ASSESSMENT OF WATER QUALITY
OF TO LICH RIVER IN HANOI CITY

Submitted in partial fulfillment of the requirements for the degree of
Bachelor of Science in Environmental Science
(Advanced Program)
Ho Nguyen Hoang

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Supervisor: Assoc. Prof., Dr. Sci., Nguyen Xuan Hai

Hanoi – 2016
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Hanoi, December, 2016

Ho Nguyen Hoang
<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>BOD</td>
<td>Biological Oxygen Demand</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>QCVN</td>
<td>Vietnamese Regulation</td>
</tr>
<tr>
<td>TCVN</td>
<td>Vietnamese Standard</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>PE</td>
<td>Polyethylene</td>
</tr>
<tr>
<td>TN</td>
<td>Total Nitrogen</td>
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<tr>
<td>TP</td>
<td>Total Phosphorous</td>
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<tr>
<td>NO$_3^-$</td>
<td>Nitrate</td>
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<tr>
<td>NH$_4^+$</td>
<td>Ammonium</td>
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<tr>
<td>PO$_4^{3-}$</td>
<td>Phosphate</td>
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<td>PWQO</td>
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INTRODUCTION

Environment is currently a burning issue worldwide. In every country not only developed but also developing, environmental problems currently being first attention. Environmental pollution, environmental degradation and environmental incidents happening more and more, putting people face the terrible revenges of nature, especially in the developing countries where demands of human life and strong society development conflict with the necessity of natural resources protection and the environment. Big cities which gather numerous factories, industrial zones, hospitals and the population density is very high, daily suffer a large volume garbage and waste water even hazardous waste. Therefore, environmental pollution in cities is becoming ever more serious, especially contaminated water causing serious consequences for the economic and social development and the environment.

Hanoi is the capital, is the center economy, politics, culture and society in Vietnam. In recent years, Hanoi has developed very fast pace with its environmental issues. One of the most worrying problems is water pollution, especially water system of To Lich River. To Lich River system includes of distributary: To Lich, Lu, Set, and Kim Nguu. Currently these rivers are receiving large amounts of residential garbage, waste water, along with sewage from urban areas, industrial zones without treatment, although has been renovated water is still in serious pollution.

Confronting with such problems, the rehabilitation of the water system of To Lich River in Hanoi becoming increasingly urgency in order to remedy the water pollution, improves the environment, landscape, nature of Hanoi and contributing one sustainable development in Vietnam.

Stemming from the current situation, I carried out the thesis: “Assessment of water quality of To Lich River in Hanoi city” with the aim are study about the current situation of river pollution of To Lich river in urban system river in Hanoi city, reflecting the effectiveness of management of water quality, thereby offering solutions to overcome pollution.
CHAPTER 1. LITERATURE REVIEW

1.1. Causes of water pollution

1.1.1. Domestic waste water

The fact that billions of people on the planet, disposing of domestic waste water is a major problem. According to the World Health Organization, some 780 million people do not have access to safe drinking water, while 2.5 billion people do not have proper sanitation in 2013; although there have been great improvements in securing access to clean water, relatively little progress has been made on improving global sanitation in the last decade. Sewage disposal affects people's immediate environments and leads to water-related illnesses such as diarrhea that kills 760,000 children under five each year. In developed countries, most people have flush toilets that take sewage waste quickly and hygienically away from their homes.

Yet the problem of sewage disposal does not end there. When you flush the toilet, the waste has to go somewhere and, even after it leaves the sewage treatment works, there is still waste to dispose of. Sometimes sewage waste is pumped untreated into the sea. According to 2002 figures from the UK government's Department for the Environment, Food, and Rural Affairs (DEFRA), the sewers of Britain collect around 11 billion liters of waste water every day, some of it still pumped untreated into the sea through long pipes.

In theory, sewage is a completely natural substance that should be broken down harmlessly in the environment: 90 percent of sewage is water. In practice, sewage contains all kinds of other chemicals, from the pharmaceutical drugs people take to the paper, plastic, and other wastes they flush down their toilets. When people are sick with viruses, the sewage they produce carries those viruses into the environment. It is possible to catch illnesses such as hepatitis, typhoid, and cholera from river and sea water.

1.1.2. Industrial waste water

Industries produce huge amount of waste water which contains toxic chemicals and pollutants which can cause water pollution and damage to us
and our environment. Around half of all ocean pollution is caused by industrial waste water. Each year, the world generates perhaps 5-10 billion tons of industrial waste, much of which is pumped untreated into rivers, oceans, and other waterways. Factories are point sources of water pollution, their waste water contain pollutants such as lead, mercury, sulfur, asbestos, nitrates and many other harmful chemicals. The toxic chemicals have the capability to change the color of water, increase the number of minerals, also known as eutrophication, change the temperature of water and pose serious hazard to water organisms.

Different from the domestic wastewater or urban waste water, there is no similarity in the basic components of industrial waste water, which depends on the type of industry. For example, industrial wastewater of food industry often contains large quantities of organic matter; waste water from leather production industry contains not only organic matter but also heavy metals, sulfur. Many industries do not have proper waste management system and drain the waste in the fresh water which goes into rivers, canals and later in to sea and cause aquatic pollution.

1.1.3. Chemical waste

One kind of toxic pollution comes from heavy metals, such as lead, cadmium, and mercury. Lead was once commonly used in gasoline, though its use is now restricted in some countries. Mercury and cadmium are still used in batteries. Until recently, a highly toxic chemical called tributyltin (TBT) was used in paints to protect boats from the ravaging effects of the oceans. Ironically, however, TBT was gradually recognized as a pollutant: boats painted with it were doing as much damage to the oceans as the oceans were doing to the boats.

Detergents are relatively mild substances. For example, at the opposite end of the spectrum are highly toxic chemicals such as polychlorinated biphenyls (PCBs). They were once widely used to manufacture electronic circuit boards, but their harmful effects have now been recognized and their use is highly restricted in many countries. Nevertheless, an estimated half
million tons of PCBs were discharged into the environment during the 20th century.

1.1.4. Nutrients

Suitably treated and used in moderate quantities, sewage can be a fertilizer: it returns important nutrients to the environment, such as nitrogen and phosphorus, which plants and animals need for growth. The trouble is, sewage is often released in much greater quantities than the natural environment can cope with. Chemical fertilizers used by farmers also add nutrients to the soil, which drain into rivers and seas and add to the fertilizing effect of the sewage. Together, sewage and fertilizers can cause a massive increase in the growth of algae or plankton that overwhelms huge areas of oceans, lakes, or rivers. This is known as a harmful algal bloom. It is harmful because it removes oxygen from the water that kills other forms of life, leading to what is known as a dead zone.

1.1.5. Oil pollution

When we think of ocean pollution, huge black oil slicks often spring to mind, yet these spectacular accidents represent only a tiny fraction of all the pollution entering our oceans. Even considering oil by itself, tanker spills are not as significant as they might seem: only 12 percent of the oil that enters the oceans comes from tanker accidents; over 70 percent of oil pollution at sea comes from routine shipping and from the oil people pour down drains on land. However, what makes tanker spills so destructive is the sheer quantity of oil they release at once - in other words, the concentration of oil they produce in one localized part of the marine environment.

1.1.6. Radioactive waste

People view radioactive waste as great alarm. At high enough concentrations, it can kill; in lower concentrations, it can cause cancers and other illnesses. The biggest sources of radioactive pollution over the world are factories that reprocess waste fuel from nuclear power plants such as Fukushima I in Japan, Sellafield on the north-west coast of Britain and Cap La Hague on the north coast of France in Europe.
1.1.7. Plastics

If you've ever taken part in a community beach clean, you'll know that plastic is far and away the most common substance that washes up with the waves. There are three reasons for this: plastic is one of the most common materials, used for making virtually every kind of manufactured object from clothing to automobile parts; plastic is light and floats easily so it can travel enormous distances across the oceans; most plastics are not biodegradable, which means that things like plastic bottle tops can survive in the marine environment for a long time. A plastic bottle can survive an estimated 450 years in the ocean and plastic fishing line can last up to 600 years.

While plastics are not toxic in quite the same way as poisonous chemicals, they nevertheless present a major hazard to seabirds, fish, and other marine creatures. For example, plastic fishing lines and other debris can strangle or choke fish. Or about half of the world's seabird species are known to have eaten plastic residues.

1.1.8. Other causes of pollution

Thermal pollution from factories and power plants also causes problems in rivers. By raising the temperature, it reduces the amount of oxygen dissolved in the water, thus also reducing the level of aquatic life that the river can support. These are the most common forms of pollution—but no means the only ones.

Another type of pollution involves the disruption of sediments that flow from rivers into the sea. Dams built for hydroelectric power or water reservoirs can reduce the sediment flow. This reduces the formation of beaches, increases coastal erosion, and reduces the flow of nutrients from rivers into seas. Increased sediments can also present a problem. During construction work, soil, rock, and other fine grains sometimes enter nearby rivers in large quantities, causing it to become turbid. The extra sediment can block the gills of fish, effectively suffocating them.
1.2. Current state of water pollution in the world and Vietnam

1.2.1. Water pollution in the world

Water, simply put, makes the existence of the human race on this planet possible. With few exceptions, water has always been a natural resource that people take for granted. Today, the situation has changed.

The ocean remains one of the most expansive, mysterious and diverse places on Earth. Unfortunately, it is being threatened by pollution from people on land and from natural causes. Marine life is dying, and as a result the whole oceanic ecosystem is threatened simply by various sources of pollution. If we are to preserve ocean and its natural beauty, drastic measures have to be taken to combat this pollution and keep what we hold most dear.

As the situation of oceans, freshwater sources in the world are also increasingly polluted seriously. Our rivers, lakes, aquifers, and coastal waters are not unlimited resources that can handle whatever we take out or dump in. As technology improves, scientists are able to detect more pollutants, and at smaller concentrations, in Earth’s freshwater bodies. Containing traces of contaminants ranging from birth control pills and sunscreen to pesticides and petroleum, our planet's lakes, rivers, streams, and groundwater are often a chemical cocktail. Beyond synthetic pollution, freshwater is also the end point for biological waste, in the form of human sewage, animal excrement, and rainwater runoff flavored by nutrient-rich fertilizers from yards and farms. These nutrients find their way through river systems into seas, sometimes creating coastal ocean zones void of oxygen and therefore aquatic life-and making the connection between land and sea painfully obvious.

The fact that, serious water pollution incidents increased by 50% in England and Wales last year with farmers responsibilities for more than a quarter of them, according to Environment Agency. The organization's annual pollution report is expected to show that industry as a whole is continuing to get cleaner but that there are worrying exceptions. The most serious incidents of water pollution increased in number from 77 in 2000 to 118 last year, bucking the recent trend. There is particular concern about pollution from
farms, which accounted for 27% of the most serious offences. In one incident, silage waste leaked into a river in Leicestershire. This wiped out the river's population of native brown trout, which cannot be replaced because of their unique genetic make-up [17].

Another example in the UK is Thames River. The Thames used to be horribly polluted, especially in mid-Victorian times, when waste was just dumped straight in. The Great Stink of 1858 was probably the worst time, and led to the creation of the sewerage system. But even 50 years ago, the oxygen levels were so low, the Thames was declared biologically dead. Today, though Thames has improved, but the parameters of coliform, phosphorus, nitrates, E.coli still exceeded permissible standards [19]. In 2011, the results of the analysis of water samples in the upstream and downstream in dry reason points out.

- Total phosphorus concentrations exceeded the Provincial Water Quality Objective (PWQO) of 0.03 mg/L at all stations. Values ranged from 0.049 mg/L to a high of 0.119 mg/L;
- Total coliform exceeded acceptable standards E. coli counts exceeded the PWQO of 100 CFU/100 mL at 14 stations. Values ranged from 460 to 1420 CFU/100 ml;
- Nitrate ranged from 7.72 to 9.16 mg/L, over 7-9 times than acceptable standard that is 0.1 mg/L;
- Ammonium concentrations exceeded the PWQO of 0.05 mg/L at all stations 0.088 to 0.229 mg/L [21].

In America, a new report by the Environmental Protection Agency found that the majority of rivers and streams in America can't support healthy aquatic life and the trend is going in the wrong direction. The report labels 55 percent of the nation's water ways as being in "poor" condition and another 23 percent as just "fair." The reason for these failing grades is, of course, pollution; specifically, phosphorus and nitrogen pollution that comes from fertilizer and wastewater run-off. Those chemicals, which come from farms and industrial sites, choke off healthy plant growth, which turn leads to more
soil erosion, more flooding, and unhealthy fish and wildlife. The study also found increased bacteria that in some areas "exceeds thresholds protective of human health" and another 13,000 miles of the rivers that have fish with unhealthy amounts of mercury in them. The worst areas for river pollution are the Northeast and South, where a shocking 71 percent of rivers rated “poor” [13].

For instance, Animas River in Colorado; waste water from an abandoned gold mine near Silverton, Colorado, is spilling into a small tributary called Cement Creek; this runs into the Animas River, which eventually joins the San Juan river. The spill happened when a crew working at the site on behalf of the EPA accidentally knocked a hole through a dam that was holding the toxic stew in place. Three million gallons of contaminated effluent escaped at a rate of 550 gallons a minute, the Animas was turned a horrifying orange. In the past few days, the noxious plume, containing a cocktail of heavy metals, including arsenic, lead and cadmium, has entered the San Juan as it leaves Colorado for New Mexico and Utah. The long-term impact has yet to be fully calculated, but it has been a scary week for those along the rivers. People living close to either of the rivers were forbidden from using water from their wells, even for showers or baths [20].

In India, Ganges River, which is the most sacred river in Hinduism and the third largest river in the world, holds water that can purportedly cleanse people of sin. Many Hindus think the river’s water is so healthful they actually drink it as if it were an elixir. Be that as it may, the importance of the river cannot be overestimated, as it affects the lives of 400 million people who live near it. Unfortunately, people dump their waste into the Ganges as they use it for drinking, bathing and cooking, giving rise to many water-borne illnesses. In fact, people who cannot afford cremation throw corpses into the river. Besides, other factor causing pollution of Ganges River is heavily influenced of industry; chemicals, untreated industrial waste was also released directly into the river; the results of water quality are becoming seriously polluted. With the construction of dams, rivers are losing 30-40% of water; this causes Ganges River becomes drying up and at risk of disappearing.
River water cannot be used not only eating, bathing and washing but also for agricultural production. The studies also found that the proportion of toxic metals in the river is very high, such as mercury (concentration from 65 to 520ppb), lead (from 10 to 800ppm), chromium (10-200ppm) and nickel (10-130ppm) [7].

China's extraordinary economic growth, industrialization, and urbanization, coupled with inadequate investment in basic water supply and treatment infrastructure, have resulted in widespread water pollution. In China, today approximately 700 million people—over half the population—consume drinking water contaminated with levels of animal and human excreta that exceed maximum permissible levels by as much as 86% in rural areas and 28% in urban areas. By the year 2000, the volume of wastewater produced could double from 1990 levels to almost 78 billion tons. These are alarming trends with potentially serious consequences for human health [15].

The condition of the Yellow River, whose water is filled with a yellow sediment known as loess, hence its name, is essential to the well-being of China, though at times the river has flooded, killing millions of people. These days, the river is troublesome in another way: The water in it is so egregiously polluted that it’s unfit even for agricultural use. In fact, in any given year, more than four billion tons of sewage is dumped into the river. And, as China continues to industrialize at breakneck speed, the Yellow River has become a toxic waste dump, turning river water colors other than yellow, at the very least [14].

1.2.2. Water pollution in Vietnam

a) General state

There are more than sixty four export processing zones and industrial zones with thousands of production facilities in Vietnam; besides, the effect of population growth, agricultural production, the development of services, and mining with high speed. All these factors lead to a serious problem for developing countries such as Vietnam is waste; especially, liquid waste is a special problem. Most of Vietnam's rivers are polluted, especially where have
key development of the economy. In the Red River watershed, Saigon-Dong Nai River watershed, Mekong River watershed, the areas have high population density but no wastewater treatment system. Therefore, waste water is discharged directly into rivers and polluting the water source.

Similar to the developing countries, the main sources of water pollution in Vietnam are domestic waste water, industrial wastewater, agricultural waste water (mostly chemicals, pesticides, fertilizers) and waste water from irrigation and transportation operations. Therefore, the typical indicators for water pollution are DO, BOD, COD, NH₄⁺, NO₃⁻, TN, TP, and microorganisms. Current reality, water pollution occurs primarily in the industrial zones (causes are industrial wastewater) and urban areas (domestic waste water). In addition, some contaminated river systems in Vietnam are:

– Cau River basin and its tributaries flow through the provinces of Bac Kan, Thai Nguyen, Vinh Phuc, Bac Giang, Bac Ninh and Hai Duong;

– Nhue River, Day River flow through the provinces of Hoa Binh, Hanoi City, Ha Nam, Nam Dinh and Ninh Binh;

– Dong Nai River basin and Saigon River basin, including the provinces of Lam Dong, Dak Lak, Dak Nong, Binh Phuoc, Binh Duong, Tay Ninh, Dong Nai, Ho Chi Minh City, Ba Ria Vung Tau, Ninh Thuan and Binh Thuan;


**b) Pollution of some rivers in Hanoi**

According to a recent survey by Institute for Environmental Sciences and Development VESDEC, river and lake systems in Hanoi city receive millions of cubic meters per day of industrial waste water, urban waste water, waste water from fields and some aquaculture sectors. According to forecasts, the volume of domestic waste water in Hanoi is going to increase to 440,934m³/day in 2020. Thus, in the near future, the risk of water pollution in
rivers and lakes in Hanoi will increase quickly, especially pollution caused by industrial waste water, domestic waste water.

According to the Hanoi Department of Industry and Trade, from 2010 to 2015 the number of craft villages has increased dramatically from 1,280 to 1,350. Hanoi city currently has 1,350 craft villages, including 244 traditional craft villages. Preliminary results of the VESDEC’s survey show pollution levels caused by sewage and garbage in the villages in Hanoi City increased over the years. Meanwhile, according to the Hanoi Environmental Protection Department, the reasons why state of the river water in Hanoi becomes seriously polluted are waste water is not treated and directly discharged into river and lake systems.

i) Nhue River

The fact that, in the Nhue River upstream, at sewer Lien Mac where receive water from Red river, water river is almost not polluted. Pollution level increases along river section flowing through the territory of Ha Dong district, Thanh Tri district and Thanh Oai district. The reason is reception of domestic waste water and production waste water from urban areas and production facilities, trade villages in central region. According to the survey data of Ministry Of Natural Resources And Environment in 2008, Nhue-Day watershed receives about 1.5 billion cubic meters of waste water per year, which means about 4 million cubic meters of wastewater per day from sources of agricultural fields, industrial activities, tourism, trade villages and hospitals. Among the sources, agricultural waste water accounts for the highest proportion about 3,292 million m$^3$/day, nearly 81% of all waste water; domestic waste water accounts for 15% of emissions with the number of 610,000 m$^3$/day; industrial waste water is about 54,000 m$^3$/day, accounting for 1.33%; hospital waste water occupies approximately 15,000 m$^3$/day, representing 0.35%; the amount of waste water from trade villages is nearly 94,000 m$^3$/day, occupies 2.31% of total number and wastewater from tourism accounts for a very small part that only 0.01%, equivalent to nearly 3,100 m$^3$/day.
ii) **To Lich River**

To Lich River receives thousands of cubic meters of domestic waste water every day. The pollution level becomes more and more seriously, the river is becoming "dead river" [8]. According to the monitoring data of the Hanoi Department of Natural Resources and Environment Hanoi, in the dry season of 2008, concentration of dissolved oxygen is 2.5 times lower than the allowed standard, demand chemical oxygen exceeds 4.2 times the acceptable standard, levels of ammonium is in excess of 17.3 times the average standard, total coliform is 9550 times higher than the average acceptable standard. Although Hanoi People's Committee has implemented many measures to improve pollution for To Lich river pollution state has not changed much because there is a huge amount of waste water flows into the river continuously every day. Monitoring data from Hanoi Sewerage and Drainage Limited Company in 2012 has shown some information of pollution state of To Lich River;

- Concentration of BOD$_5$ exceeds from 2 to 3.56 times than standard, the average concentration exceeds 2.27 times. COD concentration ranges from 96 to 173 mg/L, surpassing QCVN from 1.92 to 3.46 times, the average concentration of COD is 2.6 times more than standard level as following;

- River condition is anaerobic; the dissolved oxygen concentration only ranges from 1.39 to 1.81 mg/L, less than 2 mg/L of QCVN although this is flexible flow;

- Ammonium concentration ranges from 24 to 43.1 mg /L, increases to 43.1 mg/L at Thanh Liet Dam, the average value is 30 times higher than the acceptable standard.
CHAPTER 2. RESEARCH SUBJECTS AND METHODS

2.1. Research Subjects

2.1.1. Water drainage system in Hanoi

Water drainage system of Hanoi city consists of four major rivers is To Lich River, Lu River, Set River and Kim Nguu River. Currently, because of the strong development of urbanization environmental issues are increasingly aggravated. In particular, the rivers are becoming more shallow and narrower due to backfilling and encroachment of the people living around. Another reason is the littering of people into the river causing congestion and affecting the flow. During the rainy season, rain water cannot flow into Nhue River causing flooding in the city Hanoi city.

On the other hand, the current sewer system of central area in Hanoi is combinatorial sewerage system to drain for rainwater and wastewater. Former water drainage systems were designed and built according to the free flowing mode with the ultimately position is Nhue river. Watershed of To Lich river is divided into eight smaller sub-watersheds, which has four main drainage rivers acting as first level wastewater drainage network: To Lich river, Lu river, Set river and Kim Nguu river, with a total length of 38.2 km of the river, the average width of 10 ÷ 45 m. Water from the watershed area of To Lich river can be reused as irrigation water for agricultural production and fish farming in the southern region of Hanoi.

Table 1. Information about the rivers in center area of Hanoi

<table>
<thead>
<tr>
<th>Name</th>
<th>Length (km)</th>
<th>Width (m)</th>
<th>Depth (m)</th>
<th>Watershed area (ha)</th>
<th>Wastewater flow rate (1.000 m$^3$/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Lich</td>
<td>13.5</td>
<td>30 ÷ 45</td>
<td>3 ÷ 4</td>
<td>6,820</td>
<td></td>
</tr>
<tr>
<td>Kim Nguu</td>
<td>12.2</td>
<td>25 ÷ 30</td>
<td>3 ÷ 4</td>
<td>1,800</td>
<td>660 ÷ 710</td>
</tr>
<tr>
<td>Set</td>
<td>6.7</td>
<td>10 ÷ 30</td>
<td>3 ÷ 4</td>
<td>580</td>
<td></td>
</tr>
<tr>
<td>Lu</td>
<td>5.8</td>
<td>20 ÷ 25</td>
<td>2 ÷ 4</td>
<td>560</td>
<td></td>
</tr>
</tbody>
</table>

Source: Hanoi People’s Committee, 2005 [10].
Now a day, the main parts in the sewer system includes:

– Underground culverts: with 120 kilometers in long and the average diameter is 600-1000 millimeters;

– Land drainage ditch: 38.113 kilometers with an average bottom width of 3-5 meters;

– The regulation reservoir in the inner city and the suburbs;

– The system of lakes in Hanoi, which functions as water treatment tanks, where the waste water from some waste sources flows into through the canals [10].

2.1.2. Drainage canal level I

Water drainage system of central area of Hanoi includes four river basins belong to To Lich River, working as a waste water drainage canal system level I in the drainage system of the city. Water from To Lich River basin also is reused for agricultural production and aquaculture in the south region of Hanoi.

a) To Lich River

To Lich River originates at sewer Phan Dinh Phung (Ba Dinh district), flows through canal Thuy Khue and runs along Thuy Khue Street toward Buoi market then cuts across Lac Long Quan toward Hoang Quoc Viet. On Hanoi map, starting point at Hoang Quoc Viet is considered the point of coming out of To Lich River, the width of the river here is about 30 meters, and water levels can reach 3 meters. Next, the river flows along Buoi Street to Cau Giay, then along Lang Street intersects with Nguyen Trai Street at Nga Tu So. The section of the river has a width in the range of 30-40 meters; its depth is 3-4 meters. Then, the river continues to run along Kim Giang, Dai Kim, Thinh Liet and passes through Khuong Dinh Bridge, Lu Bridge and flows toward the South of Hanoi city. Before Thanh Liet dam, To Lich River forks into two branches. The first branch continues flowing to the South and passes through Thanh Liet dam then merges into Nhue River. The other branch turns toward the East to Yen So Park [10].
Main supply sources for To Lich systems are rain water, domestic waste water and production waste water. Along To Lich River, there are many sewers discharging waste water into the river with different flows. The upstream area of To Lich River (from Hoang Quoc Viet to Nga Tu So) receives waste water from some areas of Ba Dinh district, Cau Giay district, Dong Da district, Thanh Xuan district and Hai Ba Trung district. The region downstream (from Nga Tu So to Thanh Liet dam) receives waste water from Hoang Mai district and Thinh Liet commune, Tam Hiep commune, Tu Hiep commune, Vinh Quynh commune and Dong My commune (Thanh Tri district) [10].

Since the late 1990s, Hanoi People’s Committee started dredging, embanking to clean and against the encroachment. The period from 2009 to present, To Lich River, Lu River, Set River, and Kim Nguu River were dredged. The process of building city made To Lich River as starting at Hoang Quoc Viet on the map and it was only act as a drainage canal level I of waste water drainage systems of Hanoi for many years [10].

b) **Kim Nguu River**

Kim Nguu River like To Lich River, the role is a waste water drainage canal level I for water drainage system of central area of Hanoi. Kim Nguu River starts from sewer Lo Duc; its length is about 12.2 kilometers, the average width of 25-30 meters and the depth of 2-4 meters. Kim Nguu river basin covers an area of Hoan Kiem, Hai Ba Trung district, the whole region of Quynh Loi, Mai Huong Vinh Tuy and a past of Thanh Tri districts. There are fourteen main outlets along Kim Nguu River. Kim Nguu River water has been polluted by the discharge of waste water from the process of living, production directly into the river [10].

c) **Set River**

Set River originates at Tran Khat Chan ditch then flows through Hanoi University of Science and Technology, to Dai La bridge merges into Kim Nguu River. One other branch comes from sewer Nam Khang, receives waste water from Tran Binh Trong - Quang Trung areas and flows through Thien
Quang Lake and Bay Mau Lake then merges into main branch at Hanoi University of Science and Technology. Set River has more 3.6 kilometers in long and average width of 10-30 meters, originates from Bay Mau Lake in the Thong Nhat Park, flows from North to South and pours into Yen So Lake. When flowing through Giap Bat, it receives more water from a distributary of Lu River flowing from Phuong Lien. The width and depth of Set River have dropped dramatically in some places because of sedimentation and encroaching construction in many years. Somewhere just has about 5 meters in wide, the average depth of the river just over 1 meter. Since early 2003, Set River was dredged and concreted by investment of Japan (1997-2005) [10].

d) **Lu River**

Lu River has approximately 10 km in length; its width is 10-20 m, starting at sewer Trinh Hoai Duc then flows through Dong Da Lake, Trung Tu Lake, Linh Dam Lake and merges onto To Lich River in Dinh Cong area. Lu River flows through some wards in Dong Da district; to Phuong Lien, Lu River divides into two branches. First branch flows toward the East to Giap Bat and merges with Set River, other branch flows toward the South through Dinh Cong and matches with To Lich River in Linh Dam area. When implementing projects on amelioration of the drainage system of Hanoi since 1998 until now, Lu River has been diverted so much for Lu River water pours into Set river and then into Yen So Lake [10].

e) **Yen So pumping station**

Yen So pumping station was built with a capacity of phase 1 is 45 m$^3$/s, length of canals is 1.2 kilometers, length of pipelines connecting the lakes is 1.9 kilometers. In phase 2, the capacity of the Yen So pumping station is being raised to 90 m$^3$/s (2010) [10].

2.1.3. **State of water drainage system in Hanoi**

The total wastewater flow from the central area of Hanoi city water discharging into drainage systems level I in 2002 was 429,000 m$^3$/day but increased by about 1.8 times to approximately 795,000 m$^3$/day in 2013 [4]. In addition, the amount of wastewater from the central area of Hanoi is
discharged into the river To Lich approximately 290,000 m$^3$/day, in 2013 the figure increased 1.3 times to 382,000 m$^3$/day [4]. The total volume of domestic wastewater of the central area in Hanoi in 2013 is about 291,163 m$^3$/day, in which the volume discharging into the sub-basin To Lich River occupies the most; accounting for 48.1% compared to the total flow of waste water of the region[4]. The amount of waste water discharged into Kim Nguu River is 31.9%, 12.7% for Set River, 3.0% for Lu River and sub-basin Hoang Liet is 4.3% respectively [4].

The total volume of waste water from central area of Hanoi in 2013 is approximately 795,000 m$^3$/day, of which the amount of production waste water is 490,410 m$^3$/day. The amount of industrial wastewater in 2011 is estimated at 100,000 m$^3$/day and only 30% is handled [4]. In 2013, flow of industrial waste water from the central area discharging into drainage systems level I is about 117,774 m$^3$/day and service waste water is 337,136 m$^3$/day. The proportions of different types of waste water are shown as follows [4]. The percentage of services wastewater is the highest and accounting for 47%, following by the production of production waste water accounted for 36.6%, industrial wastewater contributed only 14.8% and medical waste water has the lowest contribution rate only 1.6% of the total discharge flow [4].

To Lich river: The total flow of wastewater discharged into To Lich river in 2013 is estimated approximately 382,000 m$^3$/day, of which the amount of domestic waste water is approximately 140,000 m$^3$/day; production waste water is about 236,000 m$^3$/day and medical waste water is about 6,000 m$^3$/day (including water drainage direction from downstream of Lu river) [4].

Kim Nguu river: The total flow of wastewater discharged into Kim Nguu river in 2013 is estimated at approximately 254,000 m$^3$/day, in which domestic waste water is approximately 93,000 m$^3$/day, production waste water is about 157,000 m$^3$/day and medical waste water is about 4,000 m$^3$/day [4].

Set River: The total flow of wastewater discharged into Set River in 2013 is estimated at 101,000m$^3$/day, in which domestic waste water is
approximately 37,000 m$^3$/day, production waste water is about 62,000 m$^3$/day and medical waste water is about 2,000 m$^3$/day [4].

Lu river: The total flow of wastewater discharged into Lu river in 2013 is estimated at approximately 24,000 m$^3$/day, in which domestic waste water is approximately 9,000 m$^3$/day, production waste water is about 14,500 m$^3$/day and medical waste water is about 500 m$^3$/day [4].

2.1.4. Water quality of To Lich River

The assessment of surface water quality is expressed through the assessment of some following indicators.

Dissolved oxygen (DO): Dissolved oxygen concentration is an evaluation index the status of water resources. If water has high concentration of DO, the decomposition process of organic matter will occur in the direction of aerobic, in the opposite, with low concentration of DO even zero the process of decomposition of organic matter in water will occur towards anaerobic. At that time, water is sniffty and become black due to the occurrence of the anaerobic decomposition processes, many organisms cannot live anymore in this water. When the DO concentration drop to about 4-5 mg/L, the organisms living water will plummet down.

Biochemical Oxygen Demand (BOD): The BOD value indicates the amount of oxygen which is needed for the biological degradation of organic substances in water in mg O$_2$/L. In the aquatic environment, when bio-oxidation process occurs, bacteria use oxygen to oxidize organic matters and converting them into durable inorganic products such as CO$_2$, CO$_3^{2-}$, SO$_4^{2-}$, PO$_4^{3-}$ and NO$_3^-$.  

Chemical Oxygen Demand (COD): Value indicates the amount of oxygen which is needed for the oxidation of all organic substances in water in mg/L or g/m$^3$. The COD is closely related to the laboratory standard method named Dichromate-Method. With this method, the chemical oxygen demand is determined during chromic acid digestion of organic loads in waste water. Based on this method the COD became a commonly used sum parameter in waste water analysis. It is used for planning of waste water treatment plants,
for controlling the cleaning efficiency and for the calculation of waste water
taxes.

Nitrate: The presence of nitrates and nitrites in the water to find the
cause of water pollution is the fertilizer application in agriculture, septic
tanks, wastewater treatment systems, animal waste, and industrial waste. In
addition, high level of nitrate in water indicates the water was contaminated
with other contaminants such as bacteria or pesticides, these contaminants can
infiltrate into the water source and the water distribution system.

Ammonium: Ammonium is not toxic to human too, but if present in
water at concentrations exceeding the permissible standards, it can transform
into carcinogens and other dangerous diseases. The study showed that, when
1g ammonium transforms completely will form 2 gram nitrite and 3.65 gram
nitrate. While the nitrite concentration allowing is 0.1 mg/L and nitrate is 10-
50 mg/L.

Total Nitrogen: Nitrogen is an essential nutrient for humans and nature.
In wastewater, nitrogen compounds exist as three forms: organic compounds,
ammonium compounds and oxidized form (nitrite and nitrate). In domestic
wastewater nitrogen exists in the form of inorganic (65%) and organic (35%).
Today the nutrient contents in water are very high. A further increase would
lead to eutrophication.

Therefore, it is required to monitor this parameter by online
measurement systems and thus enabling the regulation of nutrient
concentrations in public water. The total nitrogen bound defines the total
pollution of water by nitrogen compounds. It is an analytical parameter for
water and is specified in mg/l. The pollution of nitrogen can appear in form of
ammonia, ammonium salts, nitrites, nitrates and organic nitrogen compounds.

Total Phosphorus: Phosphorus is an essential nutrient of plant, animal
and human. In water, it exists primarily as orthophosphate (PO$_4^{3-}$) or in
organic compounds. Increased phosphorus concentration leads to the
eutrophication of the aquatic environment. Impacts are oxygen deficiency
with deadly consequences to fish and other aquatic organisms.
This results in the need of monitoring this parameter. Phosphorus can pass via waste water discharges or drainage of agriculture areas into the waters. In addition, nowadays detergents that are often used for dish washers contain phosphorus. Their increased usage and disposal leads to increased concentrations in the waste water. With the expansion of waste water treatment plants with phosphorus elimination the pollution that occurs from waste water discharges, sustainably reduced.

Chlorine: Chlorine is an important chemical in water purification, in disinfectants, in bleach and in mustard gas. Chlorine is also used widely in the manufacture of many products and items directly or indirectly, i.e. in paper product production, antiseptic, dyestuffs, food, insecticides, paints, petroleum products, plastics, medicines, textiles, solvents, and many other consumer products. It is used to kill bacteria and other microbes from drinking water supplies.

Effects of chlorine on human health depend on how the amount of chlorine that is present, and the length and frequency of exposure. Effects also depend on the health of a person or condition of the environment when exposure occurs. Chlorine causes environmental harm at low levels. Chlorine is especially harmful to organisms living in water and in soil.

2.2. Methods

2.2.1. Document collection method

Collecting, looking for and eliminating documents from internet, libraries, and journals appropriately with research purposes and serve as a basis for the process of empirical research [5].

Preparing a following summary of the steps in the process of document collection in order to serve research purposes:

– Identify topics and content will be mentioned throughout the thesis;
– Identify selection criteria document and exclusion criteria. Do not select all available documents, should have specific selection criteria;

– Collect relevant documents from different sources such as scientific journals, research reports, and other databases (master thesis, PhD thesis, professional documents, monographs concerning environment especially water resources, etc.);

– Supplement monitoring data collected from the: Department of Natural Resources and Environment in Hanoi, Center of Environmental Monitoring in Hanoi, environmental companies;

– Keep abreast of related information on television, radio, newspapers to update the latest news related to the thesis;

– Read a summary of those documents, skimming to have overview and get some main points;

– Select the appropriate documents with the required standard. Save these documents carefully, arranging these documents depending on purposes. In particular, pay an attention to some documents, references from articles in scientific magazines, journals, scientific thematic reports relating to the contamination of water sources in To Lich River;

– Read carefully selected materials, record relevant contents and add comments, personal opinions;

– Write overview document;

– Read the overview once more time, editing and finishing.

2.2.2. Field research method

a) Observation, Surveying and Sampling

– Locations of sampling: Taking and symbolizing from Hoang Quoc Viet to Yen So Park for twelve samples at twelve locations on To Lich River.
- Sampling techniques: TCVN 6663-1: 2011 [2].
- Sampling instruction in rivers: TCVN 6663-6: 2008 [1].

**Table 2. Locations of sampling on To Lich River**

<table>
<thead>
<tr>
<th>No</th>
<th>Coordinate</th>
<th>Place</th>
<th>Symbol</th>
<th>Sampling layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21°02’45.30” N 105°48’18.97” E</td>
<td>Hoang Quoc Viet</td>
<td>HQV</td>
<td>Middle layer</td>
</tr>
<tr>
<td>2</td>
<td>21°01’48.81” N 105°48’03.52” E</td>
<td>Giay bridge</td>
<td>CGY</td>
<td>Middle layer</td>
</tr>
<tr>
<td>3</td>
<td>21°00’54.06” N 105°48’15.21” E</td>
<td>Tran Duy Hung</td>
<td>TDH</td>
<td>Middle layer</td>
</tr>
<tr>
<td>4</td>
<td>21°00’06.04” N 105°48’04.26” E</td>
<td>Nga Tu So</td>
<td>NTS</td>
<td>Middle layer</td>
</tr>
<tr>
<td>5</td>
<td>20°59’05.71” N 105°48’50.54” E</td>
<td>Khuong Dinh bridge</td>
<td>CKD</td>
<td>Middle layer</td>
</tr>
<tr>
<td>6</td>
<td>20°58’49.02” N 105°49’09.48” E</td>
<td>Lu bridge</td>
<td>CLU</td>
<td>Middle layer</td>
</tr>
<tr>
<td>7</td>
<td>20°58’13.33” N 105°49’29.25” E</td>
<td>Dau bridge</td>
<td>CDU</td>
<td>Middle layer</td>
</tr>
<tr>
<td>8</td>
<td>20°57’36.31” N 105°48’45.71” E</td>
<td>Dap Thanh Liet</td>
<td>DTL</td>
<td>Middle layer</td>
</tr>
<tr>
<td>9</td>
<td>20°57’22.13” N 105°48’34.38” E</td>
<td>After Thanh Liet dam</td>
<td>STL</td>
<td>Middle layer</td>
</tr>
<tr>
<td>10</td>
<td>20°57’35.01” N 105°48’48.03” E</td>
<td>Before Thanh Liet dam</td>
<td>TTL</td>
<td>Middle layer</td>
</tr>
<tr>
<td>11</td>
<td>20°57’04.51” N 105°50’39.40” E</td>
<td>Van Dien bridge</td>
<td>CVD</td>
<td>Middle layer</td>
</tr>
<tr>
<td>12</td>
<td>20°57’26.53” N 105°51’30.99” E</td>
<td>Yen So park</td>
<td>TYP</td>
<td>Middle layer</td>
</tr>
</tbody>
</table>
Figure 1. Monitoring points on To Lich River
b) Sample preservation

Preservation of water samples in order to preserve the elements, while maintaining the nature and characteristics of water samples in a short time before analysis. Preservation instructions of samples: TCVN 6663-3:2003.

Table 3. Sampling tools and sample preservation conditions

<table>
<thead>
<tr>
<th>No</th>
<th>Target</th>
<th>Bottle</th>
<th>Preservation conditions</th>
<th>Maximum preservation time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TSS</td>
<td>PE</td>
<td>Cold 4°C</td>
<td>4 h</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>PE</td>
<td>No</td>
<td>6 h</td>
</tr>
<tr>
<td>3</td>
<td>DO</td>
<td>Glass</td>
<td>Winkler method</td>
<td>6 h</td>
</tr>
<tr>
<td>4</td>
<td>BOD</td>
<td>PE</td>
<td>Cold 4°C</td>
<td>4 h</td>
</tr>
<tr>
<td>5</td>
<td>COD</td>
<td>PE</td>
<td>Cold 4°C</td>
<td>24 h</td>
</tr>
<tr>
<td>6</td>
<td>TN</td>
<td>PE</td>
<td>Cold 4°C + 2mL ( \text{H}_2\text{SO}_4 ) concentrated /L sample</td>
<td>24 h</td>
</tr>
<tr>
<td>7</td>
<td>( \text{NH}_4^+ )</td>
<td>PE</td>
<td>Cold 4°C + 2mL ( \text{H}_2\text{SO}_4 ) concentrated /L sample</td>
<td>24 h</td>
</tr>
<tr>
<td>8</td>
<td>( \text{NO}_3^- )</td>
<td>PE</td>
<td>Cold 4°C + 2mL ( \text{H}_2\text{SO}_4 ) concentrated /L sample</td>
<td>24 h</td>
</tr>
<tr>
<td>9</td>
<td>( \text{PO}_4^{3-} )</td>
<td>Glass</td>
<td>Cold 4°C</td>
<td>24 h</td>
</tr>
<tr>
<td>10</td>
<td>TP</td>
<td>Glass</td>
<td>Cold 4°C</td>
<td>24 h</td>
</tr>
<tr>
<td>11</td>
<td>Cl(^-)</td>
<td>PE</td>
<td>Cold 4°C + 2mL ( \text{H}_2\text{SO}_4 ) concentrated /L sample</td>
<td>24 h</td>
</tr>
</tbody>
</table>

2.2.3. Laboratory research method

* \( pH \)
Measurement of pH value of the sample was conducted in the field using portable pH meter ADWA, model AD111.

* DO

Measurement of pH value of the sample was conducted in the field using portable machine HANNA with electrode of DO, model HI1942.

* COD

COD value was determined by the method of bichromate TCVN 6491: 1999, the reaction was carried out on the device Thermoreactor ECO25.

* Ammonium($N-NH_4^+$)

Ammonium was determined by spectrometric method using mixture reagent of sodium salicylate, trisodium citrate, sodium diclorosoxyanurat and sodium nitroprusiat (ISO 179-1: 1996), measured at 655 nm wavelength by device UV-Vis JASCO V- 630.

* Nitrate ($N-NO_3^-$)

Nitrate is determined by the spectrometric method using sunfosalixilic acid, which is formed by the reaction of sodium salicylate and sulfuric acid (TCVN 6180:1996), measured at 419 nm wavelength by device UV-Vis JASCO V- 630.

* Phosphate ($P-PO_4^{2-}$) and total phosphorous

Phosphorus in the form orthophosphate and total phosphorus in water samples were determined by the spectrometric method using ammonium molybdate, antimony and ascorbic acid to form dark blue molybdenum complex (TCVN 6202: 2008), measured at 880 nm wavelength by device UV-Vis JASCO V- 630.

* Chloride ($Cl$)

Chloride was determined by using Mohr’s method (TCVN 6194: 1996). This method is silver nitrate titration with chromate indicator.
2.2.4. Method of analysis, assessment, treatment of experimental data

In this research, to be able to use the data from the experimental process, first of all need to collect information from textbooks, articles, journals publications related content. The next step, need to master the theory, the nature of the process and the factors that affect the movement of data, thereby controlling the operation of experimental devices. Experimental data is recorded and stored daily careful analysis and compare to published research related content. From the analysis, assess the reliability of the data would have changed the working mode and then supplement circumscribe affecting factors.

Data were recorded on personal notebook at the laboratory when experimenting, then entered into the Excel spreadsheet to easily calculate, manage and monitor the volatility of the data, thereby can assess and adjust the conditions, operating modes to achieve the expected results.

2.2.5. WQI calculation method of surface water

Determination of water quality index (WQI) based on pollution indicators for each surface water contaminants including TSS, COD, TN, TP, As and Coliform, according to the formula [9].

\[
WQI_{(i)} = \frac{1}{n} \sum_{i=0}^{n} \frac{C_i}{C_o} \times 100
\]

Source: Vietnam Environment Administration. 2010 [9].

The formula determination of WQI

\[
WQI = k_1 \times WQI \ (TSS) + k_2 \times WQI \ (COD) + k_3 \times WQI \ (N) + k_4 \times WQI \ (P) + k_5 \times WQI \ (As) + k_6 \times WQI \ (Coliform)
\]

Source: Vietnam Environment Administration, 2010 [9].

WQI index rating scale [9]:

- Good quality surface water environment: WQI ≤ 50;
- Non-pollution surface water environment: 50 < WQI ≤ 100;
– Pollution surface water environment: $100 < \text{WQI} \leq 200$;
– Heavily pollution surface water environment: $200 < \text{WQI} \leq 300$;
– Serious pollution surface water environment: $\text{WQI} > 300$. 
CHAPTER 3. RESEARCH RESULTS

3.1. Water quality assessment of To Lich River

3.1.1. Water analysis results in dry season

a) pH and DO

In overall, DO and pH indicators of monitoring samples were identified at the scene after sampling. The analytical results of 12 samples are shown in Figure.

Directly, the pH value of the monitoring samples ranged from 7.27 to 7.66, average pH value was about 7.36. In general, waste water of To Lich River is neutral because major source is waste water from the daily activities of the city's residential area, industrial wastewater or production wastewater only account for a small part.

Besides, DO values of water samples were very low, ranging from 0.1 to 1.0 mg/L. DO average value reached only 0.3 mg/L, absolutely did not meet the conditions of the habitat for aquatic plants and animals. Generally, at the monitoring points, the value of the water sample DO oscillated around the average value (0.3 mg/L). Basically, in monitoring points located at upstream, DO value are higher than the middle points of the river (HQV: 0.4 mg/L and TDH: 0.3 mg/L); while at the end of the downstream especially river branch turns toward the East to Yen So Park, DO value had a trend of ascending (DO reached 1.0 mg/L at monitoring point YSP).

The reason for the difference in the concentration of dissolved oxygen because at Yen So Park area, To Lich River has been merged with streams from Yen So Lake. So the DO value has increased slightly but still not enough to ensure living conditions for the animals. DO values generally tend to change depending on the self-cleaning mechanism of the river with a strong decomposition region is defined as the middle area (from Nguyen Trai to Thanh Liet Dam).
b) Chemical oxygen demand (COD)

The types of organic compounds are very typical contaminants founding in sewage wastewater especially in To Lich River. COD parameter is selected as the representative value for the level of organic pollution of water of To Lich River, analytical results of water samples are shown in figure. In general, the COD value of the monitored sample during the dry season ranged from 111.07 to 150.28 mg/L while the average value of COD reached at 127.85 mg/L.

Among the samples analyzed, the highest value of COD is monitoring points Nguyen Trai - NTS, the fact that there is often a forming of markets and the concentration of food shops in the area and typical example is Nga Tu So market. Thereby, it can be explained that the difference about the DO values between the monitoring points due to the concentration of residential areas following by the development of the services. The COD value movement of the monitoring points along the flow tends to decrease downstream. As the above analysis, the strong decomposition region of To
Lich River starts from Nguyen Trai to Thanh Liet Dam. Moreover, river branch turning toward the East to Yen So Park of To Lich River has been merged with streams from Yen So Lake.

![COD](image.png)

**Figure 3. Analysis result of COD in dry season**

c) **Total nitrogen, ammonium, and nitrate**

Water specific component of To Lich River mainly is waste water, so that the concentration of nutrients in river water is often very high. The results of analysis such as \( \text{NH}_4^+ \), \( \text{NO}_3^- \), TN, \( \text{PO}_4^{3-} \) and TP are shown by graphs. Concentration of N - \( \text{NH}_4^+ \) in the dry season Lich ranged from 23.52 to 55.07 mg/L, the average value was about 36.74 mg/L many times higher than prescribed standard in QCVN 08:2008/BTNMT column B2 (0.9 mg/L). Typical monitoring point having high value was Thanh Liet Dam with \( \text{NH}_4^+ \) concentration went up to 55.07 mg/L. It can be explained that because this place is point start discharging from To Lich river to Nhue River and the dam can be opened or closed depending on the current water level there. In dry season, water level in To Lich River is usually very low so the open-close cycle can be longer. When sampling in this location, there was no discharge at
the dam, in addition to the position is located not so far from Van Dien cemetery so there was an increase in concentration of NH$_4^+$.

![Ammonium and Nitrate](image)

**Figure 4. Analysis result of NH$_4^+$ and NO$_3^-$ in dry season**

Generally, concentrations of N – NO$_3^-$ of monitoring points were quite stable and no strong fluctuation as much as NH$_4^+$. The concentration of NO$_3^-$ ranged from 0.96 to 7.20 mg/L while the average value was approximately 3.69 mg/L. It can be seen that concentration of NO$_3^-$ increased slightly in the direction from North to South because the area’s topography is a valley. For river branch of To Lich River turn toward the East to Yen So Park, the NO$_3^-$ concentrations have declined slightly due to dilution.

The analytical result also shows that TN concentration ranged from 25.53 to 61.00 mg/L with an average of 40.43 mg/L. Overall TN concentrations fluctuate the same NH$_4^+$ and NO$_3^-$, it was up slightly from North to South and slightly reduce when branching toward East; monitoring points with highest concentration of TN also is Thanh Liet Dam.
Figure 5. Analysis result of total nitrogen in dry season

d) Total Phosphorous, Phosphate

Figure 6. Analysis result of total phosphorous and phosphate in dry season
For $\text{PO}_4^{3-}$ indicator, fluctuation range and average value respectively were from 1.04 to 4.26 mg/L and 2.77 mg/L; while the fluctuation range of the total phosphorus value was from 1.10 to 4.20 mg/L and the average value was 2.57 mg/L.

In this case, the values of the total phosphorus were lower than $\text{PO}_4^{3-}$, the cause of this anomaly is influences of the analysis in which the main reason is the process of digestion that convert all types of compound containing phosphorous to the orthophosphate form has not been completely. In general, concentrations of total phosphorus and $\text{PO}_4^{3-}$ did not differ too much in the monitoring points; only the monitoring points in Hoang Quoc Viet and Nguyen Trai region had values slightly higher than the average value. These are the areas have the marketplace and densely population (Buoi market and Nga Tu So market).

e) Chloride.

![Figure 7. Analysis result of chloride in dry season](image)
For Cl⁻ indicator, fluctuation range and average value respectively were from 24.82 to 40.77 mg/L and 33.24 mg/L. In general, concentrations of chloride differed slightly in first two monitoring points then did not change too much. Especially, there were three monitoring points having the same values with 31.94 mg/L in Tran Duy Hung, Thanh Liet dam and Yen So Park. The highest concentration of Cl⁻ was 40.77 mg/L at Hoang Quoc Viet where is the starting point of To Lich River on the map.

### 3.1.2. Water analysis results in rainy season

**a) pH and DO**

Compared to the dry season, generally pH and DO values of water samples did not have much significant change. For the pH parameters, sample fluctuation range of the monitoring sample was from 7.23 to 7.93 (compared to the dry season was from 7.27 to 7.66) in which the average pH value was 7.66 (dry season was 7.36).

![Figure 8. Analysis result of pH and DO in rainy season](image)

For parameter DO, the value of the samples measured during the rainy season monitoring still was at very low levels, even the value of some locations were much lower compared to the dry season. Specifically DO
samples ranged from 0.1 to 0.4 mg/L (compared to the dry season was from 0.1 to 1.0 mg/L) and the average DO value was 0.13 mg/L (compared to the dry season was 0.30 mg/L). Monitoring points in Yen So Park had a slight increase of the value DO by imported water from Yen So Lake and reached at 0.4 mg/L but still was lower than dry season.

**b) Chemical oxygen demand COD**

Result shows that in the rainy season the level of organic matter pollution on To Lich River was not much, the fluctuation range of COD value of monitoring samples was quite small, from 30.97 to 123.87 mg/L and COD values averaged at 74.36 mg/L. At monitoring points Nguyen Trai with appearance of Nga Tu So market or densely populated areas with commercial centers VINCOM Royal City, water samples at this location had COD value higher than others (123.87 mg/L). Water samples collected at Yen So Park had the lowest COD value in all of monitoring points, only 30.97 mg/L. As mentioned above, this is the position appear the mixing of water from Yen So Lake and river branch of To Lich so pollution here is not too high.

![Figure 9. Analysis result of COD in rainy season](image-url)
c) Total nitrogen, ammonium, and nitrate

The results of analysis of criteria NH$_4^+$ of monitoring samples during the rainy season show that fluctuation of NH$_4^+$ concentration in the water was from 5.43 to 27.07 mg/L and the average concentration was 19.73 mg/L. Compare to the results of the analysis in the dry season, NH$_4^+$ levels in the water of To Lich River during the rainy season was lower than dry season (ranging from 23.52 to 55.07 mg/L and the average concentration was 36.74 mg/L). Concentration of NH$_4^+$ of some samples at the east river branches is lower than others, particularly at Yen So Park concentration of NH$_4^+$ reached the lowest value at 5.43 mg/L. Concentrations of NH$_4^+$ of water samples in monitoring points from Nguyen Trai Street to Thanh Liet Dam were relatively similar and relatively high compare to the average.

![Ammonium and Nitrate](image)

Figure 10. Analysis result of NH$_4^+$ and NO$_3^-$ in rainy season

For NO$_3^-$ criteria, analytical result shows that the concentration of NO$_3^-$ in water samples ranged from 0.02 to 9.62 mg/L and the average concentration of NO$_3^-$ was about 1.56 mg/L. Compare to the results of the analysis in the dry season, the average concentration of NO$_3^-$ during the rainy season was lower (compared to 3.69 mg/L in dry season), fluctuation range of NO$_3^-$ in rainy season was broader than dry season (from 0.96 to 7.20 mg/L).
Movement of the concentration of \( \text{NO}_3^- \) was antagonistic compared to movements of \( \text{NH}_4^+ \). The truth that the concentration of \( \text{NO}_3^- \) in monitoring samples gradually increases towards Yen So Park. A possible explanation for this trend of change is concentration of DO gradually increased when the river flow toward Yen So Park; enabling the aerobic bacteria in water partially metabolizes \( \text{NH}_4^+ \) into \( \text{NO}_3^- \).

For total nitrogen values, concentrations ranged from 15.05 to 27.09 mg/L and the average concentration was 21.29 mg/L. Compare to the results of the analysis in the dry season, it can be seen fluctuation range and average concentrations during the rainy season are much lower (approximately ranging from 25.53 to 61.00 mg/L and the average concentration was 40.43 mg/L in the dry season. Overall, movements of total nitrogen concentration were similar to movements of \( \text{NH}_4^+ \). Specifically, from Nguyen Trai to Thanh Liet Dam, beat the total nitrogen concentrations do not fluctuate dramatically, almost close to the concentration of \( \text{NH}_4^+ \) at the same locations.

![Total Nitrogen](image)

**Figure 11. Analysis result of total nitrogen in rainy season**
d) Total Phosphorous, Phosphate

The concentrations of $\text{PO}_4^{3-}$ criteria and total phosphorus criteria at 12 monitoring points of To Lich River are expressed in the figure; concentration of $\text{PO}_4^{3-}$ of water samples ranged from 0.90 to 1.98 mg/L with average values was about 1.35 mg/L. These values during the rainy season was smaller than the dry season (ranging from 1.04 to 4.26 mg/L and the average value was 2.77 mg/L). For total phosphorus, the concentrations ranged from 1.50 to 2.80 mg/L and the average value of 2.11 mg/L. In this case, when analyzing these monitoring samples about total phosphorus criteria during the rainy season, the results did not meet the state that concentration of total phosphorus was lower than $\text{PO}_4^{3-}$ on the same location. Overall, the concentrations of total phosphorus and $\text{PO}_4^{3-}$ between the monitoring points were not much different.

![Total Phosphorous and Phosphate](image_url)

**Figure 12.** Analysis result of total phosphorous and phosphate in rainy season

e) Chloride

For $\text{Cl}^-$ indicator, fluctuation range and average value respectively were from 39.7 to 48.79 mg/L and 45.24 mg/L. In general, concentrations of
chloride did not differ too much in the monitoring points; specially, the monitoring points in Khuong Dinh Bridge and Thanh Liet Dam had the same values with 48.79 mg/L.

![Chloride](image)

**Figure 13. Analysis result of chloride in rainy season**

### 3.1.3. Water quality assessment of To Lich River

After sampling, water samples of To Lich River are preserved and analyzed, the analysis results are compared to QCVN 08: 2015/BTNMT column B2. Because To Lich River is sewage in Hanoi, ingredient of river water is mostly waste water from domestic areas, inability to use as fresh water for agricultural production.

Generally, water qualities of To Lich River are similar in two seasons, the concentrations of PO$_4^{3-}$, COD, and NH$_4^+$ exceed QCVN and DO concentrations are very low.

- Average concentration of NH$_4^+$ was 40 times higher in dry season and 25 times in rainy season compared to QCVN;
- Average concentrations of DO was low in both seasons (<0.5 mg/L), water becomes smelly and no appearance of the organism;
- Average content of COD in dry season was 127.85 mg/L, 2.55 times higher than QCVN and 1.48 times higher than QCVN during the rainy season with the average concentration was 74.36 mg/L;
- Concentration of NO$_3^-$ was lower than QCVN in two seasons with 4.06 times in dry season and 9.63 times in rainy season;
- Concentration of PO$_4^{3-}$ was 2.69 times higher than QCVN with the number was 1.35 mg/L in rainy season even in dry season, which was 5.53 times higher than QCVN (average concentration in rainy season was 2.76 mg/L).

### 3.2. WQI result of To Lich River water

The WQI of To Lich River water was determined according to six main parameters including five physical-chemical parameters (TSS, COD, As, TN, TP), a biological indicator (Coliform) and was compared with QCVN 08: 2015/BTNMT column B2. The result is shown in following table.

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<td>2012-2013</td>
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<td>Rainy season 2016</td>
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</table>

In 2003, the WQI of To Lich River was 264 and river situation was considered heavily contaminated. By 2009, the pollution level became very serious with WQI was 961, 3.6 times higher than in 2003. The period of 2012-2013, the value WQI has decreased compared to 2009; however, the
river water was still heavily contamination with WQI value was 738, 2.8 times more than the value in dry season in 2003.

For the dry season in 2016, the WQI value peaked at 1013, the highest number in the statistics, exceeded 3.84 times compared to 2003 and 1.37 times higher than 2012-2013 period. It means that the state of the river water was heavily pollution. During the rainy season in 2016, the level of water pollution of To Lich River has not changed much with WQI number was 940, 1.27 times higher than 2012-2013.

![Figure 14. Analysis result of WQI from 2003 to 2016](image-url)
CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. To Lich River has been contaminated by direct discharge of domestic waste water, industrial waste water, agricultural waste water with large amount into the river, exceeds capabilities of self-cleaning of the river.

2. The pH value fluctuated from neutral to light alkaline, average value was 7.36 in dry season and 7.66 in rainy season. Concentration of dissolved oxygen in To Lich River water was very low, average value measured in the dry season was 0.3 mg/L and 0.12 mg/L for the rainy season, the value of pH and DO of To Lich River water did not have much difference in the two seasons.

3. The chemical oxygen demand (COD) was 127.85 mg/L in dry season and 74.36 mg/L for rainy season. About nutrient parameters, the average concentration of NH$_4^+$ was 36.74 mg/L and 19.73 mg/L for dry and rainy season, respectively. The average concentration of NO$_3^-$ and total nitrogen TN in turn was 3.69 mg/L and 40.43 mg/L for dry season, in rainy season these values tend to be lower, reached 1.56 mg/L and 21.29 mg/L. For PO$_4^{3-}$ and total phosphorus parameters, in dry season the values were 2.77 mg/L and 2.57 mg/L, higher than the values in rainy season which were 1.35 mg/L and 2.11 mg/L.


5. The WQI value of To Lich River water was 1013 in dry season and 940 during rainy season in 2016. The level of water pollution of To Lich River has not changed much in both seasons in 2016 and river water was very heavily contamination compared to previous periods. In forecast, the pollution level of To Lich River water continues increasing and there is no falling down signal.
B. Recommendations

This research indicates water quality of To Lich River which is serious pollution in rainy season and dry season. That is basic of solution, protection measures and effective use surface water resource in Hanoi city.

The necessary here is continue monitoring of changes in state of river water and proposes some effective and synchronous management solutions for To Lich River.
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APPENDIX

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### Appendix 1. Pollution parameters of To Lich River in dry season

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<tr>
<th>No</th>
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## Appendix 2. Pollution parameters of To Lich River in rainy season

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Appendix 3. Several images during research process