THE TO LICH RIVER

A research studies

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Bachelor's thesis

HAMK University of Applied Sciences
Construction Engineering

Semester and year in which the thesis will be accepted

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Degree Programme in Construction Engineering
Visamäki

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Subject To Lich River

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ABSTRACT

River pollution is one of the three most problematic environmental issues in Hanoi in Vietnam. The most polluted river is called To Lich River. The pollution level of this river is so high it has been called a “dead” river. The purpose of this Bachelor’s thesis was to compile information about the river, the pollution level and the current solutions being applied by the authorities.

The thesis first provides general information about To Lich River (location, characteristics), the current status of the river and what has been done or will be done to solve or prevent the problems from getting worse. Then the causes of pollution and some mentionable events that have happened regarding the river are discussed including a description of the current situation of wastewater treatment facilities in Hanoi.

The thesis also discusses pollution on a general level compiling the results of some tests conducted to check the quality of the rivers. These results were then compared to the Vietnamese regulations. Since To Lich river has been heavily mixed with wastewater, it is the main component of the river. The waste water consists of domestic wastewater, industrial wastewater, hospital wastewater and solid waste. Each of these component was discussed in terms of treatment plans, methods and regulations.

Finally, river embankment, Yen Xa wastewater treatment plant, renovating To Lich river project and other improvement methods were dealt with. The effects of river embankment were discussed. It is a solution that has been applied by the authorities. Yen Xa wastewater treatment plant and the renovation project are upcoming plans to solve the problem. The information regarding these projects was compiled and the solution currently being applied was discussed at the end of the thesis.

Keywords Wastewater, pollution, river, renovation, legislations

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1 INTRODUCTION

Hanoi has three most problematic environmental problems: increase of smog, huge trash heaps everywhere and “dead” rivers. With 7.5 million people and increasing, the problems are getting worse.

First, Hanoi ‘s smog problem, which is becoming worse, even though the authorities have had multiple attempts to handle the situation: increase the number and routes of public buses, advertise and encourage people to use public transports, have high tax for purchasing cars (300%, higher for import cars), add and increase the cost of extra fees for having a car (insurances, applying for a plate number fee, etc.), even reduce the time for the certificate that allows cars to commute (one year reduced to six months); still, the problem remains.

Second, trash heaps spread across the city. Littering has always been a big problem in Hanoi, through many years, the situation has somewhat subsided, but a new issue has risen. To reduce littering, the authorities have hired more janitors, placed more trash bins across the city and marked points in the urban area where that would be the only place people are allowed to dump their waste. But the solution became the problem when the trash is not regularly collected and is slowly becoming a gigantic heap of trash on the side of the street.

Third and last problem is the pollution of rivers. There are five rivers around the area of Hanoi city and for years, waste (both solid waste and wastewater) has been discharged into these river, untreated or partially treated. The pollution has become so bad that the smaller rivers are considered “dead”. The most polluted is To Lich river which is the main topic of this thesis.

The objective of this thesis is to study the pollution of To Lich river: how did the river become polluted, the current pollution level, what is being done to prevent the situation from getting worse and what actions have the authorities taken to try to clean the river. The first chapter will cover some general information about To Lich river, the causes of the pollution, some notable events regarding the river and the current situation of the wastewater treatment plant. The second chapter will show the pollution level of the river and the types of waste being discharged into the river. The third and final chapter will discuss the authorities’ solutions for the pollution. There are three main solutions: the embankment of the river, the plan to “clean” the river using water from nearby rivers and the new Yen Xa wastewater treatment plant including some minor plans.

2 GENERAL INFORMATION

To Lich river is a small river that flows through Hanoi city, the capital of Vietnam. This river is approximately 14 km in length and the water basin is about 77.5 km^2. It runs through four districts: Cau Giay, Thanh Xuan, Hoang Mai and Thanh Tri. There are approximately two million people living in these areas. Most of the domestic wastewater produced in these districts is released into the river. In these four districts, there are also five different industrial parks which currently housing almost 100 factories. The industrial wastewater from these factories is also discharged into the river, directly or indirectly through the city sewage system.

In Figure 1, there is a map of the river. To Lich river is a smaller branch from the main source, Red River. The red part line drawn in the map used to be the start of the river but has now been covered and turned to sewerage and roads. According to a geographical book from the 19^{th} century, there is a small part of the river that also flows to the West Lake, north of the river. This is also covered and no longer visible. The purple lines are parts of To Lich river that flows to and merge with Nhue River. The black line is the main topic of the thesis as this is the most polluted area. The green circle marks the location of Yen So pumping station. To Lich river's basin is lower than its source, Red River. Since the original start point has been covered, To Lich river does not share the flow with Red River. Instead, the flow of To Lich river is created by a combination of sewer water being discharged directly from factories, from 239 sewage points along the river and Yen So station pumping the water out.

Figure 1. A map of To Lich river (map taken from Google Maps; the picture was edited by me

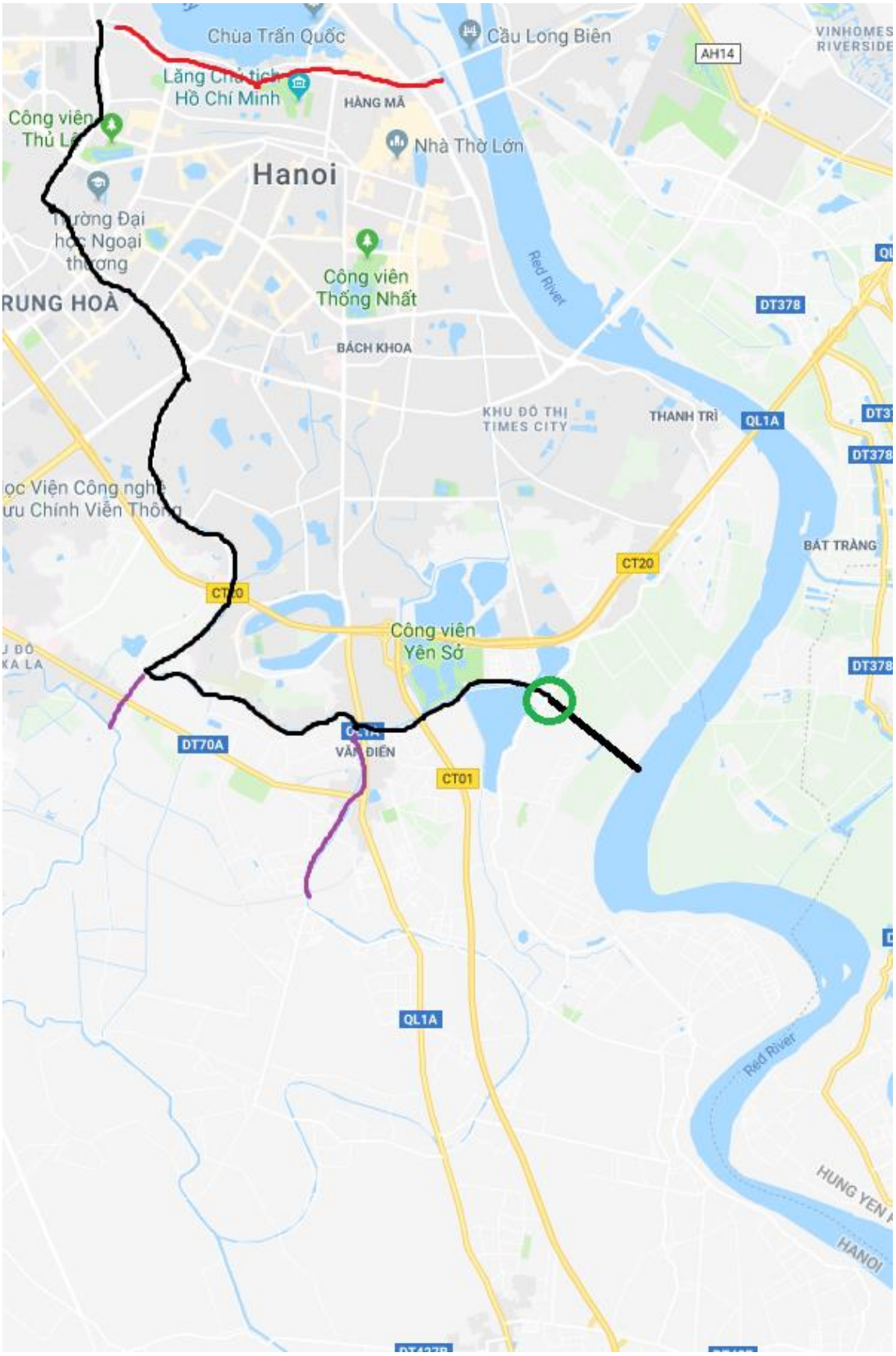


Figure 2.

Figure 3. In the 1980s, with the rise of population, urbanisation and industrialisation, To Lich river slowly became polluted. The pollution got worse when the sewage water from factories is not treated before being discharged into the river. In addition to the wastewater, there was a huge amount of solid waste being dumped into the river due to people's carelessness. By 1990s, the river's water had blackened, there were tons of sludge at the bottom and an unbearable odour (which gets worse when the weather becomes hot or when it is raining). There was also solid waste, different kinds of oil, dead animals floating on the surface; sometimes even dead bodies. The ecology of To Lich river was destroyed; and with the odour and the black water, To Lich river was nick-named the Dead river.

Since the 1980s, there were some notable events on To Lich river:

- The construction of Yen So pumping station started in 1998 and finished in 2005. The station then had a capacity of pumping 45 m^3/s, completing phase one. The station was built to help drain the water out of Hanoi, reducing flood. In November 2008, phase two started. The plan was to upgrade the capacity to 90 m^3/s with 9 pumps working 24/7. (New Newspaper, 2010)
- In the same year, 1998, was the embankment of the river. The scope was to help control and move the large amount of sediment at the bottom. The embankment was also expected to help improve the water quality. (Nguyen, Yoneda, Matsui, 2013, 361)
- In 2008, there was a huge storm, the city was flooded, To Lich river was overflowing. Hanoi's citizens were mourning the loss of unfortunate citizens that got into accidents and passed away (Hong, 2008). At the same time, there was some good news, for a few weeks, the water current was so fast and strong the river temporary cleaned itself. When the river was clear, at some location, people claim to even see the bottom of the river. In addition to a clean and clear river, there was also fish washed in from nearby rivers; people had fun fishing as long as it lasted.
- In 2007, fake news regarding the discovery of "sacred artefacts" causing some superstitious controversial theories, claiming the pollution of To Lich river has brought bad luck to Hanoi. (Nguyen, 2007)
- In 2009, there was a discussion about improving To Lich river's water quality using water from Red river. The method was expected to help neutralise the pollution in To Lich river. Although a detailed plan of this project was not announced until 2017. (Xuan, Duc, 2009)
- In 2016, the construction of, supposedly the largest wastewater treatment plant, started. Yen Xa wastewater treatment plant was designed to treat 270,000 cubic meters of water per day. The project was funded, and construction was supported by Japan and expected to be complete in 2019. (Khuong, 2016)

- Also, in 2016, authorities started a dredging operation.

There are currently six wastewater treatment plants and two under construction in Hanoi. Figure 2 and Table 1 show the location and some general information about these wastewater treatment plants.

Figure 4. A map of existing wastewater treatment plants (JICA, 2013, 1 – 4)

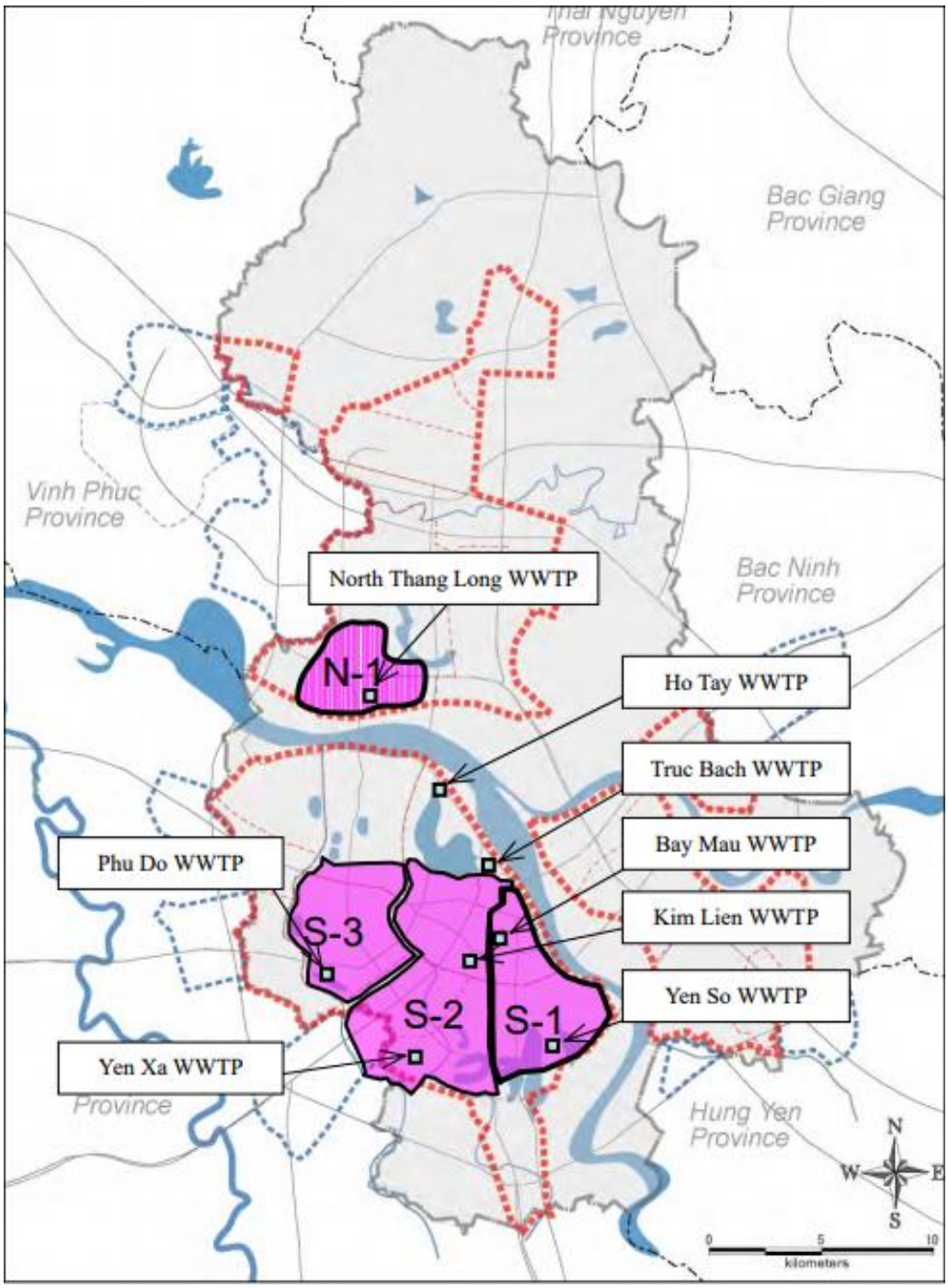


Table 1. Wastewater treatment plants in Hanoi (JICA, 2013, 1 – 5)

Wastewater treatment plant	Capacity (m^3/day)	Operation start year
Truc Bach	2,300	2005
Yen So	200,000	2012
Bay Mau	14,000	2015
Kim Lien	3,700	2005
Yen Xa	270,000	Expected 2019
Phu Do	84,000	Expected 2020
North Thang Long	42,000	2016
Ho Tay (West Lake)	15,000	2013
Total	631,000	

In Figure 2 it can be seen that To Lich river basin mostly belongs to S2 area, where there are two wastewater treatment plants, Yen Xa and Kim Lien. Of these, Yen Xa is under construction while Kim Lien has been in operation since 2015 but can only treat 3,700 m^3 of wastewater per day.

It should be noted that, Figure 2 shows a recent municipal plan, in which Hanoi has been divided into several developments (for both urban and industrial purposes) areas, using Red river as a borderline. These areas area marked N1, N2, etc. or S1, S2, etc. according to their locations compared to the Red river.

3 THE POLLUTION

In 2013, it was reported that there was approximately 382,000 m^3 of wastewater per day being poured into To Lich River. The combined wastewater consists of about 140,000 m^3 of domestic wastewater, roughly 236,000 m^3 of industrial wastewater and almost 6,000 m^3 of hospital wastewater (Ho, 2016, 17). Among the components, domestic wastewater has the highest amount of organic material. Industrial waste water brings heavy metals into the river. Hospital wastewater brings other toxic chemicals to the mix. Other than the different wastewaters, there are also solid waste (both organic and inorganic) being illegally dumped in the river. Some solid waste stays on the surface, some sinks and combines with the sludge at the bottom of the river.

There are some reports about the quality of To Lich river. Different samples were taken in various locations and tests were conducted. For example, there is a test for organic matters and another test for heavy metals and nutrients. The results are respectively shown in Table 2 and

3. Table 4 show the longitude and latitude of sample locations in Table 2.

Table 2. Results for test 1 (Luong, Nguyen, Tran, Nguyen, Pham, Dinh, Nguyen, Ho, Pham & Phi, 2016, 150)

	Unit	Sample locations	Hoang Quoc Viet bridge	Nga Tu So bridge	Dau bridge	Van Dien bridge	Yen So pumping station	Average
T	°C	-	24	26	30	30	29	27.8
pH	-	-	7.66	7.35	7.32	7.32	7.3	7.39
SO_4^{2-}	mg/l	-	56.36	54.43	38.42	42.27	25.62	43.42
DO (dissolved Oxygen)	mg/l	-	0.5	0.1	0.1	0.4	0.4	0.3
NH_4^+	mg/l	-	25	37.8	39.59	37.8	29.47	33.93
NO_3^-	mg/l	-	3.64	4.09	7.2	3.23	2.72	4.18
N_{total}	mg/l	-	28.72	41.92	46.86	41.09	32.2	38.16
PO_4^{3-}	mg/l	-	4.26	3.88	2.5	2.58	2.07	3.06
P_{total}	mg/l	-	4.3	4.01	2.59	2.62	2.09	3.12
COD	mg/l	-	133.9	150.3	142.5	138.5	150.1	143.1
BOD_5	mg/l	-	95.5	90.7	96.9	88.6	75.2	89.4
E. Coli	MPN/100ml	-	320	290	120	290	130	230
Coliform	MPN/100ml	-	42,000	39,000	57,000	39,000	36,000	42,600

In Table 2 it can be seen that To Lich river's pH seems normal and the amount of NO_3^- is within limits, although other components are a lot higher than standard. Some notable parameters include SO_4^{2-}, PO_4^{3-}, E. Coli, especially COD, BOD_5 and Coliform. The pH value ranges from 7.3 to 7.66; SO_4^{3-} ranges from 25.62 to 56.36; DO ranges from 0.1 to 0.5; NH_4^+ ranges from 25 to 39.59; NO_3^- ranges from 2.72 to 7.2; N_{total} ranges from 28.72 to 46.86; PO_4^{3-} ranges from 2.07 to 4.26; P_{total} ranges from 2.09 to 4.3; COD ranges from 133.9 to 150.3; BOD_5 ranges from 75.2 to 96.9; E. Coli ranges from 120 to 320 and Coliform ranges from 36,000 to 42,600.

Table 3. Results of test 2 (Pham, Nguyen, Pham, Tran, 2013, 27)

Components	Units	Samples locations	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8	Average
pH		-	7.05	7.17	7.3	7.16	7.21	7.26	7.26	7.2	7.2
TSS (total suspended solid)	mg/l	-	31	30	56	28	33	41	70	85	47
COD	mg/l	-	56	72	50	24	32	32	32	160	55
N_{total}	mg/l	-	12.2	15.3	12.4	14.2	15.2	11.2	11.2	15.6	15.2
P_{total}	mg/l	-	0.57	0.66	0.56	0.63	0.71	0.67	0.59	0.71	0.64

K_{total}	mg/l	-	6.07	5.66	4.31	6.27	6.52	3.67	7.8	7.13	5.93
Cd	mg/l	-	0.3	0.2	0.5	0.1	0.2	0.2	0.9	0.3	0.3
Pb	mg/l	-	11	3	27	66	58	15	27	10	27
Cu	mg/l	-	61	94	75	66	89	74	69	42	71
Zn	mg/l	-	226	160	167	<50	178	334	1,368	126	326
Mn	mg/l	-	124	78	133	62	163	94	134	101	111

Table 4. Locations of sampling sites for test 2 (Pham, Nguyen, Pham, Tran, 2016, 25)

Sample locations	Longitude	Latitude
TL1	105°48’55.59	21°02’45.04
TL2	105°48’22.50	21°02’24.43
TL3	105°47’54.01	21°01’36.41
TL4	105°48’50.32	21°01’12.59
TL5	105°48’38.43	21°00’38.56
TL6	105°48’58.30	21°00’22.01
TL7	105°48’51.01	20°59’34.68
TL8	105°49’89.58	20°58’48.94

Similar to previous results, only the pH value is within the limit. The amount of heavy metals Lead, Copper, Zinc and Manganese are very high, especially the results for Zn at sampling site 7. The amount of Cadmium is also over the limit but not as alarming as the other. In Table 3, pH value ranges from 7.05 to 7.3; TSS ranges from 28 to 85; COD ranges from 24 to 160; N_{total} ranges from 11.2 to 15.6; P_{total} ranges from 0.56 to 0.71; K_{total} ranges from 3.67 to 7.8; Cd ranges from 0.1 to 0.9; Pb ranges from 3 to 66; Cu ranges from 42 to 94; Zn ranges from <50 to 1,368 and Mn ranges from 62 to 163.

These results can be compared to the latest legislation about river water quality, the National Technical Regulation on Surface Water Quality, published on 21st December 2015 by the Ministry of Natural Resources and Environment of Vietnamese government. In this regulation, surface water is divided into four groups: A1, A2, B1 and B2. A1 is water that can be used for municipal purposes, after being treated regularly; A2 is similar to A1 but requires specific treatments depending on the usage purposes; B1 is water that can be used for agriculture and irrigation; and B2 is water used for water transportation and other purposes that can use low quality water. To Lich river is classified as B2 water, used for disposing of waste water. Average results of To Lich river quality and surface water standard set by Vietnamese legislation are shown in Table 5.

Table 5. Vietnamese standard for river water quality

Parameters	Unit	Vietnam standard	To Lich river
pH		5.5 – 9	7.3
DO	mg/l	≤2	0.3
TSS	mg/l	100	47
NH_4^+	mg/l	0.9	33.93
NO_3^-	mg/l	15	4.18
PO_4^{3-}	mg/l	0.5	3.06
COD	mg/l	50	99
BOD_5 (20°C)	mg/l	25	89
E. Coli	CFU / 100 ml	200	230
Coliform	CFU / 100 ml	10,000	42,600
Cd	mg/l	0.01	0.3
Pb	mg/l	0.05	17.4
Cu	mg/l	1	37.8
Zn	mg/l	2	185.2
Mn	mg/l	1	166
TOC	mg/l	-	7.3
Cr	mg/l	1	2
Ni	mg/l	0.1	6.8
As	mg/l	0.1	40.6

In Table 5, some details can be concluded as the following:

- The river's pH, dissolved oxygen (DO) and suspended solids (SS) values are within Vietnamese standards for B2 quality water.
- About nutrients, even though the amount of Nitrate (NO_3^-) is within the limit, the amount of Ammonium (NH_4^+) and Phosphate (PO_4^{3-}) are not.
- Chemical Oxygen Demand (COD) and (Biological Oxygen Demand) results are also quite high.
- There are too many harmful microorganisms.
- The river is polluted with many types of heavy metals: Cadmium (Cd), Lead (Pb), Copper (Cu), Zinc (Zn) and Manganese (Mn).

The results shown in this chapter were collected and measured by tests demanded by the National Technical Regulation on Surface Water Quality, Ministry of Natural Resources and Environment (shown in Table 6):

Table 6. Demanded tests

Parameters	Legislations
pH	TCVN 6492:2011 (ISO 10523:2008)
DO	TCVN 7324:2004 (ISO 5813:1983) TCVN 7325:2004 (ISO 5814:1990)
TSS	TCVN 6625:2000 (ISO 11923:1997) SMEWW 2540.D
NH_4^+	TCVN 6179-1:1996 (ISO 7150-1:1984) TCVN 6660:2000 (ISO 14911:1988) TCVN 5988:1995 (ISO 5664:1984) SMEWW-4500-NH_3.F:2012
NO_3^-	TCVN 6180:1996 (ISO 7890-3:1988) TCVN 6494-1:2011 (ISO 10304-1:2007) TCVN 7323-1:2004 (ISO 7890-1:1986) TCVN 7323-2:2004 (ISO 7890-2:1986) SMEWW-4500 NO_3^-.E:2012 EPA 352.1
PO_4^{3-}	TCVN 6494-1:2011 (ISO 10304-1:2007) TCVN 6202:2008 (ISO 6878:2004) SMEWW-4500-P.E:2012 SMEWW-4500-P.D:2012
COD	TCVN 6491:1999 (ISO 6060:1989) SMEWW 5220.C:2012 SMEWW 5220.B:2012
BOD_5 (20°C)	TCVN 6001-1:2008 (ISO 5815-1:2003) TCVN 6001-2:2008 (ISO 5815-2:2003) SMEWW-5210.B:2012
E. Coli	TCVN 2187-2:1996 (ISO 9308-2:1990 (E))
Coliform	TCVN 2187-2:1996 (ISO 9308-2:1990 (E)) SMEWW 9221.B:2012
Cd	TCVN 6197:2008 SMEWW 3113.B:2012 SMEWW 3120.B:2012
Pb	TCVN 6193:1996 (ISO 8288:1986) SMEWW 3113.B:2012 SMEWW 3120.B:2012
Cu	TCVN 6193:1996 (ISO 8288:1986) EPA 6010.B SMEWW 3111.B:2012 SMEWW 3120.B:2012
Zn	TCVN 6193:1996 (ISO 8288:1986) EPA 6010.B SMEWW 3111.B:2012 SMEWW 3120.B:2012
Mn	TCVN 6002:1995 (ISO 6333:1986) SMEWW 3111.B:2012
TOC	TCVN 6634:2000 (ISO 8245:1999)

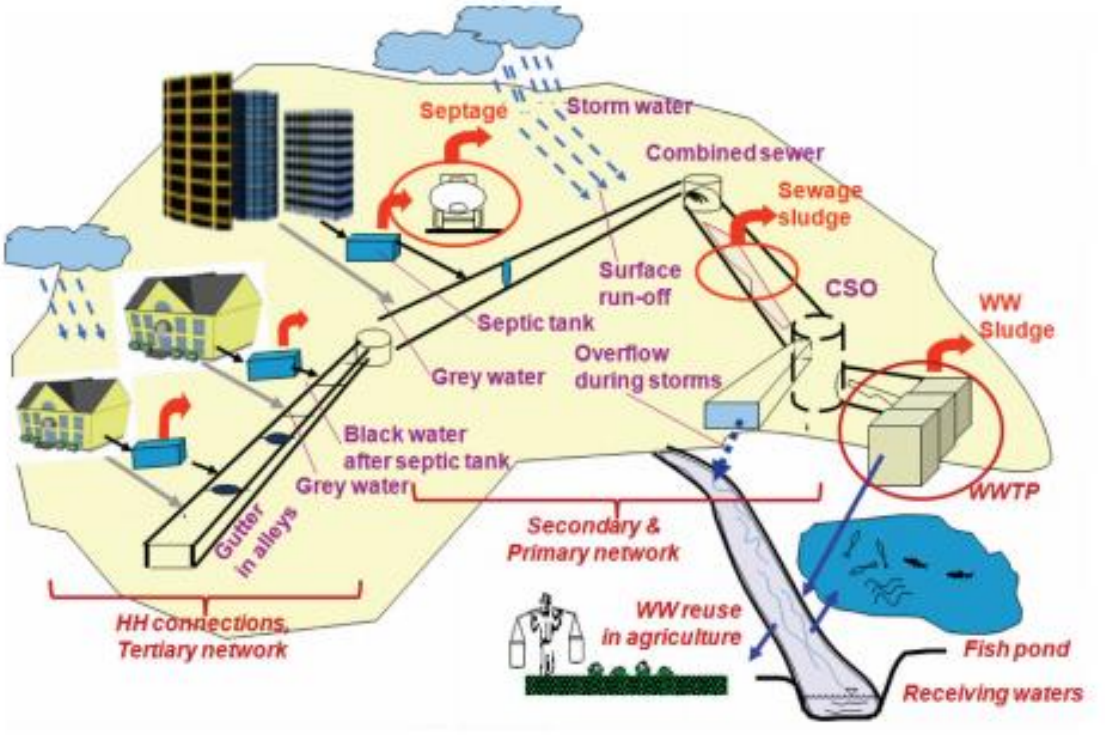
	SMEWW 5319.B:2012 SMEWW 5310.C:2012
As	TCVN 6626:2000 (ISO 11969:1996) SMEWW 3114.B:2012 SMEWW 3120.B:2012
Cr	TCVN 6222:2008 SMEWW 3111.B:2012 SMEWW 3120.B:2012
Ni	TCVN 6193:1996 (ISO 8288:1986) EPA 6010.B SMEWW 3111.B:2012 SMEWW 3120.B:2012

In addition to the pollutants found in the water, To Lich river has three more problems. The first problem is the colour of the water. With all these pollutants, not only was the quality of water affected but they have also blackened the water. The second problem is the sediment. After a long time mixing together, nutrients and heavy metals slowly sink to the bottom of the river, creating a large amount of sludge. The third problem is the odour. In other tests, the Eh value in To Lich river is about -265 mV to -95 mV, combine with the average temperature of Hanoi, 24°C to 31°C, the right level of pH and the high amount of nutrients, there is plenty of H_2S created per day (Luong, Nguyen, Tran, Nguyen, Pham, Dinh, Nguyen, Ho, Pham & Phi, 2016, 153). The high level of H_2S created a horrible smell around To Lich river basin. This odour spreads further and lasts longer when it rains.

3.1 **Domestic wastewater**

The sewage system in Vietnam is a bit different from the system in Finland. In Finland, household wastewater (greywater) and blackwater are collected together while rain water run-off is collected separately. Only in a few regions of Finland do all three types of water are mixed. In Vietnam, all three types of wastewater are always mixed and collected together. Earlier, rain water run-off was collected separately; but the system could not handle the large amount of rain water and the city was flooded often; to reduce floods, authorities decided to merge the system with the city's sewage system. As to the blackwater, there are septic tanks, but in the end, the septage would still be mixed the common sewage system, even when the septage was collected by special trucks. Figure 3 shows the usual wastewater collection system, not just in Hanoi, but in Vietnamese cities.

Figure 5. Domestic wastewater collection system (World Bank, 2013, 24)



Due to this mixture of wastewater, the domestic wastewater in Hanoi has a very high amount of nutrients and microorganisms. In Figure 2, it is shown that the wastewater is transferred to a wastewater treatment plant, but in reality, that is not always the case. There will be eight wastewater treatment plants in Hanoi, but only two of them will discharge wastewater around To Lich river. The two plants are Yen Xa and Kim Lien of which one is under construction while the other one only has the capacity of handling roughly 4,000 m^3/day, compared to 140,000 m^3 of domestic wastewater discharged into the river.

Within the mixture, rain water run-off has the least effects on the final domestic wastewater. The characteristics of domestic wastewater are largely based on household wastewater, which comprises greywater and blackwater. Greywater is a combination of wastewater from showers, laundry, kitchen sinks and others (air conditioners, wastewater from cleaning the house, etc.). Blackwater is from toilets (faeces and urine). According to a study done by Büsser, Pham, Antoine & Nguyen in 2007, greywater made up the most of household wastewater, 68 – 90%, while blackwater is about 10 – 32%. Within greywater, most wastewater comes from showers, then laundry and finally kitchen sinks. The differentiate of wastewater percentage depends on how many people live in a household, how many times people use the toilet, the types of toilet, their eating habits, etc. Most of household wastewater is discharged during the evening, due to showering habit of the Vietnamese.

Blackwater contains mostly phosphorus, nitrogen and pathogens. It comes from a mixture of faeces, urine, toilet paper and toilet cleaning chemicals. The amount of P and N varied depending mainly on how many people there are, their ages, how many times they use the toilet, a person's diet; sometimes also on what people flush down their toilets, e.g. some people flush down dead fish.

The compounds of greywater are a little more complicated. The content of greywater depends even more on the household's dynamics, the number of people, their ages and lifestyles, the household's installation (e.g. old piping system), the use of chemical products, etc. Some of the concern substances include phosphorus, nitrogen, pathogens, ammoniac, grease, solids, organic compounds, heavy metals and persistent pollutants. These substances can be found in detergents, soaps, shampoo, cooking oil, food remains, hair, textile fibres, bleach, etc. The study done in 2007 also reveals that greywater has a very high amount of phosphorus (from detergents) and COD, mostly comes from laundry activities.

Table 7 shows the parameters for domestic wastewater as listed in QCVN -14:2008/BTNMT (National Technical Regulation on Domestic Wastewater). The domestic wastewater discharging into the river is classified as B-class, wastewater released into river that is not used to supply water for domestic usage.

Table 7. Vietnamese standard for domestic wastewater

Parameter	Unit	B-class
pH		5 – 9
BOD_5	mg/L	50
TSS	mg/L	100
Total dissolved solid	mg/L	1000
Sulphur	mg/L	4
NH_4^-	mg/L	10
NO_3^-	mg/L	50
Cooking oil	mg/L	20
Total active surface agents	mg/L	10
PO_4^{3-}	mg/L	10
Coliform	CFU / 100 ml	5000

3.2 **Industrial wastewater**

Along To Lich river basin, there are five industrial zones, housing a total of 99 factories. The industrial zones are called Thuong Dinh, Minh Khai, Truong Dinh, Van Dien, Cau Buou. Table 8 shows the number of factories in these five areas and what their products are.

Table 8. List of factories (Nguyen, 2013, 4)

Type of industry	Thuong Dinh	Minh Khai	Truong Dinh	Van Dien	Cau Buou
Mechanical	14	13	3	8	3
Construction materials	-	6	-	2	1
Food processing	1	3	6	-	-
Textile	4	11	2	-	-
Leather	3	1	-	-	-
Printing	-	1	-	-	-
Paper	1	-	-	-	-
Ceramic	2	-	1	-	-
Chemicals	2	-	-	2	1
Other	3	3	1	1	-
Total	30	38	13	13	5

There are 41 mechanical factories (cars, electronics, etc.), 9 produce construction material, 10 do food processing, 17 textile factories, 4 for leather, 1 printing, 1 paper, 3 for ceramic, 5 chemicals and 8 for other types of industry (Incense, cigarette, etc.). Within some of these factories, wastewater is discharged directly into the river, some connect with the city's wastewater treatment system, or they have their own wastewater treatment plant within the industrial zone.

Due to new legislation and regulations, all of these factories have installed a wastewater treatment system. Factories now either have a preliminary (simple screening, filtering) treatment system before connecting to a centralized treatment plant or sophisticated systems (treat wastewater to fit the standard for industrial wastewater standard in general, or the standard set for a specific industry type). If factories are not equipped with a proper treatment system, they will be fined heavily. Even though the majorities of factories claimed to have installed wastewater treatment systems, To Lich river's water quality still has a high amount of heavy metals.

Wastewater from factories usually have a high amount of heavy metals, TOC, different types of grease and oils, and high COD value. There are three measures of wastewater treatment commonly used in Vietnamese factories, they are listed as follows:

- (1) Traditional technology with biological treatment using activated sludge and trickling filters.
- (2) Wastewater treatment technology with biological treatment process by aerobic microorganism
- (3) Wastewater treatment technology with a biological treatment process using activated sludge prolonged aeration.

If the factories use a centralised wastewater treatment plant in the industrial zone, there are also three different lines of process, presented as follows:

- Line 1: Pre-treatment (trash, sand and grease removal) ➔ Balancing tank ➔ Mixing tank and pH adjustment tank, flocculation ➔ Sedimentation tank ➔ Biological treatment tank with activated sludge ➔ Secondary sedimentation tank ➔ Chlorination
- Line 2: Pre-treatment (trash, sand and grease removal) ➔ Balancing tank (with/without aeration) ➔ Mixing tank and pH adjustment tank, flocculation ➔ Sedimentation tank ➔ Balancing tank before sequencing batch reactor (SBR) tank ➔ Biological treatment tank with activated sludge according to SBR ➔ Chlorination
- Line 3: Pre-treatment (trash, sand and grease removal) ➔ Balancing tank (with/without aeration) ➔ Mixing tank and pH adjustment tank, nutrients ➔ UASB (Upflow Anaerobic Sludge Blanket) anaerobic tank ➔ Aeroten tank (a rectangular aerobic reactor) with fix bio-support ➔ Secondary sedimentation tank ➔ Mixing tank and pH adjustment tank, flocculation ➔ physicochemical sedimentation tank ➔ Chlorination

Most of these centralised effluent treatment plants (CETP) in industrial zones have circadian reservoirs before disinfection/antiseptic step to additionally treat wastewater before being discharged or recycled. (NGO, 2013)

According to QC 40:2011/BTNMT (the National Technical Regulations on Industrial Wastewater), wastewater disposing into the river is B-class, wastewater disposing into river not used to supply domestic usage. Some parameters can be shown in Table 9:

Table 9. Vietnamese standard for industrial wastewater

Parameter	Unit	B-class
Temperature	°C	40
pH		5.5 – 9
BOD_5	mg/L	50
COD	mg/L	150
TSS	mg/L	100
As	mg/L	0.1
Hg	mg/L	0.01
Pb	mg/L	0.5
Cd	mg/L	0.1
Cu	mg/L	2
Zn	mg/L	3

Ni	mg/L	0.5
Mn	mg/L	1
Fe	mg/L	5
NH_4^-	mg/L	10
N_{total}	mg/L	40
P_{total}	mg/L	6
Total grease	mg/L	10
Coliform	CFU / 100 ml	5000

3.3 **Hospitals wastewater**

There are approximately ten big hospitals and several other smaller hospitals, clinics and other medical facilities around To Lich river basin. The medical wastewater is usually discharged directly into the river if they are close by; if not, the wastewater will be transferred to a common treatment plant. If a hospital is discharging wastewater directly into the river, they would have applied one of these five wastewater treatment technologies/methods: (NGO, 2013)

- 1: Wastewater is pre-treated and sterilized: Wastewater WCs ➔ Septic tanks ➔ Disinfection
- 2: Wastewater is treated according to a scheme: water at underground sewer network ➔ Pump station ➔ Sand sedimentation tank ➔ two-shell clarifier ➔ Biological filtered tank ➔ 2nd standing clarifier ➔ Disinfection ➔ Discharge outside
- 3: Water discharge from septic tanks ➔ Underground sewer network ➔ Reservoirs + trash filters ➔ Pump station ➔ Aeroten tank ➔ 2nd deposition ➔ Disinfection ➔ Discharge outside
- 4: Water discharge from septic tanks ➔ Underground sewer network ➔ Reservoirs + trash filters ➔ Pump station ➔ Balancing tank: combine aeration and preliminary transient paddings ➔ treatment equipment anaerobic-anoxic-aerobic (biofilm + activated sludge + biological product BIOWC96 + DW97; according to each module with flocculation and sedimentation) ➔ antiseptic ➔ Discharge outside
- 5: A wastewater treatment system financed, designed and installed by private foreign contractors through special programs; e.g. wastewater treatment systems in Hanoi's Children hospital and Uong Bi hospital were supported by Sweden. The systems have advanced technology in wastewater disinfection, sterilization and coagulation, drying sludge.

Although there are different wastewater treatment schemes available, not all medical facilities apply one. Only large scale (city level) hospitals possess a proper wastewater treatment system, such as Hanoi hospital (newly constructed), Vinmec International hospital, 108 Military hospital, Vietnam – Germany hospital, etc. Medium scale (district

level), the chances for having a wastewater treatment system is 50/50; even then, the treated wastewater might not meet the standard. Small scale clinics are most likely to only have a plan to handle solid waste. Medical wastewater in Hanoi has a high amount of COD, BOD, Ammonia, Chlorine, TSS, pathogens, microorganisms and other persistent pollutants. Medical wastewater is quite similar to domestic wastewater. The difference lies in the extra urine from samples, drugs and disinfection liquid.

Some parameters for hospital wastewater is shown in Table 10, according to QCVN 28:2010/BTNMT (National Technical Regulation on Health Care Wastewater). Wastewater discharging into the river is classified as B-class, wastewater released into the river that is not used as a domestic water's supply.

Table 10. Vietnamese standard for medical wastewater

Parameter	Unit	B-class
pH		6.5 – 8.5
BOD_5	mg/L	50
COD	mg/L	100
TSS	mg/L	100
Sulphur	mg/L	4
NH_4^-	mg/L	10
NO_3^-	mg/L	50
PO_4^{3-}	mg/L	10
Cooking oil	mg/L	20
Coliform	CFU / 100 ml	5000
Salmonella	Bacteria / 100 ml	None detected
Shigella	Bacteria / 100 ml	None detected
Vibrio Cholerae	Bacteria / 100 ml	None detected

3.4 **Solid waste**

Beside the mixture of wastewater being discharged into the river, there are also other types of solid waste found in To Lich river. Some solid waste float on the surface with oil and grease, some sink to the bottom and join the sediments. Nowadays, the amount of solid waste being discharged into the river has reduced, ever since the authorities became more serious about environmental problems. Still, some people do not care and still dump solid waste into the river, as long as it is convenient to them.

The most common type of solid waste found in the river is a mixture of household waste: cans, food remains, textile, papers and plastic bags. Household waste is usually stored in plastic bags, when the bags are full, they are thrown into the river. The second type of solid waste

is small dead animals, rats, birds, fish, frogs, sometimes there are even cats and dogs. The third type is construction materials, debris, broken bricks, sand, cement, broken tools. Although construction waste is not often released into the river, only from sites that are located near the river. Last and rarely appearing are human corpses, usually just an unfortunate drunken driver, or some unlucky person got caught in a stormy day.

4 SOLUTIONS

4.1 River embankment

During the 1990s, urbanisation and industrialisation were increasing in Hanoi, causing an increase of sedimentation and the pollution of To Lich river. To try to solve the problems, the government decided to embank the river. The project started in 1998 and finished in 2002. The river since then has a width of 20 – 45 m, a depth of 2 – 4 m and the maximum water flow capacity of 30 m^3/s. After the embankment, the quality of To Lich river improved mildly for a short time. The wastewater produced by over two million people living in four districts, almost factories from five industrial parks and the deterioration of the embankment all gradually reduced the river quality again.

Even though embanking the river did not improve water quality, it did help to maintain the soil quality of the shore, to reduce soil contamination caused by wastewater and slowly move the large amount of sediment at the bottom. The embankment was built using rocks and cement. Over time, the river water and rain started having effects on the construction. The deterioration brought more heavy metals into the river. In 2013, some few random deteriorating points of the embankment were selected, and the water was collected for heavy metal testing. Figure 4 shows the locations of sampling sites and some nearby hospitals and factories. The results of the said tests are shown as follows:

- Table 11: The concentration of Total Organic Carbon (TOC) and heavy metals at sampling sites
- Table 12: Total load of TOC and heavy metals in sediment in river reaches
- Table 13: pH value, concentration of TOC and heavy metals in water at sampling sites
- Table 14: TOC and heavy metals discharged to river reaches

Figure 6. A map of sampling sites (Nguyen, Yoneda, Matsui, 2013, 362)

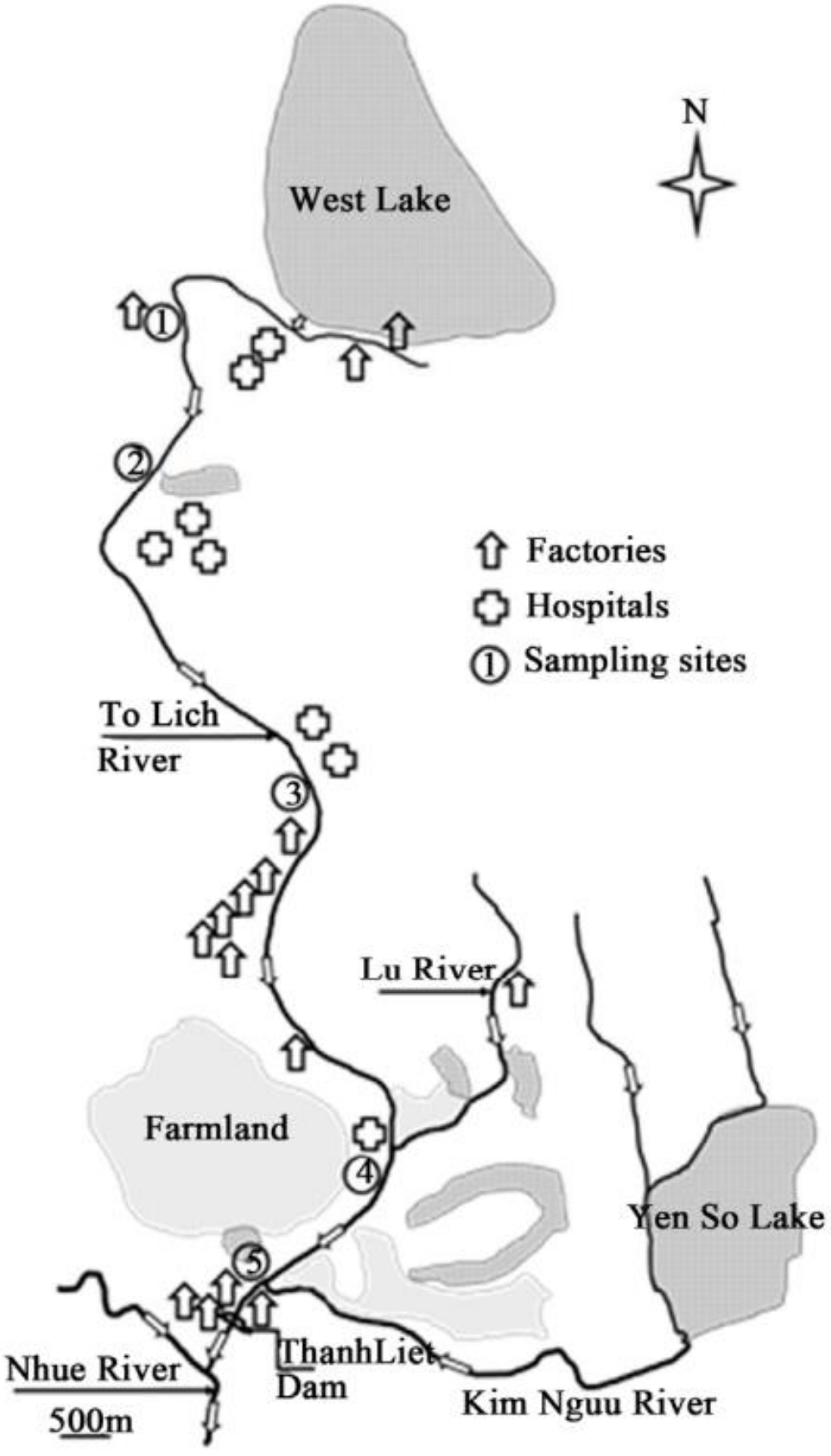


Table 11. The concentration of Total Organic Carbon (TOC) and heavy metals at sampling sites (Nguyen, Yoneda, Matsui, 2013, 365)

	Unit	Site 1	S2	S3	S4	S5
TOC	g/kg	48.3	33.5	60.8	11.7	34.7
Cr	mg/kg	229	144.7	128.4	90.1	132.7
Mn	mg/kg	392	610.9	438.5	572	538.8
Fe	mg/kg	13139.5	21718.3	16783.3	22442.8	21585.3
Ni	mg/kg	51.4	77.4	98.4	68.7	70.2
Cu	mg/kg	103.6	146.8	139.7	57.8	74.1
Zn	mg/kg	513.4	770.6	783.1	255.2	412.5
As	mg/kg	21.6	24.7	28.9	16.7	23.7
Cd	mg/kg	1	2.3	35.3	4	13.2
Pb	mg/kg	75.9	90.4	92.3	58.7	63

In Table 11 it can be seen that the concentration of TOC ranges from 11.7 to 60.8; Cr ranges from 90.1 to 229; Mn ranges from 392 to 610.9; Fe ranges from 13139.5 to 22442.8; Ni ranges from 51.4 to 98.4; Cu ranges from 57.8 to 146.8; Zn ranges from 255.2 to 783.1; As ranges from 16.7 to 28.9; Cd ranges from 1 to 35.3 and Pb ranges from 58.7 to 92.3. The average concentration of heavy metals increases in the following order: Cd < As < Ni < Pb < Cu < Cr < Mn < Zn < Fe. The concentration of TOC and heavy metals is very toxic to the surrounding soil. (Nguyen, Yoneda, Matsui, 2013, 365)

Table 12. Total load of TOC and heavy metals in sediment in river reaches (Nguyen, Yoneda, Matsui, 2013, 366)

	Unit	S1 – S2	S2 – S3	S3 – S4	S4 – S5
TOC	Total (ton)	1470.3	5019.8	5301.5	896.5
	kg/m^3	43.041	56.314	44.971	21.147
Cr	ton	6.7	14.5	16	6.4
	kg/m^3	0.197	0.163	0.136	0.151
Mn	ton	18	55.9	74	32
	kg/m^3	0.528	0.627	0.628	0.754
Fe	ton	626.9	2050.6	2871.7	1266.5
	kg/m^3	18.353	23.005	24.359	29.873
Ni	ton	2.3	9.4	12.2	4
	kg/m^3	0.068	0.105	0.104	0.094
Cu	ton	4.5	15.3	14.5	3.8
	kg/m^3	0.132	0.171	0.123	0.089
Zn	ton	23.1	82.8	76	19.2
	kg/m^3	0.676	0.928	0.645	0.453
As	ton	0.8	2.9	3.3	1.2
	kg/m^3	0.024	0.032	0.028	0.027
Cd	ton	0.1	2	2.9	0.5
	kg/m^3	0.002	0.022	0.024	0.012
Pb	ton	3	9.7	11	3.5
	kg/m^3	0.088	0.109	0.094	0.083

Between these reaches, the amount of TOC and heavy metals in sediments is huge. The total amount of components in sediments is as follows: 12,688.1 tons of TOC; 43.6 tons of Cr; 179.9 tons of Mn; 6,815.7 tons of Fe; 27.9 tons of Ni; 38.1 tons of Cu; 201.1 tons of Zn; 8.2 tons of As; 5.5 tons of Cd and 27.2 tons of Pb. The sediments found in these reaches contain so much heavy metals that it cannot be reused. In order to use the sediments for agriculture or industrial purposes, specific treatments are required.

Table 13. pH value, concentration of TOC and heavy metals in water at sampling sites (Nguyen, Yoneda, Matsui, 2013, 366)

	Unit	S1	S2	S3	S4	S5	Average
pH		7.2	7.3	7.2	7.3	7.2	7.24
TOC	mg/l	4.7	8.3	7.7	8.1	7.8	7.32
Cr	µg/l	2	2	2	2	2	2
Mn	µg/l	83.7	400.8	230.7	188.7	200.9	220.96
Ni	µg/l	5	5	8	9	7	6.8
Cu	µg/l	5	4	3	7	4	4.6
Zn	µg/l	58	40	36	60	28	44.4

As	µg/l	47.3	76.2	13.1	38.2	28.1	40.58
Cd	µg/l	<2	<2	<2	<2	<2	<2
Pb	µg/l	8	7	6	8	10	7.8

In Table 13 it can be seen that pH value ranges between 7.2 and 7.3; TOC ranges from 4.7 to 8.3; Cr value is around 2 µg/l; Mn ranges from 83.7 to 400.8; Ni ranges from 5 to 9; Cu ranges from 3 to 7; Zn ranges from 28 to 60; As ranges from 13.1 to 76.2; Cd value is <2 µg/l and Pb ranges from 6 to 10. The tests done at this sampling show that pH value, the amount of TOC and most heavy metals are within the Vietnamese standard. Only the amount of Mn is higher than the allowed limit.

Table 14. TOC and heavy metals discharged to river reaches (Nguyen, Yoneda, Matsui, 2013, 367)

	Unit	S1 – S2	S2- -S3	S3 – S4	S4 – S5
TOC	kg/day	338	360	1697	2036
Cr	kg/day	0.07	0.12	1.35	-
Mn	kg/day	18.55	3.25	34.4	58.51
Ni	kg/day	0.18	0.6	2.04	1.4
Cu	kg/day	0.14	0.15	1.88	0.27
Zn	kg/day	1.25	2.07	15.19	-
As	kg/day	3.16	-	10.49	5.01
Pb	kg/day	0.24	0.32	1.91	3.42

The amount of TOC and other heavy metals discharged into the river at different reaches: TOC ranges from 338 to 2036; Cr ranges from 0.07 to 1.35; Mn ranges from 3.25 to 58.51; Ni ranges from 0.6 to 2.04; Cu ranges from 0.14 to 1.88; Zn ranges from 1.25 to 15.19; As ranges from 3.16 to 10.49 and Pb ranges from 0.24 to 3.42. Based on these results, it can be determined that reaches S1 – S2 and S2 – S3 are mostly domestic wastewater while reaches S3 – S4 and S4 – S5 are industrial wastewater, thus explaining the higher amount of heavy metals.

4.2 **Yen Xa wastewater treatment plant**

In October 2016, the Hanoi Municipal People's Committee has started the construction of a new wastewater treatment plant. The project's fund was mostly supported by ODA (Official Development Assistance) from Japan International Cooperation Agency (JICA). The project is expected to be complete and start operation in 2019, two years ahead of schedule. The construction of the project is divided into four parts: the plant itself and the sewerage pipe lines running along the three rivers, To Lich river, Lu river and Nhue river. Yen Xa wastewater treatment plant (YXWTP) will be built by 68 Trading Construction and Service JSC (Joint Stock Company), short name Company 68. This is one

of many companies that have had a contract with Japanese ODA. Company 68 had it first contract in 2015, working on the 2nd Hanoi Drainage Project for Environment Improvement. The construction of the three sewerage pipe lines is to be decided.

With 16.3 billion VND, or 61 million J¥, or 800 million US$, or 670 million € (85% fund is supported by ODA, the remaining 15% is from the city) Yen Xa is expected to be the largest wastewater treatment plant not just in Hanoi but in Vietnam. The plant is designed to have a working capacity of treating 270,000 cubic meters per day. YXWTP locates in a 13 hectares area in Thanh Liet commune, Thanh Tri district. In addition to the plant, there will be 52.621 km of sewerage pipes with a diameter of 400 – 2,400 mm, running along To Lich river, Lu river and a part of Nhue river. The new wastewater treatment plant is expected to benefit residences in seven districts: Ba Dinh, Cau Giay, Thanh Xuan, Dong Da, Hoang Mai, Ha Dong and Thanh Tri. This includes more than 900,000 households, over 100 factories, offices and apartment buildings. Figure 5 shows the model of YXWTP. (Khuong, 2016)

Figure 7. Yen Xa wastewater treatment plant (Thu, 2016)

YXWTP will apply an improved traditional wastewater treatment process. The improvement lies in the A/O process treatment for activated sludge. The process uses an anaerobic selector to create biomass. The biomass first stores BOD anaerobically. Subsequently, in an aerobic zone, or oxic, this biomass will assimilate phosphorus. The

process particularly resists hydraulic and organic upsets due to the usage of anaerobic uptake of BOD. A/O process also minimizes the presence of bulking-sludge organisms commonly found in activated sludge plants. (Brandnew Chapters of Toprak, 2005)

Through extensive piloting tests, this process has been applied in over 85% of Japan's wastewater treatment plants (Khuong, 2016). It is proven to have the following qualities: (Brandnew Chapters of Toprak, 2005)

- Non-bulking sludge: Resistant to proliferation of bulking organisms
- Settles rapidly and compacts well
- Precise process control
- Improved thickening and dewatering properties
- Improved stability: Anaerobic selector permits operation over a wide range of hydraulic and organic loading conditions
- Ease of operation: Equipment is common to most treatment plant
- Physical layouts and flow schemes are similar to conventional activated sludge plants
- Reduced construction cost: High rate design results in less tankage
- Better use of existing facilities
- Air or Oxygen aeration: Compatible with either air or pure Oxygen aeration system

The treated dewater sludge is calculated to have approximately 82% of moisture. The sludge will be dried in Solar Green House facilities to have its moisture drop to 60%. The process will continue with mechanical sludge dryer to make the final dry sludge with 10% moisture. Dry sludge will then be used as an alternative fuel in cement factories. (JICA, 2016, 5 – 4)

Because To Lich river's pollution cannot be treated using only conventional methods, the government has decided to fix the problem at its' sources. Yen Xa wastewater treatment plant will be the first of many other treatment plants to clean the city's wastewater before releasing it into rivers. Old treatment plants will be upgraded, new treatment plants will be connected to and share the existing 269 sewer gates.

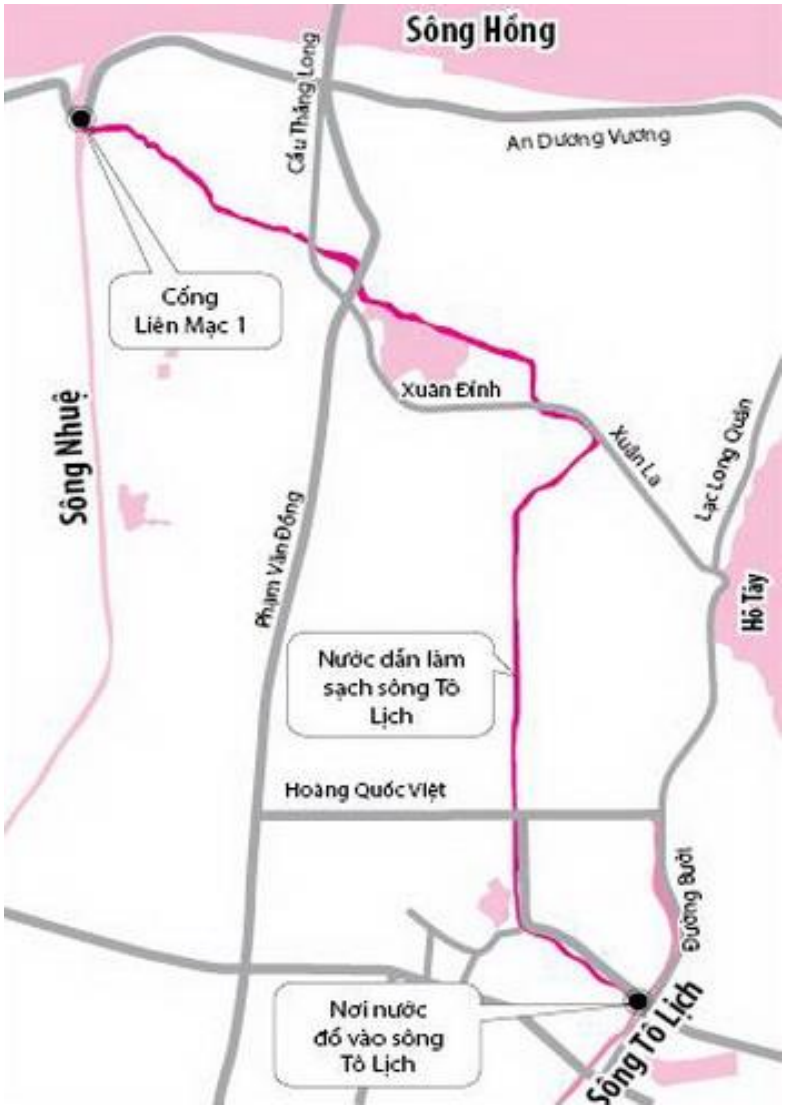
4.3 **Renovation project of To Lich river**

In 2009, Hanoi Government was discussing to renovate and improve the quality of To Lich river. The 18th meeting of Hanoi People's Assembly about the three most pressing problems in the city came up with a sub-scheme for To Lich River. This sub-scheme entails "cleaning" To Lich river using water from the Red river. It is believed

that this project will help balance the amount of water in To Lich river and also neutralize the pollution level. (Kim, 2009)

The method, at the time, had already been used for Nhue river, which is located somewhat parallel and to the west of To Lich river. The pump that was used for Nhue river was adding 36.3 m^3 of Red river water per second. The plan was to double the capacity of this pump to 75 m^3/s, find a suitable location to install a new pump and pipe line to connect Nhue river and To Lich river. The second pump will have a capacity of 5 m^3/s and be placed somewhere near the beginning of Nhue river to have the maximum amount of clean water. The selected location was right after Lien Mac sewerage gate, using the canal system Chem – Dong Ngac (Tu Liem commune). The canal runs along Nguyen Hoang Ton street (Ho Tay district), to Co Nhue street (Tu Liem commune), to Nghia Do street (Cau Giay district) and finally feeding into To Lich river (Xuan & Duc, 2009) (Figure 6).

Figure 8. Proposed route to deliver water from Red river (Xuan & Duc, 2009)



The sub-scheme was in discussed and was planned to start as soon as 2010. Although, due to problems with the canal system, funding issues and plenty of calculations to be made, the plan did not have clear and proper details until 2017. September 2017, the People's Committee of Hanoi City approved decision 6570/QD-UBND about project Construction of Lien Mac Sewerage (Phase One) in the form of build-transfer (BT) contract. The detailed plan was made public in October 2017. (Hanoi City's Planning and Investment Department, 2017)

The plan's objectives are as follows:

- Taking water from Red river to pump into Nhue river at 72 m^3/s, to be used for irrigation of 40,483 ha of agriculture soils; supply water to clean To Lich river at 5 $m^3/$ and for other usages.
- Drain water from Nhue river to Red river for 9,200 ha of agriculture soil belongs to these following communes western of Hanoi: Dan Phuong, Tu Liem, Hoai Duc. Total drainage will be 170 m^3/s (70 m^3/s phase one and 100 m^3/s phase two).
- Improving the river's ecology and water quality, combining with developing aquatic transportation.
- Actively response to climate change.

Investment scale:

- Construct Lien Mac drainage system at Km52+626, Huu Hong dam, with design capacity of 72 m^3/s, underground pipe lines, BTCT (reinforced steel concrete) structure; the sewer will have three gates with a diameter of 6×5m and one boat pass 6×8m.
- Construct a pumping station with a capacity of 70 m^3/s next to the drainage system. The station will consist of control room, discharge pit, suction pit, discharge culvert through the dyke, discharge channel to Nhue river.
- Construct a channel system from sewerage gate Lien Mac to sewerage gate Mieng Ho (Tiger's Mouth) with the capacity of 170 m^3/s (enough for both phases).
- Construct a regulatory sewer downstream of the drainage system, capacity of 170 m^3/s, contains six gates of 6m in diameter.
- Construct a discharge channel from a discharge pit to the new channel system, placed after the regulatory sewer, box drain style, BTCT structure, gate dimension 2×2.5m.
- Construct a bridge over Nhue river, load H30-XB80 (truck max load of 30 tons, 18-wheelers max load of 80 tons), three spans, each span is 22m, width 9m.
- Improve the river's water quality at reach Lien Mac – Mieng Ho.
- Construct an office to overlook the operation of the entire system.
- Construct high-voltage, low-voltage system to power the pumps.

- Purchase and install any necessary mechanical equipment for the station.

The project is located at North Tu Liem district, Hanoi. Estimated investment costs are to be 3.6 billion VND (1.5 million €). The construction will start in 2018 and is expected to be complete in 2020. (Hanoi City's Planning and Investment Department, 2017)

4.4 **Other improvement plans**

4.4.1 Legislations and regulations

Vietnam did not have any laws or regulations regarding the environment or the protection of environment until 1995. Since then, there has been plenty of changes, six different revisions from 2000 to 2011. The continuity of major changes had caused uncertainty and confusion to authorities and people responsible for implementing wastewater treatment and other environmental protection projects. Environmental issues were only taken into account if they affect a large group of people, especially their health. With the climate change happening and the constant complaint about To Lich river's pollution, Hanoi government finally takes the issue seriously. Starting from 2010, environmental protection laws have been applied more strictly, environmental standards have raised, more major legislation and regulations were added in 2014 and 2017. Punishments for violations have also increased.

Some notable new legislation and regulations worth mentioning are as the following:

- Environmental Protection Laws 2014 numbering 55/2014/QH13 applied in 2015, replacing Environmental Protection Laws 2005.
- 18/2015/ND-CP: Regulations about Environmental Protection Planning, Strategic Environmental Assessment, Environmental Impact Assessment and Environmental Protection Plans (2015).
- Decree number 19/2015/ND-CP detailing the implementation of some articles in Environmental Protection Laws.
- Decree 155/2016/ND-CP: Provisions on penalizing of administrative violations in the field of environmental protection: increasing fines multiple times.
- QCVN 62-MT:2016/BTNMT: Regulations about Agriculture Wastewater (15/06/2016)
- QCVN 11-MT:2015/BTNMT: Regulations about Industrial Wastewater when Processing Sea Food (31/12/2015)
- QCVN 01-MT:2015/BTNMT: Regulations about Industrial Wastewater when Pre-processing natural rubber (01/06/2016)

- QCVN 12-MT:2015/BTNMT: Regulations about Industrial Wastewater when Producing Paper and Pulp (01/06/2015)
- QCVN 13-MT:2015/BTNMT: Regulations about Industrial Wastewater when Producing Textile and Textile Dyeing (01/06/2015)
- QCVN 40-MT:2011/BTNMT: Regulations about Industrial Wastewater (replacing TCVN-5945:2005)
- QCVN 29-MT:2010/BTNMT: Regulations about Industrial Wastewater from Petrol Storage and Petrol Station
- QCVN 14-MT:2008/BTNMT: Regulations about Domestic Wastewater
- QCVN 28-MT:2010/BTNMT: Regulations about Medical Wastewater

There are also updates on legislation and regulations regarding storing and disposing of solid waste to prevent illegal dumping into rivers. Starting from the 1st of February 2017, any individuals can be fined up to 7 million VND (260 €) if caught littering (Decree on penalizing of administrative violations in the field of environmental protection, 155/2016/ND-CP). Emissions control has also been considered so that rain water would not carry more harmful chemicals down to the rivers.

4.4.2 Dredging the river

Since 2016, the authorities have started a plan to dredge the sediments out of the river. This project helps create positive impacts on the river. Removing the sludge has helped reduce the pollution level and also reduce the workload for Yen So pumping station. The dredging will be carried out every dry season (November to March). The operation is overseen and done by Hanoi Sewage and Drainage Limited Company. (Nguyen, 2017)

4.4.3 Other minor improvement projects

While large scale wastewater treatment plants are being designed and constructed, minor projects are being done while waiting. Old apartment buildings, housing units and factories are attempting to install small scale wastewater treatment plans. If the buildings are too old or there are insufficient funds, then new pipe lines will be installed/old pipe lines redirected to the closest wastewater treatment plants. Some wealthier residents would apply both strategies. New factories and large buildings (apartments, offices, mega malls, etc.) are required to have a wastewater treatment plan, either handling the problem themselves or connecting their system to nearby facilities. Some advance companies who have the capabilities even attempt to reuse their wastewater to reduce the amount of waste being disposed of. Most of the reused wastewater is for irrigation purposes; there has

not been any recorded success in reusing wastewater for domestic usage and consumption. Unfortunately, not all communities and companies are contributing to this effort.

5 CONCLUSION

In conclusion, To Lich river became polluted due to the increase of urbanization and industrialization. To be specific, the pollution is caused by illegal dumping of solid waste and the disposal of partially treated/untreated wastewater directly into the river. The lack of a sufficient number of wastewater treatment plant also indirectly contributed to the pollution.

The four main contributors of the pollution are domestic wastewater, industrial wastewater, hospital wastewater and solid waste. Although there are many treatment methods and technologies, not all of the wastewater is properly treated. The pollution level of To Lich river can be generalized as follows:

- High amount of nutrients and heavy metals.
- Extremely high level of pathogens and other microorganisms.
- The water colour is blackened.
- Huge amount of sediments at the bottom.
- High level of H_2S has caused horrible odour around the river.
- Visible solid waste and grease floating on the surface.

There are some solutions to solve the problems that the authorities and the people are using, some major scale and some minor scale. There are two ongoing projects expected to greatly improve the situation, Yen Xa wastewater treatment plant is under construction and the plan to renovate To Lich river that is planned to start soon. The river embankment only temporarily improves the situation for a short time before it partially becomes the problem. New legislation and regulations are added, old ones get updated but they are not applied strictly enough. The dredging plan is helpful but unstable. Finally, small scale wastewater treatment plants are useful but will only show positive effects in the long term.

With the current condition and existing solutions, to prevent the problem from becoming worse, some of the following plans should be applied, or attempted to try:

- Apply legislations and regulations more strictly combining with an increase of fines for illegal dumping or disposing of untreated/partially treated waste.
- Build new wastewater treatment plants and upgrade existing plants.

- Regularly check factories and hospital wastewater and their treatment plants.
- Increase funding for the dredging project.
- Increase awareness about environmental pollution.
- Plant more tress around the river for shade, creating a better view and help reducing the horrible smell.

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