Bansong Water Treatment Plant
Changwon 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. Bansong Water Treatment Plant (BWTP) is one of 37 water treatment plants which is operated by K-water. Bansong WTP was constructed in 1977 with the capacity of 120,000 m^3/d. In 2005, the plant was rehabilitated which included the installment of advanced treatment process: Granular Activated Carbon (GAC). The background information of BWTP is presented in **Table 1.**

Table 1 Overall information of Bansong water treatment plant

Constructed Year/Rehabilitation Year	1977/2005
Water Source	Nakdong River
Number of connections	1,100
Peak operating flow (m^3/h)	4,595
Design capacity (m^3/d)	120,000
No. of operators working at the plant	8
Treated water standard	Ministry of Environment (2015)
Automation	Yes
Date of access of the source information	2016
References	K-water waterworks database (2015)

Raw water is extracted from Nakdong River. Main units of treatment process are pump diffuser mixer (PDM), mechanical flocculator, rectangular sedimentation basin and tube settlers, GAC filter-adsorber, and upflow water wash with air scour. In 2015, BWTP provided an average of 67,003 m^3/d to its service area which includes three cities.

2. Water treatment process flow

BWTP was constructed in 1977 and rehabilitated in 2005 with the advanced treatment process, such as PDM, tube settler, and GAC. Sludge and waste generated is processed through the sludge thickener and dewatering machine. The major water treatment processes of BWTP is presented in **Figure 1**:

- Raw water extraction (Nakdong River) → Raw water pumping → Pump Diffuser Mixer (alum, pre-chlorine) → Flocculation (paddle type) → Sedimentation (rectangular, sludge collector, tube settler) → Granular Activated Carbon → Disinfection (Chlorine) → Clear well → High lifting pumping → Distribution

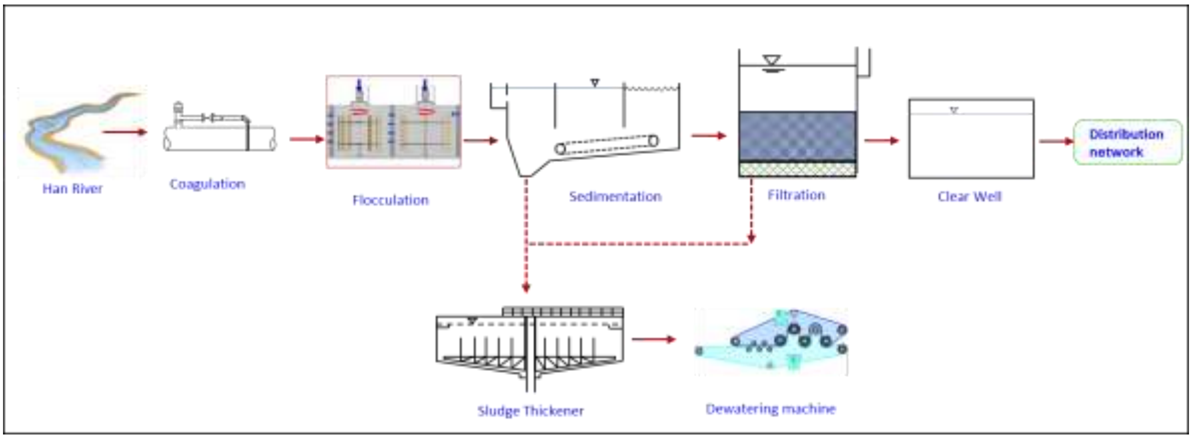


Figure 1 Water Treatment Process

2.1 Chemicals

Bansong WTP has used five kinds of chemicals, which are: (1) poly aluminum chloride for coagulation, (2) chlorine (Cl_2) for pre-and-post chlorination, (3) carbon dioxide (CO_2) for decreasing pH of raw water in the dry season, (4) Lime for increasing alkalinity in the rainy season, and (5) polymer as a dewatering aid. Poly aluminum chloride, chlorine, and polymer are continuously used for water treatment process. Carbon dioxide and lime are intermittently injected into raw water when the pH of raw water is high (more than 8.0) or low (less than 7.0). **Figure 2** presents coagulant storage tank (left) and chemical feed system (right). **Figure 3** represents chlorine storage tanks and lime feed system.

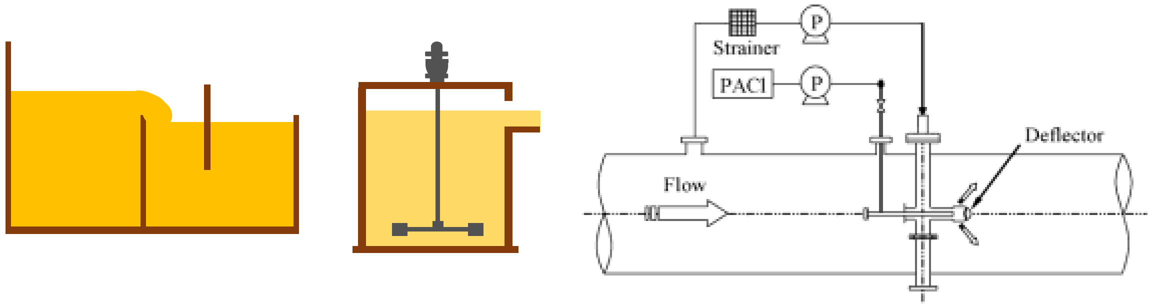
Figure 2 Coagulant storage tank (left) and feed system (right)

Figure 3 Chlorine storage tank (left) and lime feed system (right)

2.2 Rapid mixing

As presented in **Figure 4**, BWTP has three types of mixing methods, such as hydraulic jump mixing, mechanical flash mixing, and PDM. Hydraulic jump and mechanical flash mixing method was initially installed at the time of its construction in 1977. PDM was however introduced in 2005 (when rehabilited) to increase coagulation efficiency through the quick dispersion of hydrolyzing metal salts.

BWTP are selectively using two mixing methods according to raw water quality and mixing efficiency. For example, hydraulic jump mixing is mainly used to save energy when raw water quality and coagulation efficiency are generally stable. However, when coagulation efficiency is not good or raw water quality is rapidly changing, rapid mixing is switched to PDM method. Mechanical flash mixing is a substitute (backup) method employed when the PDM break down or fails to function.



(a) Hydraulic jump (b) Mechanical mixing (c) PDM

Figure 4 Rapid mixing methods

2.3 Flocculation

South Korea has four distinct seasons; thus the temperature varies greatly from -6 to 22 ℃ (daily mean). Generally, G value (velocity gradient) should be controlled on the basis of water temperature, namely by increasing it in the winter season and by decreasing it in the summer season. Most WTPs introduces mechanical types of mixers for flocculation because mechanical flocculators have greater flexibility for adjusting G value according to the season.

As presented in **Figure 5**, BWTP introduced a horizontal shaft with paddle flocculator type mixer. The flocculation process is equipped with the automatic control system for the adjustment of appropriate G values on a seasonal basis and is independent of manual control by operators. The detention time of flocculation tank is 31 minutes.

Figure 5 Horizontal shaft with paddle flocculator (4 basins)

2.4 Sedimentation

As presented in **Figure 6**, the sedimentation tank is of rectangular type. Prior the installation of tube settler in 2005, surface loading rate of the sedimentation tank was 63 $m^3/m^2 \cdot d$. Typically, the standard guideline of this design factor ranges from 20 to 60 $m^3/m^2.d$ according to Kawamura (2000). BWTP installed tube settler to increase surface area in 2005 and this renovation work decreased the surface loading rate to 14 $m^3/m^2 \cdot d$. The hydraulic retention time at the sedimentation tank is 1.8 hours. Mechanical sludge collector system, i.e. chain-and flight collector is used to remove the settled solid wastes.

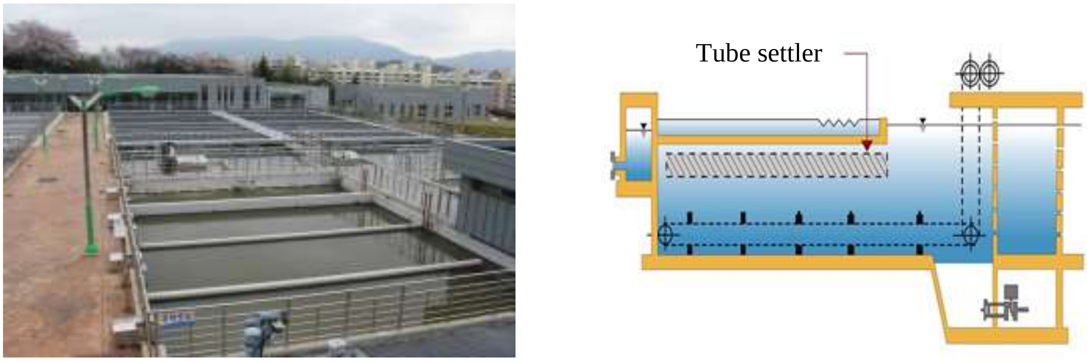


Figure 6 Sedimentation Tank (4 basins) and tube settler (right)

2.5 Filtration

Before the rehabilitation in 2005, BWTP had conventional sand filter with the depth of 65cm. However it upgraded to granular activated carbon (GAC) filter absorber to remove organic matter (taste, odor) in 2005. Currently, GAC filter absorber contains 25cm of silica sand (effective size 0.4 to 0.5 mm) overlaid by 120 cm of GAC (effective size 1.0 to 1.2 mm) as presented in **Figure 7**. Filter media washing method adopted is upflow water wash with air scour. The average filter run time is around 5 days.

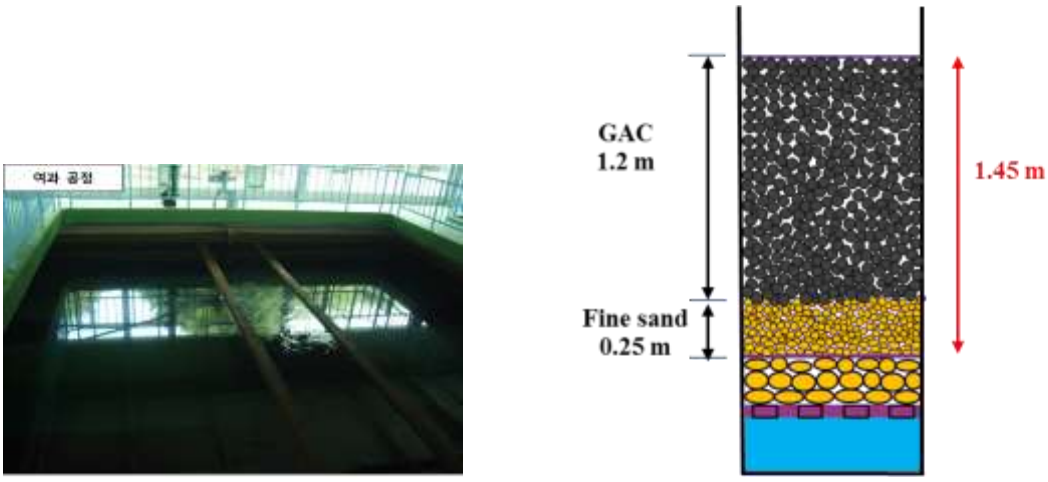


Figure 7 Filter basin (10 basins) and configuration of filter media (right)

2.6 Sludge disposal

As present in **Figure 8**, BWTP has operates gravity thickener and belt press for dewatering solid waste. K-water (2014) quantifies sludge cake generation of 3,081 ton/y with the solids content of 29 percent in 2013. Dewatered sludge cakes is reused as raw material for cement production.

Figure 8 Gravity thickener (left) and dewatering machine (belt press)

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

As presented in **Figure 9**, pH of the Nakdong River (raw water source of BWTP) can vary significantly and can peak as low as 8.7 in the dry season (January to May). According to Kawamura (2000), alkalinity and pH of raw water are critical factors for both coagulation and flocculation, and appropriate pH range for metal salt coagulations are suggested to be between 6 and 7. If pH of raw water is more than 8.0, the turbidity of treated water could further be increased by bad pretreatment optimization, and coagulant could be overdosed than the optimum dosage. Thus, the adjustment of the pH is vital to BWTP.

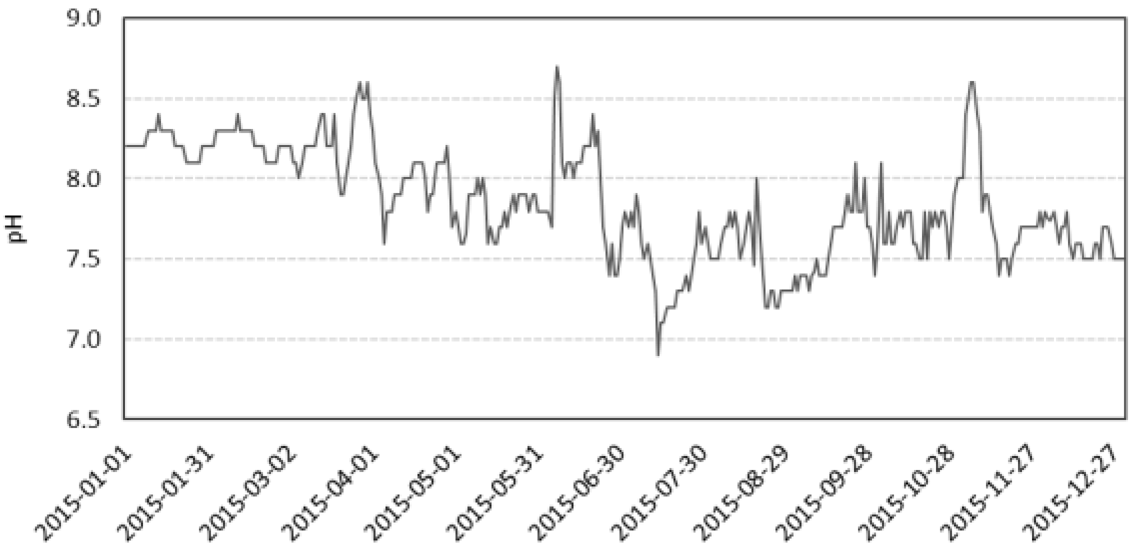


Figure 9 pH trend of raw water (Nakdong River) in Bansong WTP (2015)

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

Various phytoplankton groups have been observed in the raw water received by BWTP. In particular, three phytoplankton genera, such as Synedra, Anabaena and Microcystis were identified as the problem-causing phytoplankton due to their ability to interfere with the water treatment process and it negatively impacts the water quality. As presented in **Figure 10**, Synedra usually spreads in winter and spring season and causes rapid clogging of the filters. Indeed, BWTP experienced serious filter clogging by Synedra in 2012. The number of backwash was increased by 3.7 times (44 times/month to 163 times /month) and the amount of backwash water was increased by about 4.7 times (960 m^3/d to 4,500 m^3/d).

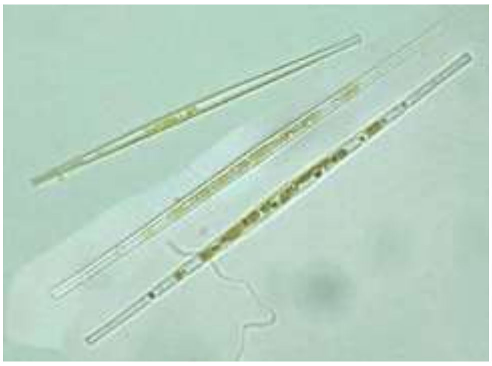


Figure 10 Synedra acus of diatomaceae

As presented in **Figure 11**, Anabaena and Microcystis were the most frequent causes of unpleasant taste and odor in the water supply system during the summer season. Taste and odor due to algae are not generally removed and can sometimes be increased during the treatment process because of cell lysis. The detection and intensity of taste and odor are very subjective issues because some people are highly sensitive to it.

Figure 11 Anabaena and Microcystis of filamentous cyanobacteria

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

Bansong WTP installed carbon dioxide (CO_2) injection device to control pH of raw water in 2012 **(Figure 12)**

Figure 12 Facility of carbon dioxide injection in Bansong WTP

- Bansong WTP installed algae curtain boom to prevent inflow of algae into water intake in 2012 as presented in **Figure 13**.

Figure 13 Algae curtain boom of Nakdong River (water intake)

6. Recent investment made for the plant's improvement

Unpleasant taste and odor by algae are major cause of customer's complaint in drinking water service. According to Kawamura (2000), ozonation is an effective method of oxidation because this process actually changes the characteristics of the odor and flavor, in addition to reducing the level of the odor-producing compounds. Bansong WTP installed pre ozone injection system in 2014 to control taste and odor during algae bloom (**Figure 14**)

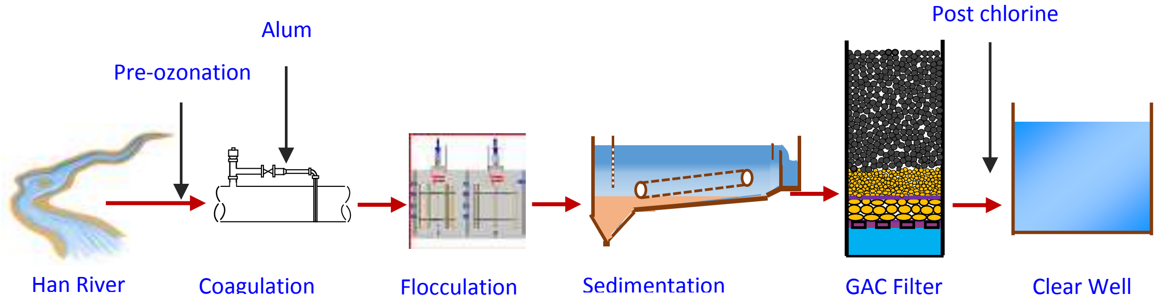


Figure 14 Water treatment process with pre ozonation

7. Technologies, facilities or other types of assistance needed to better cope with operational and management difficulties in 3) and 4).

Filter beds of BWTP are composed of GAC media with an effective size of 1.0 to 1.2 mm and fine sand at the bottom. As presented in **Figure 15**, fine grains of GAC were accumulated on the surface of the filter because the grains of GAC becomes smaller during backwashing process which leads to clogging of the filter. Thus, to prevent quick clogging of filter by algae, it may be wise to scrape off a thin layer of top media periodically.

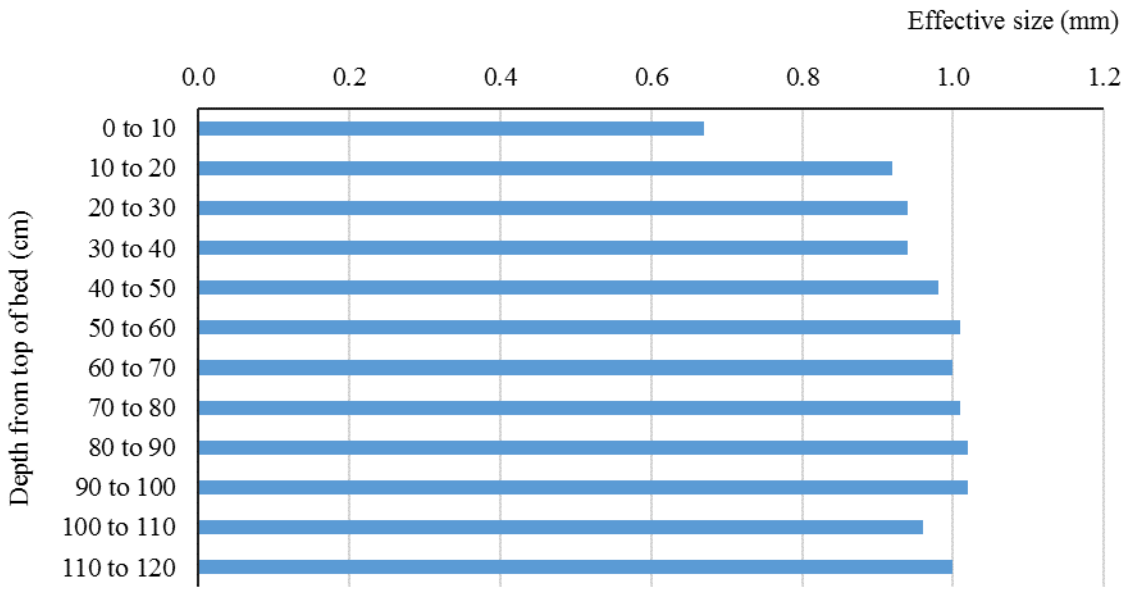


Figure 15 Effective size of GAC in depth from top of bed in BWTP (Filter no 5)

8. Customer's opinion on water quality and water services in general

The Nakdong River is the longest river (around 510 km) in South Korea. The Nakdong and its tributaries also serve as a major source of drinking water for the inhabitants of the river basin and others nearby.

BWTP is also extracting raw water in the Nakdong River and its water intake is located in the lower reaches of the river as presented in **Figure 16**. However, water pollution due to domestic and agricultural wastewater remains a serious concern. Most citizens served by BWTP want the raw water to be provided through safe and clean raw water source.

Figure 16 Location map of water intake

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

With concern the detection of chemical contaminations in raw water, early warning systems (EWS) have been introduced additionally to provide a rapid warning of the occurrence of contaminants. EWS are generally an integrated systems consisting of monitoring instrument technology, with an ability to analysis and interpret in real time (Grayman et al. 2001; USEPA 2005). As presented in **Figure 17**, BWTP installed EWS, including auto sampler, online oil and phenol analyzer, and GC, at water intake in 2008.

Auto sampler

Online oil analyzer

Online phenol analyzer

Online Gas Chromatographs

Figure 17 Early warning system of Bansong WTP

10. Other Highlights

As a new alternative for energy management, solar renewable energy has widely been installed in water supply system site such as a water intake, treatment plant, and other available sites. BWTP also installed photovoltaic generating facilities (130 kW of capacity) near the water intake at the end of 2007 (**Figure 18**).

Figure 18 Solar panels installed at nearby water intake of Bansong WTP

11. Water quality data

The water quality data at BWTP (2015) are presented in **Table 2**. All measured parameters were under the standard of the Ministry of Environment (Korea).

Table 2 Water quality data in 2015

Parameters	Unit	Raw water		Treated water		Standard (Korea)
		Min	Max	Min	Max	
pH	-	6.9	8.7	6.6	7.8	5.8 - 8.5
Turbidity	NTU	1.0	111.5	0.04	0.09	0.5
Alkalinity	mg/L	23	99	13	89	-
Conductivity	µs/cm	169	502	180	515	-
Total hardness	mg/L	-	-	53	121	300
Total dissolved solid	mg/L	-	-	201	438	500
NH_4-N	mg/L	0.01	0.06	N.D	N.D	0.5
NO_3-N	mg/L	1.5	4.1	1.0	3.5	10
Iron	mg/L	-	-	N.D	N.D	0.3
Manganese	mg/L	-	-	N.D	N.D	0.05
Chloride	mg/L	-	-	22	63	250

(Source: Bansong WTP)

12. References

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