Namkhan Water Treatment Plant
Luang Prabang City, Lao PDR

1. Background information

Luang Prabang is a touristic city situated in northern part of Lao PDR and was declared a World Heritage City by UNESCO in 1995. It has a population of about 460, 000. It is located approximately 300 m above the sea level. The water supply system in the city is managed by Luang Prabang Water Supply State Enterprise (LWSSE). The latter has been entrusted with the following roles and responsibilities:

a. Operating and maintaining water supply business in order to be self-sufficient in planning, financial and administrative management and operation, and so on.
b. Producing and distributing clear water that meets the standard of the Ministry of Public Health to the people of Luang Prabang Province.
c. Expanding distribution pipeline network and house connection in service areas.
d. Surveying, designing, constructing, repairing and renovating new and existing water supply facilities.

LWSSE currently has four water treatment plants (WTPs) under its authority: Phouphueng WTP, Namkhan WTP, Souphanouvong WTP and Phouxang WTP. Namkhan WTP (NWTP) was constructed in 2000 under the support of German Government. It was first constructed with the design capacity of 6000 m^3/d, and was later expanded to the capacity of 12,000 m^3/d. **Table 1** presents the background information of NWTP.

Table 1 Overall Information of Namkhan Water Treatment Plant

Constructed /Expanded Year	2000/2010
Water Source	Khan river
Number of connections	12,693
Design capacity (m^3/d)	12,000
Peak Operating Flow (m^3/d)	8,000
No. of operators working at the plant	11
Treated water standard	Ministry of Public Health (2014)
Automation	No
Date of access of the source information	2016
Reference	Luang Prabang Water Supply State Enterprise Waterworks

2. Water treatment process flow

The major water treatment process is presented as below (**Figure 1**):

- Raw water extraction (Khan river) → Raw water pumping → Pipe-line static mixing (alum) and hydraulic jump (pre-chlorination) → Flocculation (baffled channel type) → Sedimentation (rectangular, mechanical sludge collector) → Rapid sand filters → Disinfection (post-chlorination) → Clean water tank → High lift pump building

There is no sludge treatment process at NWTP. Sludge generated from sedimentation and backwashing is drained directly to the Khan River.

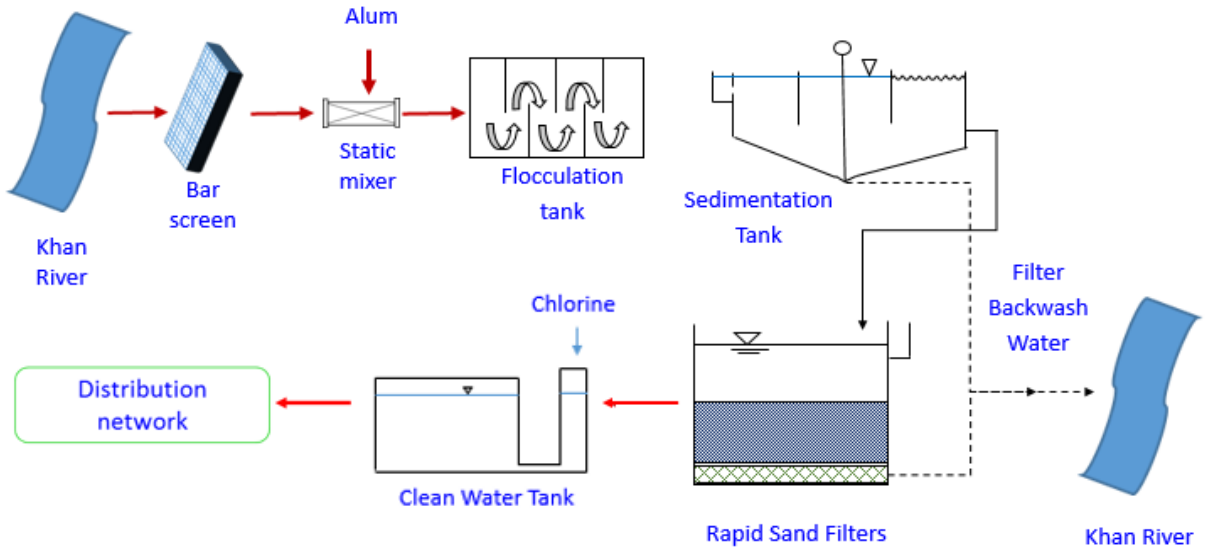

Figure 1 Water Treatment Process (top) and location of the plant (bottom)

2.1 Water Intake

The raw water is extracted from the Khan River. The raw water pumping stations is located around 200 m away from the NWTP. Intake consists of a bar screen of 1.5cm. These have also been shown in **Figure 2.**

Figure 2 Khan river, pumping station (left), and bar screen (right)

2.2 Chemicals used

Three types of chemicals are used for water treatment; solid alum as a coagulant and calcium hypochlorite ($CaOCl_2$) for pre-and-post chlorination, and polymer for coagulant aid. However, polymer is used temporarily only when raw water is highly turbid (during wet season). Solid alum is first dissolved in water in the solution tank (**Figure 2**). Then, it is transferred to the alum storage tank to inject into the static mixer. Calcium hypochlorite is dissolved in water in the solution tank (**Figure 3**), and is transferred to the receiving tank and clear well to inject into hydraulic jump. Polymer is injected inlet part of flocculation basin from storage tank **(Figure 4)**.

Figure 2 Alum Solution Tank

Figure 3 Calcium Hypochlorite Tank

Figure 4 Storage Tank of Polymer

The dosage of the chemicals is calculated using the jar test.

Figure 5 Jar Test Equipment

The turbidity of raw water differs greatly during the dry and wet seasons. In the dry season, the turbidity of the raw water is normally in the range of 10 to 180 NTU. However, during the wet season, the turbidity rises drastically upto 3000 NTU, creating problems in the treatment process.

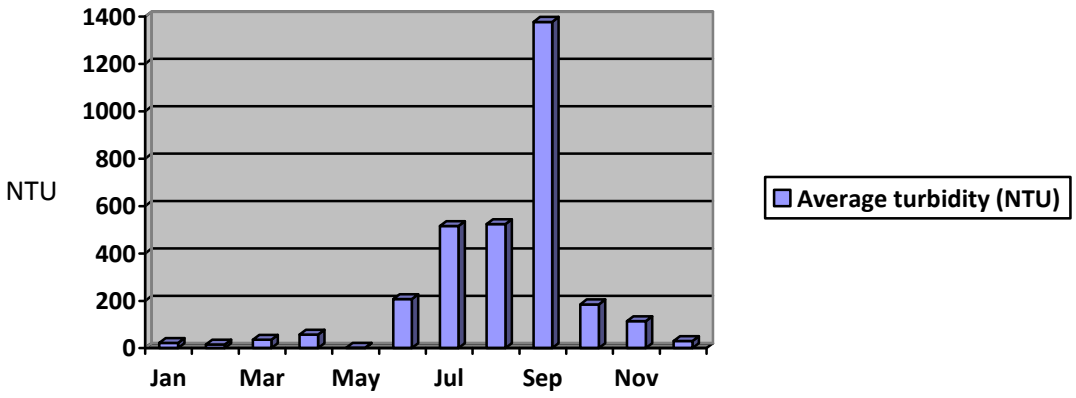

Figure 6 Average monthly turbidity of raw water (Khan river)

2.3 Rapid mixing

A static mixer is installed as a part of the influent pipeline (**Figure 7**). Here, alum is injected into raw water. Chlorine is injected into receiving tank by a hydraulic jump. The main purpose of pre-chlorination is to prevent algae growth in flocculation and sedimentation basins.

Figure 7 Static Mixer (Alum)

2.4 Flocculation

There are usually two kinds of baffle channel types, the horizontally baffled (around-the-end flow) and the vertically baffled (over- and under flow) channels. The NWTP uses vertical baffle channel type **(Figure 8 and 9).** There are two flocculation units installed in NWTP.

Figure 8 Vertical baffle channel

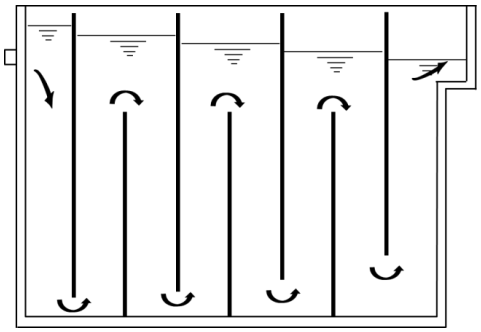

Figure 9 Over-and under type (section)

2.5 Sedimentation

Sedimentation tank at NWTP is designed with the rectangular type. Settled sludge in sedimentation tank is cleaned manually and has the provision of flusing the sludge through the sludge valve which is located at the bottom of the sedimentation tank. The regular cycle of cleaning in the dry season is once every two months and once every month in the rainy season. The generated sludge is drained to the downstream of the Khan river without any treatment **(Figure 10)**. The hydraulic retention time of the sedimentation tank at the WTP is 2.7 h while this value for conventional basins ranges from 1.5 to 3.0 h (Kawamura, 2000).

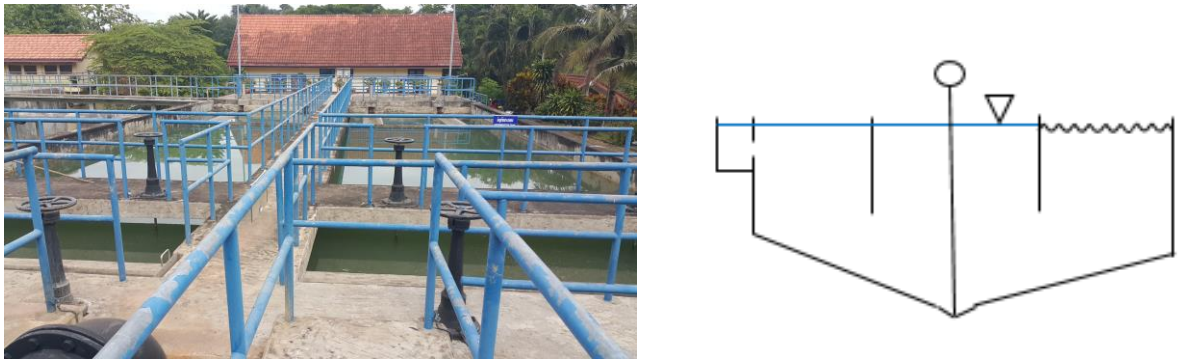

Figure 10 Sedimentation Tank (4 basins)(left) and a schematic diagram of the tank (right)

2.6 Filtration

The media utilized in NWTP is single media deep-bed filter (coarse sand) with the effective size of 1.0 to 1.2 mm, and filter depth of 100 cm. There are four filtration units in NWTP. There are two basic types of filter backwashing system, fluidized-bed backwash with surface wash and air scour and water backwash. Backwash method of NWTP is water backwash with air scour, using backwashing pump. The filtration rate of the treatment plant is 5 m^3/m^2h. The filter is backwashed every 2-3 days during the dry season while during the wet season, it is backwashed every day.

Figure 11 Filter Tank (4 basins) and arrangement of materials in the filtration unit

2.7 Distribution

There are 12, 693 service taps that LWSSE supplies water to. The treated water from NWTP is distributed along the treated water from other WTP. The end pressure of 0.4 bar is maintained at the distribution end while the water is supplied at 6 bar pressure from NWTP.

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

The major difficulties currently faced by the NWTP are as follows:

i. The turbidity of raw water differs greatly during the dry and wet seasons. In the dry season, the turbidity of the raw water is normally in the range of 10 to 180 NTU. However, during the wet season, the turbidity rises drastically upto 3000 NTU, creating problems in the treatment process.

ii. The plant was expanded from 6,000m^3/d to 12,000 m^3/d in 2010. However, the expansion included only the construction of filtration unit. The number of sedimentation unit remained (and still remains) unchanged. Thus, the pressure on the sedimentation unit during the wet season has increased.
iii. The manual cleaning of the settled sludge in the sedimentation basins causes lack of water supply by decreasing the plant capacity.
iv. Interruptions in the power supply has created problems in the treatment and supply of water.

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

The difficulty in the water management services management are as follows:

i. The non-revenue water of LWSSE ranges from 20 to 30%, which means a lot of water, and consequently the possible revenue that could have been generated, is either lost through leakages, poor connection or malfunctions of water meters.
ii. Reports of vandalism in the water distribution system.
iii. Areas in higher elevations are reported to have received water for only 8 hours a day.

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

The following measures are being considered in order to cope with the pertinent issues in the water supply system:

i. LWSSE is working to reduce the NRW by minimizing the leakages
ii. Installation of laminar tubes in the sedimentation unit is being planned as a future upgradation of the treatment plant

6. Recent investment made for the plant's improvement

In 2010, the RSF unit was added to increase the production capacity from 6000 m^3/d to 12,000 m^3/d.

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

The following steps are required to better cope with operational and management difficulties:

i. Improvement of chemical dosing system such as automated systems to replace the prevalent manual systems
ii. Better laboratory equipment to test the water quality
iii. Stable power supply and/or provision of power backup in cases of interruptions
iv. Provision of spare parts and storage to get hold of equipment during time of repairs or emergencies
v. Inclusion of tube settlers as part of the sedimentation tank to enhance the efficiency of the water treatment plant

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

LWSSE takes a good care of the customers. Call centres are operated where the users can register their complaints. On November 2016, there were 244 complaints out of which 217 were solved. However, the water quality is still not upto the consumer's taste. Consumers hardly use the supplied water for drinking purpose.

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

No advanced technologies are used in the NWTP.

10. Water quality data

Table 2 shows the raw water and treated water quality, which are obtained from NWTP annual report (2014)

Table 2 Water quality data

Parameters	Unit	Raw water	Treated water	Standard (Lao PDR)
Temperature (water)	°C		**25**	
pH	-	7.4	7.5	6.5-8.5
Turbidity	NTU	3.09	0.44	10
Alkalinity	mg/L	290	286	-
Conductivity	µs/cm	499	507	<1000
Total hardness	mg/L	84	80	<300
NO_3-N	mg/L	0.7	0.5	<50
NO_2	mg/L	0.007	0.005	<3
Chlorine	mg/L		0.53	0.1-2.0
Chloride	mg/L	5	6	<250
Total dissolved solids	mg/L	108	113	<500
Aluminium	mg/L	0.013	0.048	<0.2
Colour	CU		<2	<5
Order and taste		Not offensive	Not offensive	Not offensive

11. Reference

- Annual report of Namkhan Water Treatment Plant 2014 (Internal Document)
- Kawamura, S. (2000). Integrated design and operation of water treatment facilities (2nd edition). John Wiley and Sons. ISBN: 978-0471350934

Prepared by:

C Visvanthan, PhD
Professor
Environmental Engineering and Management Program,
School of Environment, Resources and Development
Asian Institute of Technology

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Published on: 03 January 2017

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

Email: newtap@jwrc-net.or.jp