Sources and causes of surface water pollution in Hanoi (Vietnam)

Nguyen Dinh Dap, Valery I. Telichenko, Mikhail Yu. Slesarev

Moscow State University of Civil Engineering (National Research University) (MGSU),
26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation

ABSTRACT

Introduction. One of the most significant environmental problems facing the Vietnamese city of Hanoi is anthropogenic pollution of surface water, especially in the To Lich river system. Currently, these rivers accept large quantities of wastewater from urban areas and industrial zones, which effluents are not treated prior to discharge into water bodies. The results of the study show that surface water in Hanoi has been contaminated by direct discharge of domestic and industrial wastewater. Considered the To Lich river system, including the To Lich, Lu, Set and Kim Nguu rivers, which receive sewage pollution from urban areas, industrial zones and other sources.

Materials and methods. The most common approach to improving the situation is to identify sources of surface water pollution and assess the quality of To Lich river and its tributaries in order to develop and propose effective and synchronous solution for the management of water safety and quality in the water bodies of Hanoi city. The water samples were preserved and analysed in the laboratory of Environmental Analysis in accordance with standard Vietnamese methods. For this purpose, analytic apparatus, including Shimadzu AAS 6800 atomic absorption spectrophotometre (Japan), UV-VIS spectrometre, as well as a number of common laboratory instruments and equipment, are used.

Results. The results of the study show that surface water in Hanoi has been contaminated by direct discharge of domestic and industrial wastewater. For many years, the rivers have been covered with rubbish, with the water turning black in colour and having an unpleasant smell. The primary cause of the pollution is drainage from many surrounding households discharging waste water directly into the rivers.

Conclusions. In order to restore the aqueous ecosystems of Hanoi city, it is necessary to conduct continuous environmental monitoring of changes in the state of water bodies and develop effective and timely solutions for the management of safety and quality of water in the waterways of Hanoi.

KEYWORDS: water pollution, wastewater, wastewater treatment, water quality, To Lich river system, wastewater discharge, water quality index, urban area, industrial wastewater, surface water

FOR CITATION: Nguyen Dinh Dap, Telichenko V.I., Slesarev M.Yu. Sources and causes of surface water pollution in Hanoi (Vietnam). *Vestnik MGSU* [Proceedings of Moscow State University of Civil Engineering]. 2018; 13(10):1234-1242. DOI: 10.22227/1997-0935.2018.10.1234-1242

Источники и причины загрязнения поверхностных вод водоемов в Ханое (Вьетнам)

Нгуен Динь Дап, В.И. Теличенко, М.Ю. Слесарев

Национальный исследовательский Московский государственный строительный университет
(НИУ МГСУ), 129337, г. Москва, Ярославское шоссе, д. 26

АННОТАЦИЯ

Введение. Представлен подход к изучению одной из наиболее острых проблем города Ханой — антропогенного загрязнения воды наземных водных объектов, особенно водных объектов системы реки Толь. В настоящее время эти реки принимают большое количество сточных вод из городских районов, промышленных зон. Результаты исследования показали, что поверхностные воды в г. Ханое загрязнены бытовыми и промышленными сточными водами. Рассмотрены система безопасности и качество воды в водных объектах реки Толь, включающей реки: Толь, Лы, Шет и Кимнгу, в которые сбрасывают бытовые и производственные сточные воды из городских районов, промышленных зон и других источников.

Материалы и методы. Наиболее распространенным подходом к улучшению ситуации являются выявление источников загрязнения поверхностных вод и оценка качества воды реки Толь и впадающих в нее притоков рек для выработки и предложения эффективных и синхронных решений для управления безопасностью и качеством воды в водных объектах города Ханоя. Были отобраны пробы воды и проанализированы в лаборатории экологического анализа в соответствии со стандартными методами Вьетнама. Для проведения анализов использовались атомно-абсорбционная спектрометрия (AAS 680, Япония), UV-VIS спектрометр и некоторые другие приборы, и оборудование аккредитованной лаборатории.

Результаты. Одним из преимуществ рассмотренного подхода является выработка эффективных и синхронных решений для управления безопасностью и качеством воды в водных объектах г. Ханоя. Результаты исследования показали, что поверхностные воды Ханоя загрязнены сбросом бытовых и промышленных сточных вод. В течение длительного времени от реки исходит неприятный запах из-за скопления мусора на поверхности воды. Причиной этому являлся сброс сточных вод из прилегающих населенных пунктов непосредственно в реку.

Выводы. Для восстановления водной экосистемы г. Ханоя необходимо проводить постоянный экологический мониторинг состояния воды рек для разработки эффективных и своевременных решений для управления безопасностью и качеством воды в водных объектах г. Ханоя.

КЛЮЧЕВЫЕ СЛОВА: загрязнение воды, сточные воды, очистка сточных вод, качество воды, система реки То-Лич, сброс сточных вод, индекс качества воды, городской район, промышленные сточные воды, поверхностные воды

ДЛЯ ЦИТИРОВАНИЯ: *Нгуен Динь Дап, Теличенко В.И., Слесарев М.Ю.* Sources and causes of surface water pollution in Hanoi (Vietnam) // Вестник МГСУ. 2018. Т. 13. Вып. 9. С. 1234–1242. DOI: 10.22227/1997-0935.2018.10.1234-1242

INTRODUCTION

Hanoi is the capital city and the socio-economic, political and cultural centre of Vietnam, covering a total area of 3329 km² and comprising a population of 7.7 million people in 2016. The drainage and sewerage systems of Hanoi are very old, with many of the facilities having been built before 1954 [1]. Moreover, over the years these systems have become degraded due to lack of maintenance and having a limited drainage capacity. Moreover, Hanoi has lacked a proper wastewater treatment plant [2]. This state of affairs has resulted in frequent flooding, with serious economic loss and

damage in the urban area as well as deterioration of water quality in the rivers and lakes of the surrounding area, creating a serious problem in the urban environment and hampering economic development activities [3–5].

In recent years, Hanoi's extremely rapid pace of development has caused many serious environmental issues. One of the most worrying problems is water pollution, especially affecting the water of the To Lich river system, including the To Lich, Lu, Set and Kim Nguu rivers (Fig. 1). Currently these rivers are receiving large amounts of untreated residential effluent and wastewater, along with sewage from urban areas and industrial

Fig. 1. River system in central Hanoi

zones, which, although has been partially treated, still contributes to serious pollution problems [6–8].

Confronted with such problems, the rehabilitation of the water system of the To Lich river in Hanoi is becoming a task of increasingly urgency in order to rectify the water pollution, improve the environment, landscape and nature of Hanoi, thus contributing to sustainable development in Vietnam [9].

The statement of the scientific problem, its relevance and connection with the most important tasks to be solved, is a key step in the development of a particular field of science or practical activity. The introduction should include information that will allow a reader to understand and assess the findings of the study presented in the article without additional reference to other literary sources. In the introduction the author also identifies the problems that have not been solved in previous studies and are to be solved in this article. In addition, the introduction expresses the main idea of the publication, which differs significantly from present-day representations of the problem, complements or deepens already known approaches to it; attention is drawn to the introduction of new facts, conclusions, recommendations and regularities in scientific circulation [7, 8, 10]. The purpose of the article follows from the statement of the scientific problem.

Due to industrialisation, increased population and urbanisation of society, the world is increasingly faced by problems related to the management of wastewater (USEPA 1993, McCasland et al, 2008). The wastewater generated from domestic and industrial activities constitute major sources of the water pollution load. This is a great burden in terms of wastewater management and can consequently lead to a point-source pollution problem, which not only increases treatment costs considerably, but also introduces a wide range of chemical pollutants and microbial contaminants into water bodies (USEPA 1993, Eikelboom and Draaijer 1999, Amir et al, 2004) [10, 11].

Wastewaters are discharged to a wide variety of receiving environments: lakes, ponds, streams, rivers,

estuaries and oceans. Wastewater typically contains pollutants of concern since even advanced treatment systems are unable to remove all pollutants and chemicals. Several environmental and health impacts resulting from insufficient wastewater treatment have been identified in the scientific literature (Musmeci et al, 2009, Saracci and Vineis 2007, Rothman and Greenland 1998, and many others); in order to reduce these impacts, actions need to be taken [2, 5].

In societies undergoing urbanisation, like Hanoi city, are dynamic wastewater problems may be assessed both in terms of both quality and quantity. A number of reasons for this have been identified, including population increase (especially from inherently unpredictable immigration and seasonal residents leading to uncertainty in terms of the quantity and quality of wastewater generated), booming construction and a number of industrial zones which have been established in Hanoi over a long period of time. In addition, wastewater treatment has lagged behind other development processes, leading to serious ecological problems especially affecting water bodies, such as rivers. Monitoring and assessment of causes and pollution levels, as well as the identification of pollution sources, should be carried out periodically. This will serve decision makers in issuing environmental regulation to improve wastewater quality at such sources before discharging to the common sewage system [12, 13].

MATERIALS AND METHODS

Study site

The total volume of wastewater from central area of Hanoi in 2016 is approximately 795 000 m³/day, of which the amount of production wastewater is 490 410 m³/day. The amount of industrial wastewater in 2011 is estimated at 100 000 m³/day and only 30 % is handled [2, 3]. In 2016, flow of industrial wastewater from the central area discharging into drainage systems level I is about 117 774 m³/day and service wastewater is 337 136 m³/day. The proportions of different types of

Table. 1. List of manufacturing plants of five industrial zones in basin of To Lich river system [14]

Type of industry	Thuong Dinh-Nguyen Trai	Minh Khai-Vinh Tuy	Thuong Dinh-Duoi Ca	Van Dien-Phap Van	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	—	—
Chemical	2	—	—	2	1
Others	3	3	1	1	—
Total	30	38	13	13	5

wastewater are shown as follows [14]. The proportion of wastewater generated by services is highest, accounting for 47 %; this is followed by production wastewater (36.6 %) and industrial wastewater (14.8 %). Medical wastewater had the lowest rate, contributing only 1.6 % of the total discharge flow [14–16].

There are five industrial zones located in To Lich river system basin, for which no suitable wastewater treatment systems are available (Table 1). Thuong Dinh industrial park consists of 30 manufacturing plants, which have been directly discharging un- and/or partially-treated wastewater to the downstream reaches of the To Lich river. Those plants include: fourteen mechanical plants, four textile plants, three leather industry plants, two chemical industry plants (rubber and soap), two ceramics factories, one tobacco factory, one paper mill and three industrial premises of miscellaneous type. An additional four industrial zones, comprising 69 plants of all types of industries, discharge wastewaters into the Lu, Set and Kim Nguu rivers before entering the To Lich river further downstream (Fig. 2) [14, 17].

Study method

Using the statistical comparison method, string data is used to calculate the results observed over many years compared with the permitted regulation for assessing water quality applying to each type of wastewater.

Applicable regulations for evaluating the quality of wastewater: value column B of industrial wastewater regulations QCVN28:2010/MONRE (Ministry of Nature Resources and Environmental Vietnam); regulation applied for evaluating the quality of industrial wastewater; value column B of Regulation industrial wastewater QCVN40:2011/MONRE; regulations applied to assessing water quality; value column B2 of surface water quality standards QCVN08:2008/MONRE [6].

To study the influence of wastewater from some main factories on water quality for the To Lich river, previous studies of river water quality were collected and synthesised in the research findings. Then field surveying, site selecting and sampling of river water was analysed and compared with industrial wastewater from

Fig. 2. Map of study area showing sampling sites

some major factories. The water samples were preserved and analysed in the Laboratory of Environmental Analysis, Faculty of Environmental Sciences, Hanoi University of Sciences (Vietnam National University) in accordance with the applicable Vietnamese standard methods. Analytic apparatus, including Shimadzu AAS 6800 atomic absorption spectrophotometre (Japan), UV-VIS spectrometre, as well as a number of common laboratory instruments and equipment, were used [6].

RESEARCH RESULTS

Pollution of rivers in Hanoi

River and lake systems in Hanoi city receive millions of cubic metres per day of industrial wastewater, urban wastewater, as well as wastewater from fields and some aquaculture sectors. According to forecasts, the volume of domestic wastewater in Hanoi will increase to 440 934 m³/day in 2020. Thus, in the near future, the risk of water pollution in rivers and lakes in Hanoi will increase rapidly, especially in terms of pollution caused by industrial and domestic wastewater.

The number of craft villages has increased significantly from 1280 in 2010 to 1350 in 2015. Preliminary results of the VESDEC's survey show pollution levels caused by sewage and refuse generated by the villages in Hanoi City has increased over the years. Meanwhile, according to the Hanoi Environmental Protection Department, the reason why the state of the water river in Hanoi has become so seriously polluted is that wastewater is not being properly treated but instead discharged directly into river and lake systems.

To Lich river: this river receives thousands of cubic metres of domestic wastewater every day. The total flow of wastewater discharged into the river is estimated at approximately 382 000 m³/day, of which the amount of domestic waste water is approximately 140 000 m³/day, production waste water is about 236 000 m³/day and medical waste water is about 6000 m³/day (including water drainage direction from downstream of the Lu river) [17].

Kim Nguu river: the total volume of wastewater discharged into the river is estimated at approximately 254 000 m³/day, of which domestic wastewater is approximately 93 000 m³/day, production wastewater is about 157 000 m³/day and medical wastewater is about 4000 m³/day [18].

Set river: the total volume of wastewater discharged into the river is estimated at 101,000 m³/day, of which domestic wastewater is approximately 37 000 m³/day, production wastewater is about 62 000 m³/day and medical wastewater is about 2000 m³/day [18].

Lu river: the total volume of wastewater discharged into the river is estimated at approximately 24 000 m³/day, of which domestic wastewater is approximately 9000 m³/day, production wastewater is about 14 500 m³/day and medical wastewater is about 500 m³/day [18].

Determination of water quality index (WQI) of To Lich river

To Lich river originates from West Lake in North Hanoi, receiving mainly domestic wastewater in the upstream direction and a mix of domestic and industrial wastewater downstream before joining the Nhue river in South Hanoi through Thanh Liet Dam. With the pollution level becoming more and more serious, the To Lich is becoming a "dead river" [1]. According to the monitoring data of the Hanoi Department of Natural Resources and Environment, in the dry season of 2008, concentration of dissolved oxygen is 2.5 times lower than the permitted standard, chemical oxygen demand is 4.2 times the acceptable limit, average levels of ammonia are in excess of 17.3 times the permitted standard, while total coliform is 9550 times higher than the average acceptable standard. Monitoring data from the Hanoi Sewerage and Drainage Company in 2016 presents some information concerning the pollution state of the To Lich river [19]: concentration of BOD₅ exceeds the standard by between 2 and 3.56 times, while the average concentration exceeds the standard by 2.27 times; COD concentration ranges from 96 to 173 mg/l, surpassing the Vietnamese standard by between 1.92 and 3.46 times, while the average concentration of COD is 2.6 times higher than the standard level (Fig. 3).

The condition of the river is anaerobic, with dissolved oxygen concentration ranging from 1.39 to 1.81 mg/l, less than 2 mg/l of the Vietnamese standard — although this is a flexible flow. Ammonium concentration ranges from 24 to 43.1 mg/l, increasing to 43.1 mg/l at Thanh Liet Dam; the average value is 30 times higher than the acceptable standard (Fig. 4).

Determination of water quality index (WQI) based on pollution indicators for each surface water (contaminants including TSS, COD, total N, total P, As and Coliform), according to the formula [20]:

$$WQI_{(i)} = \frac{1}{n} \sum_{i=0}^n \frac{C_i}{C_0} \cdot 100,$$

where: C_i — concentration of parameter i , mg/l; C_0 — maximum permissible concentrations of parameter i ; n — number of parameters.

The calculation of water quality index is used to turn complex water quality data into information that is understandable and useable by the public. Therefore, WQI is a very useful and efficient method which can provide a simple indicator of water quality and it is based on some very important parameters (Table 2) [20, 21].

The WQI of To Lich river was determined according to six main parameters including five physical-chemical parameters (TSS, COD, As, ΣN, ΣP), a biological indicator (Coliform). The result is shown in Table 3.

In 2003, the WQI of To Lich river was 264 and the river state was considered to be heavily polluted. By 2009, the pollution level became very serious with

Fig. 3. Changes of maximum and average concentrations of COD in To Lich river

Fig. 4. Map of water pollution To Lich river (for BOD₅)

Table 2. Water quality index (WQI) level and water quality status (Chatterji and Raziuddin, 2002)

WQI level	Water quality status
0–25	Excellent water quality
26–50	Good water quality
51–75	Poor water quality
76–100	Very poor water quality
100–200	Pollution
200–300	Heavy pollution
> 300	Serious pollution

Table 3. WQI of To Lich river in period 2003–2016

Period	WQI	Water quality
2003	264	Heavy pollution
2009	961	Serious pollution
2012–2013	738	Serious pollution
Dry season of 2016	1013	Serious pollution
Rainy season of 2016	940	Serious pollution

a WQI of 961, 3.6 times higher than in 2003. During the period of 2012–2013, the WQI value decreased compared to 2009; however, the river water was still heavily polluted with a WQI value of 738, which was 2.8 times more than the value during the 2003 dry season [5].

For the dry season in 2016, the WQI value peaked at 1013, the highest number in the statistics, 3.84 times higher than the comparable period in 2003 and 1.37 times higher than the 2012–2013 period. This means that the state of the river water was heavily polluted. During the rainy season in 2016, the level of water pollution of To Lich river has not changed much with a WQI number of 940, which is 1.27 times higher than in 2012–2013.

CONCLUSIONS

The surface water of Hanoi has been contaminated by the direct discharge of domestic and industrial wastewater in large quantities into the water bodies, exceeding the self-cleaning capabilities of the water

bodies. For many years, the rivers have been covered with rubbish, turning the water black and causing a foul odour. Drainage from many surrounding households directly discharges waste water into the rivers, which is the main reason for the pollution.

The To Lich river system receives wastewater from a population of nearly two million people and 100 manufacturers of five industrial zones in inner Hanoi city. The WQI value of To Lich river was 1013 in the dry season and 940 during the rainy season in 2016. The level of water pollution of the To Lich river was very heavily polluted compared to the previous period in 2003–2016. In forecast, the pollution level of To Lich river water continues to increase with no sign of abatement.

The results of the study show that surface water in Hanoi has been contaminated by direct discharge of domestic and industrial wastewater. The study recommends that necessary measures be taken to monitor the changes in the state of river water and proposes some effective and synchronous management solutions for the river systems in Hanoi.

REFERENCES

1. *Statistical Yearbook of Hanoi. Hanoi Planning and Investment Department*. 2013; 124.
2. Nguyen Thi Lan Huong, Ohshubo M., Loreta Y.L., Higashi T., Kanayama M. Assessment of the water quality of two rivers in Hanoi City and its suitability for irrigation water. *Paddy Water Environment*. 2008; 6:257-262.
3. *Report of environmental status of Hanoi, the period 2011–2015*. Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam (MONRE Vietnam). 2015; 133.
4. *The results of environmental monitoring wastewater of the rives inner Hanoi from 2009 to 2013*. Department of Natural Resources and Environment of Hanoi. 2013; 18-24.
5. Nguyen Viet Anh, T.T.H. Hanh, V.T.M. Thanh, Parkinson J., Barriero W. *Decentralised wastewater management — a Hanoi case study*. People-centred approaches to water and environmental sanitation, 30th WEDC International Conference. Vientiane, Lao PDR, 2004; 36-43.
6. Volshanik V.V., Dzhumagulova N.T., Nguyen Dinh Dap, Pham Van Ngoc. Evaluation of environmental quality of surface water in Hanoi city (Vietnam). *Ecology of Urban Areas*. 2017; 1:36-41. (rus.).
7. Pham Thi Thuy Hoan, Ngo Thi Van Anh, Cao Hoang Hai, Le Ngoc Chau, Ha Thi Lien, Le Cong Binh. The current status and solutions for urban water environment in Hanoi city. *Water and Urban Initiative*. 2015; 5:1-7.
8. Report of environmental status of Vietnam, the period 2011–2015. *Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam (MONRE Vietnam)*. 2015; 155.
9. Nguyen Dinh Dap, Volshanik V.V., Dzhumagulova N.T. Hanoi, Vietnam Monitoring of Water Quality's Ecological Status in ToLich River in Hanoi, Vietnam. *Safety in the Technosphere*. 2017; 6(5):9-15. DOI: 10.12737/article_5a8557b5b11699.50260941 (rus.).
10. Nguyen Thi Lan Huong, Ohshubo M., Loreta Y.L., Higashi T. Heavy metals pollution of the To Lich and Kim Nguu in Hanoi city and the Industrial sources of the pollutants. *Journal of the Faculty of Agriculture Kyushu University*. 2007; 52(1):141-146.
11. Nguyen Thi Thuong, Yoneda M., Ikegami M., Takakura M. Source discrimination of heavy metals in sediment and water of To Lich River in Hanoi City using multivariate statistical approaches. *Environmental Monitoring and Assessment*. 2013; 185(10):8065-8075. DOI 10.1007/s10661-013-3155-x
12. Borovkov V.S., Volshanik V.V. Engineering systems of closed pumping water rotation and aeration with ecological reconstruction of the hydrosphere of urbanised territories. *Water and Ecology: problems and solutions*. 2016; 3(67):67-82. (rus.).
13. Nguyen Dinh Dap, Dzhumagulova N.T., Volshanik V.V. Engineering system for maintaining the ecological state of water bodies in the capital of Vietnam, Hanoi. *Integration, partnership and innovations in*

building science and education. Proceedings of international scientific Publ., MISI—MGSU. 2017; 946-953. (rus.).

14. The results of environmental monitoring wastewater of industry zone from 2009 to 2013 in Hanoi. Department of Natural Resources and Environment of Hanoi. 2013; 46-53.

15. Planning for the protection of the environment in Hanoi by 2020 to 2030. *Department of Natural Resources and Environment of Hanoi*. 2012; 86.

16. The results of environmental monitoring wastewater of hospital from 2009 to 2013 in Hanoi. *Department of Natural Resources and Environment of Hanoi*. 2013; 26-35.

17. Slesarev M.Yu., Nguyen Dinh Dap. Forecast of the distribution of pollutants in the river Tolit from the water discharge outlets. *Yakovlev readings Proceedings of XIII International Scientific and Technical Conference, dedicated to the memory of Academician S.V. Yakovleva*. Moscow, MISI—MGSU Publ., 2018; 95-103. (rus.).

18. Nguyen Dinh Dap, Volshanik V.V., Slesarev M.Yu., Dzhumagulova N.T. The content of heavy metals in the river is littered in the central part of Hanoi. *Ecology of Urban Areas*. 2018; 1:35-40. (rus.).

19. Nguyen Dinh Dap, Dzhumagulova N.T., Volshanik V.V. Calculation of the hydrochemical index of water pollution in Hanoi. *Yakovlev readings Proceedings of XIII International Scientific and Technical Conference, dedicated to the memory of Academician S.V. Yakovleva*. Moscow, MISI—MGSU Publ., 2018; 78-84. (rus.).

20. Bordalo A.A., Teixeira R., Wiebe W.J. A water quality index applied to an international shared river basin: The case of the Douro River. *Environmental Management*. 2006; 38(6):910-920. DOI: 10.1007/s00267-004-0037-6

21. Nguyen Thi Thuong, Minoru Yoneda, Yasuto Matsui. Does embankment improve quality of a river? A case study in to Lich river Inner City Hanoi, with special reference to heavy metals. *Journal of Environmental Protection*. 2013; 4(4):361-370. DOI: 10.4236/jep.2013.44043

Received July 5, 2018

Adopted in a modified form on August 27, 2018

Approved for publication September 27, 2018

ABOUT THE AUTHORS: **Nguyen Dinh Dap** — postgraduate student, Department of hydraulics and hydraulic engineering, **Moscow State University of Civil Engineering (National Research University) (MGSU)**, 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation, nguyendinhdap@gmail.com;

Valery I. Telichenko — Doctor of Technical Sciences, Professor, Academician of RAACS, Honored Worker of Science of the Russian Federation, President, **Moscow State University of Civil Engineering (National Research University) (MGSU)**, 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation, president@mgsu.ru;

Mikhail Yu. Slesarev — Doctor of Technical Sciences, Professor of the Department of Construction of Heat and Nuclear Power Facilities, Laureate of the Government of the Russian Federation Education Prize, **Moscow State University of Civil Engineering (National Research University) (MGSU)**, 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation, slesarev_m@mail.ru.

ЛИТЕРАТУРА

1. Statistical Yearbook of Hanoi // Hanoi Planning and Investment Department. 2013. 124 p.

2. Nguyen Thi Lan Huong, Ohtsubo M., Loreta Y.L., Higashi T., Kanayama M. Assessment of the water quality of two rivers in Hanoi City and its suitability for irrigation water // *Paddy Water Environment*. 2008. Vol. 6. Issue 3. Pp. 257–262. DOI: 10.1007/s10333-008-0125-y

3. Report of environmental status of Hanoi, the period 2011–2015 // Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam (MONRE Vietnam). 2015. 133 p.

4. The results of environmental monitoring wastewater of the river inner Hanoi from 2009 to 2013 // Department of Natural Resources and Environment of Hanoi. 2013. Pp. 18–24.

5. Nguyen Viet Anh, T.T.H. Hanh, V.T.M. Thanh, Parkinson J., Barriero W. Decentralised wastewater management – a Hanoi case study // People-centred approaches to water and environmental sanitation, 30th WEDC International Conference. Vientiane, Lao PDR, 2004. Pp. 36–43.

6. Воишаник В.В., Джумагулова Н.Т., Нгуен Динь Дап, Фам Ван Нгок. Оценка экологического состояния поверхностных вод в городе Ханое (Вьетнам) // *Экология урбанизированных территорий*. 2017. № 1. С. 39–44.

7. Pham Thi Thuy Hoan, Ngo Thi Van Anh, Cao Hoang Hai, Le Ngoc Chau, Ha Thi Lien, Le Cong Binh. The current status and solutions for urban water environment in Hanoi city // *Water and Urban Initiative*. 2015. No. 5. Pp. 1–7.

8. Report of environmental status of Vietnam, the period 2011–2015 // Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam (MONRE Vietnam). 2015. 155 p.

9. Нгуен Динь Дап, Волишаник В.В., Джумагулова Н.Т. Мониторинг экологического состояния качества воды в реке Толить в г. Ханое, Вьетнам // Безопасность в техносфере. 2017. Т. 6. № 5. С. 9–15. DOI: 10.12737/article_5a8557b5b11699.50260941

10. Nguyen Thi Lan Huong, Ohshubo M., Loreta Y.L., Higashi T. Heavy metals pollution of the To Lich and Kim Nguu in Hanoi city and the Industrial sources of the pollutants // Journal of the Faculty of Agriculture, Kyushu University. 2007. No. 52 (1). Pp. 141–146.

11. Nguyen Thi Thuong, Yoneda M., Ikegami M., Takakura M. Source discrimination of heavy metals in sediment and water of To Lich river in Hanoi city using multivariate statistical approaches // Environmental Monitoring Assessment. 2013. Vol. 185. Issue 10. Pp. 8065–8075. DOI 10.1007/s10661-013-3155-x

12. Боровков В.С., Волишаник В.В. Инженерные системы замкнутого насосного водооборота и аэрации при экологической реконструкции гидросферы урбанизированных территорий // Вода и Экология: проблемы и решения. 2016. № 3 (67). С. 67–82.

13. Нгуен Динь Дап, Джумагулова Н.Т., Волишаник В.В. Инженерная система поддержания экологического состояния водных объектов столицы Вьетнама Ханоя // Интеграция, партнерство и инновации в строительной науке и образовании : сб. докл. Междунар. науч. конф. М. : Изд. МИСИ–МГСУ. 2017. С. 946–953.

14. The results of environmental monitoring wastewater of industry zone from 2009 to 2013 in Hanoi // Department of Natural Resources and Environment of Hanoi. 2013. Pp. 46–53.

15. Planning for the protection of the environment in Hanoi by 2020 to 2030 // Department of Natural Resources and Environment of Hanoi. 2012. 86 p.

16. The results of environmental monitoring wastewater of hospital from 2009 to 2013 in Hanoi // Department of Natural Resources and Environment of Hanoi. 2013. Pp. 26–35.

17. Слесарев М.Ю., Нгуен Динь Дап. Прогноз распространения загрязняющих веществ в реке Толить от створов водовыпусков // Яковлевские чтения : сб. докл. XIII Междунар. науч.-техн. конф., посвящ. памяти академика РАН С.В. Яковлева. М. : МИСИ–МГСУ, 2018. С. 95–103.

18. Нгуен Динь Дап, Волишаник В.В., Слесарев М.Ю., Джумагулова Н.Т. Содержание тяжелых металлов в реке Толить в центральной части г. Ханоя // Экология урбанизированных территорий. 2018. № 1. С. 35–40.

19. Нгуен Динь Дап, Джумагулова Н.Т., Волишаник В.В. Расчет гидрохимического индекса загрязнения воды в Ханое // Яковлевские чтения : сб. докл. XII Междунар. науч.-техн. конф., посвящ. памяти академика РАН С.В. Яковлева. М. : МИСИ–МГСУ. 2017. С. 78–84.

20. Bordalo A.A., Teixeira R., Wiebe W.J. A water quality index applied to an international shared river basin: The case of the Douro River // Environmental Management. 2006. Vol. 38. Issue 6. Pp. 910–920. DOI: 10.1007/s00267-004-0037-6

21. Nguyen Thi Thuong, Minoru Yoneda, Yasuto Matsui. Does embankment improve quality of a river? A case study in to Lich river Inner City Hanoi, with special reference to heavy metals // Journal of Environmental Protection. 2013. Vol. 4. Issue 4. Pp. 361–370. DOI: 10.4236/jep.2013.44043

Поступила в редакцию 5 июля 2018 г.

Принята в доработанном виде 27 августа 2018 г.

Одобрена для публикации 27 сентября 2018 г.

ОБ АВТОРАХ: Нгуен Динь Дап — аспирант кафедры гидравлики и гидротехнического строительства, Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ), 129337, г. Москва, Ярославское шоссе, д. 26, nguyendinhdap@gmail.com;

Теличенко Валерий Иванович — доктор технических наук, профессор, академик РААСН, заслуженный деятель науки Российской Федерации, президент, Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ), 129337, г. Москва, Ярославское шоссе, д. 26, president@mgisu.ru;

Слесарев Михаил Юрьевич — доктор технических наук, профессор кафедры строительства объектов тепловой и атомной энергетики, лауреат премии Правительства Российской Федерации в области образования, Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ), 129337, г. Москва, Ярославское шоссе, д. 26, slesarev_m@mail.ru.