Al-Nahrain Journal of Science
ANJS, Vol.27 (2), June, 2024, pp 20-27

Study of the Impact of High Temperature of Cooling Water and Hydrocarbon Waste Discharged from Musayyib Thermal Station to the Euphrates River Using Remote Sensing Stations

Shams Aws Ismael[1], Omar Abdul Majeed[2], Evon Akram[3], Ahmed Aqeel[4,*], Munaf S. Majeed[2], Salam Mohammed[5]

[1]Department of Chemistry, College of Science, University of Baghdad, Baghdad, Iraq
.[2]Department of Biomass Energy, Al-Nahrain Renewable Energy Research Center, Al-Nahrain University, Jadiriya, Baghdad, Iraq
[3]Forensic DNA Center for Research and Training, Al-Nahrain University, Jadiriya, Baghdad, Iraq.
[4]Ministry of Environment, Baghdad, Iraq
[5]Department of Chemical and Petrochemical Engineering, College of Engineering and Architecture, University of Nizwa, Oman

Articles Information

Received: 07.04.2024
Accepted: 13.05.2024
Published:15.06.2024

Keywords:
Musayyib Pollution Station
Water
Waste discharge
Remote sensing

Abstract

The spread of industrial activities, especially electrical power generation stations on the banks of rivers, increases the pollution of the surrounding water environment as a result of the release of industrial water that is not treated adequately. Among these stations is the Al-Musayyib Thermal Power Station. The research focused on studying the quality of the water entering and leaving the station by installing two sensing stations. Remote monitoring of the Euphrates River, as the station contains several sensors, including measuring acidity, dissolved oxygen, turbidity, and the amount of total salts, in addition to a sensor for measuring refined fuel. These results are collected around the clock at a central station, where the results showed a decrease in the level of dissolved oxygen ranging between (3.5-5) RSD% 0.1-0.2 as well as an increase in The temperature of the excreted water ranging between from (30C°-33C°) RSD% 0.1-0.2, both of which negatively affect the environmental life of living organisms, as well as the appearance of a high percentage of pollutants resulting from refined fuel, ranging between (2.1-8.1) ppm, The findings will contribute to improving the efficiency of treatment plants to suit the environment surrounding the river, In order to preserve the water environment, it is necessary to place oil dispensers in the treatment units, as well as work to reduce the temperatures of the cooling water, which are at temperatures higher than the medical grades coming out of the station.

http://doi.org/10.22401/ANJS.27.2.03

*Corresponding author: ahmedlarayacf@gmail.com

1. Introduction

Al-Musayyib Thermal Power Station is located on the banks of the Euphrates River, south of Baghdad, 65 kilometers in the Al-Musayyib District in Babil Governorate. It consists of four units constructed by the South Korean Hyundai Company [1], which rely on running them on steam using crude oil as a fuel. It is known that electrical power production stations are considered among the main sources of environmental pollution [2], which include air pollution resulting from the emission of gases resulting from the combustion of crude oil, soil pollution resulting from spills of crude oil and basic oils, in addition to water pollution resulting from the turbine cooling system and materials resulting from the washing operations of steam boilers and oil spills [3].

1.1. Water Pollution
It is possible to describe the change in the physical or chemical properties of water as water pollution, which negatively affects the life of living organisms, including humans, animals, and plants [4]. This pollution may be natural, resulting from high temperatures or the eruption of volcanoes, leading to high salinity and an increase in suspended materials. As for unnatural pollution, which often results in a change in chemical properties [5], which causes untreated wastewater, or treatment methods may be inefficient, as well as pollution resulting from oil waste caused by industrial facilities that operate with crude fuel [6], operations to extract crude oil from the depths of the sea, and pollution resulting from the use of chemical fertilizers in agriculture. The water may contain suspended organic or inorganic substances, in addition to the presence of algae and fungi in the water that leads to its pollution, and the mixing of rainwater with gaseous pollutants leads to rain loaded with pollutants [7].

1.2. Oil pollution
Oil pollution is distributed to all forms of human life, marine, and terrestrial organisms, birds, and plants [8], and leads to the death and extinction of millions of marine organisms of all races, types, and sizes, which leads to disruption in all navigational services and destroys tourism by polluting the waters and beaches and a significant decrease in fish productivity as well as damage [9]. It causes a large number of birds and shows serious damage that reaches the human food chain, as organic petroleum compounds are stored in the livers and fats of many marine and river animals and reach humans through the food chain [10].

1.3. Pollution resulting from cooling water
The condensers are cooled by using a one-time cooling water system from the river through river water pumping and inlet machines [11], as well as through the river water inlet and pumping channel. River water is also used to produce MD (Membrane Distillation) water at the desalination site [12]. The high-temperature water coming out of cooling kills larvae, fish eggs, and microorganisms, thus threatening the natural environment [13].

1.4. PH mater
A function that measures the dynamic ability to lose or gain hydrogen ions of a solvent system [14]. The pH meter is a scientific instrument that measures hydrogen ion activity in water-based solutions, indicating their acidity or alkalinity, expressed as a pH [0-14]. A pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, so the pH meter is sometimes referred to as a "potential pH meter" [15]. The difference in electrical potential is related to the pH of the solution. The pH meter is used in many applications (16), from laboratory experiments to water quality monitoring, which range from 6.5-7 and table 3.1 shows the average pH of the water of the Euphrates River between station A and B [17].

1.5. Total Dissolved oxygen
Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids [18]. It is an essential parameter in assessing water quality because of its influence on the organisms living within a body of water [19], dissolved oxygen is a crucial factor second only to water itself. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality [20], and the table 3.2 shows the dissolved oxygen of the water of the Euphrates River between station A and B.

1.6. Turbidity
Turbidity is a measure that expresses the amount of substances suspended in the water and describes the clarity of the water and the substances that are suspended in the water [21], and works to reduce the purity of the water and cause turbidity, such as silt, clay, and algae [22]. Turbidity is a visual characteristic of the liquid and works to measure the clarity of the liquid and the levels of diffused light. The water column indicates turbidity, which is an important measurement that should be taken in the process of evaluating the quality of a water body [23], and the table 3.3 shows the Turbidity meter of the water of the Euphrates River between station A and B.

1.7. Temperature
It is an important measurement that directly affects the living organisms [24] present in the water through its impact on their life activities within certain ranges [25], and the table 3.4 shows the temperature of the water of the Euphrates River between station A and B.

1.8. Total Dissolved Solids (TDS)
Total dissolved solids (TDS), which are all the good and bad elements in drinking water and river water. These may be organic and inorganic substances such as minerals, salts, cations or anions dissolved

in the water. The TDS level is measured in parts per million (ppm) and milligrams per liter (mg/L). An increase in the TDS percentage indicates an increase in the amount of dissolved minerals in the water [26]. The numbered river maintenance law 25 for the year 1967shows the natural limits that range between 300 ppm and 900 ppm and the table 3.5 shows the TDS between the station A and B.

2. Devices Used and Measurement Methods

Remote sensing stations from the American company YSI were used at two stations to monitor water resources. The first occurs before the river water enters the station in order to determine the quality of the water entering the Musayyib thermal station. The second station is located half a kilometer from the first station, that is, at the exit. Water from the station in order to determine the quality of the water and the extent of changes occurring in the river water. The station consists of an system as shown in figure 1 that contains sensors to measure PH, D.O., TDS, Turbidity and temperature. It is linked to a data collector that operates 24 hours a day. A refined fuel measuring sensor was also connected to each station of one of the companies in order to measure the amount of oil waste leaked from the company (C3 Turner), as shown in figure 2 and table 3.6 shows the refined fuels meter between station A and B.

Figure 1: The sensors used to measure (PH, D.O, TDS, Turbidity and T from YSI company.

Figure 2: Upper image: The sensors C3 to measure (refine fuel) from turner company. Lower image: the oil waste leaked .

2.1. The procedure of work

These used stations consist of a sound immersed in water-containing sensors, in addition to a refined full measurement sensor. This sounder transmits information to the data logger so that data is collected, variables are measured every fifteen minutes, and all data is sent to a central station where the data is processed and tabulated (show in table 3.1, 3.2, 3.3, 3.4, 3.4, 3.5 and3.6). The monthly average is calculated for each sensor. For a period of four years from 2019 to 2022.

3. Station Results

Due to the large amount of data and results, the average was calculated for each month during the year, the stations were separated into station A before the water entered the power station and station B After the water left the power station, below are the results that were collected and processed.

Table 3.1: The average pH of the water of the Euphrates River

	Average of station A				Average of station B			
Month	2019	2020	2021	2022	2019	2020	2021	2022
Jan.	7.1	6.55	6.57	7.00	6.77	7.9	7.8	7.7
Feb.	6.5	6.57	7.00	7.6	7.59	7.47	7.49	7.09
Mar.	7.1	6.55	6.57	7.00	7.65	7.65	7.65	7.65
Apr.	7.6	7.00	7.2	6.79	7.65	7.65	7.65	7.65
May	7.1	6.55	6.57	7.00	6.77	7.8	7.5	7.7
Jun.	6.5	6.57	7.10	7.61	7.59	7.47	7.47	7.09
Jul.	7.1	6.55	6.57	7.00	7.65	7.66	7.65	7.65
Aug.	7.1	6.55	6.57	7.00	7.65	7.62	7.95	7.65
Sep.	7.2	6.55	6.57	7.00	7.59	7.47	7.47	7.09
Oct.	7.5	6.57	7.00	7.6	7.65	7.66	7.65	7.65
Nov.	7.1	7.55	6.47	7.10	7.65	7.65	7.65	7.65
Dec.	7.6	7.00	7.2	6.79	7.65	7.65	7.65	7.65
RSD% 0.1-0.2								

Through the results obtained, we notice a slight increase in the acidity function in the water discharged at station (B) compared to station (A), but all results are within the environmental determinants, and this increase is attributed to the increase in temperature of the water discharged from the electrical power production station.

Table 3.2: The dissolved oxygen of the water of the Euphrates River between station A and B:

	Average from station A				Average from station B			
month	2019	2020	2021	2022	2019	2020	2021	2022
Jan.	10.1	10	10.2	10	5.1	3.5	4.1	3.8
Feb.	10	10	10	10	5.3	3.8	4	4.1
Mar.	9.4	9.3	9.7	9.3	4.1	4.1	4.5	4.6
Apr.	10	9.3	10.1	9.3	4	4.6	3.5	3.8
May	8.9	9.9	8.9	9.9	4.5	5	3.8	3.5
Jun.	9.9	9.1	9.9	9.1	3.5	4.5	4.1	3.8
Jul.	9.9	9.9	10	9.9	3.8	4	4.6	4.1
Aug.	8.4	8.4	8.8	10	4.1	4.5	5	4.6
Sep.	9.2	9.2	9.4	9.9	4.6	3.5	4.1	5
Oct.	10	10.1	10	9.1	5	3.8	3.8	4
Nov.	10	10	9.9	9.9	4.5	4.1	4.1	4.5
Dec.	10	10	9.4	8.4	5	4.6	4.6	3.5
RSD% 0.1-0.2								

Through the results obtained from Station (A) and Station (B) to monitor the electric power production station, we notice a decrease in the level of dissolved oxygen in the water leaving the production station, which is less than the environmental limit according to the Iraqi standard for the River Maintenance System No 25. for the year 1967, which specifies a value higher than 8 mg/l This is due to the fact that the outlet water is mostly turbine cooling water.and thermal capacitors. Due to the high temperature, dissolved oxygen comes out of the water surface, and thus its percentage in the emerging water decreases, which affects the life of fish and living organisms

.

Table 3.3: The turbidity meter of the water of the Euphrates River between station A and B

Average station A results of NTU					Average station B results of NTU			
month	2019	2020	2021	2022	2019	2020	2021	2022
Jan.	14.45	11.45	17.05	9.96	10.50	10.9	12.45	19.9
Feb.	19.9	12.45	13.75	10.46	10.36	10.50	10.50	17.05
Mar.	17.05	12.9	14.0	9.45	10.85	10.36	10.36	13.75
Apr.	13.75	18.90	14.45	10.9	12.45	10.9	10.85	14.0
May	14.0	9.96	19.9	10.50	10.50	12.45	19.9	19.9
Jun.	14.45	10.46	17.05	10.36	10.36	10.50	17.05	17.05
Jul.	19.9	9.45	10.9	9.96	10.85	10.36	13.75	13.75
Aug.	17.05	10.9	10.50	10.46	19.9	10.85	10.46	17.05
Sep.	13.75	10.50	10.36	14.45	17.05	19.9	9.45	10.9
Oct.	14.0	10.36	11.45	19.9	13.75	17.05	10.9	10.50
Nov.	14.45	10.85	12.45	17.05	14.0	13.75	10.50	10.36
Dec.	19.9	12.45	12.9	13.75	19.9	14.0	10.46	17.05
RSD% 0.1-0.2								

We will notice from the results of stations (A) and (B) an increase in the turbidity rate of the water entering and leaving the electrical power production station. This increase is due to the decrease in the rate of river water flow and the scarcity of rain.

Table 3.4: The temperature of the water of the Euphrates River between station A and B

Average station A results of temperature in °C					Average station B results of temperature in °C			
month	2019	2020	2021	2022	2019	2020	2021	2022
Jan.	12.8	12.4	12.5	13.8	32.1	31.1	31.2	32.7
Feb.	12.1	13.1	12.4	12.9	31.1	30.4	33.2	30.1
Mar.	12.2	12.6	12.8	13.2	30.4	30.4	33.8	31.9
Apr.	17.4	16.5	18.4	15.4	30.4	31.2	31.1	32.7
May	20.5	22.5	21.9	22.6	31.2	33.2	32.1	30.1
Jun.	20.2	20.7	23.2	24.9	33.2	33.8	33.7	31.9
Jul.	23.3	22.4	22.6	24.3	33.8	31.1	31.2	32.7
Aug.	24.2	25.2	26.2	24.9	33.7	32.1	32.7	33.8
Sep.	23.4	24.5	24.4	24.7	31.2	30.4	30.1	31.1
Oct.	23.2	23.2	23.2	23.2	32.7	30.4	33.7	32.1
Nov.	20.1	19.6	18.1	20.1	30.1	31.2	31.2	33.7
Dec.	19.4	19.4	19.4	19.4	31.9	33.2	33.2	33.8
RSD% 0.1-0.2								

We will notice from the results of stations A and B an increase in the temperature of the water coming out of the electrical power production station, as the station A is directly installed at the water entrance to the station and the station B is 500 m away from. This increase is due to the fact that water is used to cool the turbine and is used to produce the steam needed to rotate the turbine. This increase negatively affects microorganisms, fish eggs and biodiversity.

Table 3.5: TDS values in stations A and B

Average station A TDS result in mg/l					Average station B TDS result in mg/l			
month	2019	2020	2021	2022	2019	2020	2021	2022
Jan.	745.1	823	670.6	712.2	843	823	823	704.6
Feb.	746.2	756	880.1	745	766	756	756	766
Mar.	650.6	760	712.2	853	750	760	700	750
Apr.	800.1	786	745.5	750	796	786	786	766
May	712.2	765	823	680.6	715	765	765	704
Jun.	745.5	700.6	756	805.1	706.6	700.6	708.6	823
Jul.	823	712.2	700	762.2	650.1	745.5	823	756
Aug.	756	745.5	786	745.8	869.3	823	756	750
Sep.	700	823	765	853	704.6	756	700	786
Oct.	786	756	700.6	757	766	650.6	786	833
Nov.	765	650.6	650.6	780	750	802.1	863	755
Dec.	700.6	800.1	860.3	823	766	745.6	756	780
RSD% 0.1-0.2								

Through the results obtained from station (A) and station (B) to monitor the electric power production station, we note that the percentage of total salts is among the environmental determinants

Table 3.6: The refined fuels meter of station A and B

Average station A fuel amount results in ppm					Average station B fuel amount results in ppm			
Month	2019	2020	2021	2022	2019	2020	2021	2022
Jan.	0.01	0.01	0.01	0.01	3.1	4.3	3.1	4.1
Feb.	0.01	0.01	0.01	0.01	3.1	2.5	3.1	5.4
Mar.	0.01	0.01	0.01	0.01	4.2	4.2	4.2	2.6
Apr.	0.01	0.01	0.01	0.01	2.1	2.1	2.1	4.1
May	0.01	0.01	0.01	0.01	4.1	4.2	3.1	3.4
Jun.	0.01	0.01	0.01	0.01	5	2.1	3.1	8.1
Jul.	0.01	0.01	0.01	0.01	8	4.1	4.2	4.1
Aug.	0.01	0.01	0.01	0.01	1	4.2	2.1	5.2
Sep.	0.01	0.01	0.01	0.01	4.3	2.1	3.1	8.1
Oct.	0.01	0.01	0.01	0.01	2.5	4.2	3.1	4.1
Nov.	0.01	0.01	0.01	0.01	4.2	2.1	4.2	5.5
Dec.	0.01	0.01	0.01	0.01	2.1	4.1	2.1	5.6
RSD%0.1-0.2								

Through the results obtained from the refined fuel measuring sensor, it was observed that the percentage of fats at the station (B) was higher than the environmental determinants, which is due to the presence of leaks of oils or crude oil from the Musayyib thermal power station, which has a direct impact on environmental systems and the life of living organisms.

4. Discussion

It was noted through the study conducted over four years from 2019 to late 2022 on the impact of the electrical power production station in Musayyib on the Euphrates River, where it was observed that there was a decrease in the percentages of dissolved oxygen in the river water leaving the station (3.5-5) RSD% (0.1-0.2), which is attributed to high water temperatures. The amount coming out of the electrical power production station at a rate ranging from 30 °C – 33 °C RSD% 0.1-0.2 to the normal limits hurts the life of living organisms. The sensor for measuring refined fuel also showed the presence of high percentages of hydrocarbon derivatives in the water discharged from the station at a rate ranging between 2.1 – 8.1 ppm RSD% 0.1 – 0.2 and the high temperature of the water helps in the spread of stains. Refined fuel, In order to preserve the water environment, it is necessary to place oil dispensers in the treatment units, as well as work to reduce the temperatures of the cooling water, which are at temperatures higher than the medical grades coming out of the station.

Funding Statement: We declare that no funding was received for this work.

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

Reference

[1] Muhammad, R.R.; Al-Akaam, I.S.; "Evaluation of the distinctive characteristics of the Euphrates affected by the wastes of Al-Musayyib thermal power station". J. Edu. Stud., 3(19): 1-5, 2022.
[2] Anufriev, I.S.;, "Review of water/steam addition in liquid-fuel combustion systems for NOx reduction: Waste-to-energy trends". J. Renew. Sustain. Energy Rev., 138: 110665, 2021.
[3] AL-Wotaify, A.S.; Al-Jaryan, R.L.; Al-Jeryan, I.L.; "Role of Mineral Component in Contamination of Soil and Plant by Some Heavy Metals for Al-Musayyib Electricity Thermal Power Station Residues". J. Ann. For. Res., 65(1): 4656-4667, 2022.
[4] Goel P. K ;"Water pollution: causes, effects and control". 2nd ed New age international: New Delhi, India, 2006.
[5] Inyinbor Adejumoke, A.; Adebesin Babatunde, O.; Oluyori Abimbola, P.; Adelani Akande Tabitha, A.; Dada Adewumi, O.; Oreofe Toyin, A.; "Water pollution: effects, prevention, and climatic impact" 2nd ed ,Water Challenges of an Urbanizing World, Croatia, 2018.
[6] Arif, A.; Malik, M.F.; Liaqat, S.; Aslam, A.; Mumtaz, K.; Afzal, A.; Javed, R.; "'Water pollution and industries". J. Pure Appl. Biol. 9(4), 2214-2224, 2020.
[7] Schwarzenbach, R.P.; Egli, T.; Hofstetter, T.B.; Von Gunten, U.; Wehrli, B.; "Global water pollution and human health". J. Annu. Rev. Environ. Resour, 35: 109-136, 2010.
[8] Zhang, B.; Matchinski, E.J.; Chen, B.Ye.X.; Jing, L.; Lee, K.; "Marine oil spills, oil pollution, sources and effects". 2nd ed., In World seas: an environmental evaluation, Elsevier Ltd. the Indian Ocean, 2019.
[9] Farrington, J.W.; "Oil pollution in the marine environment II: fates and effects of oil spills". J. Nat. Environ. Pol. Act. (4): 16-31, 2014.
[10] Horak, K.E.; Barrett, N.L.; Ellis, J.W.; Campbell, E.M.; Dannemiller, N.G.; Shriner, S.A.; "Effects of Deepwater Horizon oil on feather structure and thermoregulation in gulls: Does rehabilitation work". J. Sci. Tot. Environ., 718: 137380, 2020.
[11] Lin, H.; Xu, B.; Chen, Y.; Wang, W.; "Legionella pollution in cooling tower water of air-conditioning systems in Shanghai, China" J. Appl. Microbiol., 106(2): 606-612, 2009.
[12] Mostafa, S.K.; Mostafa, M.K.; Kirby, J.T.; "The Choice of Appropriate Scenario in Order to Reduce the Effect of Thermal Pollution at the Damietta Branch Caused by Cooling Water Discharged from Kafr-Al-Batek Power Station". J. Environ. Prot., (08): 857, 2015.
[13] Luo, M.; Zhu, W.; Liang, Z.; Feng, B.,; Xie, X.; Li, Y.; Dong, Z.; "High-temperature stress response: Insights into the molecular regulation of American shad (Alosa sapidissima) using a multi-omics approach". J. Sci. Total Environ., 916: 170329, 2024.
[14] Liu, Z.; Chen, X.; Zhang, X.; Gooding, J.J.; Zhou, Y.; "Targeted Drug Delivery: Carbon-Quantum-Dots-Loaded Mesoporous Silica Nanocarriers with pH-Switchable Zwitterionic Surface and Enzyme-Responsive Pore-Cap for Targeted Imaging and Drug Delivery to Tumor". J. Adv. Healthc. Mater., 5(12): 1380-1380, 2016.
[15] Mater, L.; Sperb, R.M.; Madureira, L.A.S.; Rosin, A.P.; Correa, A.X.R.; Radetski, C.M.; "Proposal of a sequential treatment methodology for the safe reuse of oil sludge-contaminated soil". J. Hazard. Mater., 136(3): 967-971, 2006.
[16] Zarzar, L.; Kim, P.; Aizenberg, J.; "Bio-inspired design of submerged hydrogel-actuated polymer microstructures operating in response to pH". 2nd ed Adv. Mater: New Delhi, India, 2011.
[17] Bedner, K.; Guzenko, V.A.; Tarasov, A.; Wipf M.; Stoop, R.L.; Just, D.; Schönenberger, C.; "pH response of silicon nanowire sensors:

Impact of nanowire width and gate oxide" J. Sens. Mater., 25(8): 567-576, 2013.
[18] Kılıç, Z.; "Water pollution: causes, negative effects and prevention methods". J. RENS, 3(2): 10-28. 2021.
[19] Rafiq, A.; Ikram, M.; Ali, S.; Niaz, F.; Khan, M.; Khan, Q.; Maqbool, M.; "Photocatalytic degradation of dyes using semiconductor photocatalysts to clean industrial water pollution" J. Ind. Eng. Chem., 97: 111-128, 2021.
[20] Chen, H.; Cheng, Y.; Tian, J.; Yang, P.; Zhang, X.; Chen, Y.; Wu, J.; "Dissolved oxygen from microalgae-gel patch promotes chronic wound healing in diabetes". J. Sci. Adv., 6(20), 4311, 2020.
[21] Gu, K.; Zhang, Y.; Qiao, J.;, "Random forest ensemble for river turbidity measurement from space remote sensing data". IEEE Trans. Instrum. Meas. (11), 9028-9036, 2020.
[22] Villa, A.; Fölster, J.; Kyllmar, K.; "Determining suspended solids and total phosphorus from turbidity: comparison of high-frequency sampling with conventional monitoring methods". J. Environ. Monit. Assess., (191), 1-16, 2019.
[23] Trevathan, J.; Read, W.; Schmidtke, S.; "Towards the development of an affordable and practical light attenuation turbidity sensor for remote near real-time aquatic monitoring". J. Sensors, 20(7), 1993, 2020.
[24] Alresheedi, M.T.; Basu, O.D.; "Effects of feed water temperature on irreversible fouling of ceramic ultrafiltration membranes"'. J. Water Proc. Eng., 31: 100883, 2019.
[25] Alfonso, S.; Gesto, M.; Sadoul, B.; "Temperature increase and its effects on fish stress physiology in the context of global warming", J. Fish Biol., 98(6), 1496-1508, 2021.
[26] Titilawo, Y.; Akintokun, A.; Shittu, O.; Adeniyi, M.; Olaitan, J.; Okoh, A.; "Physicochemical properties and total coliform distribution of selected rivers in Osun State, Southwestern Nigeria". Pol. J. Environ. Stud., 28(6), 4417-4428, 2019.