Raw Water Quality Assessment for Improvement Plan at Thu Duc Water Treatment Plant, Vietnam

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A conventional water treatment process is currently operated at Thu Duc Water Treatment Plant (TDWTP, Ho Chi Minh City, Vietnam) in which raw water is collected from Dong Nai River at Hoa An water intake and pumping station. The raw water quality is currently fluctuated due to the effects of run-off flows which has been increasing recently. This issue directly affects the operation and performance of existing treatment process at TDWTP since the current treatment are all based on traditional technologies and have been operating for a long time. This study is conducted to evaluate the quality of raw water collected at Hoa An intake station during the period of 2018–2020 with the aim to support the consideration of improvement and enhance the operation efficiency at TDWTP. The raw water quality is evaluated by investigating physico-chemical and biological parameters during the 36 months monitoring. This helps to produce a feasible and reliable results which may then can be used as a scientific database for the improvement plan at TDWTP. Results show that the changes of water quality during the investigated time is so complicated, and the concentration of most monitoring parameters is highly seasonal fluctuated. Specifically, the amounts of organic matters, microorganism, nitrogen compounds (NH_4^+, NO_2^-, NO_3^-) tend to increase strongly, which may be due to the urbanization and industrialization. The management of run-off flows on upstream of water intake and pumping station is also an important aspect which need to be considered to prevent the diffusion and spread of pollution. In addition, the effects of climate changes are the important reason which leads to the seasonal changes of flow and water quality. These issues cause a big challenge for TDWTP to maintain the treatment efficiency and overall performance. This study also proposes several management and technical solutions to address the changes of raw water quality in the future, which may be useful for TDWTP during their consideration to improve the treatment process.

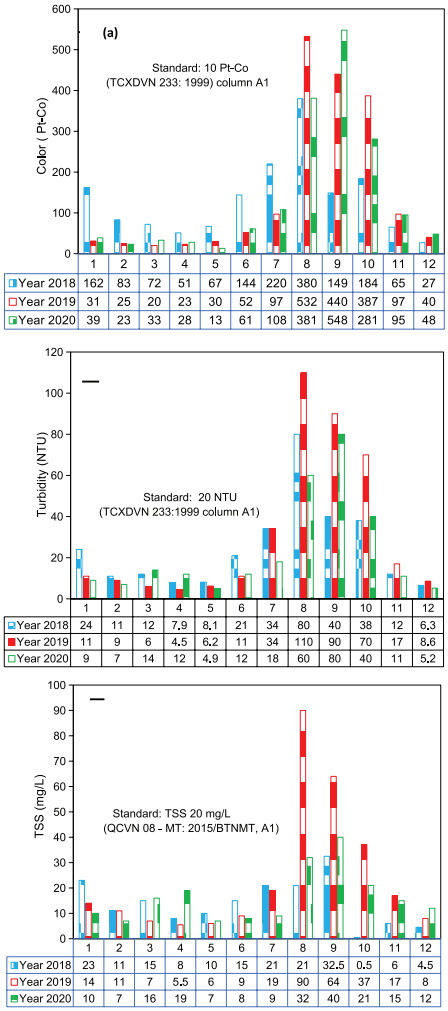
Keywords: *water intake, monitoring, run-off flow, organic matter, water treatment process, Thu Duc Water Treatment Plant, Vietnam*

1. Introduction

Thu Duc Water Treatment Plant (TDWTP) is the main water supply source of Ho Chi Minh City (HCMC, Vietnam). It is also the oldest and largest water plant, which belongs to Saigon Water Corporation (SAWACO) – the overall management agency of the HCMC water supply system. Since the inauguration in 1966 with the initial capacity of 450,000 m^3/day, TDWTP is now operated with the total capacity expanded to 750,000 m^3/day to supply clean water for urban districts of HCMC (SAWACO, 2018). A conventional water treatment process is currently operated at TDWTP, in which raw water is collected from the Dong Nai River, the upstream of Sai Gon River, at the water intake and pumping station located in Hoa An ward, Dong Nai province. The current treatment system just focuses on the removal of common pollutants, such as turbidity, colour, microorganisms by using traditional processes including coagulation-flocculation, sedimentation, rapid sand filtration, and disinfection, to produce clean water and satisfy the national standard (i.e., Standard No. QCVN 01-1:2018/MOH issued by The Ministry of Health in 2018 (MOH 2018)).

According to the periodic monitoring report conducted by SAWACO for the period of 2017–2018, the pollution of raw water at the intake stations is increasing due to the effects of run-off flows (SAWACO, 2018). This issue directly affects the operation and performance of existing treatment process at TDWTP. Specifically, surface water collected from Saigon and Dong Nai River is contaminated by organic matter, microorganisms, which causes low dissolved oxygen (DO) concentration. Furthermore, the residuals of antibiotics, fertilizer, pesticides are also found. The presence of these pollutants significantly influences the assurance of output water quality at TDWTP, because the current treatment processes are all designed and built based on traditional technologies and have been operating for a long time. Moreover, the increase of organic matter concentration in raw water sources leads to considerable risks of disinfection by-products (DBPs) formation during the chlorination at TDWTP. Thus, an assessment of raw water at Hoa An water intake and pumping station should be carried out.

This study is conducted to evaluate the quality of raw water collected at Hoa An intake station during the period of 2018–2020 with the aim to support SAWACO during their consideration to improve the operation efficiency at TDWTP. The raw water quality is evaluated by investigating physico-chemical and biological parameters during the 36 months monitoring. The results and findings obtained from this study can be used as a scientific basis for SAWACO and TDWTP in the control, assessment, and assurance of water quality before transfer to the distribution system. Furthermore, the topic can be applied to develop water quality indicators (WQC) and improve the management capacity at TDWTP. In addition, this study may help local authorities in forecasting the negative effects of the changes



	1	2	3	4	5	6	7	8	9	10	11	12
Year 2018	162	83	72	51	67	144	220	380	149	184	65	27
Year 2019	31	25	20	23	30	52	97	532	440	387	97	40
Year 2020	39	23	33	28	13	61	108	381	548	281	95	48

	1	2	3	4	5	6	7	8	9	10	11	12
Year 2018	24	11	12	7,9	8,1	21	34	80	40	38	12	6,3
Year 2019	11	9	6	4,5	6,2	11	34	110	90	70	17	8,6
Year 2020	9	7	14	12	4,9	12	18	60	80	40	11	5,2

	1	2	3	4	5	6	7	8	9	10	11	12
Year 2018	23	11	15	8	10	15	21	21	32,5	0,5	6	4,5
Year 2019	14	11	7	5,5	6	9	19	90	64	37	17	8
Year 2020	10	7	16	19	7	8	9	32	40	21	15	12

Fig. 1. The change of (a) colour, (b) turbidity, and (c) TSS (Total Suspended Solids) in raw water by time
Rys. 1. Zmiana (a) koloru, (b) zmętnienia i (c) TSS (suma cząstek zawieszonych) w wodzie surowej w czasie

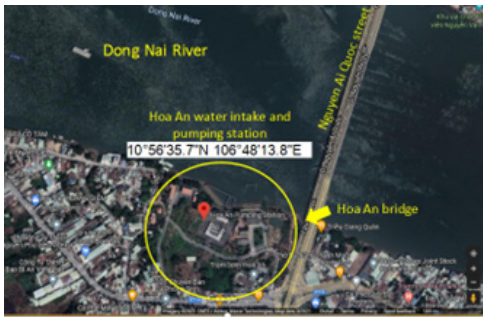


Fig. 1. Location of Hoa An Water intake and Pumping Station
Rys. 1. Lokalizacja ujęcia i przepompowni Hoa An

or fluctuation of raw water quality due to environmental pollution, which then arise awareness, behaviour, and specific activities to control waste discharge into raw water source areas.

2. Material and methods

2.1. Water samples collection

Raw water samples are collected from the Hoa An water intake and pumping station of TDWTP (10.94364, 106.80383) (Fig.1). During the raw water collection stage, composite sampling method is follow to obtain the representative water samples and the experimental water samples are produced from mixed samples. The sampling is taken at a specific time when the pumping station is operating at the average daily flow rate. Parameters, such as pH, DO are measured on-site by using water monitoring system (HACH, 85490 BASIC01).

Afterwards, all samples are preserved properly and transferred immediately to the research laboratory at Ton Duc Thang University (TDTU, Ho Chi Minh City, Vietnam). All samples before analysis are preserved according to the standard methods (APHA, 2005). The physical and chemical parameters are then analysed and measured under laboratory conditions. The properties of water samples are then characterized by physico-chemical parameters (i.e., colour, turbidity, TSS (Total Suspended Solids), N-based compounds, PO_4^{3-}, BOD, COD) and Coliforms.

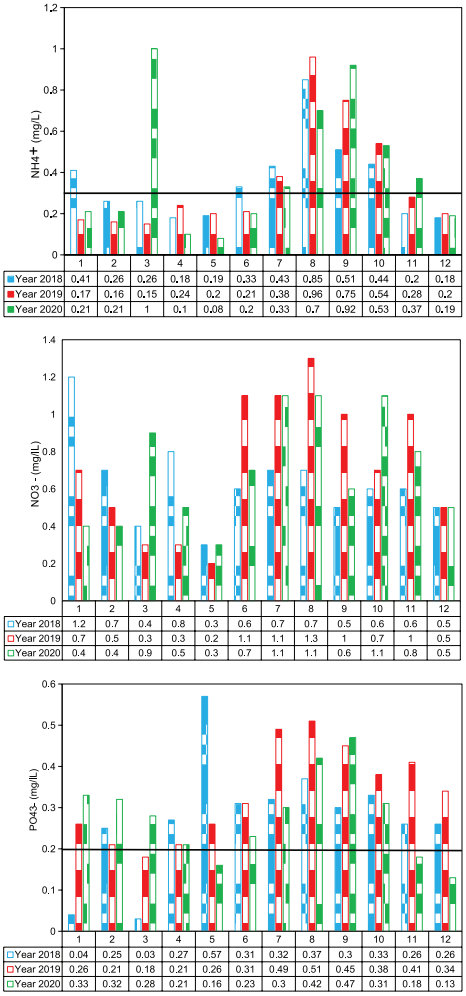


Fig. 1. The change of (a) colour, (b) turbidity, and (c) TSS (Total Suspended Solids) in raw water by time
Rys. 1. Zmiana (a) koloru, (b) zmętnienia i (c) TSS (suma cząstek zawieszonych) w wodzie surowej w czasie

2.2. Analytical methods

The physical and chemical parameters are analysed and measured under laboratory conditions and performed in triplicate. The results are obtained as the average values. Specifically, turbidity is measured by using a turbidity meter (Model: HACH 2100 Q). Colour, N-based compounds, PO_4^{3-} are analysed based on the standard methods (APHA, 2005) using UV-VIS Spectrophotometer (Model: Hach DR-6000, USA). TSS is measured by using Vacuum mini-pump (Model: N022AN18, Germany) and Laboratory furnace (Model: L15/11, Germany). Coliform is measured by 3M™ Petrifilm™ E. coli/Coliform Count Plate. BOD5 is measured by using Laboratory Research Grade Benchtop DO and BOD Meter (Model: Hanna HI5421-02). Soluble COD measurement was based on the Closed Reflux, Titrimetric method (APHA, 2005). All chemicals and reagents used during the analysis and measurement are analytical grade.

Previous monitoring data obtained from SAWACO and TDWTP is used as a database during the analysis and assessment of water quality. National technical regulation on surface water quality (i.e., QCVN 08:2008/BTNTMT, TCXDVN 233:1999 (MOC 1999)) issued by the Ministry of Natural Resources and Environment and Ministry of Construction (Vietnam) is also used as a reference to assess the water quality.

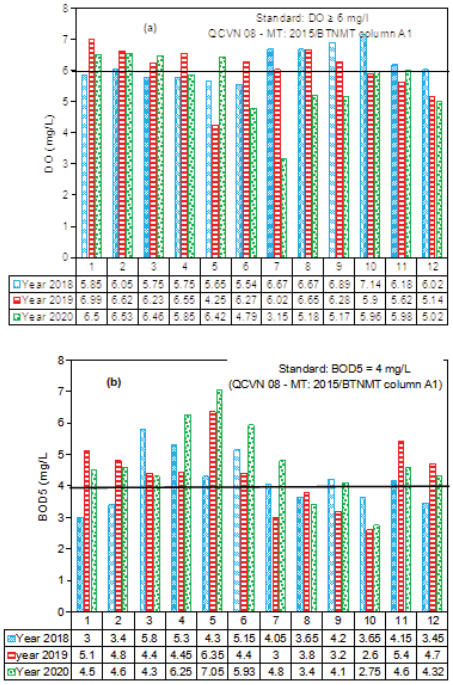
3. Results and Discussion

3.1. Assessment of water quality based on group of parameters

3.1.1. Colour, turbidity, and TSS

Physical parameters including colour, turbidity, and TSS in raw water were assessed simultaneously since they all reflect the transparency and aesthetics of water under visual observation. The variation of these parameter by time during the investigated period of 2018–2020 is shown in Fig. 1a, 1b, and 1c. Results showed that the colour, turbidity and TSS of raw water increased sharply in the rainy season months. In the southern region of Vietnam, the rainy season often occurs from July to October each year. Accordingly, the colour, turbidity, and TSS concentration as measured were 2–3 times higher than that regulated by national standard QCVN 08 – MT: 2015/BTNMT and TCXDVN 233:1999. In contrast, during the dry season months (i.e., from November to April), the value was so low and satisfied the standards. This can be explained that during the rainy season, the water quality is effected by run-off flow which normally brings silt and sediment, causing the colour, turbidity, and TSS in the raw water at the pumping station increase.

Fig. 1 also indicates that this issue occurs regularly every year since the same trend was found during 3 investigated years (2018–2020). Therefore, this helps the local authorities and TDWTP have a proper plan for management and operation of water treatment process. Specifically, the chemical used for co-



	1	2	3	4	5	6	7	8	9	10	11	12
Year 2018	5.85	6.05	5.75	5.75	5.65	5.54	6.67	6.67	6.89	7.14	6.18	6.02
Year 2019	6.99	6.62	6.23	6.55	4.25	6.27	6.02	6.65	6.28	5.9	5.62	5.14
Year 2020	6.5	6.53	6.46	5.85	6.42	4.79	3.15	5.18	5.17	5.96	5.98	5.02

	1	2	3	4	5	6	7	8	9	10	11	12
Year 2018	3	3.4	5.8	5.3	4.3	5.15	4.05	3.65	4.2	3.65	4.15	3.45
year 2019	5.1	4.8	4.4	4.45	6.35	4.4	3	3.8	3.2	2.6	5.4	4.7
Year 2020	4.5	4.6	4.3	6.25	7.05	5.93	4.8	3.4	4.1	2.75	4.6	4.32

Fig. 3. The change of (a) DO and (b) BOD5 concentration in raw water by time
Rys. 3. Zmiana zawartości (a) DO and (b) BOD5 w wodzie świeżej w czasie

agulation – flocculation during the rainy season should be higher than that used during the dry days. The frequency of backwashing in filtration tanks should also be increased to ensure the capacity of filter media and quality of water output during the rainy season. In addition, the sludge withdraw cycle from sedimentation tanks is also considered due to the high loading of suspended solid occurring in raw water.

3.1.2. N-based compounds and PO_4^{3-}

The change of N-based compounds and PO_4^{3-} concentration by time during the investigated period is presented in Fig.2.

As compared to physical parameters, similar trend was found in the case of NH_4^+ as the concentration exceeding the allowable level of the national standard occurred mostly in rainy months (i.e., from July to October). Due to the aerobic condition, NO_3^- compound was rapidly formed, however, the NO_3^- concentration was in the allowable range according to the QCVN 08 – MT : 2015/BTNMT (i.e., < 2 mg/L). In term of PO_4^{3-}, Fig.2 indicates the concern that needs the much attention since the PO_4^{3-} concentration was higher than the regulated level (i.e., 0.2 mg/L) in most of the monitoring months.

Surface run-off contamination due to domestic activities may be the reason to explain the pollution of NH_4^+ and PO_4^{3-}. This issue raises a concern considerably since the current water treatment process is not designed and operated for removal of N and P. Therefore, a surface water quality monitoring plan for nutrient contamination, especially at the area of raw water intake, should be done to forecast the possibility of pollution.

3.1.3. DO and BOD_5

Fig. 3a shows the changes of DO concentration at different monitoring time. As a result, the DO concentration in 2018 was relatively stable and indicate a good quality of surface water according to the national standard QCVN 08 - MT: 2015 / BTNMT (≥ 6 mg/l). Specifically, DO concentration was high in rainy days (from July to October), which may due to the increase of O_2 diffusion from the air. In 2019–2020, the DO concentration decreased, especially in July 2020, the DO concentration was 3.15 mg/L which was much lower as compared to the standard. The surface water pollution may be the reason since there are many industrial and production zones in this area, and the discharge into the river may affect water quality. In addition, wastewater from human activities and waterway traffic can be also the cause of pollution variables.

Monitoring data of BOD_5 (Fig. 3b) confirm the above statement since high BOD_5 concentration was mostly found when low DO concentration occurred (e.g., from April to July, 2020). High concentration of BOD_5 indicates organic contamination of water and the microorganisms consume more oxygen to degrade the organic matters. It was found that this pollution issue occurred regularly during the dry months which may cause negative impacts on water quality. Therefore further study should be carried out to find out the solution to mitigate the effects of water pollution during dry season which helps to reduce the fluctuation of raw water quality pumped to the TDWTP.

3.1.4. Coliform

In term of Coliform, results showed that this parameter were very high and exceeded QCVN 08 - MT: 2015/ BTNMT (column A1) many times during the period of 2018–2020. The reason came from active urine, domestic wastewater, and dead bodies floating in the river. Water sources heavily contaminated with Coliform need a priority treatment to ensure the health of public users. On the other hand, the current treatment of Coliform is now just based on chlorination - the common method used widely in most water treatment plants in Vietnam (MOC 2006). The more microbiological contamination, the more chlorine chemicals used during the disinfection. This lead to another concern which is related to the risk of disinfection by-products (DBP) formation

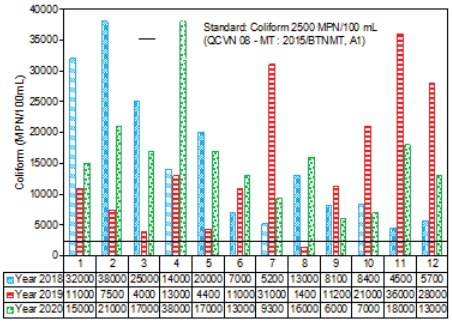


Fig. 3a. The change of Coliform in raw water by time
Rys. 3a. Zmiana miana Coli w wodzie surowej w czasie

Tab. 1. Water exploitation capacity toward 2025
Tab. 1. Możliwości eksploatacyjne wód do 2025 roku

No.	Water sources	Water exploitation capacity toward 2025 (m^3/day)
1	Dong Nai river	1,650,000
2	Tri An lake	1,000,000
3	Sai Gon river	600,000
4	Dau Tieng Lake	1,000,000
5	Groundwater	40,000
6	Small sources	7,000
Total		**4,298,000 m^3/day**

from the reaction of chlorine and organic matter existing in the raw water. Thus, the treatment system at the TDWTP should be upgraded to ensure good water quality to the consumers.

3.2. Issues of concern for water quality

During the 3-years of monitoring for water quality assessment at the TDWTP, some issues of concern for water quality was also recognized as following.

(i) The increase of surface water pollution was mostly due to inadequate control of discharge sources from industrial manufacturing, agricultural activities, and domestic wastes.

(ii) The water quality tends to deteriorate in which the occurrence and increase in concentration of organic matter, pathogen, NH_4^+, Mn^{2+} were considerable, especially in the case of Saigon River.

(iii) The flow fluctuated seasonally and was affected by climate change which led to the possibility of a sharp decrease in water level and saline intrusion at some times in the dry season.

(iv) The forecast results shows that by 2025, problems of organic pollution, saline intrusion and river water level fluctuations will have great impacts on exploitation, production and supply of clean water in Ho Chi Minh City. These are major challenges for Ho Chi Minh City's clean water supply system, requiring the preparation of technical solutions and strong resources to cope with these challenges.

3.3. Proposed solutions to TDWTP

3.3.1. Plan of mitigation of water pollution in Dong Nai river, orientation towards 2025

Since the water intake and pumping station is located in Dong Nai province, the raw water quality is thus partially controlled by Dong Nai government. At present, Dong Nai province has planned and carried out several projects to conserve the water quality, such as installation a surface water monitoring system, upgrading the urban water drainage and wastewater treatment systems, building an industrial park wastewater treatment station and effective control of discharge sources from industrial production.

Regarding the monitoring network, in the period of 2020–2025, Dong Nai will have more than 340 constructions, stations and locations for water monitoring in rivers, lakes, streams and canals. In which, there are 169 locations of flow quality monitoring and 127 groundwater monitoring stations in 9 districts and 2 cities. This will be an effective system to help the agencies control water quality parameters, and forecast risks promptly for further solutions.

In addition, Dong Nai province has invested in many domestic wastewater treatment works and drainage systems in several districts and cities, such as Bien Hoa and Long Khanh urban wastewater treatment plants. The drainage and flood control system are also carried out.

For industrial wastewater sources, in order to strengthen the inspection, monitoring and monitoring of the wastewater treatment situation, Dong Nai province has approved the investment project to install automatic wastewater monitoring system and surveillance camera since 2013. Up to now, 25/31 industrial parks have completed the installation and put into operation the automatic monitoring system and transmitted data directly to the Department of Natural Resources and Environment. It is expected that at the beginning of 2022, there will be 3 areas with automatic wastewater monitoring systems installed. In addition, manufacturers outside of industrial zones and clusters with large capacity of wastewater generation must also install automatic monitoring systems and transmit data to the Department of Natural Resources and Environment as the supervision.

3.3.2. Plan of alternatives raw water sources

In order to reduce the dependence on the current raw water sources as Dong Nai river, several expansion projects are proposed by SAWACO toward 2025. Specifically, there will be more water sources and intake stations with different exploitation capacity which is presented in Table 1.

3.3.3. Technical solutions for operation at TDWTP

Due to the fluctuations of water quality, proper changes in operation at TDWTP is essential to ensure the output water quality. Changes in chemicals used during the water treatment, for instance, is both feasible and economically option. Specifically in the flocculation stage, only PAC is currently employed for treatment. Therefore, alum as $Al_2(SO_4)_3$ and ferric chloride ($FeCl_3$) should also be studied to consider the effectiveness of treatment. In addition, in order to enhance the flocculation process, it is necessary to add polymeric compounds, such as polyacrylamide (PAM) to increase the settling rate. The use of flocculant will reduce the dose of coagulant, contributing to reducing chemical costs while ensuring treatment efficiency.

4. Conclusions

This study conducted the assessment of water quality in Dong Nai river at Hoa An pumping station in the period of 2018–2020. Results showed that the water quality fluctuated in a progressively worse direction, which is clearly demonstrated by the changes in concentration of color, turbidity, TSS, DO, BOD_5, N-based compunds, PO_4^{3-}, and Coliform. Due to the continuous development of urbanization in Ho Chi Minh City, leading to an increasing demand for domestic water of consumers, the water supply system needs to be gradually expanding and upgrading. Therefore, the management and monitoring of raw water quality should be tightened and more modern monitoring equipment should be applied. The results and finding obtained in this study may help local agencies and TDWTP to propose an appropriate and comprehensive plan to cope with the changes of raw water quality with the aim to ensure the clean water quality before pumping to the distribution system.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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Ocena jakości wody surowej na potrzeby planu poprawy w stacji uzdatniania wody Thu Duc w Wietnamie

Konwencjonalny proces uzdatniania wody jest obecnie prowadzony w zakładzie uzdatniania wody Thu Duc (TDWTP, miasto Ho Chi Minh, Wietnam), w którym surowa woda jest pobierana z rzeki Dong Nai i z przepompowni Hoa An. Jakość wody surowej podlega obecnie wahaniom ze względu na skutki spływów, które ostatnio nasilają się. Kwestia ta ma bezpośredni wpływ na funkcjonowanie i wydajność istniejących procesów oczyszczania w TDWTP, gdyż wszystkie obecne działające oczyszczalnie oparte są na tradycyjnych technologiach i działają od dłuższego czasu. Niniejsze badanie ma na celu ocenę jakości wody surowej pobieranej ze stacji poboru Hoa An w latach 2018–2020 w celu wsparcia rozważań nad poprawą i zwiększeniem efektywności działania TDWTP.

Jakość wody surowej oceniana jest poprzez badanie parametrów fizykochemicznych i biologicznych podczas 36-miesięcznego monitoringu. Pozwoliło to uzyskanie wiarygodnych wyników, które następnie mogą być wykorzystane jako naukowa baza danych dla planu modernizacji TDWTP. Wyniki pokazują, że zmiany jakości wody w badanym okresie są bardzo złożone, a stężenia większości parametrów monitoringu podlegają dużym wahaniom sezonowym. Szczególnie silnie wzrastają ilości materii organicznej, mikroorganizmów, związków azotu (NH_4^+, NO_2^-, NO_3^-), co może być spowodowane urbanizacją i uprzemysłowieniem. Ważnym aspektem, który należy wziąć pod uwagę, aby zapobiec rozprzestrzenianiu się zanieczyszczeń, jest również zarządzanie przepływami odpływowymi przed ujęciem wody i przepompownią. Ponadto skutki zmian klimatu są ważną przyczyną sezonowych zmian przepływu i jakości wody. Kwestie te stanowią duże wyzwanie dla TDWTP, aby utrzymać skuteczność oczyszczania i ogólną wydajność. W niniejszym opracowaniu zaproponowano również kilka rozwiązań w zakresie zarządzania i rozwiązań technicznych mających na celu zajęcie się zmianami jakości wody surowej w przyszłości, które mogą być przydatne dla TDWTP podczas rozważań nad poprawą procesu oczyszczania.

Słowa kluczowe: *pobór wody, monitoring, odpływ, materia organiczna, proces uzdatniania wody, zakład uzdatniania wody Thu Duc (miasto Ho Chi Minh, Wietnam)*