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Study of Physio-Chemical Parameters of Effluent from Thermal Power Plant

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Abstract: *The thermal power plant is the main source of energy for our society. In the thermal power plant huge amount of water is used for several different processes which is then discharged as a process waste. The work of present study is physio-chemical parameters of effluents from thermal power plant. The waste water sample was collected from effluent thermal power plant (koradi near Sri. Mahalaxmi mandir koradi.) Under this study the various parameters such as pH, Conductivity, TDS, TSS, DO, BOD, Chloride, Sulphate, Phosphate, Iron, Hardness, Alkalinity, and Nickel. The mean concentration of parameters is found to be beyond the permissible limits set by Indian standards set for discharge of effluent. Hence it should be closely monitored. This study clearly explains that the physicochemical parameters of effluent play a crucial role in maintaining the ecological balance and safeguarding the health of aquatic ecosystem impacted by thermal power plant operation.*

Keywords: Physical parameters, Chemical parameters, Thermal power plant waste water

I. INTRODUCTION

1. Historical Background of Thermal Power Generation

The generation of mechanical power using reciprocating steam engines dates back to the 18th century, with significant innovations attributed to James Watt. These engines played a central role in early industrialization and continued to be used well into the late 19th century. The establishment of the first commercially developed central electrical power stations in 1882—Pearl Street Station in New York and Holborn Viaduct in London—marked a pivotal moment in energy production. At the time, reciprocating steam engines powered these plants, but technological advancement soon led to the emergence of more efficient alternatives.

The invention of the steam turbine in 1884 dramatically transformed power generation. Steam turbines offered numerous advantages over reciprocating engines, including higher rotational speeds, more compact construction, and improved speed regulation. These benefits facilitated the synchronous operation of multiple generators on a common bus, a critical feature for the development of centralized power grids. By 1892, steam turbines were widely accepted as a superior solution, and their use became the norm for central power generation systems.

2. The Working Principle and Design Considerations

A thermal power station is a facility that converts heat energy into electrical energy through a complex yet structured process. At the heart of this system lies the Rankine cycle, wherein heat energy is utilized to boil water within a high-pressure vessel, generating high-pressure steam. This steam drives a steam turbine, which in turn rotates an electrical generator to produce electricity. After passing through the turbine, the now low-pressure steam enters a condenser, where it is cooled to produce hot condensate. This condensate is then recycled into the boiler, ensuring the continuity of the steam generation process.

The design of a thermal power station varies depending on the type of fuel and heat source employed. These sources include fossil fuels (coal, oil, and natural gas), nuclear energy, geothermal energy, solar thermal energy, and even biomass or waste materials. Many thermal power stations are also designed to serve multiple purposes beyond electricity generation, such as providing industrial process heat, district heating, or desalinated water.

An alternative to steam-based thermal power plants is the gas turbine system, where fuel is combusted directly within internal combustion engines. These can be configured as open cycle systems or as combined cycle plants, the latter of which significantly improves overall efficiency by using both gas and steam turbines in a two-stage energy conversion process.

Efficiency remains a critical performance metric in thermal power plants. Modern fossil-fuel-based sub-critical plants typically operate at efficiencies between 36% and 40%. Advanced technologies, such as supercritical and ultra-supercritical plants, utilize higher pressures and multiple-stage reheating to achieve efficiencies as high as 48%. These systems operate above the critical point of water (705°F or 374°C and 3212 psi or 22.06 MPa), eliminating phase transitions between water and steam and optimizing thermodynamic performance.

3. Thermal Efficiency and Environmental Trade-offs

Nuclear power stations, although highly reliable in terms of base-load power supply, currently operate at lower temperatures and pressures compared to coal-fired plants. As a result, they exhibit lower thermodynamic efficiency, generally in the range of 30–32%. However, several next-generation reactor concepts—such as the Very High Temperature Reactor (VHTR), the Advanced Gas-Cooled Reactor (AGR), and the Supercritical Water Reactor (SCWR)—are being explored to achieve thermal efficiencies comparable to advanced fossil-fuel plants.

Despite their engineering advantages and energy output capabilities, thermal power plants face growing scrutiny for their environmental impact. One of the most significant challenges involves managing the large volumes of wastewater and other effluents generated during operations. These effluents arise from various sources, including cooling water systems, boiler blowdown, flue gas desulfurization (FGD) processes, and ash handling systems. Cooling water, for instance, absorbs significant heat during the condensation phase and is discharged at elevated temperatures, contributing to thermal pollution. Boiler blowdown contains concentrated impurities and treatment chemicals, while FGD wastewater includes sulfates and other absorbed pollutants.

The combustion of coal also results in the generation of both fly ash and bottom ash, which require careful handling and disposal. Fly ash, in particular, contains fine particulate matter and trace heavy metals that pose risks to both water and air quality. Furthermore, chemical treatments for water purification introduce additional chemical residues into the plant's wastewater stream. The specific nature and composition of effluents vary based on the type of plant and fuel used, but all thermal power plants must implement robust wastewater management systems to mitigate their environmental footprint.

4. Site Selection and Operational Considerations

Selecting an appropriate site for a thermal power plant is a multifaceted decision that involves technical, economic, and environmental considerations. Key criteria include the proximity to fuel sources, availability of land and water, transportation infrastructure, and distance from densely populated areas. Coal-fired plants, which consume vast amounts of fuel, are typically located near coal mines to minimize transportation costs. Similarly, access to reliable water sources—often rivers or lakes—is essential for steam generation and cooling.

Large parcels of land are needed not only for current operations but also for potential future expansion. The land must also possess sufficient load-bearing capacity to support heavy equipment and infrastructure. Another major factor is environmental safety. Since thermal power plants emit smoke, ash, and flue gases, they are ideally sited far from residential and agricultural zones to reduce public health risks and land degradation. Additionally, noise pollution from turbines, transformers, and pumps further necessitates physical separation from populated areas.

One often overlooked yet crucial aspect of site selection is the facility for ash disposal. Ash constitutes approximately 30–40% of the total coal consumption by mass, and it must be managed through both fly ash and bottom ash handling systems. Efficient ash management and proximity to ash disposal sites are essential to prevent contamination of surrounding ecosystems.

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5. Efficiency Challenges and Pollution Impacts

The energy conversion process in a thermal power plant involves multiple stages, leading to unavoidable efficiency losses. The chemical energy in coal is first converted into thermal energy, then into mechanical energy via turbines, and finally into electrical energy by generators. Due to these multiple transformations, the overall efficiency of conventional plants remains relatively low—typically between 20% and 29%. Losses occur predominantly in the condenser and via exhaust gases and ash byproducts.

Efficiency is influenced by several factors, including the quality of coal, plant size, and technological sophistication. Two primary types of efficiency metrics are used to evaluate performance: thermal efficiency and overall efficiency. Thermal efficiency is the ratio of mechanical energy produced at the turbine to the heat energy generated by coal combustion. In contrast, overall efficiency accounts for losses throughout the entire cycle, including alternator performance. Lower-capacity plants generally suffer from reduced overall efficiency, underscoring the importance of scaling and modernization in the power sector.

However, efficiency gains must be balanced against environmental impacts. Thermal power plants are significant sources of air and water pollution. They emit carbon dioxide, sulfur dioxide, and nitrogen oxides—key contributors to global warming, acid rain, and smog formation. Moreover, fine particulate matter, particularly PM 2.5, poses serious respiratory risks and has become a pressing public health concern in many urban areas.

Equally troubling is thermal pollution—the discharge of heated water into nearby water bodies. This can raise water temperatures by 3–10°C (and sometimes even up to 20°C), disturbing local aquatic ecosystems. Elevated temperatures reduce the solubility of oxygen, accelerate chemical reactions, and cause stress or death in fish and other aquatic organisms. The impact of such pollution is particularly acute during summer months, when power demand and ambient water temperatures are already high.

II. MATERIAL AND METHODOLOGY

Location of sampling site

Koradi thermal power plant (near Sri. Mahalaxmi mandir koradi)

Sampling

Wastewater samples were collected directly from the effluent discharge point of the thermal power plant. The samples were gathered in clean, pre-washed collection containers to ensure the accuracy and reliability of subsequent laboratory analyses. Prior to sampling, the containers were thoroughly cleaned using a mild detergent, followed by multiple rinses with tap water and finally with distilled water to eliminate any potential contaminants.

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At the sampling site, key physical parameters such as pH and temperature were measured on-site to preserve the integrity of the readings. The dissolved oxygen (DO) content of the wastewater was fixed immediately at the site of collection using the Winkler method. This was done by adding Winkler Reagent A and Reagent B to the sample in dedicated DO bottles to prevent any alteration of oxygen levels before analysis.

All samples were then securely sealed and carefully transported to the laboratory under controlled conditions to minimize any changes in sample composition. Upon arrival, the samples were subjected to further physicochemical analysis following standard procedures.

III. RESULT AND DISCUSSION

The analysis of the wastewater sample collected from the thermal power plant reveals several key insights into the quality of effluent being discharged and its potential environmental impact. The pH of the sample was recorded at 8.1, indicating slightly alkaline conditions. While this value falls within the acceptable range for industrial discharge, sustained discharge of alkaline water into natural ecosystems can disturb aquatic life, particularly species sensitive to pH fluctuations.

The electrical conductivity was measured at 3.66 µS/cm, suggesting the presence of dissolved ions and indicating that the wastewater carries a moderate ionic load. This may be attributed to dissolved salts, minerals, and industrial residues present in the effluent.

A significant observation was the high concentration of Total Suspended Solids (TSS) at 1720 mg/L, which greatly exceeds permissible limits for safe discharge into natural water bodies. High levels of TSS can reduce light penetration in water, affect photosynthesis in aquatic plants, and settle as sludge, smothering benthic habitats. In contrast, Total Dissolved Solids (TDS) were recorded at 264 mg/L, which is within the tolerable limit for most aquatic organisms and does not pose immediate threats. However, when combined with high TSS, it still contributes to the overall pollution load.

The Dissolved Oxygen (DO) level was found to be 8.5 mg/L, which is adequate and indicates that the water has not yet reached a state of oxygen depletion. However, the Biological Oxygen Demand (BOD) was measured at 3.368 mg/L, suggesting a moderate level of biodegradable organic matter present in the sample. If not treated properly, continuous discharge of such effluent can reduce oxygen levels in the receiving water body over time, stressing aquatic organisms and potentially leading to eutrophication.

The chloride concentration was exceptionally high at 1619 mg/L, which could be harmful to aquatic life and may result from the use of salts in industrial processes or cooling systems. High chloride levels can disrupt osmoregulation in freshwater organisms and contribute to soil salinity if used for irrigation purposes. Sulphate was recorded at 204 mg/L, which is within the acceptable range but could still cause scaling in pipes and affect water taste and quality.

The level of phosphate, though relatively low at 0.6 mg/L, is still significant because even small amounts can accelerate algal growth in surface waters, leading to eutrophic conditions. Hardness of the sample was 288 mg/L, indicating moderately hard water, which may not be harmful directly but can impact the effectiveness of certain industrial processes and increase scaling. Alkalinity, measured at 20 mg/L, shows the water's buffering capacity is relatively low, meaning it might be susceptible to pH changes when mixed with other effluents or natural waters.

One of the most concerning aspects of the analysis is the presence of heavy metals, particularly iron and nickel, recorded at 13.1 mg/L and 2.7 mg/L respectively. These concentrations are significantly above the permissible limits set by environmental agencies for wastewater discharge. Excessive iron in water can lead to discoloration, metallic taste, and clogging of water systems, while nickel is toxic to aquatic organisms and can bioaccumulate through the food chain, posing risks to both wildlife and human health.

The results of the wastewater analysis from the thermal power plant indicate a number of environmental concerns, particularly due to elevated levels of total suspended solids (TSS), chloride, and heavy metals such as iron and nickel. The TSS concentration (1720 mg/L) greatly exceeds the Central Pollution Control Board (CPCB) permissible limit for industrial effluent, which is typically around 100 mg/L (CPCB, 2015). Excessive suspended solids in water bodies can lead to sedimentation that negatively affects aquatic habitats, blocks sunlight penetration, and disrupts the photosynthesis process essential for aquatic plants (EPA, 2006). Similarly, the chloride concentration (1619 mg/L) is

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considerably higher than the recommended limit of 600 mg/L for inland surface water discharge, indicating potential risks to aquatic ecosystems through osmotic stress and long-term salinity build-up (WHO, 2011).

The presence of heavy metals such as iron (13.1 mg/L) and nickel (2.7 mg/L) is particularly alarming. According to the World Health Organization (WHO), acceptable limits for iron and nickel in drinking water are 0.3 mg/L and 0.07 mg/L respectively (WHO, 2011). Although this effluent is not intended for direct human consumption, its discharge into freshwater bodies without adequate treatment can pose severe risks. Nickel is known to be toxic even at low concentrations and can bioaccumulate in aquatic organisms, affecting not only aquatic life but also human populations through the food chain (Ali et al., 2019). Iron, while essential in small amounts, can contribute to oxygen depletion and lead to foul odor and taste issues in water. Both metals are also known to interfere with plant growth and microbial activities in aquatic sediments (Zhou et al., 2016).

Despite some parameters being within acceptable ranges—such as dissolved oxygen (DO) at 8.5 mg/L and biological oxygen demand (BOD) at 3.368 mg/L—the cumulative effects of high TSS, chloride, phosphate, and heavy metals significantly lower the overall water quality. Elevated phosphate levels (0.6 mg/L) can trigger eutrophication, leading to algal blooms, hypoxia, and the death of aquatic organisms (Smith et al., 1999). Moreover, the relatively low alkalinity (20 mg/L) in the sample suggests a poor buffering capacity, making the receiving water body more vulnerable to pH fluctuations upon effluent discharge. The combination of chemical pollutants and thermal stress from the power plant's cooling system may result in compounded impacts on aquatic environments, emphasizing the need for integrated pollution control systems.

Table 1. Physiochemical Properties of Wastewater Sample from Thermal Power Plant

Sr.no	parameters	Sample 1
1	pH	8.1
2	Conductivity	3.66 µS/cm

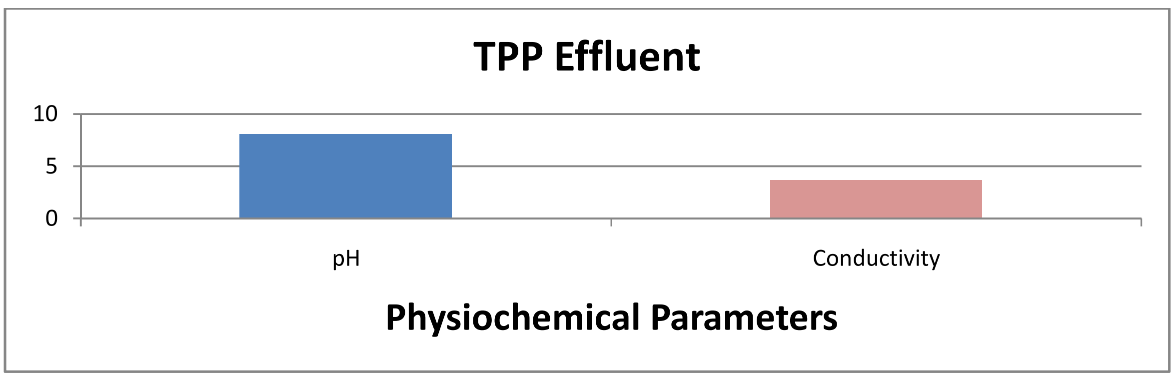

Table 2. Chemical Properties of Wastewater Sample from Thermal Power Plant

Sr. No.	Parameters	Concentration
1	Total Dissolved Solid	264mg/lit
2	Total Suspended Solid	1720 mg/lit
3	Dissolved Oxygen	8.5 mg/lit
4	Biological Oxygen Demand	3.368 mg/lit
5	Chloride	1619 mg/lit
6	Sulphate	204 mg/lit
7	Phosphate	0.6 mg/lit
8	Hardness	288 mg/lit
9	Alkalinity	20 mg/lit

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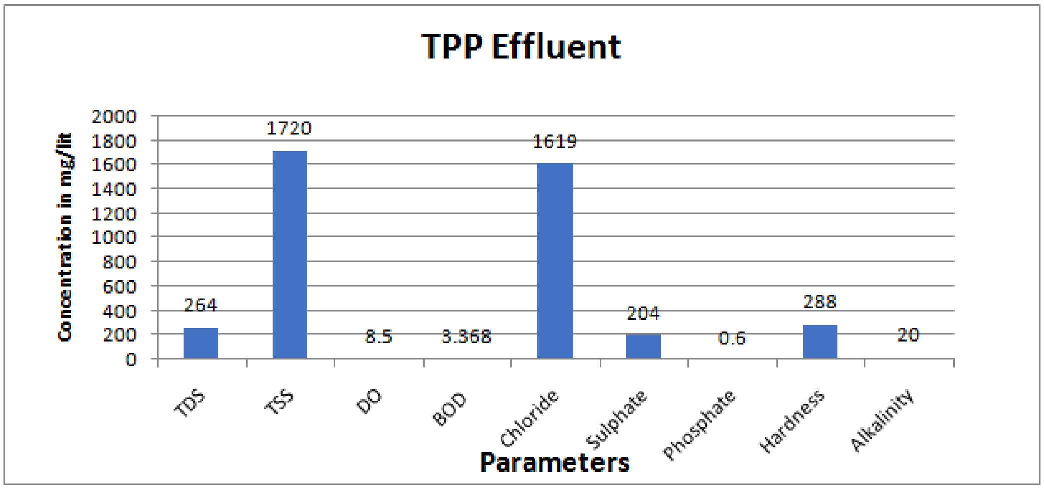
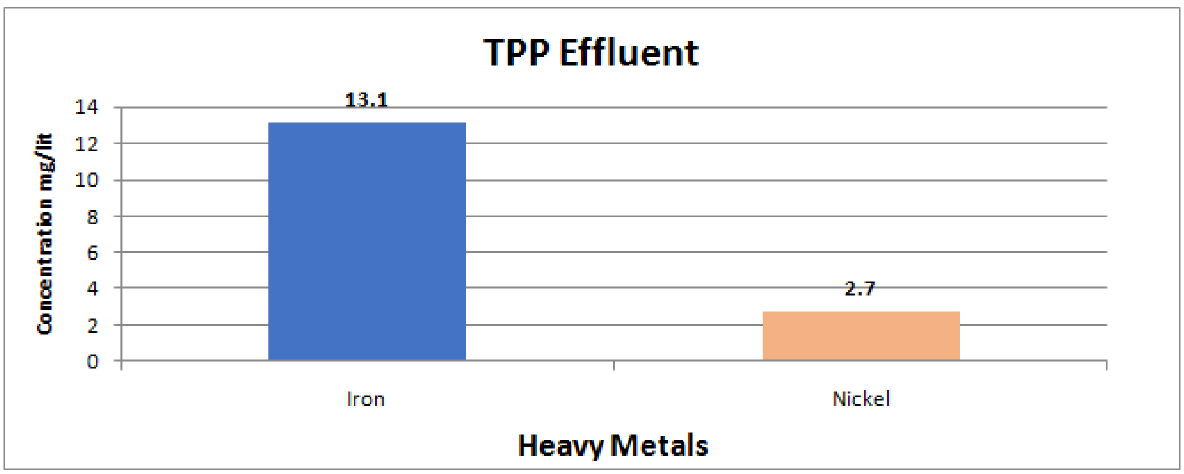


Sr. No.	parameters	Heavy Metals
1	Iron	13.1
2	Nickel	2.7

Table 3 Heavy metal analysis of Wastewater Sample from Thermal Power Plant



IV. CONCLUSION

The study of physiochemical parameters of effluent from a thermal power plant is essential for understanding the quality and potential impact of the wastewater discharged from the plant on the environment. By analyzing various parameters such as temperature, pH, turbidity, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids (TDS), heavy metals, nutrients, and oil and grease, researchers and environmental professionals can evaluate the potential risks and develop appropriate strategies for wastewater treatment and environmental protection.

Monitoring these parameters and ensuring compliance with regulatory standards, thermal power plants can minimize their environmental footprint and contribute to sustainable development. Additionally, the findings of these studies can guide the implementation of effective pollution control measures, identify areas for improvement, and support decision-making processes related to the management of effluent from thermal power plants. Overall, the study of physicochemical parameters of effluent plays a crucial role in maintaining the ecological balance and safeguarding the health of aquatic ecosystems impacted by thermal power plant operations.

BIBLIOGRAPHY

[1]. Ali, H., Khan, E., & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *Journal of Chemistry*, 2019.

[2]. American Public Health Association (APHA). (1998). *Standard methods for the examination of water and wastewater*. APHA, AWWA, WPCF. Washington, DC.

[3]. Bamal, S., &Arghode, V. (2004). Mine matters. *Wastelands News*, May–July.

[4]. Central Electricity Authority (CEA). (2012, January 12). *Minimisation of water requirement in coal-based thermal power stations*.

[5]. Central Electricity Authority (CEA). (2020, March 4). *Mandatory use of treated sewage water by the thermal power plants* [Gazette notification]. Government of India. https://www.cea.nic.in/reports/others/thermal/tppd/treatment%20sewage%20water.pdf

[6]. CPCB (2015). *General Standards for Discharge of Environmental Pollutants*. Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, India.

[7]. Edinger, J. E., & Geyer, J. C. (1965). *Heat exchange in the environment* (Report No. 65-902). Edison Electric Institute.

[8]. Goel, P. K. (2006). *Water pollution: Causes, effects and control* (p. 179). New Delhi: New Age International.

[9]. Hogan, M., Patmore, L. C., & Seidman, H. (1973, August). *Statistical prediction of dynamic thermal equilibrium temperatures using standard meteorological data bases* (EPA Report No. 660/2-73-003). Environmental Protection Technology Series.

[10]. Langbein, W. B., & Iseri, K. T. (1995). *Waterbodies*. In *The New Oxford Dictionary of English*.

[11]. Langford, T. E. L. (1990). *Ecological effects of thermal discharges*. Pollution Monitoring Series. London: Elsevier Applied Science.

[12]. NTPC Ltd. (2015, April 30). *NTPC water charges* [Affidavit to CERC].

[13]. Pokale, W. K. (2012). Effects of thermal power plant on environment. *Scientific Reviews and Chemical Communications*.

[14]. Pondja, E. A. J. (n.d.). *Treatment methods for water pollution from coal mining in Moatize (Mozambique)*. Division of Water Resources Engineering, Department of Building and Environmental Technology, Lund University.

[15]. Shrivastava, S., & Kanungo, V. K. (2013). Physico-chemical analysis of pond water of Surguja District, Chhattisgarh, India. *International Journal of Herbal Medicine, 1*(4), 35–43.

[16]. Singh, G. (1999). Water pollution issues and control strategies in mining areas. *Minetech, 20*(1), 45–53.

[17]. Singh, G. (2005). Water sustainability through augmentation of underground pumped out water for potable purpose from coal mines of Eastern India. *Environmental Geochemistry, 8*(1–2), 89–94.

[18]. Smith, V. H., Tilman, G. D., & Nekola, J. C. (1999). Eutrophication: Impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution*, 100(1–3), 179–196.

[19]. Thackston, E. L., & Parker, F. L. (1971, March). *Effect of geographical location on cooling pond requirements* (EPA Report No. 830-R-71-001). Water Pollution Control Research Series.

[20]. U.S. Environmental Protection Agency. (2003, February). *Protecting water quality from urban runoff* (Fact Sheet No. EPA 841-F-03-003). Washington, D.C.: EPA.

[21]. Vallero, D. A. (2019). Thermal pollution. In T. M. Letcher & D. A. Vallero (Eds.), *Waste: A handbook for management* (pp. 381–388). Amsterdam: Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-815060-3.00022-2

[22]. Vasistha, V. (2014). Effects of pollutants produced by thermal power plant on environment: A review. *International Journal of Mechanical Engineering and Robotics Research*.

[23]. Vinna, L. R. (2017). Physical effects of thermal pollution in lakes. *Water Resources Research, 53*(5), 3968–3987.

[24]. WHO (2011). *Guidelines for Drinking-water Quality*, 4th Edition. World Health Organization, Geneva. EPA (2006). *Volunteer Stream Monitoring: A Methods Manual*. U.S. Environmental Protection Agency, Office of Water.

[25]. Zhou, Q., Zhang, J., Fu, J., Shi, J., & Jiang, G. (2016). Biomonitoring: An appealing tool for assessment of metal pollution in the aquatic ecosystem. *Analytica Chimica Acta*, 606(2), 135–150.