Kaolieo Water Treatment Plant
Vientiane City, Lao PDR

1. Background information

The Vientiane capital water supply enterprise (Nam Papa Nakhone Luang-NPNL) is a state-owned company established in 1971. Kaolieo water treatment plant (KWTP) is one of the four water treatment plants that is owned and operated by the NPNL. The KWTP was constructed in 1964 with the capacity of 20,000 m^3/d. In 2008, the plant was expanded to the total treatment capacity of 60,000 m^3/d. The background information of KWTP is presented in **Table 1.**

Table 1 Overall information of Kaolieo water treatment plant

Constructed Year/Expansion Year	1964/2008
Water Source	Mekong River
Number of connections	32,834
Peak Operating Flow (m^3/h)	3,275
Design capacity (m^3/d)	60,000
No. of operators working at the plant	8
Treated water standard	Ministry of Health (2005)
Automation	No
Date of access of the source information	2015
References	NPNL's Annual Report (2012, 2013)

Raw water is extracted from Mekong River. Main units of treatment process are hydraulic mixing, sedimentation basin, fine sand and coarse sand filter, and up flow water backwash with air scour. In 2013, 32,834 households in Vientiane capital received 67,010 m^3/d clean water daily from the KWTP.

2. Water treatment process flow

The KWTP was established very long time ago (in 1964), thus the design technology is conventional treatment process. There is no sludge treatment unit at KWTP. Sludge generated from sedimentation and backwashing is drained to Mekong River. The major water treatment processes at KWTP is presented as below (**Figure 1**):

- Raw water extraction (Mekong river) → Raw water pumping → Hydraulic mixing (alum, pre-chlorine) → Flocculation (baffled channel type) → Sedimentation (rectangular, manual cleaning) → Rapid sand filters → Disinfection (chlorine) → Clear Well → High lift pump building

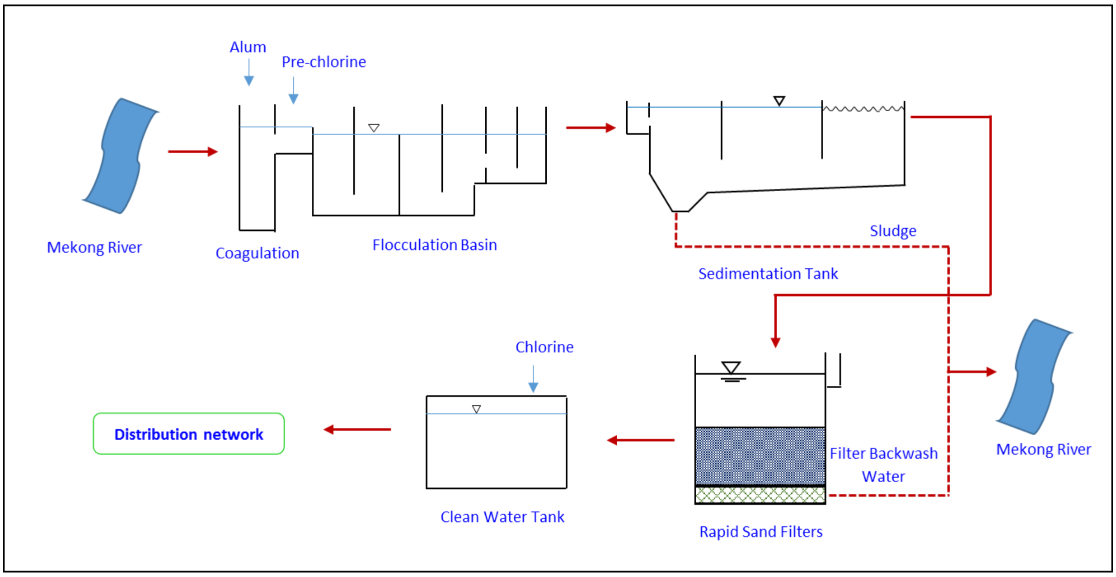

Figure 1 Water Treatment Process

2.1 Chemicals

At KWTP, three chemicals are mainly used in the water treatment process, which are: (1) solid alum for coagulation, (2) polymer for flocculation aid, and (3) calcium hypochlorite ($CaOCl_2$) for pre-and-post chlorination. These chemicals are imported from Thailand. Normally, the flocculation aid (polymer) is only used in rainy season (due to high turbidity in raw river water). Firstly, solid alum and calcium hypochlorite are dissolved in the solution tank (**Figure 2 and 3)** before transferring to the storage tank. Here, liquid alum and liquid hypochlorite solutions are injected into raw water at mixing basin (for post-chlorination, liquid hypochlorite is injected at clear well). The nature of coagulation phenomena could be controlled by the pH value of water. Polymer is injected into the entrance part of the flocculation basin from storage tank **(Figure 4 and 5)**.

Figure 2 Alum Solution Tank

Figure 3 Chlorine Solution Tank

Figure 4 Polymer Storage Tank

Figure 5 Polymer injection site

2.2 Rapid mixing

Chemical rapid mixing at KWTP is done by hydraulic jump (**Figure 6**). This phenomena happens when water at high velocity flows into the lower velocity zone. Normally, it depends on the different elevations of water before and after the jump because the energy loss is created at this jump. Both alum and chlorine are injected and mixed into the water by hydraulic jump. The purpose of pre-chlorination is to prevent algae growth in flocculation and sedimentation basins. Moreover, chlorine is also injected into the effluent weir of sedimentation for preventing algae growth in filter basin. Alkaline chemical (lime) is not used in the treatment process because alkalinity concentration is already very high (around 80 - 90 mg/L).

Figure 6 Hydraulic Jump

2.3 Flocculation

The flocculation tank at KWTP was designed with vertical baffle channel type **(Figure 7, 8).** In this type, the water flows with over-and-under flow direction. Before entering the flocculation basin, the raw water is injected with polymer solution. The hydraulic retention time of water in flocculation tank is 23.7 minutes.

Figure 7 Vertical Baffle Channel (8 basins)

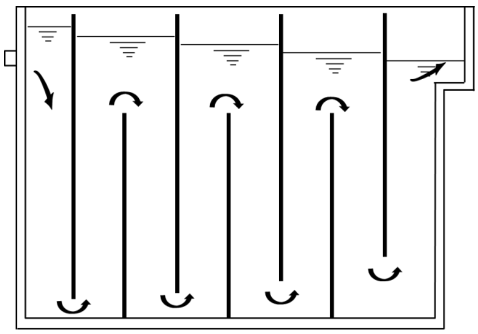

Figure 8 Over-and- under Type

2.4 Sedimentation

KWTP designed the sedimentation tank as rectangular type **(Figure 9).** The surface loading rate of sedimentation tank at Kaolieo WTP is 39 $m^3/m^2 \cdot d$. Typically, this design factor should be in the range from 20 to 60 $m^3/m^2.d$ according to the standard guideline. The surface loading rate is the primary parameter to design the sedimentation basin. The schedule for manual removing of the settled sludge is once every two months in the dry season and once every month in the rainy season. The drained waste is directly discharged to Mekong River. The hydraulic retention time at the sedimentation tank is 2.1 h. It is in the range from 1.5 to 3.0 h according to the design guideline (Kawamura, 2000). At the effluent weir of sedimentation basin, sometimes, chlorine is injected to prevent the algae growth in filter basin **(Figure 10).**

Figure 9 Sedimentation Tank (8 basins)

Figure 10 Injection Line of Pre-chlorination

2.5 Filtration

Currently, KWTP is using two types of filter media; fine sand filter media, and deep-bed coarse sand filter media. The fine sand filter media with the depth of 70 cm has been in use since the establishment of the plant in 1963 (in 4 tanks). The capacity of these initial 4 fine sand media filtration tanks is 20,000 m^3/d. In 2008, the plant constructed 4 new filtration tanks using deep-bed coarse sand filter media with the depth of 100 cm and the effective size of 1.0 mm. The filtration capacity of these additional 4 coarse sand filters is 40,000 m^3/d. Hence, KWTP currently has the total filtration capacity of 60,000 m^3/d. The average filter run time is 1 to 2 days (**Figure 11**). The backwash method is water wash combined with air scour (**Figure 12).**

Figure 11 Filter Tank (8 basins)

Figure 12 Backwashing Step

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

The KWTP conducts manual cleaning of the sedimentation basins with a constant schedule (once or twice every two months). The Japan International Cooperation Agency has compared the difference of main parameters when sedimentation basins were cleaned manually on a regular cycle **(Table 2)** (JICA, 2004). Average flow velocity and surface loading increased around 35 percent when sedimentation basin was cleaned. Manual cleaning affect bad water quality of the sedimentation as well as lack of water production.

Table 2 Comparison of main parameters in sedimentation between normal operation and sedimentation cleaning

	Normal operation	Sedimentation cleaning
Average flow velocity (m/min)	15.6	21.0
Surface loading ($m^3/m^2 \cdot d$)	39	52

As it can be observed in **Figure 13**, effluent from the sedimenation basins had very high turbidity, ranging between 5 to 20 NTU. Especially, turbidity was greatly fluctuated in wet season due to the change of raw water qaulity in Mekong River. The low water quality of sedimenation basin would affect the filtration process, such as filter run time and filtrated quality.

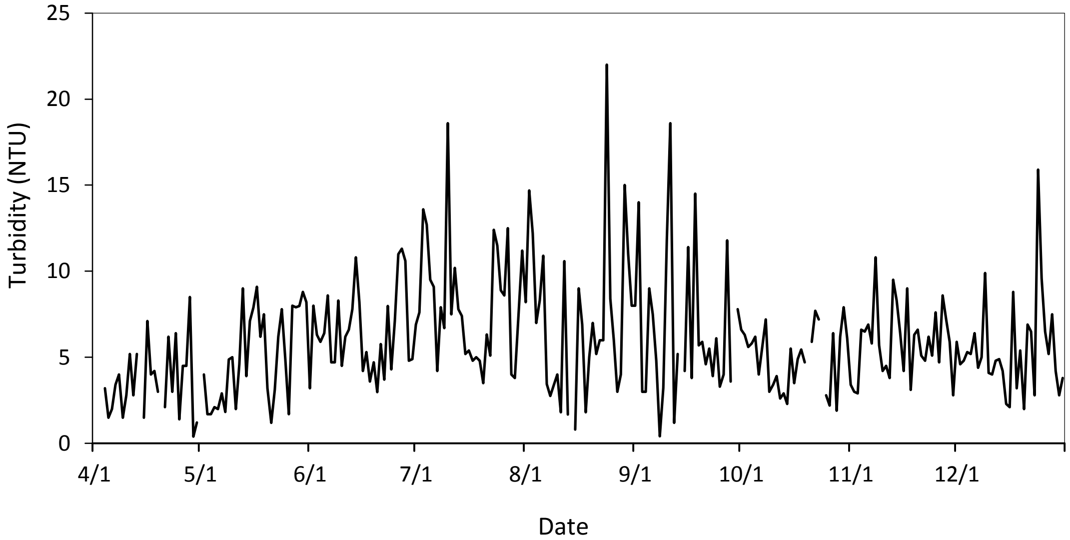

Figure 13 Turbidity of Effluent from Sedimenation Basins (2013)

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

KWTP operates at higher than the design capacity for water production **(Figure 14).** There are two main reasons for this. The first one is due to the high non-revenue water (25-30%), and second reasons is due to the low water supply rate than water demand (about 70 percent of Vientiane's population).

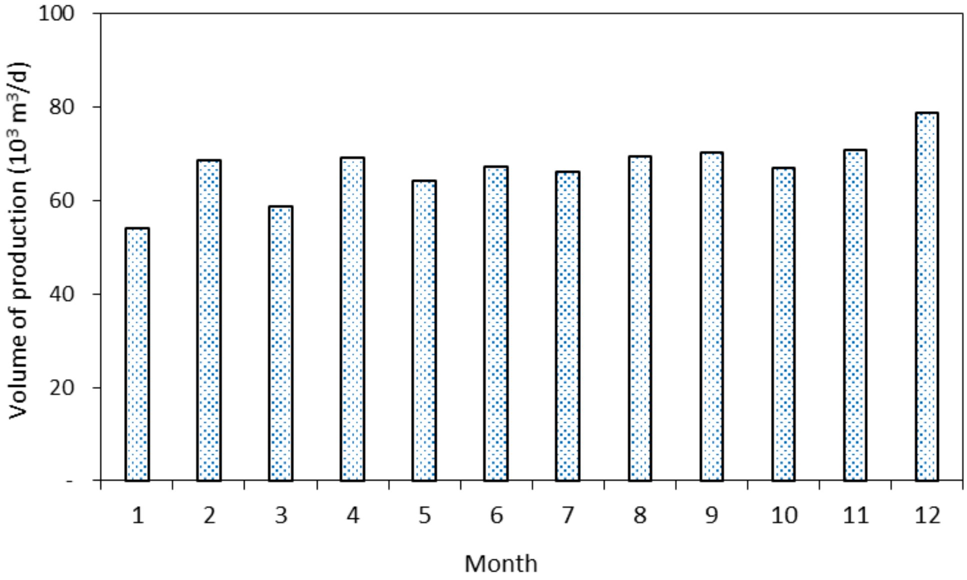

Figure 14 Water Production at KWTP (2013)

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

Figure 14 is the site of the new water treatment plant. NPNL is constructing a new water treatment plant with the capacity of 100,000 m^3/d. About 90% of water demand in Vientiane will be solved once this new WTP construction is completed in 2015.

Figure 15 New Plant under Construction

6. Recent investment made for the plant's improvement

The KWTP expanded the capacity from 20,000m^3/d (existing capacity) to 60,000m^3/d in 2008 with Japanese Grant Aid. The background information of this project is presented in **Table 3**.

Table 3 Details of the Expansion (Noriko, 2011)

Output	Main contents
1) Water intake and penstock facilities	- One set of water intake structures (44,000 m^3/d) - Water intake pump, embankment construction (90m)
2) Water purification facilities	Facility capacity (40,000 m^3/d) - Water receiving well; - Mixing basin; - Flocculation basin; - Sedimentation basin and sludge removal equipment; - Rapid filter, total flow basin and chloride mixing basin
3) Water distribution facilities	Water distribution facilities (10,600 m^3) - Distribution reservoir, pump well, distribution pump; - Chemical injection equipment
4) Electrical and instrumentation facilities:	- Electrical and instrumentation facilities
5) Development of the main administrative building and others in the premises:	- Development of the main administrative building and others in the premises

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

First, KWTP currently does not have any water quality monitoring system. Some general water quality parameters such as pH, conductivity, alkalinity and turbidity are proposed to be monitored in the raw water (Mekong River).

Second, the advanced motionless mixing (static mixer) method can be an attractive method to replace the conventional static mixing. It helps to mix the chemicals with water completely, under a limit time.

Third, mechanical sludge collector system in sedimentation basin needs to be introduced in KWTP for smooth operation and maintenance.

Fourth, Kaolieo WTP directly discharges sludge to water sources without appropriate sludge handling and treatment. Sludge lagoon drying beds are proposed as a solid waste disposal alternative.

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

Most of the customers in the hilly areas suffer lack of tap water. Moreover, it takes long time to fill up the tap water into individual storage tank due to the low pressure. Due to the old distribution pipeline system, KWTP cannot provide tap water with high pressure, as it would create chances of high leakage.

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

In filtration tank, single sand deep bed filter (coarse sand) was already introduced in 2008. About the backwash method, KWTP has uses water wash with air scour for all filters.

10. Other Highlights

Floating water intake pump is operated for supplementing lack of water when water level of Mekong River decreases during dry season.

Figure 16 Floating Water Intake Pump

Solid wastes generated from sedimentation and backwash are disposed to Mekong River.

Figure 17 Solid Waste Discharged to Mekong River

11. Water quality data

The water quality data at KWTP (2013) are presented in **Table 4**. All measured parameters were under the standard of the Ministry of Health (Lao PDR).

Table 4 Water quality data

Parameters	Unit	Raw water		Treated water		Standard (Lao PDR)
		Min	Max	Min	Max	
pH	-	7.7	7.9	7.4	7.5	6.5-8.5
Turbidity	NTU	10	1,750	less than 1		10
Alkalinity	mg/L	80	90	80	85	-
Conductivity	µs/cm	340		350		-
Total hardness	mg/L	125		120		100-300
NO_3-N	mg/L	3.0		1.0		40
Iron	mg/L	0.06		0.04		0.3
Manganese	mg/L	0.04		N.D		0.5
Chloride	mg/L	35		37		-

12. References

American Water Works Association. (1999). *Water Quality and Treatment* (6th edition). New York: McGraw-Hill. ISBN: 978-0071630115

Kaolieo. (2013*). Annual report of Kaolieo water treatment plant*. Nam Papa Nakong Luang: Lao PDR

Japan International Cooperation Agency. (2014). *The study on Vientiane water supply development project in Lao People's Democratic* Republic final report, volume III: Feasibility study.

Kawamura, S. (2000). *Integrated design and operation of water treatment facilities* (2nd edition). John Wiley and Sons. ISBN: 978-0471350934

Ministry of Health (2005). *Minister's Resolution (NO. 1371/MOH, Water quality targets of drinking water quality).* Vientiane: Lao PDR

Nam Papa Nakhone Luang. (2012). *Annual Report in 2012*. Vientiane: Lao PDR

Nam Papa Nakhone Luang. (2013). *Annual Report in 2013*. Vientiane: Lao PDR

Noriko, I. (2011*). Ex-Post Evaluation of Japanese ODA Grant Aid Project: Project for Vientiane Water Supply Development*. Retrieved Jun 10, 2015, from http://www2.jica.go.jp/en/evaluation/pdf/2011_0600600_4.pdf

Prepared by:

Mr. Khambay Vongsayalath
General Manager of Water and Environment Engineering State Enterprise (WES)
Email: kvongsayalath@yahoo.com

Disclaimer:

Date: 21 July 2015

NewTap
Network on Water Technology in Asia and Pacific

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

Email: newtap@jwrc-net.or.jp