable chlorine odour, the Yokohama city aims in its “Ten Year Plan” to remove the chlorine odour in the drinking water through methods including the reduction of sodium hypochlorite dosage.

With a goal set to reduce the average residual chlorine concentration from the fiscal 2003 level of 0.62mg/ℓ to less than 0.4mg/ℓ, the levels requisite both for the safety and quality of drinking water, the city has been conducting the following measures:

1) Improvement of chlorination facilities
   The chlorine dosing facilities at filtration plants and distribution reservoirs are to be improved for close control of the residual chlorine levels at water faucets.

2) Replacement of aged pipes
   In aged water pipes, the residual chlorine is consumed in the reaction with rust inside the pipes, lowering the chlorine levels in the water. This means that an increased amount of sodium hypochlorite is required to sustain the adequate levels of disinfection. The replacement of aged pipes, therefore, should be implemented in due course based on the renovation plans.

3) Installation of automatic water quality analyzers at consumers’ taps
   Automatic water quality analyzers installed at citizens’ houses allow for continuous measurement of water quality, providing us the data both to ensure the safety of tap water and examine the results of reduced dosage of sodium hypochlorite at the reservoir. The water quality analyzers have already been installed along streets to measure the water quality in the mains; however, a smaller analyzer set up at home enables the measurement of the actual quality of the drinking water being provided at the consumer’s tap after some chlorine is consumed in the mains.
4. Experiment overview

An experiment was conducted in the Tsurugamine reservoir and its distribution block from February 4, 2008. The amount of sodium hypochlorite injected into the reservoir was reduced to the ranges enough to lower the chlorine concentration of output water by 0.1mg/ℓ. Households in the block were asked to cooperate by installing an automatic water quality analyzer and subsequently monitoring the water quality.

The outline of methods and procedures of the experiment is as follows:

(1) Automatic water quality analyzer

1) The automatic water quality analyzer used in the experiment is a small device comparable in size to a typical outdoor unit of a residential air-conditioner. It can provide continuous measurement of the quality of drinking water in small quantities (at a flow rate of approximately 100 mℓ/minute).

2) The analyzer sends in real time the measured data (residual chlorine, turbidity, water color and temperature) through the NTT FOMA network, allowing for the data collection and storage at the central server.

3) The use of the central server allows for the remote monitoring of the data. When the server detects any abnormal values, it sets off an alarm to inform the water supply maintenance section of the local waterworks office.

(2) Roles of citizens who agreed to monitor the water quality

1) Provide the space for unit installation, electricity and tap water.
2) Observe color, turbidity, odour and taste of the water on a daily basis. Document this and submit a monthly report.
3) Report to the waterworks office in the case of detecting abnormal signs of water quality.
(3) Installation of automatic water quality analyzer

The locations of automatic water quality analyzers were determined after giving consideration to the following aspects (Figure 5).

1) Locations allowing the units to homogeneously cover the whole testing area.
2) Existence of pipe types with a high possibility of reducing residual chlorine levels
3) The results of the residual chlorine survey conducted in summer months.
4) The results of residual chlorine simulation using a distribution network analysis
5) Areas with low residual chlorine levels confirmed by local water supply maintenance sections

Incorporating the above information, the possible testing areas were chosen. The final locations of the analyzers were then determined by the type of water supply equipment, field survey results, as well as with the approval of the residents.

For reference, the specifications of the mains and the water service pipes connected to a household with the analyzer (unit No. 37) are shown in Table 1.

5. Results

The results of residual chlorine values measured in the Tsurugamine reservoir and by the automatic water quality analyzer (unit No.37) are shown in the Figure 6. In the experiment, the residual chlorine level at the reservoir outlet was reduced by about 0.1 mg/l on February 4, 2008.

In this chart, the residual chlorine concentration at the reservoir (a thin line in the chart) decreased from February 4, from approximately 0.8 mg/l to approximately 0.7 mg/l. A thick line in the chart, which represents the chlorine concentration measured by the No.37 unit at the consumer’s tap, fell in accordance with this decrease.

Comparing the data collected before and after the onset of the experiment among nine analyzers set up in the Tsurugamine block, there was a decrease in residual chlorine by an average of 0.08 mg/l (Table 2).
6. Current status of unit installation

As from the fiscal 2005, a total of 65 automatic water quality analyzers are being operated in ten water distribution blocks. Among these, the reduction of residual chlorine has been achieved in three blocks by the fiscal 2008, in which the monitoring by the analyzers is still underway. The city aims to make further efforts to reduce residual chlorine in drinking water to less than 0.4mg/l, thus ensuring the supply of safe and high-quality water to drink.

(Figure 7 shows the examples of data output on the monitoring display for unit No.37)

7. Challenges lying ahead

The issues and tasks to be undertaken in furtherance to the project:

1) Improved and reliable performance of water quality analyzers
2) Surveys on the water in storage tanks atop or inside buildings as well as the provision of guidance on their proper maintenance.
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Map of Japan

SAPPORO
OSAKA
TOKYO
YOKOHAMA
View of Central Yokohama

- Mt. Fuji
- Landmark Tower
- Port of Yokohama
- Bay Bridge

Minato Mirai 21 Area
Chinatown  Kaikoukinenkaikan

Topography of YOKOHAMA CITY
Overview of The Waterworks Facility

- Area 435 km²
- Population 3.65 million
- Water filtration plant 4
- Pipelines 9,000 km
- Amount of water supply 1.2 million m³/ day.

Schematic Chart of Improvements Required to Obtain

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply of safe, high-quality drinking water</td>
<td>Incorporation of advanced filtration technologies (i.e. membrane filtration and advanced water treatment)</td>
</tr>
<tr>
<td></td>
<td>Removal of chlorine odour by reducing level of chlorine</td>
</tr>
<tr>
<td></td>
<td>Direct feed from the city's distribution system instead of storage tank system</td>
</tr>
<tr>
<td></td>
<td>Regular inspection of water storage tanks by waterworks personnel</td>
</tr>
<tr>
<td></td>
<td>Replacement of existing lead pipes</td>
</tr>
<tr>
<td></td>
<td>Instruction on the maintenance of water supply equipment.</td>
</tr>
</tbody>
</table>
Residual Chlorine Concentration
Average of 6400 Points in Yokohama City

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Efforts for Eliminating The Chlorine Odour

1) Improvement of chlorination facilities

2) Replacement of aged pipes

3) Installation of automatic water quality analyzers at consumers’ taps
Outline of Residual Chlorine Reduction

Water Quality Monitoring System

An analyzers are installed at water taps for monitoring residual chlorine levels

Automatic water quality analyzer

Maintenance section for water supply

Monthly & daily data

Trends graph

FOMA Network

Water intake opening

Distribution reservoir

Water filtration plant

Reduction of residual chlorine levels at distribution reservoirs

Automatic water quality analyzer

Installation of Water Quality Analyzers

Water distribution blocks of Yokohama

area with water quality analyzer

Tsurugamine block

area for future installation
Water Quality Analyzer

exterior

interior

The Locations of Automatic Water Quality Analyzers were determined by

- Locations allowing the units to homogeneously cover the whole testing area.
- Existence of pipe types with a high possibility of reducing residual chlorine levels
- The results of the residual chlorine survey conducted in summer months.
- The results of residual chlorine simulation using a distribution network analysis
- Areas with low residual chlorine levels confirmed by local water supply maintenance sections
Area Selection for Unit Installation

Specifications of Pipes Connected to Unit No.37

<table>
<thead>
<tr>
<th>Water service pipes</th>
<th>Distribution pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe type</td>
<td>Diameter</td>
</tr>
<tr>
<td>VLGP</td>
<td>20mm</td>
</tr>
</tbody>
</table>
Residual Chlorine Value Chart

![Residual Chlorine Chart]

**2/4 Reduce chlorine residual level**

Data for 01/01/08 - 29/02/08

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Decrease in Residual Chlorine Concentration

<table>
<thead>
<tr>
<th>No32 ～ No40</th>
<th>Reduction of residual chlorine concentration</th>
<th>No32 ～ No40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average value of 9 units</td>
<td>【February 4, 2008】</td>
<td>Average value of 9 units</td>
</tr>
<tr>
<td>0.66 (mg/l)</td>
<td>▲0.08mg/l</td>
<td>0.58 (mg/l)</td>
</tr>
</tbody>
</table>
Challenges Lying Ahead

The issues and tasks to be undertaken in furtherance to the project:

• Improved and reliable performance of water quality analyzers
• Surveys on the water in storage tanks atop or inside buildings as well as the provision of guidance on their proper maintenance.
Thank You for Your Attention

Character of
Yokohama water works Bureau
Hamapyon