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The Practice of Purification Plant in Response to High Turbidity Raw Water —Especially in Extreme Weather

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Abstract

The aim of this investigation is: A hydrology and water turbidity monitoring mechanism in Great Taipei catchment area which can be used as precautionary warning for raw water turbidity and flux of Xindian Creek during typhoon. Emergency plan for purification plant before typhoon approaches includes: 1. emptying sludge in all sedimentation basins; 2. timely measurement of turbidity at raw water intake by technicians during typhoon; 3. reserving back-up sedimentation basins; 4. reducing the water influx treatment when water turbidity above control level; 5. maintaining the flux of full raw water tunnel if purification process stops water inflow; 6. diluting high turbidity raw water with reservoir water. Limited to existing devise, Zhitan Purification Plant has enhanced effectiveness of the desilting basin to reduce the turbidity level of raw water. Most importantly, accurate coagulation dosing helps to ensure excellent water quality and stable water supply.

Keywords

Purification Plant, High Turbidity Raw Water, Extreme Weather

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1. Introduction

Extreme weather has brought unprecedented challenge for water treatment. In 2015, two worst storms, Typhoon Soudelor and Dujuan, severely stroke Taiwan. The heavy rain rose up sharply the level of raw water turbidity of Zhitan Purification Plant, and Changxing Purification Plant to over 10,000NTU, and soared the level of raw water turbidity as high as 39,000NTU. Consequently, how to deal with high turbidity raw water to maintain water supply and water quality will be the goal for water business.

The water source of Zhitan Plant, Changxing Plant, and Gongguan Plant is Xindian Creek water system which contributes 97% water supply (about 2.4 million tons of water) of Taipei Water Department (TWD). Owing to establishment of Greater Taipei Water Conservation Region, restrictions of watersheds development, as well as water pollution prevention, the Xindian Creek raw water turbidity is below 20NTU for more than 70% over the years of record. Therefore, most of the time, the water plants could maintain optimizing operations and keep turbidity level of water supply below 0.1NTU by applying tranditional water treatment procedures (coagulation→sedimentation→filtering).

2. Precaution and Emergency Plan for High Turbidity Raw Water

There are typhoons striking Taiwan in summer and even in autumn. Either riverbank erosion caused by heavy rain runoff or landfall in catchment area due to torrential downpour will result in raw water turbidity rising sharply. Therefore, Water Resources Agency Taiwan, Taipei Feitsui Reservoir Administration, and Taipei Water Department have jointly established a hydrology

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and water turbidity information gathering platform, which includes the precipitation data in the mountains and water flux of streams, and discharged flux from Feitsui Reservoir, the turbidity of confluence of Nashi River and Feitsui Reservoir water, and the turbidity of intake of Zhitan Plant, and Changxing Plant etc (Figure 1). The information gathering platform can be used as precautionary warning for change of water quality and quantity of the Xindian Creek.

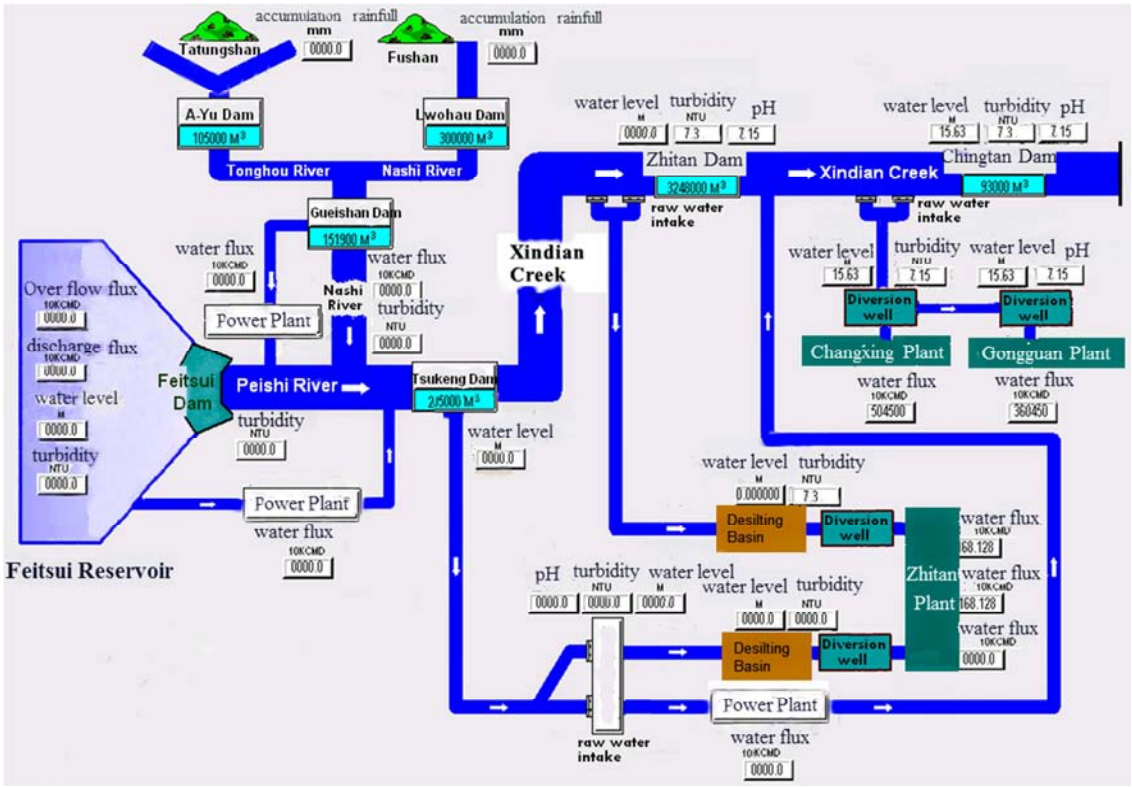

Figure 1. The hydrology and water turbidity monitoring system in catchment area of Xindian Creek.

Purification plant's emergency plan to prepare for an approaching typhoon contains:

1. Make sure all the cleaning and calibration of water quality measure equipment is complete before typhoon hitting. In addition, maximum detection level of the raw water turbidity meter is 9,999NTU only, and turbidity meter needs continuous calibration and mud clean-up in detect cell when turbidity is rising rapidly. As a result, technicians are suggested to timely measure raw water turbidity at the confluence of Nashi River and Feitsui Reservoir water, and at the intakes of Zhitan Plant and Changxing plant during typhoon to update turbidity information for the use of dosing prediction.

2. Empty sludge in all sedimentation basins before typhoon hitting and spare a portion of sedimentation basins as back-up basins. In case dosing coagulation is failed or too much sludge in sedimentation basin is produced due to high turbidity raw water, renew-dosed raw water can be precipitated in the back-up basins and high turbidity water of sedimentation basins must be discharged to wastewater basins as soon as possible.

3. Reduce the influx raw water turbidity exceeds 6,000NTU or process water turbidity is above the control level. Decelerated velocity will help water quality of precipitation and filtration, while reduced amount of high turbidity raw water will also slow down accumulation of sludge in sedimentation basins.

4. When stopping the water treatment process, a minimum flux of raw water is required to full the raw water tunnel. Otherwise, it must take very long time to refill raw water tunnel, and long-term sediment in raw water tunnel will be washed out which makes raw water quality worse, and makes dosing estimate more difficult.

5. Request Feitsui Reservoir Administration to release reservoir water to dilute the Xindian Creek high turbidity raw water. As Table 1 illustrates, Nanshi River's flux and turbidity depend on the total accumulative rainfall of Fushan water source area. When the rainfall is massive in Fushan water source area, Nanshi River's flux is too huge that the dilution effect of Feitsui reservoir water release is limited. But when the rain is getting smaller in Fushan water source area, the smaller flux of Nanshi River, as well as higher Feitsui reservoir water released all together could significantly reduce raw water turbidity. As a result, proper release of reservoir water will dilute raw water and lower raw water turbidity which helps purification plant to operate stably.

Table 1. The change of raw water turbidity when reservoir water mixed in Nanshi River and The accumulation rainfall of water source area (Data collected during Typhoon Dujuan).

Nanshi River flux (CMS)	**483**	**413**	**1300**	**1747**	**2390**	**3540**	**3438**	**2600**	**2783**	**1999**
Feitsui Reservoir water flux (CMS)	74	310	310	310	310	310	310	310	310	310
The accumulation rainfall per hour of Fushan water source area (mm)	29	18	70	60	65	76	54	16	22.5	9
The total acumulative rainfall of Fushan water source area (mm)	163	204	356	416	481	557	611	627	676.5	685.5
The accumulation rainfall per hour of Tatungshan water source area (mm)	12	9	25	37	30	48	33	31	15	0
The total acumulative rainfall of Tatungshan water source area (mm)	85	103	167	204	234	282	315	346	389	389
Zhitan Plant raw water turbidity(NTU)	2994	5017	11520	11320	17350	20500	17900	14154	12340	11736

Nanshi River flux (CMS)	**1600**	**1400**	**1200**	**1081**	**1160**	**990**	**681**	**550**	**514**	**240**
Feitsui Reservoir water flux (CMS)	310	310	310	310	310	500	500	500	500	500
The accumulation rainfall per hour of Fushan water source area (mm)	1	6	5	3	1	0	0	0	0	0
The total accumulative rainfall of Fushan water source area (mm)	686.5	692.5	697.5	700.5	701.5	701.5	701.5	701.5	701.5	701.5
The accumulation rainfall per hour of Tatungshan water source area (mm)	2	3	3	1	0	0	0	0	0	0
The total accumulative rainfall of Tatungshan water source area (mm)	391	394	397	398	398	398	398	398	398	398
Zhitan Plant raw water turbidity(NTU)	10400	10237	11487	11000	11200	5110	4520	3385	2525	1650

3. Improvement Proposal

The best design to deal with high turbidity of raw water is to set the desilting basin before water treatment. In addition to sedimentation, desilting basin can help to homogenize water quality. For example, in front of raw water intake of Kaohsiung Cheng Ching Lake Purification Plant, there is 1,030,000m^2 of Cheng Ching Lake to work as desilting basin. As a result, when typhoon hits, the raw water turbidity does not exceed 40NTU.

On the other hand, the capacity of the desilting basin in front of diversion well of Zhitan Plant of Taipei Water Department is 4800m^3 which is not enough to improve the water quality when raw water turbidity at high level and sludge still flowing with raw water into the water treatment process. To maximize function of the desilting basin of Zhitan Plant, setting two flashboards in the desilting basin (Fig. 2) to create raw water effluent effect upon flashboard will prevent sedimentation from water flow impact. At the same time, proper open of sludge gate and continuous emission of sludge will significantly lower raw water turbidity and effectively reduce water purification plant's workload when raw water turbidity level is high.

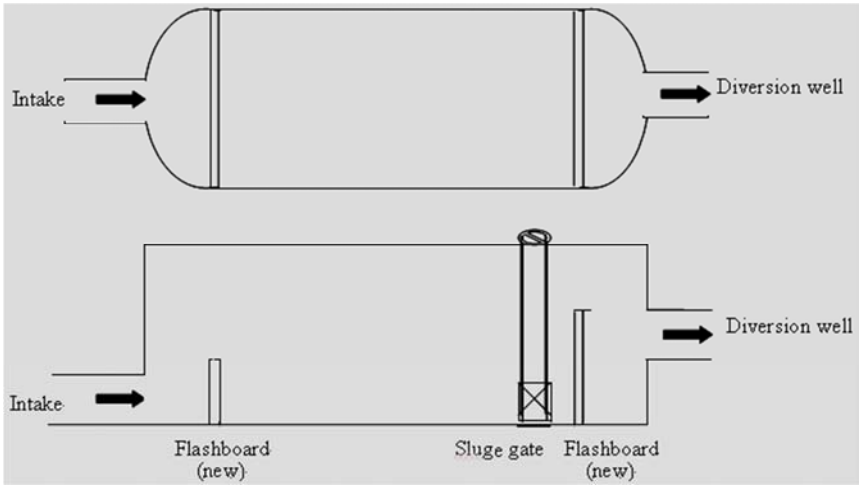

Figure 2. Establishment two flashboards setting in the desilting basin.

Additionally, appropriate Polymer flocculant injection at inlet of the desilting basin will rapidly bring together sediment particles in high turbidity raw water and consequently lead to better solid-liquid separation results.

4. Strategy for Coagulation Dosing

To increase the coagulation efficiency for high level of raw water turbidity, Changxing Plant of Taipei Water Department optimizes dose rate of coagulant and Polymer flocculant aid at two locations where are water intake and diversion well, according to coagulation empirical data (Table 2). Both observation of floc formation in coagulation basins and the jar test result will be feedback to trim dose of coagulant at diversion well.

Table 2. Coagulation empirical data of Changxing Plant (Data collected during Typhoon Dujuan).

Chingtan Raw water turbidity(NTU)	0~5	5~10	10~15	15~20	20~30	30~50	50~70	70~100	100~150	150~300
Chingtan intake PAC dose (ppm)	—	—	—	—	—	—	2	2	3	5
Chingtan intake Polymerr dose (ppm)	—	—	—	—	—	—	—	—	—	—
Diversion well PAC dose (ppm)	5~8	6~10	7~13	12~16	13~20	17~23	18~24	20~29	19~31	24~39
Diversion well NaOH dose (ppm)	—	—	—	—	—	—	2	2	4	6

Chingtan Raw water turbidity(NTU)	300~500	500~1000	1000~2000	2000~3000	3000~4000	4000~6000	6000~8000	8000~10000	10000~12000
Chingtan intake PAC dose (ppm)	10	20	20	30	30	30	30	30	30
Chingtan intake Polymerr dose (ppm)	—	0.5	1.0	1.5	1.5	2.0	3.0	4.0	4.0
Diversion well PAC dose (ppm)	25~41	30	40	40	50	60	70	80	100
Diversion well NaOH dose (ppm)	10	15	20	23	25	27	29	30	30

NOTE: Feedback NaOH dose depends on the pH value of coagulated water of different raw water turbidity.

Chingtan Weir intake begins proper coagulant (PAC) dose when raw water turbidity is above 50NTU. While raw water turbidity is above 250NTU, employ polymer flocculant, in addition to coagulant, at Chingtan Weir intake. Before raw water transmitted to the diversion well of Changxing plant, there will be enough time and stirring energy for impurities of water mixed with coagulant and polymer flocculant in the 8.9 kilometre long raw water tunnel. At diversion well, following NaOH dose results in pH of mixed water within range of 6.8~7.2; In addition, conduct second-time coagulant dose will allow the remaining colloidal particles and small floc destroyed by shear flow to bond and form completely. The two-time dosing mechanism provides sufficient G value for coagulation, on the other hand, Chingtan Weir intake's appropriate coagulant dose will change the chemical activity of colloidal particles of water which helps to modify the abrupt abnormal precipitated water quality due to overdose or underdose at the diversion well.

5. Conclusion

Taiwan is located in the area where typhoons have a frequent occurrence. On top of that, the mountains are steep and streams are rapid. Purification plants, as a result, are challenged to deal with high turbidity of raw water in flood seasons. Especially in the past two years, mountain forest in catchment area had been damaged by super typhoons. The raw water turbidity always rises sharply once the heavy rain hits catchment area. In order to strengthen the ability to cope with high turbidity raw water. purification plants have to enhance the efficiency of equipment as well as to reinforce monitoring and precaution of the hydrological information and water quality. In addition, to maintain the water treatment function effective during typhoon, purification plants could strategically avoid the peak of raw water turbidity, timely adjust treatment quantity based on water quality of precipitation and filtration. and use proper reservoir water to dilute high turbidity raw water. Moreover, a rapid discharge sludge desilting basin could help to improve raw water quality and two-time dosing mechanism will lower the risk of dosage failure.

The required condition for safe drinking water is that water quality has to meet water standard. Improper dosing practice or sky rocket high raw water turbidity will lead to drinking water turbidity exceeding the national standard or purification plant stopping to supply drinking water. Therefore, propaganda from the water department should be in place to encourage people to reserve of drinking water for typhoon preparedness as well as escape purification plant water outage crisis.

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