# Dukso Water Treatment Plant
# Namyangju City, South Korea

## 1. Background Information

Korea Water Resources Corporation (K-water) is a state-owned company established in 1967. K-water has operated multi-regional water supply system, a facility designed to provide tap water to more than two local governments, with 37 drinking water treatment plants. Dukso water treatment plant (DWTP) is one of 37 water treatment plants which is operated by K-water. DWTP was constructed in 1999 with the initial capacity of 200,000 $m^3$/d. In 2008, the plant was expanded to the total treatment capacity of 450,000 $m^3$/d. The background information of DWTP is presented in **Table 1.**

**Table 1 Overall Information of Dukso Water Treatment Plant**

| | |
|---|---|
| **Constructed Year/Expansion Year** | 1999/2008 |
| **Water Source** | Han River |
| **Number of connections** | 209,945 |
| **Peak Operating Flow ($m^3$/h)** | 15,556 |
| **Design capacity ($m^3$/d)** | 450,000 |
| **No. of operators working at the plant** | 8 |
| **Treated water standard** | Ministry of Environment (2014) |
| **Automation** | Yes |
| **Date of access of the source information** | 2014 |
| **References** | Statistical book of K-water waterworks (2014) |

Raw water for DWTP is extracted from the Han River. Main units of the treatment process are pump diffuser mixer (PDM), mechanical flocculator, rectangular sedimentation basin, coarse sand media filter, and up flow water backwash with air scour. DWTP supplied 281,327 $m^3$/d of tap water to six cities (Namyanju, Uijeongbu, Goyang, Yangju, Pocheon and Dongbucheon) in 2013.

## 2. Water treatment process flow

DWTP uses advanced treatment process such as PDM, coarse sand filter media with air and water backwash. In addition, sludge generated is treated by sludge thickener and dewatering machine. The major water treatment process is presented as below (**Figure 1**):

Raw water extraction (Han River) → Raw water pumping → Pump diffuser mixer (alum, chlorine) → Flocculation (hydrofoil type) → Sedimentation (rectangular, sludge collector) → Rapid sand filters → Disinfection (chlorine) → Clear Well → High lift pump building

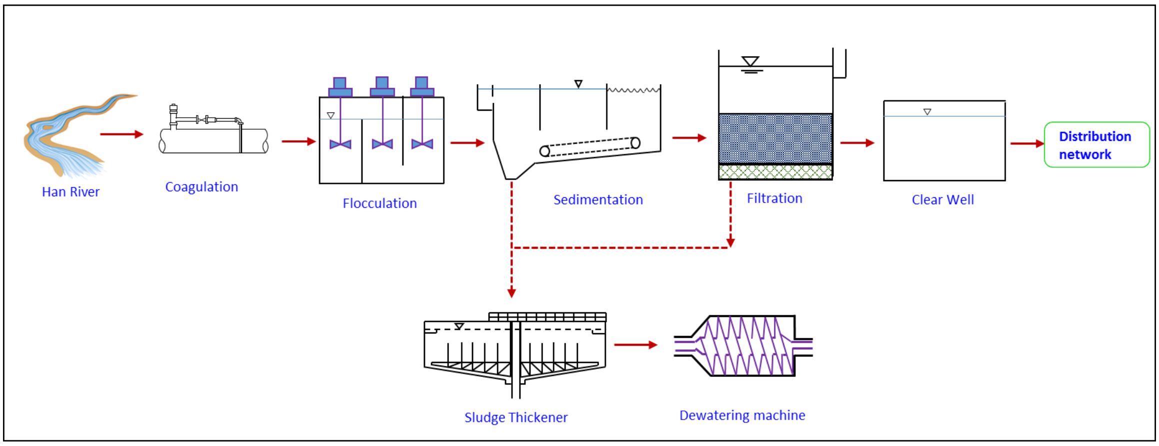

**Figure 1 Water Treatment Process**

### 2.1 Chemicals

At DWTP, five kinds of chemicals are mainly used in the water treatment process, which are: (1) poly aluminum chloride for coagulation, (2) chlorine for pre-and-post chlorination, (3) carbon dioxide for pH control of raw water, (4) powdered activated carbon (PAC) for removing odor and taste, and (5) polymer for sludge dewatering operation.

Poly aluminum chloride, chlorine, and polymer are continuously used in water treatment process. While carbon dioxide and powdered activated carbon are intermittently injected into raw water, i.e. when pH of raw water is high (more than 8.0) or unpleasant odor and taste are generated in raw water **(Figure 2)**.

Coagulant chemicals are stored in several storage tanks after they are purchased from chemical companies **(Figure 3)**. Chlorine gas is heavier than air and high corrosive potential when it contacts to the moist tissues. Therefore, the facility of chlorine feeding system is located underground with the neutralization equipment **(Figure 4)**.

**Figure 2 Carbon Fioxide Storage Tank (left) and Powdered Activated Carbon Feeding System (right)**

Polymer which is currently used at DWTP is anionic polymer, supplied by SNF Company (**Figure 5**). Polymer solution has the pH of 6-8, specific gravity of 1,000 -1,060 kg/m$^3$ (at 25 ℃) and the viscosity of 200 - 500 g/cm·s (for the solution 0.5 %)

Figure 3 Coagulant Storage Tank (left) and Feeding System (right)

Figure 4 Chlorine Storage Tank (left) and Feeding System (right)

Figure 5 Polymer Storage Tank for Dewatering Aid (emulsion)

### 2.2 Rapid mixing

Pump diffuser mixer (PDM) has been introduced and operated at several water treatment plants in South Korea since early 2000s for the purposes of rapid mixing. The PDM is an effective equipment for the quick dispersion of hydrolyzing metal salts, although the results of their performance evaluation showed that uneven dispersion of the injected coagulant was often observed in a full-scale PDM (Park et al. (2009)). However, PDM is a suitable method for the quick dispersion of the hydrolyzing coagulant and also has the potential to solve problems, such as noise, energy waste and high maintenance cost, associated with the use of a mechanical mixer (Kim and Lee, 2006).

DWTP first installed in-line blender mixer because it could often provide more efficient rapid mixing than traditional complete-mix type from several experiences. However, this mixing method experienced some problems such as scale form and non-uniform dispersion of coagulant chemical from plant operation. As follow-up alternatives, PDM replaced existing mixing method (in-line blender) in 2003 because PDM has the potential to solve these problems **(Figure 6**).

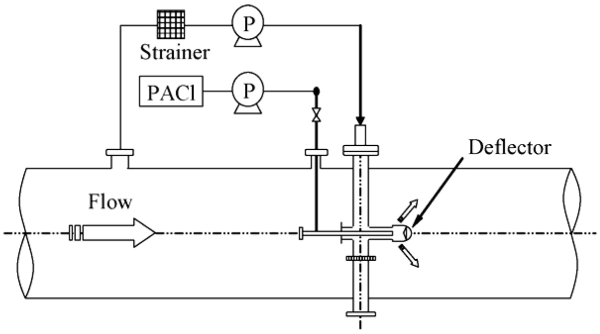

**Figure 6 Pump Diffuser Mixer**

### 2.3 Flocculation

In K-water, most water treatment plants introduced mechanical types of mixers for flocculation because the mechanical flocculators have great flexibility in varying G value (velocity gradient) according to the season. South Korea has distinct four seasons, thus temperature greatly varies from -6 to 22 ℃ (daily mean). Generally, the G value should be controlled on the basis of water temperature, namely by increasing it in the winter season and decreasing it in the summer season.

As shown in **Figure 7,** DWTP introduced the hydrofoil type mixing because of high mixing efficiency comparing to the pitched blade mixer (Tomas and Frantisek, 2011). With the application of automatic control system in water treatment plant, flocculation process was also employed the automatic control system for adjustment of appropriate G value on a seasonal basis without manual control by operators. The hydraulic retention time of water in flocculation tank is 37 minutes.

**Figure 7 Hydrofoil Type Mixer (12 basins)**

## 2.4 Sedimentation

Most of sedimentation basins are in horizontal-flow type with the rectangular or circular design. The choice is based on local conditions, economics, and personal preference. Camp (1946) stated that long, rectangular basins exhibit more stable flow characteristics and better sedimentation performance than very large square basins or circular tanks. DWTP designed the sedimentation tank as rectangular type **(Figure 8).**

The surface loading rate of sedimentation tank at DWTP is 37 $m^3/m^{2\cdot}d$. Typically, this design factor should be in the range from 20 to 60 $m^3/m^2.d$. The hydraulic retention time at the sedimentation tank is 3.6 h. It is in the range from 1.5 to 3.0 h according to the design guideline (Kawamura, 2000). DWTP installed mechanical sludge collector system, i.e. chain and flight collector as shown in **Figure 9** for removing settled sludge.

**Figure 8 Sedimentation Tank (12 basins)**

**Figure 9 Chain-and-Flight Type Collector**

## 2.5 Filtration

Dukso WTP installed coarse sand media filter (single media) with the depth of 110 cm and the effective size of 1.0 mm **(Figure 10)**. The backwash method is the procedure of water wash with air scour. The average filter run time is around 3 days.

According to AWWA (1999), the coarse sand filter media (single deep-bed media filter) differs from the conventional sand filter in two ways. First, the single media coarse sand filter can achieve higher removal efficiency because the medium is coarser. Second, this media can be washed without fluidization by the concurrent up flow of air and water. The excessive wash rates would be required to fluidize the coarse medium by only water wash.

**Figure 10 Filter Basin (26 basins)**

### 2.6 Sludge disposal

Mechanical dewatering systems are normally used at the plant where the drying bed cannot be constructed, due to the lack of land, frequent rainfall, and required a high solids content (Kawamura, 2000). These systems include gravity thickening and dewatering machine such as filter press, belt press, and vacuum filters.

Belt press is the most popular dewatering method in K-water due to relatively low cost (capital, operate and maintain), minimal attention and maintenance although filter press can get high solid contents. As it can be seen in **Figure 11 and 12**, DWTP currently operates the gravity thickener and belt press for sludge handling.

**Figure 11 Gravity Thickener**

**Figure 12 Dewatering Machine (belt press)**

## 3. Aspects of treatment processes posing most difficulty for daily operation

**Figure 13** shows the variation of the pH value of the Han River, the water source of DWTP. In the dry season (November to April), pH detected was very high (8.5). Kawamura (2000) stated that alkalinity and pH in raw water are the two critical factors in both coagulation and flocculation process. The appropriate pH ranges for metal salt coagulation are suggested from 6 to 8. If the pH of raw water is more than 8.0, the turbidity of treated water could be increased due to the pre-treatment failure, and coagulant could be overdosed than the optimum dosage.

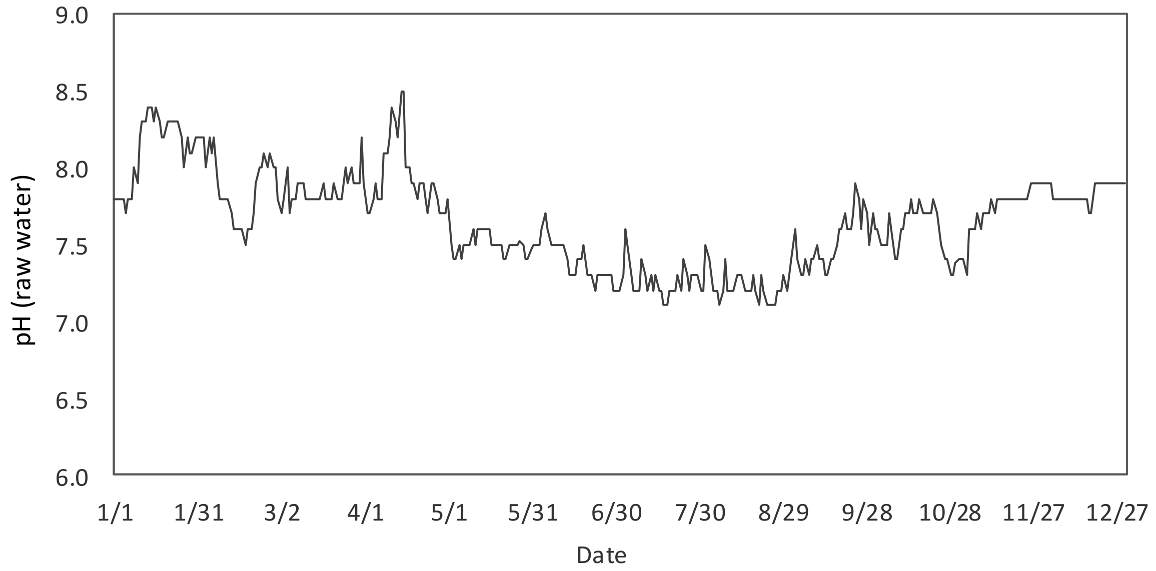

Figure 13 pH Trend of Raw Water (Han River) in DWTP

## 4. Aspects of water services management in general posing most difficulty at the moment

In the last 10 years, water supply in K-water has continuously increased 4 % per year, but electricity consumption also increased 5.6 % for the same period. In **Figure 14**, energy is the second highest budget item (30 %) for drinking water facilities, after labor costs which is accounting for 33 %. Recently energy efficiency is one of the hottest issues in drinking water service because it is at the core of measures to reduce the operational cost of water supply system. The energy intensity of DWTP, including intake facility, water production processes, and distribution system, was 0.579 kWh/m$^3$ in 2013.

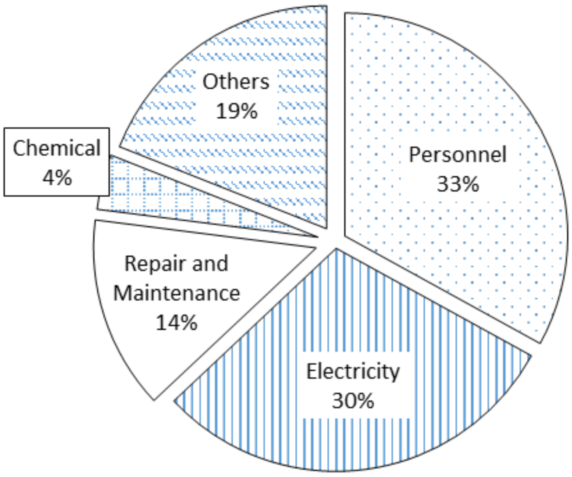

Figure 14 Breakdown of drinking water production cost in 2013

## 5. Measures taken now to cope with 3) and 4)

DWTP installed the carbon dioxide injection device to control pH of raw water when the pH of raw water is more than 8.0 **(Figure 15).**

**Figure 15 Facility of carbon dioxide injection in Dukso WTP**

To increase energy consumption efficiency, K-water conducted the diagnosis to evaluate the performance of all pumps (extraction, distribution, and booster pump), because pumping stage accounted for around 95 % of total energy consumption. From the result of diagnosis, the deteriorated pump (lower 7 % than the standard efficiency) was replaced as the new high efficiency pumps.

As a new alternative energy management, solar energy has installed widely in the water supply system site, such as a water intake, treatment plant, and available space site **(Figure 16)**. DWTP also installed photovoltaic generating facilities (capacity of 327 kW) on the roof of filter building at the end of 2013.

**Figure 16 Solar Panels Installed in K-water**

## 6. Recent investment made for the plant's improvement

Activated carbon is commonly used to adsorb the natural organic compounds (taste and odor compounds) in drinking water treatment. There are two most common options to install a granular activated carbon (GAC) treatment unit in water treatment plants: (1) post-filtration adsorption, where the GAC unit is located after the conventional filtration process (post-filter contactors or adsorbers); and (2) filtration-adsorption, in which some or all of the filter media in a granular media filter is replaced with GAC. DWTP has installed filtration-adsorption for removing unpleasant taste and odor by retrofitting existing rapid sand filter media (12 filter basins) to the granular media with GAC (the depth of 1.5 m) with pre-ozone. The other filters (14 basins) also will be replaced by 2016.

## 7. Customer’s opinion on water quality and water services in general

Due to the rapid urbanization and industrialization, several big water quality episodes occurred in succession in the early 1990s: disinfectant by-products (THMs) in 1990, phenol runoff into the water source from industrial plants in 1991, and pungent odor from the water source in 1992. These big episodes brought out serious public distrust in tap water from customers.

According to the tap water satisfaction investigation report (ATWI, 2012), people evaluated that the quality of tap water was not suitable for drinking because of obscure anxiety (31.9%), taste and odor (15.0%), and etc. (**Figure 17**), although the tap water had a very good quality (less than 0.5 NTU). Therefore, K-water seeks to actualize the smart water services to earn public trust and satisfaction by supplying not only clean and safe, but also stringent management of the whole production and transport processes.

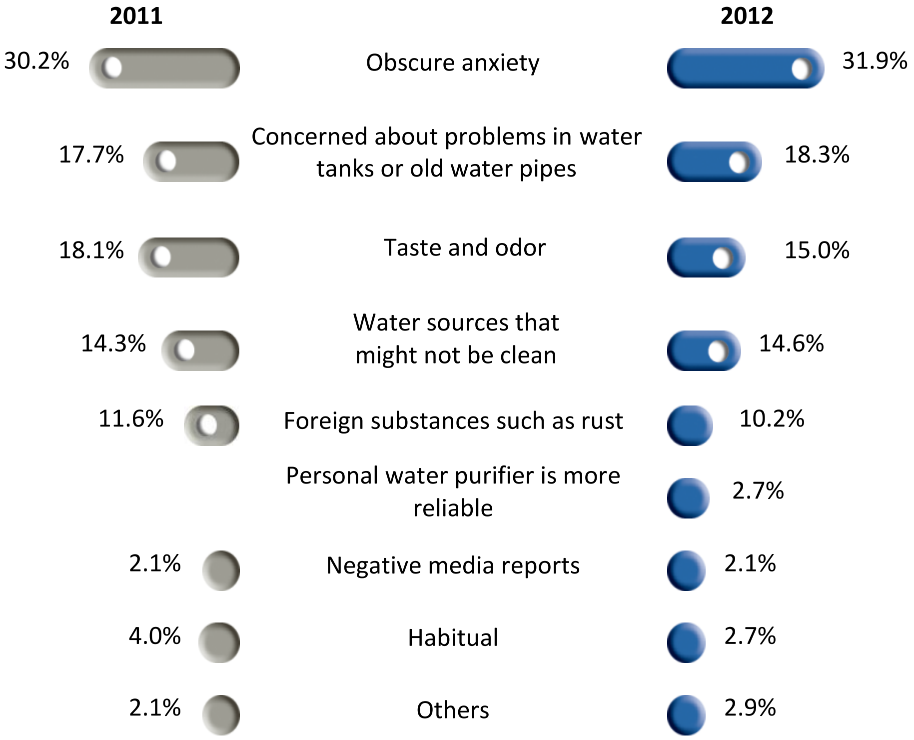

**Figure 17 Reasons of Public Distrust in Korean Tap Water**

## 8. Advanced technology used in this water treatment plant or any points to improve the process, water quality and capacity.

The existing laboratory-based methods are too slow to develop the operational response (Michael et al. 2011). There is a need for better on-line monitoring of water treatment systems. DWTP installed water quality instrument, including temperature, pH, turbidity, conductivity, alkalinity for continuous measurement of each water treatment process (**Figure 18**).

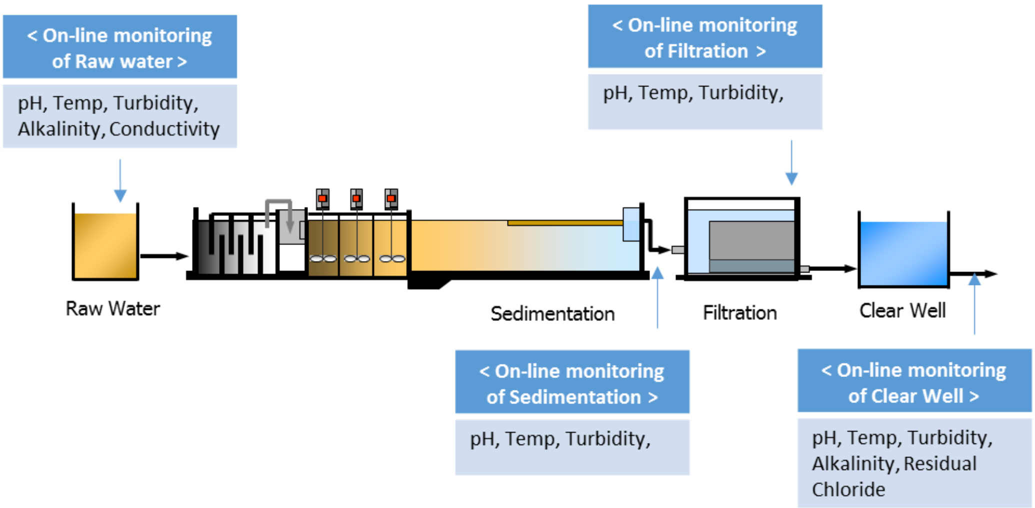

**Figure 18 On-line Monitoring System of Each Water Treatment Step in DWTP**

To detect the chemical contaminations in raw water, the early warning system (EWS) was introduced to provide a rapid warning of the occurrence of contaminants which could be the immediate threat to living organisms since 2010. EWS is generally an integrated system consisting of monitoring instrument technology, with an ability to analysis and interpret in real time (Grayman et al. 2001).

The government of South Korea obligated the installation of biological EWS such as daphnia (water flea), algae toximeter, and fish activity monitoring system in a given size facility of water intake (more than 10,000 $m^3$/d) by regulation (MOE, 2012). Thus, DWTP are also preparing the introduction of a biological early warning system from the existing fish monitoring system.

## 9. Other Highlights

- The dewatered sludge (dry cake) had been recycled and reused 100 % as the materials for cement industry since 2006
- Ozone generator was installed for pre-ozonation, as shown in **Figure 19**.

**Figure 19 Ozone Generator**

## 10. Water quality data

The water quality data at DWTP (2014) is presented in **Table 4**. All measured parameters were under the standard of the Ministry of Environment (Korea).

**Table 2 Water Quality Data (2014)**

| Parameters | Unit | Raw water | | Treated water | | Standard (Korea) |
|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | |
| pH | - | 7.1 | 8.5 | 7.4 | 7.5 | 5.8 - 8.5 |
| Turbidity | NTU | 1.6 | 15.7 | 0.04 | 0.08 | 0.5 |
| Alkalinity | mg/L | 33 | 67 | 28 | 62 | - |
| Conductivity | µs/cm | 127 | 226 | 141 | 232 | - |
| Total hardness | mg/L | 53 | 82 | 52 | 82 | 300 |
| Total dissolved solid | mg/L | 107 | 145 | 78 | 139 | 500 |
| $NH_4$-N | mg/L | 0.01 | 0.22 | N.D | N.D | 0.5 |
| $NO_3$-N | mg/L | 0.9 | 2.4 | 1.0 | 2.4 | 10 |
| Iron | mg/L | 0.04 | 0.23 | N.D | N.D | 0.3 |
| Manganese | mg/L | 0.01 | 0.07 | N.D | N.D | 0.05 |
| Chloride | mg/L | 7 | 15 | 11 | 19 | 250 |

## 11. References

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