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Treatment of Polluted Hindon River Water by Electrochemical Technique

R. S. Dubey [1*], D. Chand[2]
[1]Department of Applied Chemistry, Amity Institute of Applied Sciences, Amity University, Noida, India
[2]Department of Applied Chemistry, Amity University Dubai Campus, Dubai, UAE

ABSTRACT

River Hindon is one of the most polluted rivers in western Uttar Pradesh, India. Treatment of Hindon river water is a challenging task due to large variety of inorganic, organic chemicals and microorganisms. The objective of present work is to study the application of electrochemical technique in the treatment of polluted Hindon river water. Experiments were carried out in an electrochemical cell by sacrificial electrodes, iron as anode and aluminium as cathode in a batch process. Effect of operating variables, viz., current density and electrolysis period was studied for reduction of Biological Oxygen Demand (*BOD*), Chemical Oxygen Demand (*COD*), Total Dissolved Solid (*TDS*), Total Suspended Solid (*TSS*), Dissolved Oxygen (*DO*), Total Hardness (*TH*), Total Alkalinity (*TA*) and Microbial Population (*MP*) at room temperature (25 ^{0}C). Other parameters like pH and power consumption were also investigated. The applied current density and electrolysis period were found to effect significantly in reducing all parameters. The benefits of this process were observed in reducing capital and operating costs compared to other conventional treatment processes.

Keywords: Electrochemical Technique, Biological Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, Total Suspended Solid, Total Dissolved Solid, Microbial Population, Total Alkalinity

I. INTRODUCTION

Hindon river pollution due to domestic sewage and industrial effluents has been a main cause at present days. Several investigators reported that the environmental deterioration, surface and underground water pollution are the most serious problems of many developing countries due to unplanned urbanization, improper wastewater management and unavailability of suitable technologies[1-4].

The river Hindon originates from Upper Shivaliks and flows through four major districts, viz., Saharanpur, Muzaffarnagar, Meerut and Ghaziabad in western Uttar Pradesh and covers a distance of about 200 km before joining the river Yamuna downstream of Delhi. The urban population of Saharanpur, Muzaffarnagar, Meerut and Ghaziabad is 455,754, 331,668, 1,161,716 and 968,256. The river Hindon is one of the important rivers in western Uttar Pradesh, India, with a basin area of about 7,000 km respectively. The major land of river is used for agriculture. The study area is a part of Indo-gangetic Plains, composed of Pleistocene and subrecent alluvium.

River Hindon received sewage of Saharanpur, Muzaffarnagar, Ghaziabad districts and industrial effluents of distilleries, metal industries pulp and paper, sugar, and other miscellaneous industries through tributaries as well as direct outfalls. River Kali meets river Hindon on its left bank near the village of Atali, which carries sewage and effluents of industries located in the city of Muzaffarnagar. Another tributary called Krishni meets Hindon on its right bank at village Binouli in Meerut district and carrying the sewage and wastewater from distillery and sugar mill. River Hindon flows further downstream and joins river Yamuna at village Tilwara. The physico-chemical characteristics of different waste effluents and their impact on river water quality have been described by several investigators [5-9].

Ghaziabad and Noida are fast growing industrial cities in UP, India and more than 300 industrial units as shown in Table 1. These industries discharge their industrial effluents directly to the Hindon river without any treatment. The quality of Hindon river water has deteriorated due to the continuous discharge of municipal and industrial effluents from various drains. The preservation and maintenance of our river water resources is a very difficult task due to rapid growth of population on the river bank sites and increased human activities. The quality of river water is deteriorating day-by-day due to continuous addition of undesirable pollutants[10,11]. On the other hand, the demand for clean water is increasing continuously due to the increase in population.

Table 1: Number of industries at Ghaziabad*

S. No	Name of Industries	No of units
1	Sugar industry	3
2	Distillery and beverage	5
3	Tannery	3
4	Pulp and paper	8
5	Dyes	4
6	Pesticides and formulation	10
7	Drug and pharmaceutical	11
8	Textiles	115
9	Induction/foundry	79
10	Galvanising/electroplating	79
11	Chemicals	67
12	Synthetic rubber and fibres	4
13	Asbestos products	5
14	Lead reprocessing	27
15	Frozen meat processing	11
16	Dairy	5
17	Metal industries	56

*UPPCB-2007

Polluted Hindon river water contains very complex industrial effluent with variety of inorganic and organic chemicals[5]. The potential environmental impact of the toxic chemicals used in many industries is well known. Conventional physico-chemical treatments of industrial effluents consist of pre-treatment, coagulation, flocculation, sedimentation and proper sludge handling. Coagulation process has been used for long times to destabilize suspended materials in the effluents and to effect the precipitation process in the aqueous conditions. Alum, lime, and/or polyelectrolytes have been used as chemical coagulants. Conventional processes, however, tend to generate large amounts of loose sludge which create another problem. Toxic metals are not removed from industrial effluent by chemical precipitation or sedimentation process. Ultimately, all these toxicities are throughout directly in the main water streams.

Recently, electrochemical process called electrocoagulation has attracted attention of the scientists significantly for the treatment of sewage, wastewater and industrial effluent due to its simple and economical operation[12-14]. Electrochemical process does not require costly chemicals due to the redox reactions which take place. This influences the reduction of physico-chemical parameters. Therefore, the process maintenance and operation is very simple. While, in activated sludge processes, during microbial activities the total content of total dissolved materials (TDM) is increased in treated effluent which is more dangerous by environmental point of view and causes other serious problems. Treated effluent is not suitable for any use and also not throughout in surface water bodies. The present study is aimed to investigating the effect of electrochemical process on reduction of physico-chemical parameter of polluted Hindon water.

II. METHODS AND MATERIAL

A. Background of Electrochemical Process

The electrochemical process depends on effluents contaminants to strong electric potentials and electrically induced redox reactions. When potential is applied, the anode undergoes oxidation, while the cathode will be subjected to reduction or reductive deposition of elemental metals. The electrochemical reaction may be represented as follows:

At the anode:

$$M_{(s)} \longrightarrow M^{n+}_{(aq)} + ne^-$$

$$2H_2O_{(l)} \quad 2e^- \longrightarrow 4H^+_{(aq)} + O_{2(g)} + 4e^-$$

At the cathode

$$M^{n+}_{(aq)} + ne^- \longrightarrow M_{(s)}$$

$$2H_2O_{(l)} + 2e^- \longrightarrow H_2 + OH^-$$

During electrochemical reactions, metal ions react with hydroxyl ion to produce corresponding hydroxides and/or polyhydroxides which depend on the pH of the aqueous environment. The coagulation process easily performed with the help of hydroxides, polyhydroxides and polyhydroxymetallic complexes. The gases evolved at the electrodes and help flotation of the coagulated complex materials.

Polluted water contains toxic metal ions which can be removed by electrochemical technique. The sacrificial iron anode produced ferrous ion (Fe^{2+}) by oxidation of iron anode which also reduce metal ions under basic conditions and ferrous ion self-oxidized to ferric ions (Fe^{3+}).

B. Experimental

Polluted water samples used in this investigation were collected from Hindon River near Kolesara Bridge in the end of May, 2011. Analytical grade chemicals were used throughout the experiment without any purification. To prepare all the reagents in double glass distilled water was used. All experiments were carried out in triplicate. Various parameters of water were analysed by standard methods. Detailed procedures are represented in Table 2. The typical characteristics of these samples are represented in Table 3.

Table 2 Analytical methods used for measurement of various parameters of polluted Hindon river water

S. No	Parameters	Abbreviation	Units	Analytical methods	Instruments
1	pH	pH	-	Instrumental	pH meter
2	Electrical Conductivity	EC	mS	Instrumental	Conductivity meter
3	Biological Oxygen Demand	BOD	Mgl^{-1}	5-days incubation, 20^0C	BOD incubator and titration assembly
4	Chemical Oxygen Dmand	COD	Mgl^{-1}	Potassium dichromate oxidation	Refluxing assemble
5	Dissolved Oxygen	DO	Mgl^{-1}	Titrimetric	Titration assembly
6	Total Dissolved Solids	TDS	Mgl^{-1}	Filtration and gravimetric	Temperature controlled oven
7	Total Suspended Solids	TSS	Mgl^{-1}	Filtration	Filtration assembly
8	Total Hardness	TH	Mgl^{-1}	Titrimetric	Titration assembly
9	Total Alkalinity	TA	Mgl^{-1}	Titrimetric	Titration assembly
10	Total Turbidity	TT	NTU	Filtration	Turbidity meter
11	Microbial Population	MP	No/100/ml	Plate count method	Microbial culture assembly

Table 3: The physico-chemical and microbial characteristics of Hindon river water

S. No	Parameters	Value
1	pH	8.5
2	Colour	Dark black
3	Biological Oxygen Demand (mg/l)	34
4	Chemical Oxygen Demand (mg/l)	380
5	Dissolved Oxygen (mg/l)	0-.23
6	Total Suspended Solids (mg/l)	897
7	Total Dissolved Solids (mg/l)	2426.3
8	Total Hardness	485
9	Total Alkalinity	614
10	Electrical Conductivity (mS)	5.75
11	Microbial Populations (No/100 ml)	8.7×10^6

In the present investigation, an electrochemical experiment was performed in three litres electrochemical cell. The effective volume of test sample from Hindon water was 2 litres for each batch. The anode and cathode were properly connected to the respectively terminals of DC power system. The electrodes used are iron and aluminium square shape (cm x 5cm). The effective area of electrode is 25 cm^2. In this study, iron plate was anode and aluminium plate was cathode.

The Hindon water is poured in an electrochemical cell. The anode and cathode were connected to the respective terminals of DC power supply. The DC current was varied from 0.5 to 4.0 A and electrical potential was varied from 5 to 20 V. The sludge is removed from the bottom of electrochemical cell after each run. The test sample was treated at three different current densities, viz., 20, 40 and 60 mA/cm^2. The duration of electrolysis was 30, 60, 90, and 120 minutes. The pH was maintained 6.5 to 8. The pH of solution was adjusted by sulfuric acid and NaOH solution. Standard methods[15] were used for estimation of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Hardness (TH), Total Alkalinity (TA), Dissolved Oxygen (DO), Electrical Conductivity (EC), and Microbial Population (MP). Microbial population was also observed after each run. Details of methods for microbial process were followed from Dubey [16].

After experiments, the sludge produced was collected, dried in furnace at 120 ^{0}C, cooled in a desiccator and weighted on electronic balance. The amount of sludge is calculated by the Faraday's law. The electrochemical process produces lower quantity of sludge compared to the conventional chemical and biological processes.

III. RESULTS AND DISCUSSION

River systems are playing very important role for living being and developmental processes. The fast urbanization rate of residences and industrial establishments on the bank of rivers are totally responsible to damage the natural river systems and water quality. It is essential to changes in modern thinking and lifestyles for saving rivers and environment. However, microbial and chemical parameters assessment of such rivers can widely represent the anthropogenic pressure and pollution load on river water qualities. Finally, in modern concept rivers are the end points of urban runoff.

The effects of current density and electrolysis time on the reduction of BOD, COD, TSS, TDS, TH, TA, DO, EC and MP were studied by performing experiments at different current densities viz., 20, 40 and 60 mA/cm^2. The pH was maintained between 6.5 and 8. Figures 1, 2, 3, 4, 5, 6, 7, 8 and 9 show the effect of current density on the reduction BOD, COD, TSS, TDS, TH, TA, DO, EC and MP. The experimental results showed that the current density influences the reduction of BOD, COD, TSS, TDS, TH, TA, DO, EC and MP. The reduction of BOD, COD, TSS, TDS, TH, TA, DO, EC and MP increased with increasing current density and electrolysis time due to redox reactions. In previous investigation, it is proved that by increasing the current density and electrolysis period, efficiency of removal process, power consumption, and quantity of produced sludge were increased, while total reaction period was decreased compare to convention processes[17-19].

The electrochemical process is complex and may be affected by several operating parameters. In the resent study, the operating parameters such as current density, electrolysis period and pH were varied to explore their effect on BOD, COD, TSS, TDS, TH, TA, DO, EC and MP. The results showed that the reduction of BOD, COD, TSS, TDS, TH, TA, DO, EC and MP increased with increasing current and electrolysis period. The results showed the current induced on significant changes in the microbial population. Fig. 9 revealed that the microbial population decreased with increasing current density. It assumed that current density will also be helpful to control the growth of microorganisms.

Fig.10 shows that at 7 pH the performance of electrochemical process is better. Some investigators reported that the pH is an important factor and also has a considerable effect on the performance of electrochemical process for wastewater treatment[20-22]. pH indicate the water is acidic or basic in nature. pH of Hindon water varied from 6.5 to 8.5.

Electric conductivity indicates the presence of charge particles in river water (Fig.8). Electrical conductivity of Hindon water was significantly very high due to mixing of domestic sewage and industrial effluents. Consequently, conductivity was also decreased with increasing current density and electrolysis period because charge particles oxidised or reduced to form new formulations during electrochemical process and finally converted into sludge.

The main origin of TSS and TDS in Hindon water is influenced from sewage, industrial effluents, urban runoff, cleaning agents and natural resources. High TSS and TDS of Hindon water indicates the salinity behaviour due to the fine gradients of sewage, industrial and domestic effluents (Table 2). Higher level of TSS and TDS in Hindon water samples also increases BOD and COD which ultimately affect the DO level of water. Fig. 3 and 4 shows that 90 % TSS and TDS have been removed by electrochemical process. Percentage of removal increased with increasing the current density and electrolysis period.

Total hardness of Hindon water is a very important parameter from its various applications such as domestic, industrial and agricultural purposes. High Hindon hard water (Table 2) causes several problems in any applied fields. The experimental results clearly indicate that 84 % hardness was reduced by electrochemical process (Fig. 5). Many workers reported that due to increasing the density, efficiency of removal process and the amount of sludge increased, while, hardness was decreased[23-26].

BOD is a good indicator of organic pollution of surface water, which directly influenced by human activities. Self-purification capacity of surface water bodies are continuously damage due to increasing of BOD level my many ways. Hindon water at Kolesara, BOD and DO have remarkable relationships and directly introduce organic pollution load due to urban runoff and anthropogenic load. Experimental results indicated that relationship between BOD and DO is opposite (Fig. 1 and Fig. 7). This pattern is also supported by other investigators[27-28]. The experimental results also clearly support the traditional hypothesis that unban and industrial wastewater has been direct contributing to deteriorate quality of Hindon river water

The oxygen and hydrogen gas evolved at electrodes which also influences the reduction process during the redox reactions. Pollutants are floated on water surface due to hydrogen gas evolved at cathodic region which indicate that TDS is removed from polluted water. All parameters such as BOD, COD, TSS, TDS, TH, TA, DO, EC and MP are also reduced when current density is increases, because current density is defined as the ratio of current input to the electrochemical cell to the surface area of the electrode.

Studies on electrolysis time performed for BOD, COD, TSS, TDS, TH, TA, DO, EC and MP at four different time intervals viz., 30, 60, 90, and 120 minutes showed remarkable reduction in all physiochemical parameters in the test samples. Higher electrolysis period showed significant reduction due to maximum interaction between oxidants and coagulants and ultimately produced sludge which settles down in the bottom of electrochemical cell. Many investigators reported that electrochemical technique is being used for the removal of charge particles, organic materials, colloidal and suspended materials, dyes, surfactants, oil, and toxic metals from wastewater [29-31]. Fig. 11 shows that turbidity decreased with increasing the current density and electrolysis period. The decreasing turbidity at different current density and electrolysis periods was due to the flow turbulences and settling factors. They attributed the lowering turbidity in subsequent current density to oxidation of turbulences. After removing all studied parameters, high turbid Hindon water (Table 2) converted to 92 % clean water.

Fig. 12 shown that the electricity consumption for reducing BOD, COD, TSS, TDS, TH, TA, DO, EC and MP increases with increase in the current density. Power consumption is directly related to oxidation process resulting in high coagulant formation which reduce BOD, COD, TSS, TDS, TH, TA, DO, EC and MP respectively. The experimental results also indicate that the electrolysis periods are significantly affected the electricity consumption. Experimental results indicated that the optimum current density was found to be 60 mA/cm^2, electrolysis time 120 minutes and all physicochemical parameters reduced significantly. This is ascribed to the fundamental fact that at higher current density, the rate of anode oxidation increased, resulting in a greater amount of pollutants precipitated from the polluted Hindon water. In addition, it was demonstrated that bubbles density increases with increasing current density which directly influence the electrochemical reaction at metal/solution interface[32]. Moreover, it was previously reported that the bubble size decreases with increasing current density, which is more beneficial to the treatment process[33].

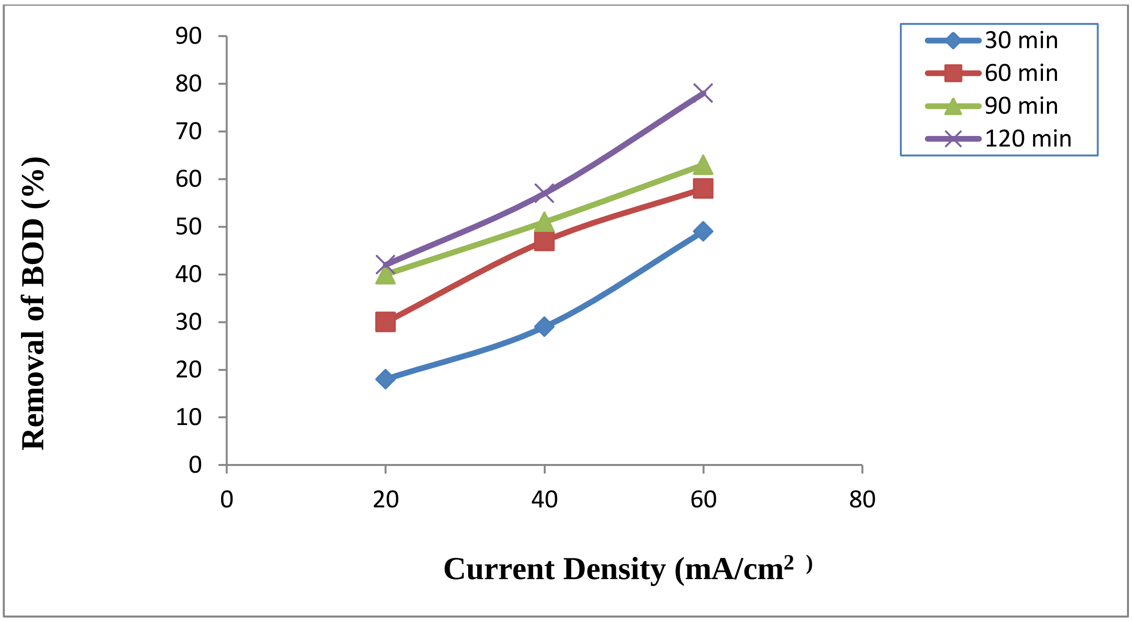

Fig. 1. Effect of current density on removal of biological oxygen demand of Hindon water at 25.0 ^{0}C.

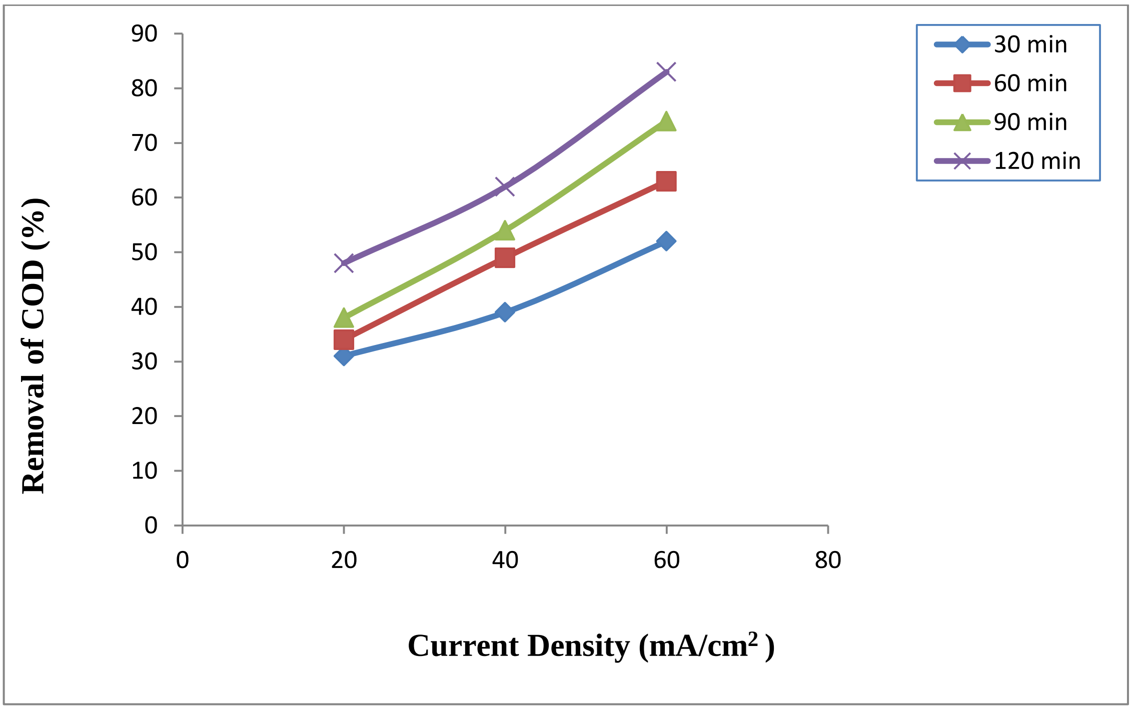

Fig.2. Effect of current density on removal of chemical oxygen demand of Hindon water at 25.0 ^{0}C.

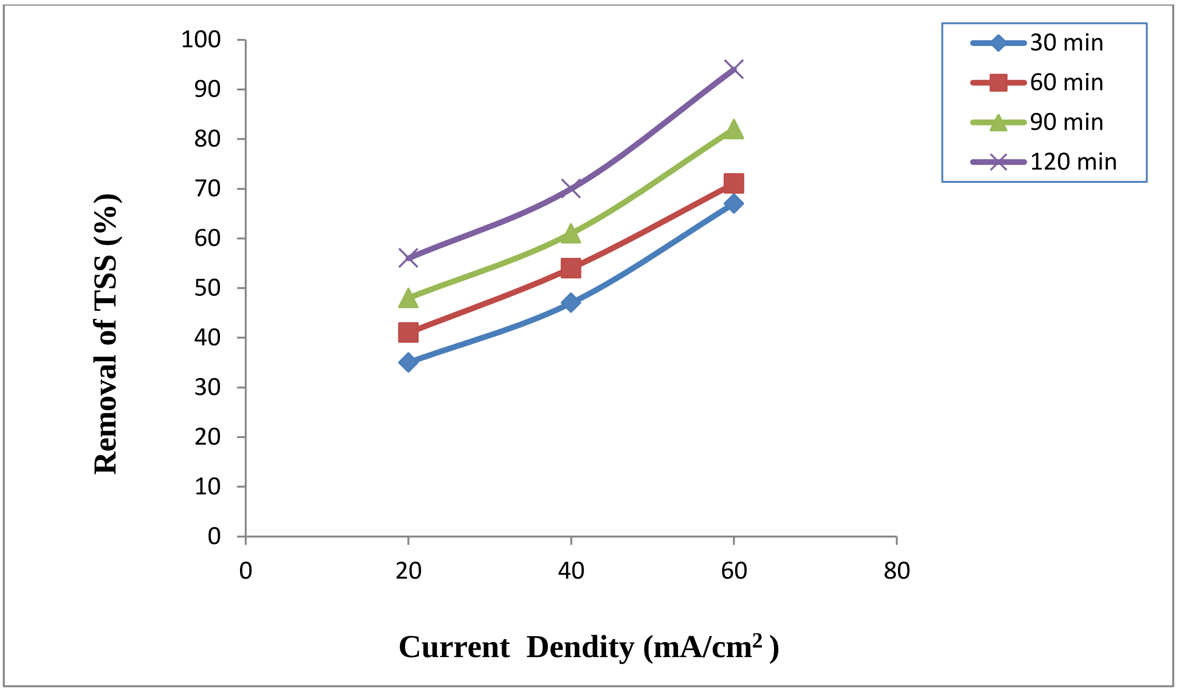

Fig. 3. Effect of current density on removal of total suspended solids of Hindon water at 25.0 ^{0}C.

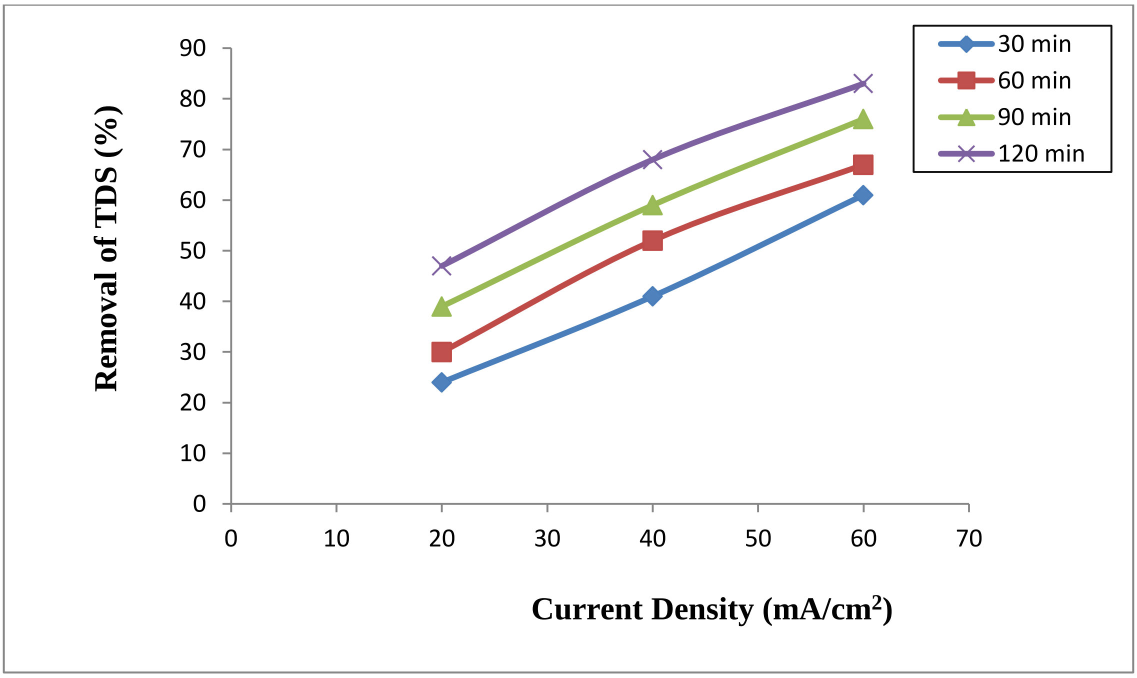

Fig. 4. Effect of current density on removal of total dissolved solids of Hindon water at 25.0 ^{0}C.

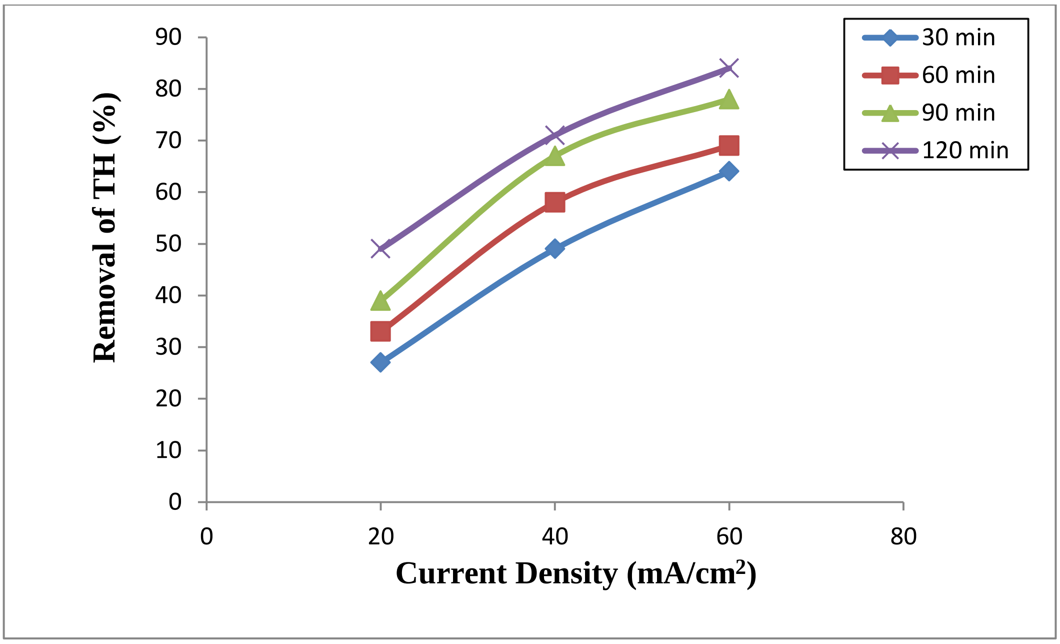

Fig. 5. Effect of current density on removal of total hardness of Hindon water at 25.0 ^{0}C.

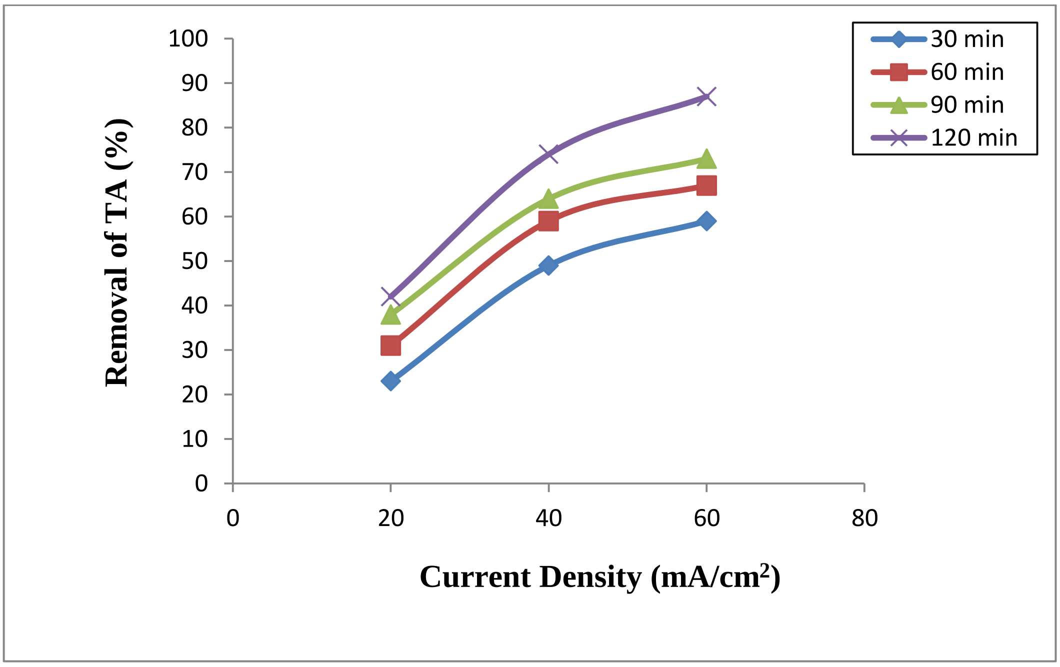

Fig. 6. Effect of current density on reduction of microbial population of Hindon water at 25.0 ^{0}C.

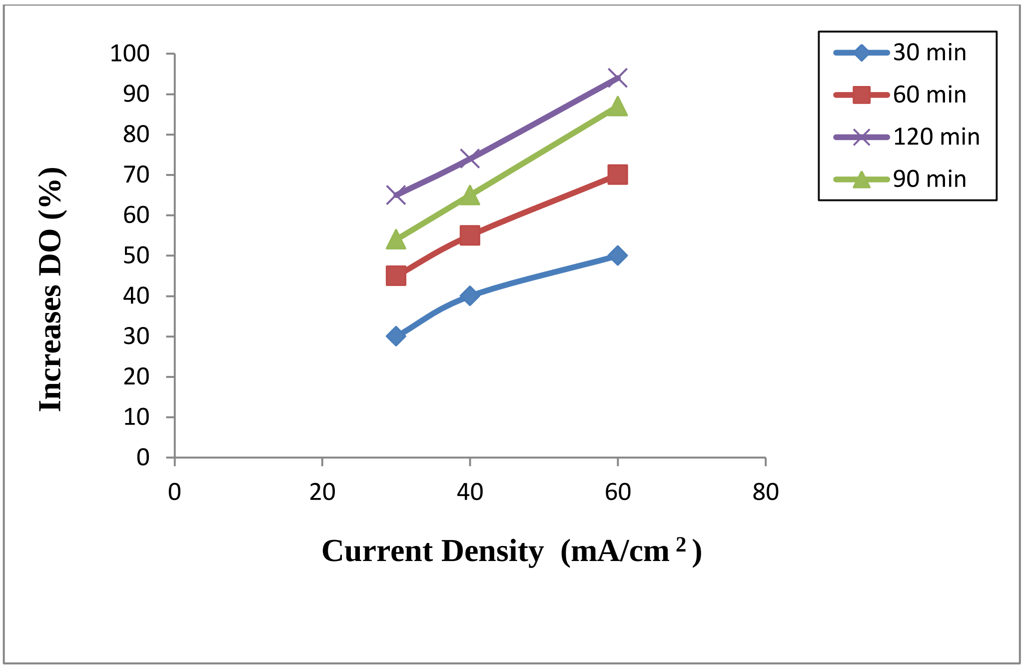

Fig. 7. Effect of current density on increasing of dissolved oxygen of Hindon water at 25.0 ^{0}C.

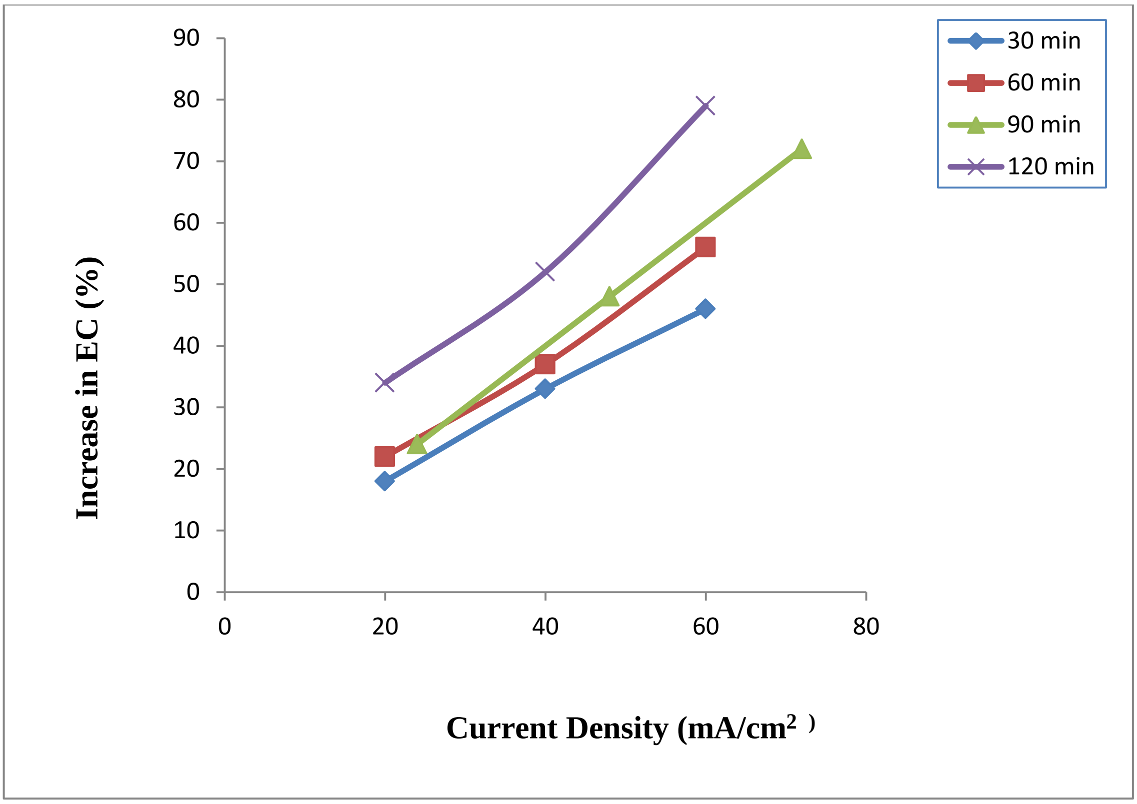

Fig. 8. Effect of current density on electrical conductivity of Hindon water at 25.0 ^{0}C.

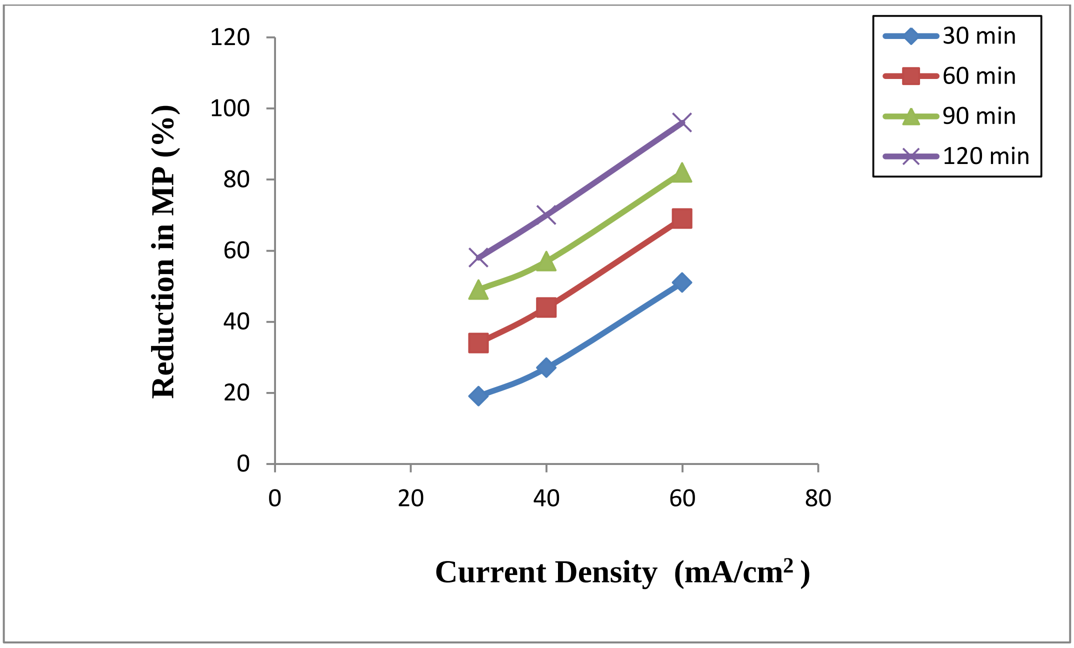

Fig. 9. Effect of current density on reduction of microbial population of Hindon water at 25.0 ^{0}C.

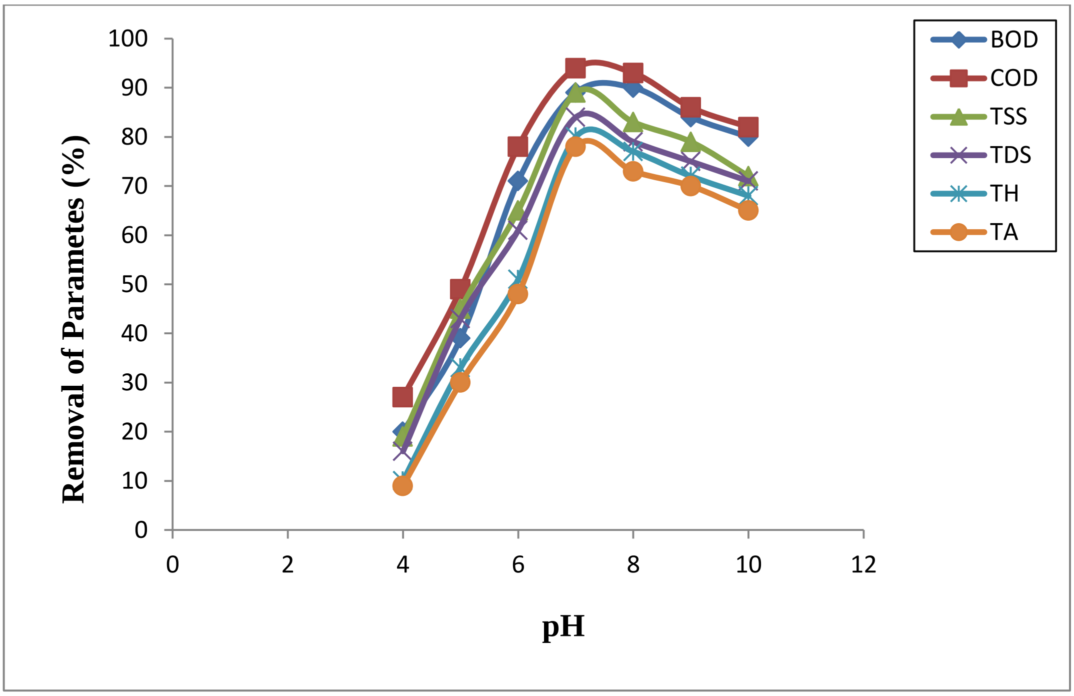

Fig. 10. Effect of pH on selected various parameters of Hindon water at 25.0 ^{0}C.

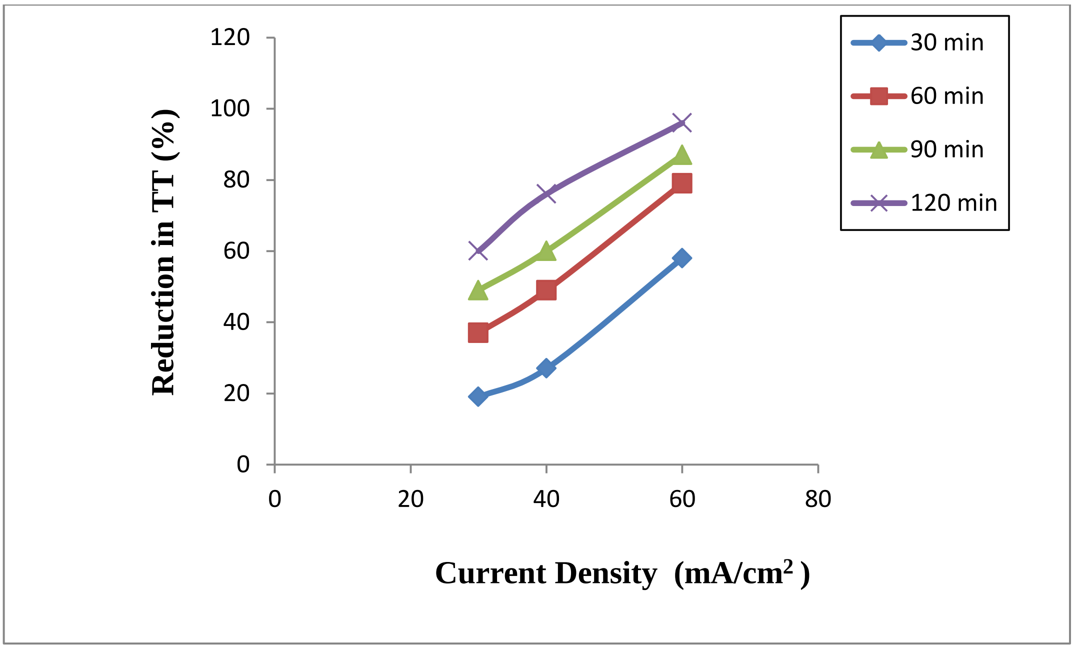

Fig. 11. Effect of current density on reduction of total turbidity Hindon water at 25.0 ^{0}C.

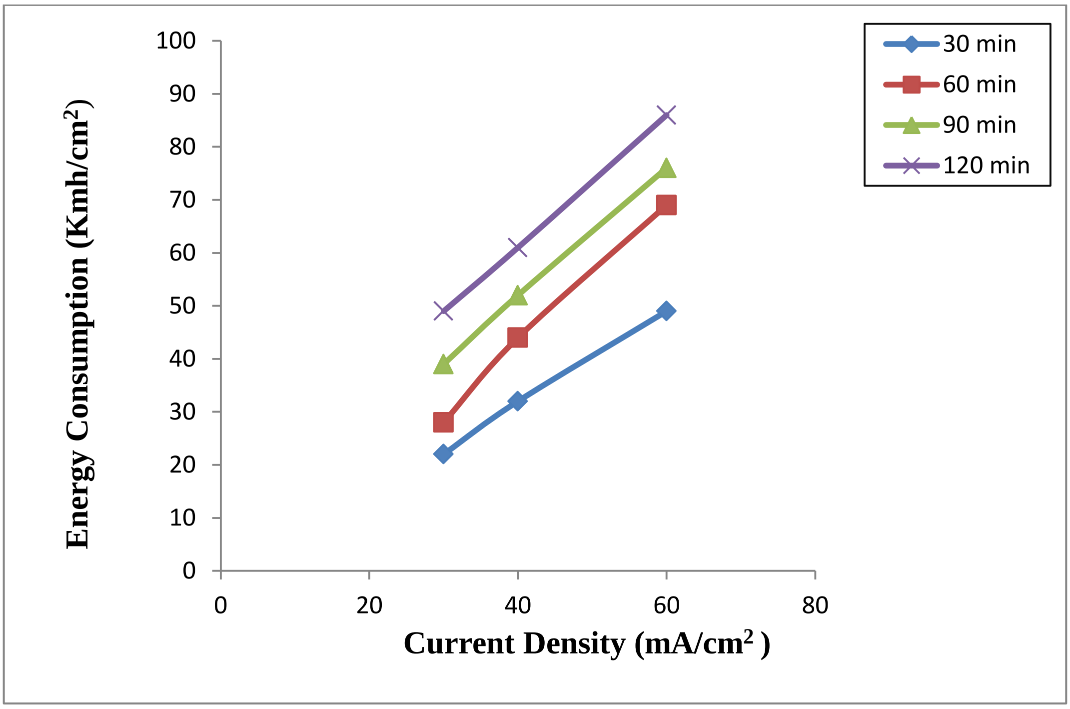

Fig. 12. Effect of current density on power consumption

IV. CONCLUSION

From investigated results, it can be concluded that the electrochemical process can be effectively applied for the treatment of polluted water of Hindon river. During the electrochemical process, produced oxygen and hydrogen gas at electrodes surface play significant role to reduction of BOD, COD, TSS, TDS, DO, TH, EC and TA. Current density and electrolysis period also significantly reduced selected all physicochemical parameters. The summary of quality of Hindon river water presented in Table 1. Clearly, indicates that the Hindon river water is not suitable for domestic, industrial and irrigation purposes. However, after treatment clean Hindon river water can be used for irrigation or any other purpose frequently.

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