Sungai Dua Water Treatment Plant
Seberang Perai, Malaysia

1. Background Information

Sungai Dua Water Treatment Plant (SDWTP) is located at Seberang Perai and occupies about 13 hectares of land. SDWTP is the most important WTP in the Penang as it supplies 80% of the total volume of treated water to Penang. SDWTP was first commissioned in the year 1973 and after series of upgrading in 1994, 1999, 2004, 2011 and 2013, it now has the design capacity of 1,113,792 m^3/day . SDWTP usually draws water from Muda River as a primary source and Mengkuang Dam as the secondary source which is the largest dam in the Penang. Currently, the Mengkuang Dam is temporarily decommissioned since February 2014 to facilitate its expansion project.

SDWTP is owned and operated by Perbadanan Bekalan Air Pulau Pinang (PBAPP). SDWTP also serves as the control center for PBAPP's "on-line" supervisory control and data acquisition (SCADA) system to facilitate remote operation. SCADA gathers real-time data from remote location and empowers the operator to remotely control equipment and conditions. The plant operates at 3 shifts per day. The general information of SDWTP is shown in **Table 1**.

Table 1: Overall Information of Sungai Dua Water Treatment Plant

Location	Seberang Perai, Penang
Constructed Year	1973 (1994, 1999, 2004, 2011 & 2013 upgrading)
Raw Water Source	Muda River (primary) & Mengkuang Dam
Maximum Design Capacity (m^3/d)	1,113,792
Operating Capacity (m^3/d)	1,002,412
Number of employees	120
Topography	Tropical
Automation	Yes
Water Quality	Exceeds Standards for Drinking Water set by Ministry of Health, Malaysia
Supply Areas	Seberang Perai, Penang Island
Reference	Perbadanan Bekalan Air Pulau Pinang (PBAPP)

Source: Making Sure Penang's Taps Keep Flowing. Available at http://penangmonthly.com/making-sure-penangs-taps-keep-flowing/

Figure 1: Sungai Dua Water Treatment Plant

2. Water treatment process flow

SDWTP has three independent water treatment plants which utilize three types of water treatment technologies, mainly Sedimentation, Dissolved Air Floatation (DAF) and Lamella Clarifier. There is total of 5 treatment plants consisting of 2 Sedimentation Plants (Phase 1 & Phase 2), 1 DAF Plant (Package 3) and 2 Lamella Clarifier Plants (Package 10 & Package 11). The capacities of each plant are as follow:

Table 2: Capacity of Sungai Dua Water Treatment Plant

Treatment Plant	Unit	Max. Design Capacity (m^3/day)	Operating Capacity (m^3/day)
Sedimentation Tank	Phase 1	318,226	286,403
	Phase 2	454,609	409,148
Dissolved Air Floatation (DAF)	Package* 3	113,652	102,287
Lamella Clarifier	Package 10	113,652	102,287
	Package 11	113,652	102,287

**Package refers to the building or facilities number. Individual units are named as package or phase.*

The major processes are as follow:

Raw water intake → Balancing Pond → Pre-chlorination → Coagulation → Flocculation → Sedimentation/Dissolved Air Flotation/Lamella Clarifier →Rapid Sand Filter →Treated water tank → Distribution

The process flow diagram of each water treatment process at SDWTP is illustrated in **Figure 2**.

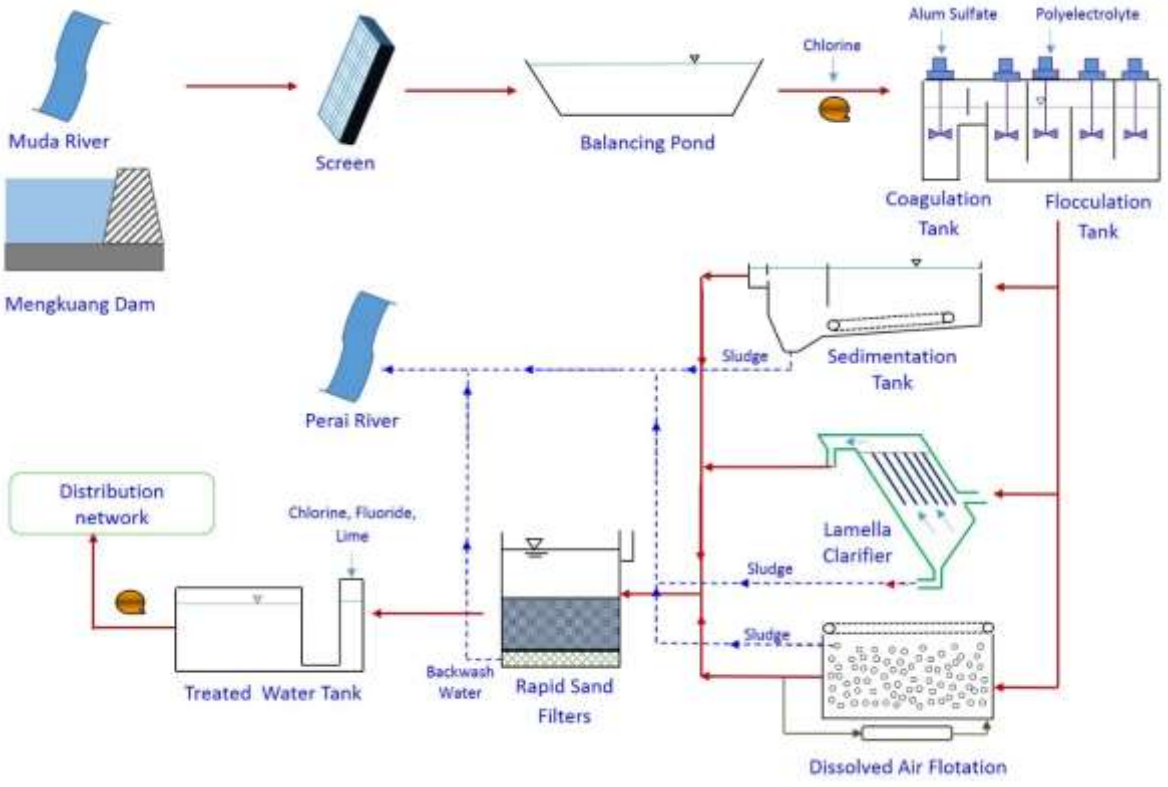

Figure 2: Schematic Diagram of Sungai Dua Water Treatment Plant

2.1 Water intake

SDWTP raw water pumping station is located in Lahar Tiang, north of Kepala Batas, Penang, near the Penang-Kedah border of Muda River. Five 170,343 m^3/day centrifugal pumps transfer raw water from the Muda River into a 14 km Sungai Dua canal (**Figure 3**) to SDWTP. The intake consists of the bar screens to avoid debris from entering the treatment facility. The screens are designed to minimize the intake of sediments, oil, and other floating materials to enter the treatment plants. Raw water travels the 14km canal into a balancing pond located beside the treatment plant. The retention time of the canal is 8 hours.

Source: Penang Water Supply Infrastructure. Available at http://pba.com.my/?page_id=571

Figure 3: Sungai Dua Canal from Muda River to SDWTP

Source: Penang to face water crisis if no rain soon. Available at http://www.thestar.com.my/metro/community/2016/04/15/trickling-to-danger-level-hot-spell-putting-stress-on-reservoirs-in-northern-states/

Figure 4: SDWTP Raw Water Pumping Station

Source: Penang to face water crisis if no rain soon. Available at http://www.thestar.com.my/metro/community/2016/04/15/trickling-to-danger-level-hot-spell-putting-stress-on-reservoirs-in-northern-states/

Figure 5: Raw Water from Muda River into Sungai Dua Canal

2.2 Balancing Pond

Raw water from Sungai Dua canal flows into the balancing pond, where equalization takes place. Bar screens (**Figure 6**) are placed ahead of the pond to trap debris from entering the pond. The retention time of the balancing pond is about 3 days. The water is then pumped into the treatment plant using 12 (9 running, 3 standby) submersible pumps; 2 units of 120,470 m^3/d pumps, 8 units of 136,382 m^3/d pumps and 2 units of 68,190 m^3/d pump. Raw water then enters into the mixing chambers (coagulation and flocculation) of each phase/package.

Figure 6: Bar Screens at the inlet of the Balancing Pond

Figure 7: Balancing Pond

Figure 8: Low Lift Pump Pipe flow to Treatment Plant

2.4 Coagulation and Flocculation

Coagulation and flocculation process occurs in a 3 stage system. In the first tank, chlorine (pre-chlorination) is added at 0.5 ppm. In the second tank, 8% liquid aluminum sulfate is added at 40 ppm as a coagulant. In the third tank, 0.1% liquid polyelectrolyte is added at 0.1 ppm as flocculant prior feeding into the sedimentation/DAF/Lamella clarifier system. Chlorine and coagulant are added into each tank using diaphragm dosing pumps while flocculant is added using metering dosing pumps. All

pumps are located in chemical room. The mixing of chemicals occurs on-line with the help of baffles and the current of the water flow. Each stage has a retention time of 3 minutes. The exact dosing amount of every chemical is determined by jar test conducted before the start of every shift.

Figure 9: Pre Chlorine, Coagulant, and Flocculants Dosing Point

Figure 10: Chemical Room

2.5 Sedimentation Tank/ DAF/ Lamella Clarifier

2.5.1 Sedimentation Tank

Phase 1 and Phase 2 of SDWTP consists of 8 sedimentation tanks running parallel in each phase. Each tank consists of HDPE multi-trays for flocculation and sedimentation. The trays are placed at an inclined angle of 60°. The function of the multi-tray is to decrease the velocity of the water, hence allowing the sludge to settle at the bottom of the tank. Each tank has a retention time of 30 minutes. The addition of trays greatly reduced the settling time needed compared to conventional sedimentation tanks. The surface flow rate is 2.7 m/h. Clear water spills over the tank into the clear water tank. Sludge generated at the bottom of the tank is periodically pumped out into the Perai River.

Source: PBA Holdings Bhd Annual Report 2015. Available at http://www.pbahb.com.my/pdf/annual-report/AR2015.pdf

Figure 11: Multi-tray Sedimentation Tank

2.5.2 Dissolved Air Floatation (DAF) Unit

Package 3 of SDWTP consist of 6 DAF units running in parallel. Flocculation process prior to DAF is performed with the help of mechanical mixers. White water (treated water with micro bubbles) is pumped into each DAF unit to float flocs produced. The micro bubbles are maintained at 50 microns to increase contact surface area and increase solid separation efficiency. Floating sludge is skimmed using mechanical skimming unit. The sludge produced is periodically pumped into the Perai River.

Figure 12: Dissolved Air Floatation Units

2.5.3 Lamella Clarifier

Package 10 and 11 of SDWTP consists of 6 lamella clarifiers in parallel each. Flocculation process prior to the clarifier is performed with the help of mechanical mixers. The lamella clarifier consists of inclined stainless steel plates with a retention time of 30 minutes. The surface flow rate is much higher than the sedimentation multi-tray, which is 8 m/h. The presence of trays helps sludge settle down faster by gravity thus enabling the clarifier to have a shorter retention time. The sludge produced is periodically pumped into the Perai River.

Source: Salcon Berhad: Sg. Dua Water Treatment Plant in Pulau Pinang, 2014. Available at http://www.salcon.com.my/project/construction-of-water-works-package-11-25-million-gallon-per-day-mgd-process-unit-and-associated-works-sg-dua-water-treatment-plant-in-pulau-pinang

Figure 13: Lamella clarifier with inclined stainless steel plates

2.6 Rapid filtration tank

Both the sedimentation systems (Phase 1 & 2) are coupled with 10 rapid sand gravity filters each. The DAF system (Package 3) is coupled with 6 rapid sand gravity filters. Lamella clarifier systems (Package 10 & 11) are coupled with 6 rapid sand gravity filters each. The media utilized in the filter is fine sand with an effective size of 0.6 – 1.0 mm with a uniformity coefficient of 1.7. The media has a depth of 100 cm. Backwashing of filters is performed depending on running phase hours of 72 hours or head loss of filters. When the differential pressure of the filters increases, backwashing is performed regardless of running hours. Backwashing is done by water wash.

2.7 Clear Water Tank

Filtered water is transferred to the clear water tank. Post-chlorination, pH adjustment, and the addition of fluoride are performed. Chlorine is added at 2.0 ppm, sodium silicofluoride is added at 0.4-0.6 ppm while pH is maintained at around 7.5 with the addition of lime. Treated water is then pumped for distribution using 28 (15 running, 13 standby) 72,737 m^3/day centrifugal pumps. The retention time of the tank is 15 minutes. Treated water from the plant is then transported through 27.2 km of steel pipelines laid in Seberang Perai for distribution to Butterworth and Perai, and through 3.66 km of twin submarine pipelines to Penang Island.

Figure 14: High lift pump for treated water distribution

2.8 Sludge disposal

Currently, SDWTP does not treat the backwash water and sludge generated. Backwash water from filters and sludge produced from Sedimentation, DAF, and Clarifier systems are channeled into the Perai River without any treatment.

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

SDWTP has three kinds of treatment systems, mainly sedimentation tank, dissolved air floatation (DAF) unit and lamella clarifier. These systems have significantly different operation mode even though they perform the same function. Therefore, more operators are required on shift to monitor the performance of these three systems. Operators need to pay more attention to operating these systems. For example, the microbubbles produced in the DAF unit need to be constantly monitored to avoid a drop in suspended solids removal efficiency.

Varied turbidity in the raw water source (Sungai Muda) often leads to the turbid water supply to the customers. Normally the turbidity of the raw water is about 90 NTU which is reduced to 5 NTU by the treatment processes. However, during the wet session, it can peak as high as to 341 NTU. High turbidity raw water will affect the performance of the treatment system, decreasing the percentage removal.

Power failure occurs in the raw water pumping station, in the bank of Muda River. Short time power failures do not disturb the treatment plant much since the retention time of the canal is long. However, long hour's power failure at the raw water pumping station decreases the volume of water in the canal, hence decreasing the volume of water entering the treatment plant.

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

- Sludge generated from the treatment process is not treated and disposed of. The sludge is channeled into the Perai River together with backwash water from backwashing of filters.

- In 2015, Penang domestic water consumption per capita was 291 liters/capita/day. It is the highest water consumption state in Malaysia, about 39.7% higher than the national average.

- SDWTP draws its raw water from Muda River which is also the water source for the neighboring state, Kedah. If this continues, Muda River can only sustain till Year 2020.

- Penang registered 18.25% of non-revenue water (NRW) or water loss. It is the lowest in the country where the national average stands at 36.6%. Since Penang is a water-stressed state, PBAPP aims to reduce further the NRW.

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

- In order to make sure the plant operates at the optimum condition with optimum performance in terms of turbidity removal, jar tests are performed every shift for all treatment systems to determine the optimum dosing of coagulant and flocculants.

- PBAPP are currently in discussion with Tenaga Nasional Berhad (TNB), Malaysia's official power provider to ensure that electrical power to the raw water pumping stations of SDWTP is always guaranteed.

- PBAPP has built a sludge treatment facility in SDWTP that will be fully functional by the end of 2016.

- PBAPP has proposed to tap a second raw water source for SDWTP from the Perak River which is located in the southern neighboring state of Perak. This scheme is subjected to approval from the federal government.

- PBAPP's has aimed to reduce the Penang's per capita consumption to 260 L/c/d. The national per capita of Malaysia was 210 L/c/d in 2013 while that of Singapore was 150 L/c/d in 2014. PBAPP needs to reduce the per capita consumption due to the limited raw water source. PBAPP has now started public campaigns and has different tariff rate for the different level of consumption (Table 2) with water conservation surcharge (WCS) in order to promote water conservation.

Table 3 Penang Domestic Water Tariffs

Volume Consumed (Liter)	RM per 1000 Liter
0 - 20000	0.22
20000 - 35000	0.42
35000 - 40000	0.90
40000 - 60000	1.00
60000 - 200000	1.38
> 200000	1.48

Source: Water Conservation Surcharge. Available at http://www.pba.com.my/?page_id=1826

- PBAPP is now looking to expand its NRW management program to minimize water loss throughout the water supply value chain. The proposed new areas of focus are water catchment areas and raw water supply systems upstream, and internal reticulation systems downstream. Moreover, PBAPP will also ensure that all its major hardware for raw water extraction and storage, including intakes, canals, dams, mains and pumping stations are carefully maintained to perform optimally. At the same time, PBAPP is planning to work with the Penang State Government to draft legislation to compel mandatory annual inspections of internal reticulation systems in all high-rise buildings, as in Singapore, to prevent and reduce water loss, while ensuring continuous good supply of water for all the residents. To tackle with the NRW, PBAPP is taking following steps:
    - Ensuring consumer meter accuracy, meter reading accuracy and calibration
    - Ensuring production output meter accuracy, meter reading, and calibration
    - Working in meter management and replacement
    - Optimizing quality management of materials, technical and engineering practices
    - Speedy pipe repairs of the damaged pipes
    - Replacing the old pipe with new one
    - Monitoring and managing the pressure of water supply
    - Metering the district to locate the area of high NRW
    - Zone metering for analysis of base night flows
    - Taking active leakage control measures

6. Recent investment made for the plant's improvement

In 2016, SDWTP completed the installation and commissioning of an 113,652 m^3/day design capacity of new treatment facility equipped with the mixing chamber, lamella clarifiers consisting of flocculation and settling tanks, filters and filter gallery.

SDWTP has also successfully built a sludge dewatering system consist of settling tanks, filter presses and flocculating units. The new sludge treatment facility will treat the backwash water and sludge

generated. The backwash water and sludge will flow into sludge settling tanks, returning the liquid fraction back into the balancing pond. The settled sludge is then passed into the filter press where the sludge is dewatered. The resulting cake will be recycled as fertilizers.

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

- Since PBAPP is a large organization under the management of the state government, collaborations can be made with large industrial sectors that utilize high amount of raw water in order to treat and recycle the water. Hence, the water consumption can be reduced.
- Ensure that the sludge generated and backwash water is treated properly before releasing into the Perai River. Treated sludge can be converted into valuable products such as fertilizers.
- Install a generator at the raw water pumping station near the Muda River to prevent disruption in raw water supply to the treatment plant in case of any power failure.

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

There is 9 customer care center where the unsatisfied customers can report their problem. It also has 24-hour Call Centre to register the complaints. The customer can further register their complaints through email which gets responded back by 48 hours.

Customers opinion on the water quality and services provided are presented in **Table 3**. The majority of the customers have evaluated both the quality and services to be good. 130 trade consumers and 1650 domestic consumers in Penang were surveyed to analyze the water quality and services of PBAPP.

Table 4 Water quality and service rating of PBAPP

Rating	Water Quality		PBAPP Services	
	Domestic Consumers (%)	Trade Consumers (%)	Domestic Consumers (%)	Trade Consumers (%)
Very Good	10	11	16	11
Good	59	69	65	77
Average	21	11	16	12
Poor	9	7	2	-
Very Poor	1	2	1	-

Source: The Road to Corporatisation, Public Listing, and Beyond. Available at http://www.pba.com.my/pdf/news/2014/SKMBT_C20314021114500.pdf

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

SDWTP is equipped with SCADA (Online Supervisory Control and Data Acquisition) room. The SCADA system located in the SDWTP facilitates the following:

- Remote operation of the WTP
- Real-time monitoring of the treatment performance
- Real-time monitoring of the water quality and distribution process
- Online recording and analysis of the monitored water parameters
- Storage of the data and generation of daily and monthly report

PBAPP also uses iRMS (Integrated Revenue Management System) for facilitating the finance, customer care, and its services. PBAPP collected 93.2% of the bills through this system It further helps to keep accurate records of customers. PBPAA is utilized Strumap GIS (Geographical

Information System) which integrates engineering data, consumer's data, aerial photos, catchment plans and computer-generated strategic network model. It helps in the real time analysis of distribution networks, surveillance of the catchment area and functions to increase the operational efficiency. Systems like iRMS and Strumap GIS acts as a tool for decision making.

10. Other Highlights

To ensure the quality of the water supplied, PBAPP does water quality sampling at 111 sampling points in Seberang Perai and 96 sampling points on Penang Island. The sampling points are at roadside mains and pipelines. The number of samples analyzed per month (375 samples per month) is above both the Ministry of Health's requirement and WHO recommendations. Physical parameters such as pH, residual chlorine, turbidity (the measure of murkiness in water) and color are examined on site while the other key parameters are examined in the laboratory within 72 hours of collection. Moreover, online measurements of the parameters are monitored and recorded regularly.

11. Water quality data

Table 4 presents the quality of raw water and treated water at SDWTP in 2015. All the measured parameters of treated water are reported to be under the national drinking water standard regulated by Ministry of Health, Malaysia standards, and World Health Organization (WHO) guidelines.

Table 5 Raw Water and Treated Water Quality in 2015

No.	Parameters	Unit	Raw Water		Treated Water		Standard (MOH)
			Min	Max	Min	Max	
1	Color	Pt-Co	20	30	5	10	15
2	Turbidity	NTU	104	220	0.74	1.20	5
3	pH		6.35	6.96	7.23	8.50	6.5 – 9.0
4	Hardness	$mgCaCO_3/L$	30.5	45.2	15.4	23.5	500
5	Ammonium	mg/L	2	3	<1	<1	1.5
6	Fluoride	mg/L	ND	ND	0.40	0.63	0.4 – 0.6
7	Chloride	mg/L	25.3	42.8	20.6	35.9	250
8	Manganese	mg/L	0.05	0.08	<0.01	0.02	0.1
9	Nitrate	mg/L	0.54	1.06	0.05	0.96	10
10	Nitrite	mg/L	0.02	0.10	<0.01	0.05	-
11	Iron	mg/L	1.0	1.5	<0.02	0.03	1.0
12	Sulfate	mg/L	<0.05	0.10	5.90	10.50	250
13	Total Chlorine	mg/L	<0.05	<0.05	1.3	2.4	0.2 – 5.0
14	Total Coliform	CFU/100mL	1000	3000	0	0	0

12. References

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Prepared by:

Vjayan Thrumakunasagran (MSc Candidate)
Vel Murugan Vadivelu (Ph.D)

School of Chemical Engineering
Universiti Sains Malaysia
14300 Nibong Tebal, Penang, Malaysia
chvel@usm.my

Date: 20 June, 2016

URL: http://www.jwrc-net.or.jp/aswin/en/newtap

Email: newtap@jwrc-net.or.jp