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FORECAST OF WATER QUALITY OF TO LICH RIVER BASED ON SCENARIOS OF HA NOI SEWERAGE PLANNING BY USING MODEL QUAL2K

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Abstract. To Lich River is well-known as a main drainage river and plays a vital role to the landscape distribution of Ha Noi city, which is currently polluted due to improperly untreated wastewater flow. Thanks to QUAL2K model, the variation of the river water quality has been forecasted by 4 particular scenarios. In the first scenario, the whole generated wastewater along To Lich River is not totally collected and treated. Scenario 2 is similar to scenario 1 except that To Lich River receives an addition of diluted water of 5 m^3/s from Red River. In the third scenario, wastewater is mostly well managed but minor sources are not collected. Finally, the whole generated wastewater is properly treated and added with a diluted amount of 5 m^3/s from Red River. The study pointed out that to meet standard of column B1, QCVN 08-MT:2015/BTNMT (Vietnam National Regulation), centralized and decentralized generated sewerage water need treated appropriately to lower BOD_5 concentration below 20 mg/L to reach column B of National Standard 02:2014/BTNMT.

Keywords: To Lich River; river water quality, modelling, QUAL2K.

Classification numbers: 3.4.2, 3.8.1, 3.8.3.

1. INTRODUCTION

To Lich River is about 14 kilometers long, flowing through the area of six districts of Ha Noi City: Ba Dinh, Cau Giay, Dong Da, Thanh Xuan, Hoang Mai, and Thanh Tri. To Lich River, along with Kim Nguu River, Lu River and Set River, have formed the main drainage system of Ha Noi. It receives wastewater and storm water from To Lich basin of 77.5 km^2. Discharged from Thanh Liet gate, it joins to the Nhue River at Ha Dong district [1].

Currently, the main source of water for the drainage systems is wastewater in the dry season and rainwater in the rainy season. The main discharge to To Lich River is the sewage system on both sides of the river. In the dry season, To Lich River is the waterbody to receive almost all wastewater in the old inner city (basin S2). Most domestic wastewater treated by septic tanks and untreated industrial wastewater was discharged directly into the river. It is estimated that

300,000 m^3 of untreated wastewater has been directly discharged to the river, not including the amount of wastewater in Lu River and Kim Nguu River [2]. The flow rate ranges from 3 to 8 m^3/s, depending on the location of the river. In recent years, rapid urbanization has seriously affected to the water quality. Thus, there is an urgent need to forecast the change of water quality along the river as a sustainable path of water resource management in To Lich River.

In the drainage master plan of Ha Noi City, wastewater from To Lich Basin is collected to centralized sewerage treatment plants named Yen Xa and Phu Do with the capacity of 270,000 m^3/day and 84,000 m^3/day, respectively. Afterward, properly treated wastewater is discharged to Nhue and To Lich River. Furthermore, an additional volume of 5 m^3/s from Red River is planned to recharge in dry season [1]. However, a number of decentralized wastewater that cannot be collected along the banks of To Lich River can cause local pollution and dispersion for river water environment [3]. Therefore, it is necessary to assess the water quality of To Lich River according to various scenarios of wastewater collection and treatment plans and clean water supply. The assessment will provide a basis for building a comprehensive solution of river basin water environment protection.

Water quality models as powerful support tools for decision – making is globally accepted and increasingly used in the process of water quality management. Thus, its application to the To Lich River is essential, providing more scientific basis for appropriate management strategies in the future. Among the current models of river water quality, QUAL2K has been widely applied to assess surface water quality and predict the effects of urban wastewater discharge on oxygen regime in the tropical rivers [4, 5]. In this study, QUAL2K is applied to calculate and forecast water quality of To Lich River. Various scenarios of wastewater collection, treatment and clean water supply on river basin will be considered.

2. MATERIALS AND METHODS

2.1. Research objects and modeling tool

The study case is To Lich River (Ha Noi, Viet Nam). Initially, the river is divided into separated parts in the model of QUAL2K [6]. Based on the length of the river, natural conditions, flow rate and discharge points, there are totally 14 parts with the length of 1 kilometer (Figure 1).

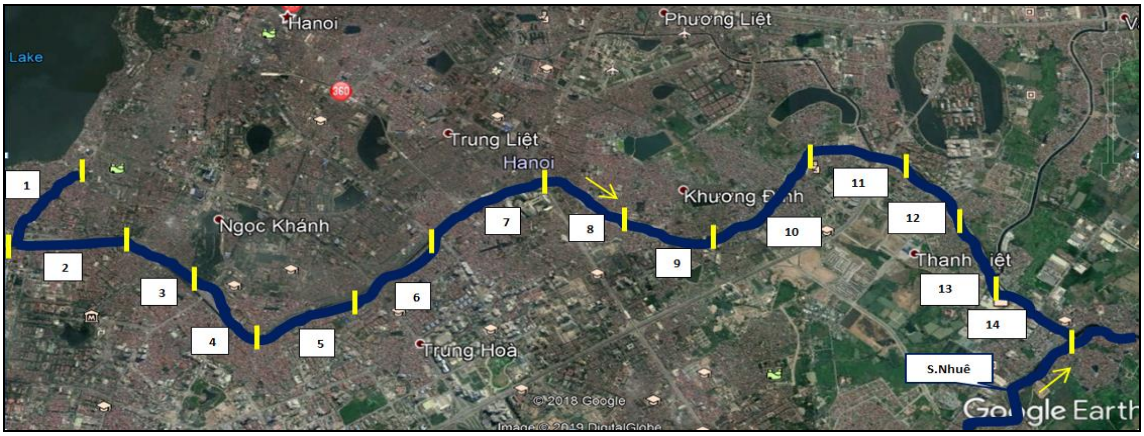

Figure 1. Dividing the rivers into smaller parts for the model.

QUAL2K is applied to calculate the spread of pollutants from the upstream to the downstream of a river. The program is modeled based on 15 indexes: electrical conductivity (EC), Total Suspended Solid (TSS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), etc. In the case of To Lich River, the major pollutant is derived from households; thus, Total Suspended Solid (TSS), Biological Oxygen Demand (BOD_5) and Ammonium nitrogen (NH_4-N) were used to build the model. The water quality is evaluated based on the Vietnam National Technical Regulation on Surface Water Quality QCVN 08-MT: 2015/BTNMT [7].

2.2. The inlet indexes

The hydrological data of Ha Noi City [8] and the longitudinal section of To Lich River [9], as shown in Table 1, were used.

*Table 1***.** The current longitudinal section of To Lich River.

No.	Part	Cross section of the river						River bottom elevator	
		Distance, *km*	Upstream, *m*	Upstream, *m*	Width, *m*	River bank slope, *m*	Right side, *m*	Upstream, *m*	Downstream, *m*
1	km+0.5	14.00	0.000250	0.023	4.00	1.00	1.00	2.100	1.850
2	km +1.5	13.00	0.000200	0.023	16.00	050	0.50	1.850	1.650
3	km +2.5	12.00	0.000067	0.023	19.00	0.50	0.50	1.650	1.583
4	km +3.5	11.00	0.000067	0.023	19.00	0.50	0.50	1.583	1.517
5	km +4.5	10.00	0.000067	0.023	19.00	0.50	0.50	1.517	1.450
6	km + 5.5	9.00	0.000067	0.023	19.00	0.50	0.50	1.450	1.383
7	km +6.5	8.00	0.000067	0.023	21.50	0.50	0.50	1.383	1.317
8	km +7.5	7.00	0.000067	0.023	21.50	0.50	0.50	1.317	1.250
9	km +8.5	6.00	0.000067	0.023	21.50	0.50	0.50	1.250	1.183
10	km +9.5	5.00	0.000067	0.023	21.50	0.50	0.50	1.183	1.117
11	km +10.5	4.00	0.000067	0.023	21.50	050	0.50	1.117	1.050
12	km +11.5	3.00	0.000067	0.023	22.00	0.50	0.50	1.050	0.983
13	km +12.5	2.00	0.000067	0.023	22.00	0.50	0.50	0.983	0.917
14	km + 13.5	1.00	0.000067	0.023	16.00	0.50	0.50	0.917	0.850

Discharging source data used are statistic data from discharging points related to future wastewater generated. According to the research number 01C-09/01-2016-3 for To Lich River, there are totally 336 sewers with the diameter ranging from 300 to above 3000 mm. In detail, 15 % of sewers have the diameter greater than 1000 mm, 33 % are in the diameter range 600 to 1000 mm, while the rest (less than 600 mm) occupied the highest proportion with 52 %. Additionally, there are above 400 small sewers with the diameter less than 300 mm discharging unfrequently 7,000 to 10,000 m^3/day to the river [3]. The content of pollutants from major pipelines in dry season of 2017 and 2018 were summarized from Hanoi Center for Resource and Environmental Monitoring and Analysis [10].

The data of water quality from the point 1 to point 14 are collected in dry season in 2017-2018 from Hanoi Center for Resource and Environmental Monitoring and Analysis [10] and the research No. 01C-09/01-2016-3.

Water quality data of Red River in the location of Lien Mac discharging point, where is the point for recharging water to To Lich River, was collected from the monitoring data of Institute of Environmental and Science Engineering [11].

Coefficient K1 is the rate constant of the biochemical oxidation reaction (reaction level 1) of organic matter in the mixture of wastewater and To Lich River. This coefficient characterizes the ability of biodegradable organic matter (BOD) to be cleaned in river water due to temperature factors, flow velocities and other environmental factors. Therefore, K1 is an experimental parameter [12, 13]. From the relationships between the coefficient K1 and the flow time t on the To Lich River sections in the dry season,

$$K1 = 18.657e^{-7.511t}, d^{-1} \quad \text{and} \quad R^2 = 0.9305.$$

Due to the relatively slow flow velocity (0.2 - 0.3 m/s), the coefficient K1 is considered constant across the river. Let t be the average time in the model calculation to determine the K1 coefficient.

The other parameters of the calculation model used for calibration are taken from the QUAL2K manual [6].

3. RESULTS AND DISCUSSION

3.1. Scenario 1 (SC1)

Currently, there is a volume of 300,000 m^3 of untreated wastewater directly discharging to the river, in addition to 55,000 m^3 from Lu river in Dau sewer and 60,000 m^3 from Kim Nguu river in To Bridge. Furthermore, there is no replenishment for To Lich River from Red River.

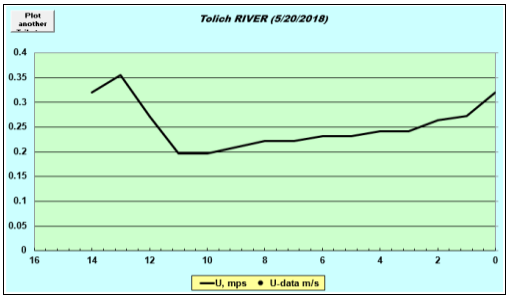

Figure 2. Flow rate as in SC1

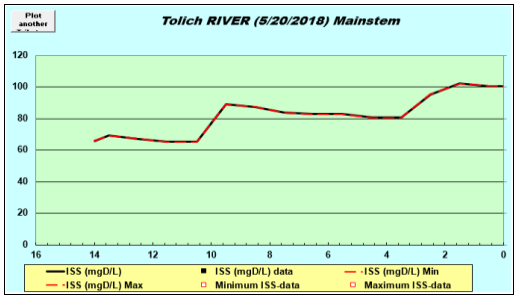

Figure 3. TSS along the river as in SC1

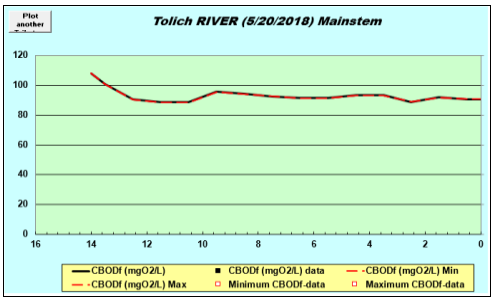

Figure 4. BOD_5 along the river as in SC1.

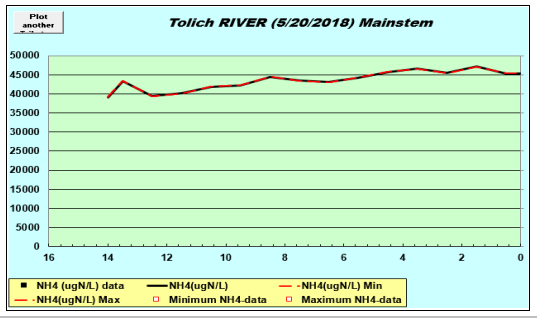

Figure 5. NH_4 –N TSS along the river as in SC1.

The result from Figures 2, 3, 4, and 5 shows that:

- The flow rate is relatively low, ranging from 0.2 – 0.35 m/s, the lowest and highest level can be witnessed in the point located 4 and 1 kilometers from the upstream, respectively.

- TSS ranges from 60 – 100 mg/L, which is similar to the data of Center of Monitoring and Analyzing Environmental Resource of Ha Noi from 2010 – 2017 [10]. The TSS exceeded the column B1 – QCVN 08-MT: 2015/BTNMT [7].

- BOD_5 reaches the range of 90 – 110 mg/L and exceeds the column B1 – QCVN 08:2015/BTNMT. BOD_5 level experienced a decline to downstreatm due to the self-purification of the river.

- NH_4-N ranges from 40 – 50 mg/L and does not meet column B1, QCVN 08-MT:2015/BTNMT. The level of ammonia also remained unchanged along the river due to the face that nitrification process does not occur.

3.2. Scenario 2 (SC2)

Thanks to a plan to replenishment for To Lich River, a pumping station is planned to re-charge a volume of 5 m^3/s from Red River to To Lich River through Lien Mac sewer. The existing situation of collecting wastewater, however, maintains unchanged. The forecasted results of river water quality are illustrated in Figures 6, 7, 8 and 9.

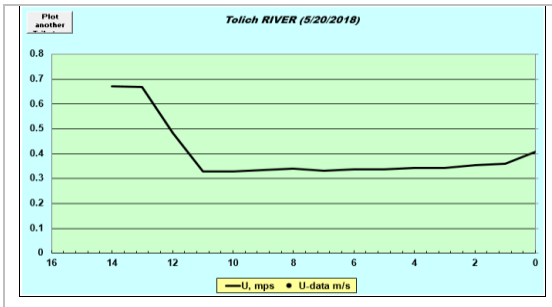

Figure 6. Flow rate as in SC2.

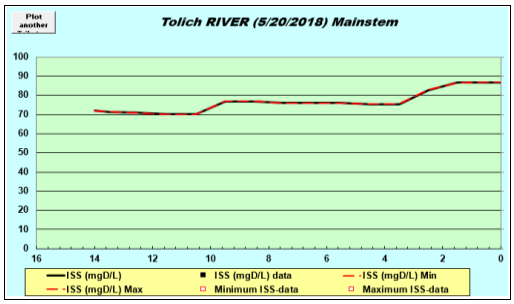

Figure 7. TSS along the river as in SC1.

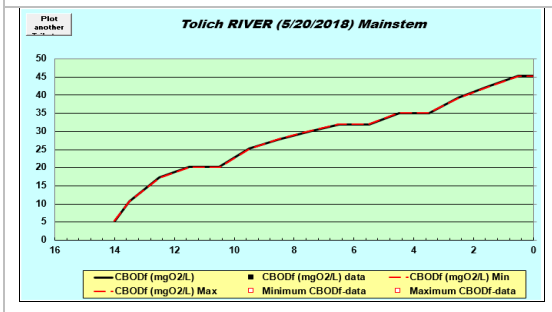

Figure 8. BOD_5 along the river as in SC2.

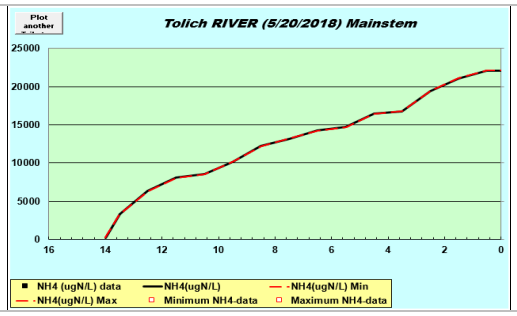

Figure 9. NH_4 –N TSS along the river as in SC2.

It can be seen that:

- Thanks to the replenishment with the volume of 5 m^3/s, the flow rate rises up to 0.3 – 0.7 m/s, which facilitate self-purification of the river.

- TSS reduces to 70 – 90 mg/L. However, TSS still exceeds the column B1 – QCVN 08-MT:2015/BTNMT.

- BOD_5 ranged from 5 – 45 mg/L. The figure still exceeds the column B1 – QCVN 08-MT:2015/BTNMT.

- NH_4-N reaches 0.22 – 23 mg/L. The result does not meet the standard of B1 – QCVN 08:2015/BTNMT.

3.3. Scenario 3 (SC3)

As the master plan of drainage in Ha Noi, the collecting system and centralized wastewater treatment plant, especially Yen Xa Project, will be constructed for the proper of wastewater management to meet the column B of QCTĐHN 02:2014/BTNMT [14]. However, the decentralized discharging points (infrequent sewers with the diameter less than 300 mm along the river) still disposed directly with the daily volume of 10,000 m^3. The forecasted results of river water quality are illustrated in Figures 10, 11, 12 and 13.

It can be seen that:

- Because there is a replenishment of 5 m^3/s from Red River, the flow rate is kept at the rate of 0.3-0.7 m/s as KB2

- Almost wastewater is collected to centralized sewerage treatment plants, the TSS level reduces to 55-75 mg/L; however, the figure still exceeds B1 – QCVN 08-MT:2015/BTNMT.

- BOD_5 ranged from 5 – 23 mg/L (a reduction of 50 % compared to KB1), it is believed to exceed B1 – QCVN 08-MT:2015/BTNMT.

- NH_4 reaches the range of 0.22 – 11 mg/LL, lower than its figure in KB1 and KB2, but greater than B1 – QCVN 08-MT:2015/BTNMT.

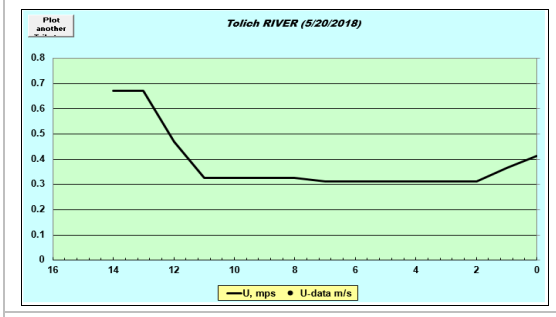

Figure 10. Flow rate as in SC3.

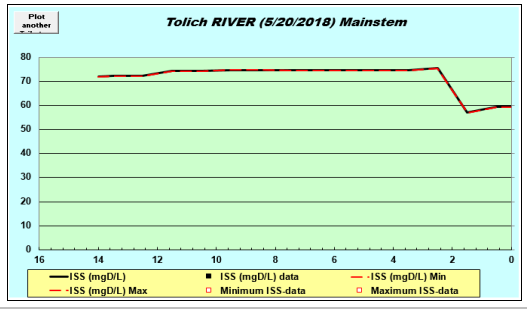

Figure 11. TSS along the river as in SC3.

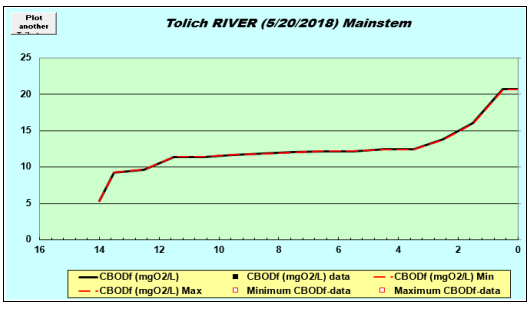

Figure 12. BOD_5 along the river as in SC3.

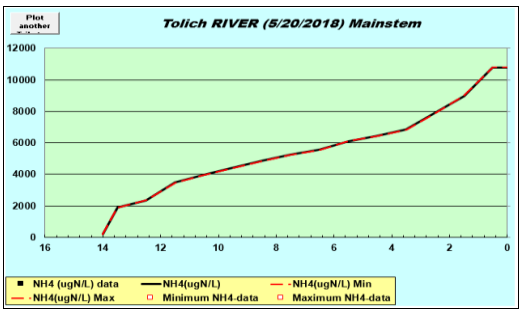

Figure 13. NH_4 –N TSS along the river as in SC3.

3.4. Scenario 4 (SC4)

All wastewater (discharging waste water concentrated or dispersed into Lu and To Lich Rivers) in the basin is collected and treated to level B according to NDT 02: 2014 / BTNMT [14], in which to ensure oxygen regime, BOD_5 must be ≤ 20 mg/L. To Lich River will be supplemented with Red River water Q = 5 m^3/s in the dry season. The calculation results of forecasting the water quality state in To Lich River in this case are shown on Figures 14, 15, 16 and 17. The calculation results of forecasting the water quality state in To Lich River in this case are shown on Figures 14, 15, 16 and 17.

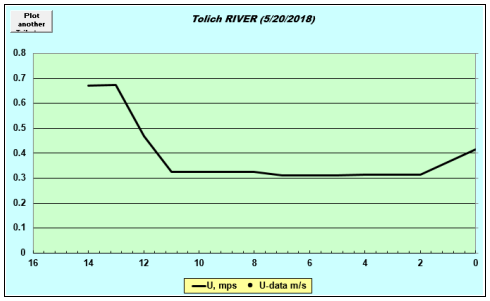

Figure 14. Flow rate as in SC4.

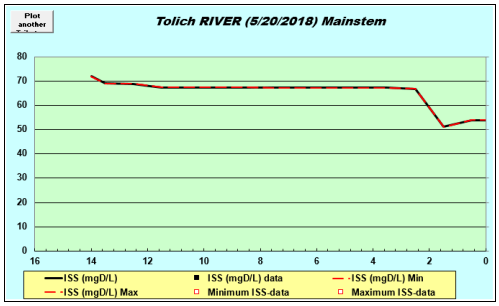

Figure 15. TSS along the river as in SC4.

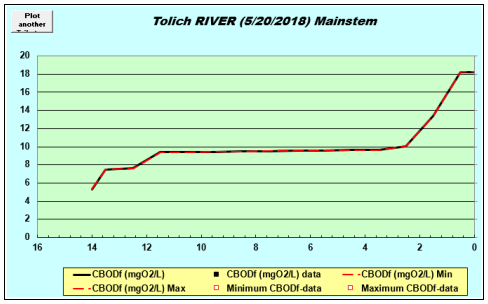

Figure 16. BOD_5 along the river as in SC4.

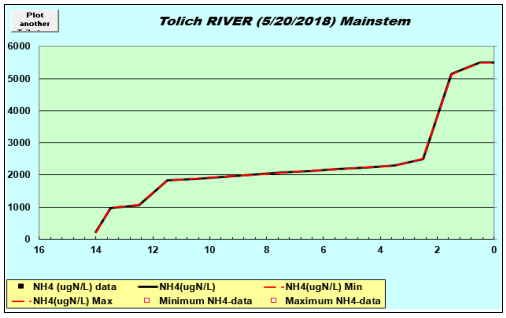

Figure 17. NH_4 –N TSS along the river as in SC4.

Table 2. Summary of river water quality of To Lich River in various scenarios.

Scenario	Content of pollutants, mg/L		
	TSS	BOD_5	NH_4-N
SC1	60 - 100	90 - 110	40 - 45
SC2	70 - 90	5 - 45	0.22 - 23
SC3	55 - 75	5 - 23	0.22 - 11
SC4	50 - 70	5 - 18	0.22 - 5.5

The forecast calculation results according to SC4 show that:

- Due to the pumping of water from the Red River (5 m^3/s), the velocity is almost unchanged compared to SC2 and SC3 (0.3 - 0.7) m/s.

- Compared to SC3, TSS concentrations in river water have decreased (at 50 - 70 mg/L) because decentralized wastewater has been collected and treated. At the end of the river, TSS is approximately B1 - QCVN 08-MT: 2015 / BTNMT.

- BOD_5 content is in the range of 5 - 18 mg/L. The content of BOD_5 along the river has reached B1 level of QCVN 08-MT: 2015 / BTNMT. However, at the end section of the river, due to the water flowing from the Kim Nguu River, BOD_5 content increased beyond B1 level.

- Concentration of NH_4 –N ranges from 0.22 to 5.5 mg/L. N-NH_4 content has decreased but many upstream points still exceed B1 - QCVN 08-MT: 2015 / BTNMT.

4. CONCLUSIONS

After simulating the water quality of To Lich River in the dry season according to different scenarios, it can be seen that:

- The water of To Lich River is now seriously polluted (TSS = 60÷100 mg/L, BOD_5 =, 90÷100 mg/L, NH_4-N = 40-45 mg/L) at level of B2 - QCVN 08-MT: 2015 /BTNMT. At most locations along the river flow, the state of the water quality is typical value of the α-mezosaprobe zone.

- If fresh water from Red River is added Q = 5 m^3/s in the dry season, the pollutants in river water will be diluted. However, the water quality of To Lich River according to TSS, BOD_5 and NH_4-N parameters still exceeds the permitted level B1 of QCVN 08-MT: 2015 / BTNMT.

- In order to ensure in the dry season, the whole river has water quality of B1 level of QCVN 08-MT: 2015 / BTNMT and flow velocity of 0.3 ÷ 0.7 m / s (river ecological flow requirement inner city), all concentrated wastewater sources (discharge points with D > 300 mm) and decentralized (dispersed discharge points with D ≤ 300 mm) need to be collected and treated to level B according to the QCTĐHN 02:2014/BTNMT- Technical regulation on industrial wastewater in Ha Noi Capital, in which BOD_5 must be ≤ 20 mg / L and supplement the fresh water from the Red River Q = 5 m^3/s.

Acknowledgements. The content of this study was funded by Hanoi Department of Science and Technology under the framework of the project: Research on integrated technical solutions to protect the environment of urban water in Ha Noi City (code: 01C-09/01-2016-3).

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