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# The Wastewater Treatment by Electrocoagulation & It's Reuse

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## Abstract

Growing water scarcity in India is compelling people to use the treated wastewater at least for landscape irrigation and plantation to augment available water resources. In the present study, a laboratory scale electrocoagulation (EC) process was utilized to treat the raw wastewater in order to bring the quality up to the international wastewater reuse standards. Effect of various operating parameters such as operating time, current density and inter-electrode spacing was evaluated to achieve the maximum possible treatment efficiency. It was found that the application of 24.7 $mA/cm^2$ current density with an inter-electrode spacing of 5 cm may provide 91.8%, 77.2% and 68.5% removal in turbidity, COD and TSS within 30 minutes of EC treatment. The quality of treated wastewater was compared with various international standards/guidelines for wastewater reuse. It was found that the studied parameters such as BOD, COD, TDS, TSS, turbidity, $NO_3$-N, $NH_3$-N, chloride, $Na^+$, $Ca^{2+}$, $Mg^{2+}$, sulfate, total phosphorus, electrical conductivity Oil and Grease (O & G) and total coliform (TC) were within allowable limits. Electrical conductivity, TDS and Sodium Adsorption Ratio (SAR) are mainly used for the determination of wastewater suitability for safe irrigation. Their values do not exceed the international wastewater reuse standards. The study shows that the raw wastewater generated at the study site after EC treatment is safe for landscape irrigation and plantation.

**Keywords**: Electrocoagulation, Wastewater, Removal efficiency, operating parameters

## 1. Introduction

Water is essential to sustain life on the biosphere. However; with the increasing population and industrial growth, its resources are becoming limited and/or contaminated. Due to growing demand globally more than a billion people lack access to sufficient water of good quality. Studies reported that one third of the world's population will experience severe water scarcity within the next 20 years (CGIAR, 2002). Rapid urbanization and high population growth in major cities of Pakistan has led to a deterioration of living conditions. Problems are compounded as most of the fresh water resources are severely polluted with untreated industrial and municipal
wastes (Malik, 2005).

### Solution to Augment water Resources

Among other water management alternatives, the reuse of treated wastewater gained considerable attention (Saleem, 2009; Ruma and Sheikh, 2010). The treated wastewater has several advantages over other sources of water, it minimizes pollution, augments groundwater resources by artificial recharge and it is a good nutrient source for landscape and farm irrigation (Saleem *et al*., 2000). While wastewater reuse in agriculture has been taking place for centuries, in countries like Mexico, Vietnam and China (Shuval *et al*., 1986). It is now receiving renewed recognition as a potential water source under conditions of increased freshwater scarcity. In many Middle Eastern and Asian countries, the reuse of wastewater is now a common practice. Wastewater may be used in agricultural sector especially for landscape irrigation and plantation (Al Salem and Abouzaid, 2006).

**Limitations of Wastewater Reuse**

Wastewater carries a wide spectrum of pathogenic organisms, which pose risk to agricultural workers, crop handlers and consumers (Al-Malack *et al*., 2002; Saleem *et al*., 2000, 2003; Saleem, 2009). High levels of nitrogen in wastewater may result in nitrate pollution of groundwater resources. Accumulation of heavy metals in soils and its uptake by plants is another risk associated with wastewater irrigation (Saleem, 2009).

**Water Scenario in the Study area**

Coastal industries at Karachi such as Karachi Nuclear Power Complex (KNPC) have been facing the water shortage problem for many years. It is expected that with the commissioning of next power plant in the vicinity of KNPC, the problem will augment. Municipal water supply to the plant is intermittent and limited. Estimated average municipal water consumption is about 180 to 190 $m^3/d$. The range of annual wastewater generated at KNPC is 165-175 m3/d. Monthly average value noted is 170±5 $M^3/d$ and 120±5 $m^3/d$ during summer and winter seasons respectively. Amount of municipal water being used for landscape irrigation and plantation at the plant is about 53±5 $m^3/d$ which is about 29 percentage of total municipal water being consumed per day (Personnel communication). The use of wastewater for landscape irrigation and plantation at KNPC could be a promising option to conserve municipal water so as to manage the shortage of water. Present study is carried out first to characterize the wastewater quality generated at KNPC and then to treat it by electrocoagulation (EC) technology to bring the pollutants within the guidelines of international environmental protection agencies (Daneshvar *et al*., 2004; Vigneswaran and Sundaravadivel, 2004). Electrocoagulation is an alternative technology for wastewater treatment in addition to its other conventional applications. The main advantages of electrocoagulation over other conventional techniques, such as chemical coagulation and adsorption, are “in situ” delivery of reactive agents, no generation of secondary pollution, and compact equipment. The earlier studies have reported the potential of electrocoagulation to treat a variety of industrial and domestic wastewater (Vlyssides *et al*., 2000; Kobya *et al*., 2003; Can and Kobya, 2006; Holt *et al*., 2006; Bensadok *et al*., 2008; Merzouk *et al*., 2009; Virkutyte *et al*., 2010).

**Electrocoagulation Process**

In the electrocoagulation process when electrical current flows between two electrodes, coagulant is generated in situ by electrolytic oxidation of the anode material. With an iron anode, Fe(OH)2 or $Fe(OH)_3$ is formed at the anode. Reaction mechanism of iron electrode at the anode

and cathode are reported by many authors (Mollah *et al*., 2004; Othman *et al*., 2006; Babu *et al*., 2007; Murthy and Raina, 2008):

(a) Mechanism 1 :

Anode : $Fe\,(s) \longrightarrow Fe^{2+}\,(aq) + 2\,e^{-}$

$Fe^{2+}\,(aq) + 2\,OH^{-}\,(aq) \longrightarrow Fe(OH)_2\,(s)$

Cathode : $2\,H_2O\,(l) + 2\,e^{-} \longrightarrow H_2\,(g) + 2\,OH^{-}\,(aq)$

Overall : $Fe\,(s) + 2\,H_2O\,(l) \longrightarrow Fe(OH)_2\,(s) + H_2\,(g)$

(b) Mechanism 2 :

Anode : $4\,Fe\,(s) \longrightarrow 4\,Fe^{2+}\,(aq) + 8\,e^{-}$

$4\,Fe^{2+}\,(aq)+10\,H_2O\,(l)+O_2\,(g) \longrightarrow 4Fe(OH)_3(s)+8\,H^{+}(aq)$

Cathode : $8\,H^{+}\,(aq) + 8\,e^{-} \longrightarrow 4\,H_2\,(g)$

Overall : $4\,Fe\,(s) + 10\,H_2O\,(l) + O_2\,(g) \longrightarrow 4\;\;Fe(OH)_3\,(s) + 4\,H_2\,(g)$

According to Larue and Vorobiev (2003), the generation of iron hydroxides Fe(OH)n is followed by an electrophoretic concentration of colloids (usually negatively charged) in the region close to the anode. The produced ferrous ions hydrolyze to form monomeric hydroxide ions and polymeric hydroxide complexes that depend on the pH of the solution. The polymeric hydroxides, which are highly charged cations, destabilize the negatively charged colloidal particles allowing their aggregation and formation of flocs. It also, depends on the solubility of the metal hydroxide. When the amount of iron in water exceeds the solubility of the metal hydroxide, the amorphous metal hydroxide precipitates is formed, which causes sweep-floc coagulation (Benefield *et al*., 1982). Electrocoagulation process is used in the present study to evaluate the effects of EC time, applied current density and inter-electrode spacing on the EC process efficiency for the removal of studied parameters. The treated wastewater is compared with the international guidelines for its reuse.

## 2. Methodology

Present study carried out at Indian Institute of Technology,Mumbai. Wastewater generated from offices, washrooms, toilets, kitchen and other domestic activities are collected in a sewage tank within KINPOE boundary before discharging to the Arabian Sea. Samples were collected from sewage tank in sterilized 300 ml glass bottles. Separate clean bottles were used for sampling. Nitric acid was added to bring the pH of samples below 2 to minimize precipitation and adsorption on container walls (APHA, 2000). After collection, the samples were transferred immediately to the laboratories in iceboxes within 2 hours and were analyzed. Strictly sterilize conditions were maintained throughout collection and transportation of the samples. Analysis of raw wastewater samples was performed in triplicate for various physical, chemical and biological parameters **(Table 1).** In the second part of study the collected raw samples were treated by electrocoagulation process for predetermined time intervals and were analyzed for various parameters **(Table 2).** All the sampling and analysis procedures were adopted from Standard Methods for the Examination of Water and Wastewater (APHA, 2000). Details of methods and instruments utilized during analysis are presented in Table 1.

### Experimental Setup

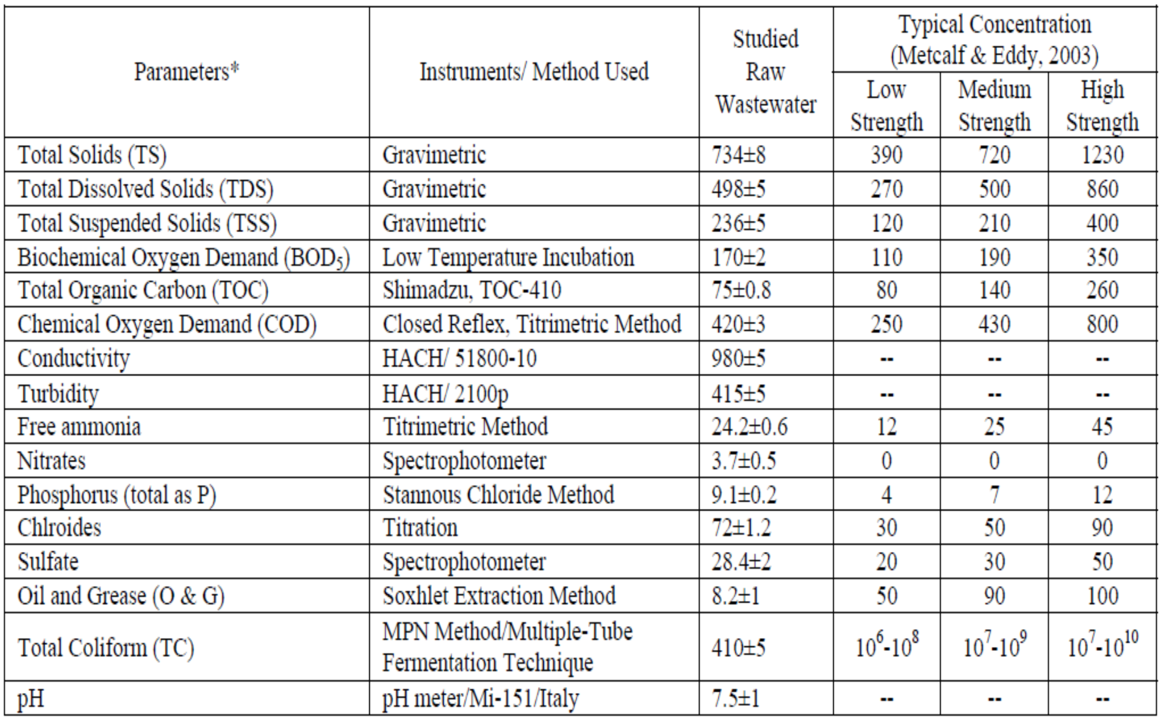
A laboratory scale electrochemical setup made up of circular cell, electrodes and other accessories were arranged (Fig. 1). Electrocoagulation cell having 20 cm and 50 cm of internal diameter and height respectively provide an effective volume of 5 liters. However, in each electrocoagulation process. Two electrodes of iron with surface area of 32 $cm^2$ were used in undivided cell based on the study elsewhere (Saleem, 2010). The separation between the anode and the cathode was kept at 3 cm following the method of Abuzaid and coworkers (1999) during all the runs except in the investigation of electrode spacing. The temperature was maintained between 25-30 °C. The solution in the reactor was stirred by a plate impeller at a rotating velocity of 100 rpm (Heidolph RZR-2101). Controlled direct current was supplied by a DC power supply (Hitachi Model- 17858). The current was kept invariant in each test by a rheostat (Engfield-Middlesex, U.K.) and measured by an ammeter (ATAGO, Japan).

### Experimental Procedure

After detailed characterization of raw wastewater, several EC batch experimental runs were performed in the laboratory. Initially wastewater was rigorously stirred for few minutes by stirrer for homogenization of sample. During the study of EC, time current density of 24.7 $mA/cm^2$ was applied for various time periods (ranging from 5 minutes to 60 minutes). Treated wastewater samples were collected after settling at predetermined time intervals to see the effect of EC treatment time on removal efficiency of TSS, COD and turbidity. In order to see the influence of current density, 0.03, 0.2, 0.4, 0.79 and 1.0 A currents were passed for a contact time of 30 minutes. The currents provided current densities of 0.94, 6.25, 12.5, 24.7 and 31.25 $mA/cm^2$ respectively in these runs. After passing each current, the sample was allowed to settle for 30 minutes so that the flocs and the coagulates that were formed during electrocoagulation may settle. In each experimental run, after settling, about 100 ml supernatant sample was collected for laboratory analysis. Various parameters were analyzed in the laboratory namely; BOD, COD, TDS, TSS, turbidity, $NO_3$-N, $NH_3$- N, chloride, $Na^+$, $Ca^{2+}$, $Mg^{2+}$, sulfate, total phosphorus, electrical conductivity and Oil and

Grease (O & G). Later, SAR was calculated from the values of $Na^+$, $Ca^{2+}$, $Mg^{2+}$ of the samples. In addition to indicator microorganism, total coliform (TC), concentration of important metals (such as Hg, Zn, Cd, Fe, Cr and Al) were also determined **(Table 2).**

Table 1. Characteristics of raw wastewater and a comparison between raw wastewater at KNPC with typical untreated domestic wastewater



| Parameters* | Instruments/ Method Used | Studied Raw Wastewater | Typical Concentration (Metcalf & Eddy, 2003) | | |
|---|---|---|---|---|---|
| | | | Low Strength | Medium Strength | High Strength |
| Total Solids (TS) | Gravimetric | 734±8 | 390 | 720 | 1230 |
| Total Dissolved Solids (TDS) | Gravimetric | 498±5 | 270 | 500 | 860 |
| Total Suspended Solids (TSS) | Gravimetric | 236±5 | 120 | 210 | 400 |
| Biochemical Oxygen Demand ($BOD_5$) | Low Temperature Incubation | 170±2 | 110 | 190 | 350 |
| Total Organic Carbon (TOC) | Shimadzu, TOC-410 | 75±0.8 | 80 | 140 | 260 |
| Chemical Oxygen Demand (COD) | Closed Reflex, Titrimetric Method | 420±3 | 250 | 430 | 800 |
| Conductivity | HACH/ 51800-10 | 980±5 | -- | -- | -- |
| Turbidity | HACH/ 2100p | 415±5 | -- | -- | -- |
| Free ammonia | Titrimetric Method | 24.2±0.6 | 12 | 25 | 45 |
| Nitrates | Spectrophotometer | 3.7±0.5 | 0 | 0 | 0 |
| Phosphorus (total as P) | Stannous Chloride Method | 9.1±0.2 | 4 | 7 | 12 |
| Chlroides | Titration | 72±1.2 | 30 | 50 | 90 |
| Sulfate | Spectrophotometer | 28.4±2 | 20 | 30 | 50 |
| Oil and Grease (O & G) | Soxhlet Extraction Method | 8.2±1 | 50 | 90 | 100 |
| Total Coliform (TC) | MPN Method/Multiple-Tube Fermentation Technique | 410±5 | $10^6$-$10^8$ | $10^7$-$10^9$ | $10^7$-$10^{10}$ |
| pH | pH meter/Mi-151/Italy | 7.5±1 | -- | -- | -- |

*All units are in mg/l, except pH, conductivity ((μmho/cm), coliform MPN/100ml, and turbidity (NTU)

## 3. Result And Discussion

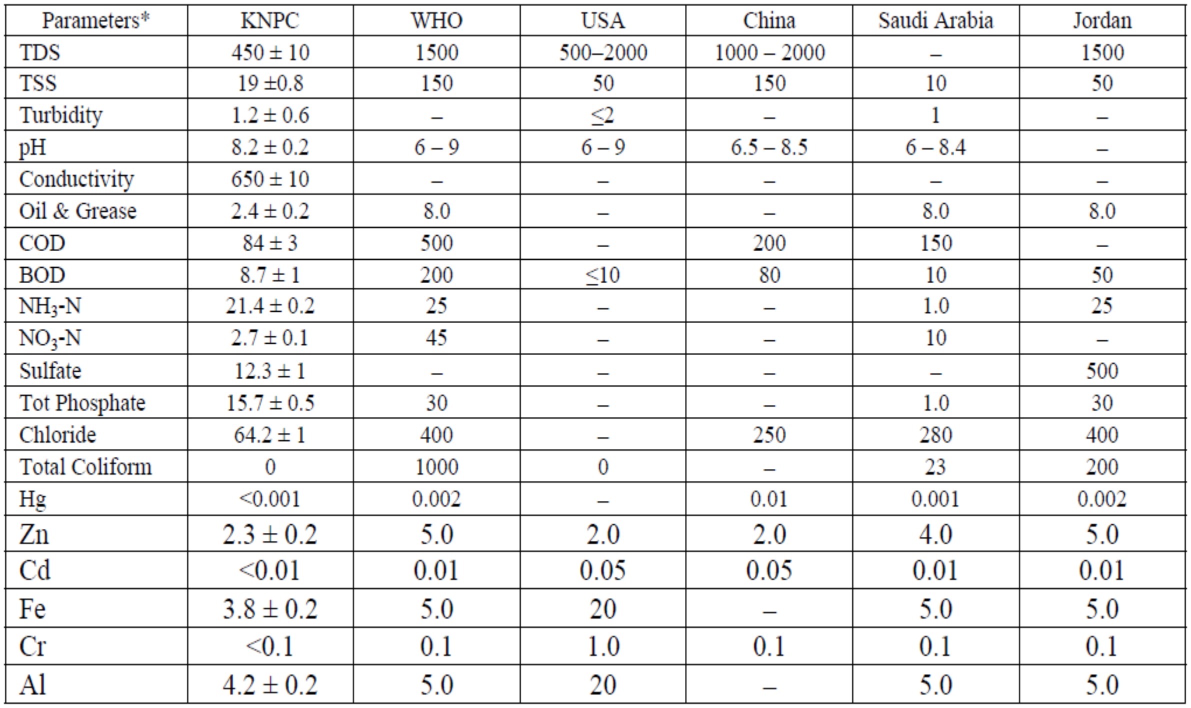
### Characteristics of Raw Wastewater

Characteristics of the raw wastewater used in the experiments are presented in **Table 1**. As observed, the average BOD, COD and TSS concentrations are at the medium strength side as compared to the characteristics of typical domestic wastewater (Metcalf & Eddy, 2003). The high value of TDS or electrical conductivity is advantageous to the EC treatment of wastewater since it will eliminate the need to add an electrolyte that is necessary to facilitate the passage of current in the wastewater solution. Also, the presence of chloride at relatively high concentrations helps in the production of chlorine as a result of the electrochemical process. Chlorine is an oxidizing agent that can participate in oxidizing soluble ferrous ions into insoluble ferric ions as discussed earlier (Larue and Vorobiev, 2003). Furthermore, low values of TC shows the quality of wastewater is favorable for reuse purpose. Value of O&G is also very low showing that this wastewater may be treated easily. A comparison of raw wastewater (table 1) with typical municipal wastewater characteristics showed it to be of weak to medium strength (Metcalf & Eddy, 2003). Later, EC experiments were performed and the effect of various operating parameters on the process efficiency was evaluated. Results obtained in each run are discussed below.

**Effect of Operating Time**

The effluent treated with iron electrode, appeared greenish first and then turned yellow and turbid. This green and yellow color may be resulted from $Fe^{2+}$ and $Fe^{3+}$ ions generated during EC process. $Fe^{2+}$ is the common ion generated in situ of electrolysis of iron electrode. It has relatively high solubility at acidic or neutral conditions and can be oxidized easily into $Fe^{3+}$ by dissolved oxygen in water (Benefield *et al*., 1982; Babu *et al*., 2007). The effect of time was studied at constant current density of 24.7 mA/cm$^2$. **Figure 2** illustrates the removal of TSS, COD and turbidity as a function of operating time, which shows that EC time has a significant effect on the pollutant removal. When the operating time increased from 10 to 30 minutes, the removal of TSS increased from 39.5% to 68.5% and COD from 49.6% to 77.2%. Similarly turbidity removal increased from 52.9% to 91.8%. In this process, EC involves two stages which are destabilization and aggregation. The first stage is usually short, whereas the second stage is relatively long. Results show that maximum efficiency of EC process was obtained at a treatment time of 30 minutes and further increase in treatment time has insignificant improvement in the removal efficiency for the studied parameters. Kobya *et al*. (2003) and Daneshvar *et al*. (2003) observed that pH significantly

Table 2. Comparison of studied treated wastewater quality with various wastewater reuse standards (Vigneswaran and Sundaravadivel, 2004)



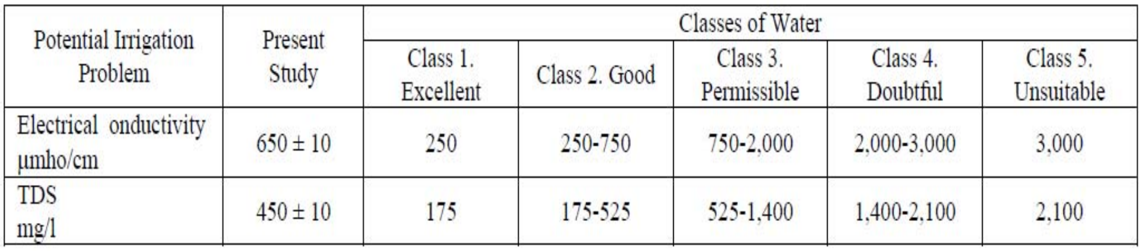
| Parameters* | KNPC | WHO | USA | China | Saudi Arabia | Jordan |
|---|---|---|---|---|---|---|
| TDS | 450 ± 10 | 1500 | 500–2000 | 1000 – 2000 | – | 1500 |
| TSS | 19 ±0.8 | 150 | 50 | 150 | 10 | 50 |
| Turbidity | 1.2 ± 0.6 | – | ≤2 | – | 1 | – |
| pH | 8.2 ± 0.2 | 6 – 9 | 6 – 9 | 6.5 – 8.5 | 6 – 8.4 | – |
| Conductivity | 650 ± 10 | – | – | – | – | – |
| Oil & Grease | 2.4 ± 0.2 | 8.0 | – | – | 8.0 | 8.0 |
| COD | 84 ± 3 | 500 | – | 200 | 150 | – |
| BOD | 8.7 ± 1 | 200 | ≤10 | 80 | 10 | 50 |
| $NH_3$-N | 21.4 ± 0.2 | 25 | – | – | 1.0 | 25 |
| $NO_3$-N | 2.7 ± 0.1 | 45 | – | – | 10 | – |
| Sulfate | 12.3 ± 1 | – | – | – | – | 500 |
| Tot Phosphate | 15.7 ± 0.5 | 30 | – | – | 1.0 | 30 |
| Chloride | 64.2 ± 1 | 400 | – | 250 | 280 | 400 |
| Total Coliform | 0 | 1000 | 0 | – | 23 | 200 |
| Hg | <0.001 | 0.002 | – | 0.01 | 0.001 | 0.002 |
| Zn | 2.3 ± 0.2 | 5.0 | 2.0 | 2.0 | 4.0 | 5.0 |
| Cd | <0.01 | 0.01 | 0.05 | 0.05 | 0.01 | 0.01 |
| Fe | 3.8 ± 0.2 | 5.0 | 20 | – | 5.0 | 5.0 |
| Cr | <0.1 | 0.1 | 1.0 | 0.1 | 0.1 | 0.1 |
| Al | 4.2 ± 0.2 | 5.0 | 20 | – | 5.0 | 5.0 |

influences the treatment performance of the electrocoagulation process. Therefore, the effect of the operating time on the value of pH was noted. The initial pH of solution was kept constant at 6.5. According to **Figure 3** the pH value increases as the operating time of EC process is increased and reached to 8.4. This is due to the $OH^-$ ion accumulation in aqueous solution during the process. The increase of pH at acidic condition was attributed to hydrogen evolution at cathodes (Abuzaid *et al*., 1998). Generally, the pH of the medium changes during the process (Othman *et al*., 2006; Yildız *et al*., 2008). However, the value of pH remained within the allowable limits (Table 2).

### Effect of Applied Current Density

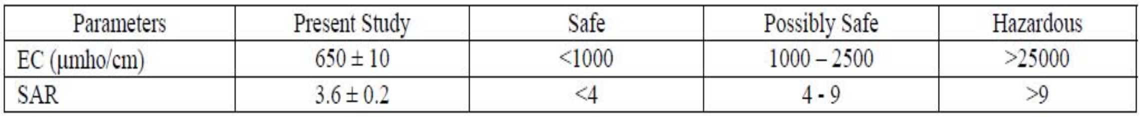
Effect of current density on the removal efficiency of EC process was investigated. Results are presented in **figure 4**. As expected, it appears that for a given time, the TSS removal efficiency increased significantly with the increase in current density. As the current density decreased, the time needed to achieve similar efficiencies increased. According to Chen and coworkers (2000) the treatment efficiency was mainly affected by charge loading. However, the cost of the process is required to determine by the consumption of sacrificial electrode and electrical energy. As the increase in current density augment the cost of treatment, one may use an optimum value of current density for efficient treatment and minimum cost. The result shows that the current density of 24.7 $mA/cm^2$ is reasonable because above this value insignificant improvement in removal efficiency is observed.

Table 3. Permissible limits for interpretation of water quality for irrigation (Fipps, 2004)



| Potential Irrigation Problem | Present Study | Classes of Water | | | | |
|---|---|---|---|---|---|---|
| | | Class 1. Excellent | Class 2. Good | Class 3. Permissible | Class 4. Doubtful | Class 5. Unsuitable |
| Electrical onductivity µmho/cm | 650 ± 10 | 250 | 250-750 | 750-2,000 | 2,000-3,000 | 3,000 |
| TDS mg/l | 450 ± 10 | 175 | 175-525 | 525-1,400 | 1,400-2,100 | 2,100 |

Table 4. Comparison of SAR and EC values of studied wastewater with the irrigation water guidelines in Alberta, Canada (AEP, 2000)



| Parameters | Present Study | Safe | Possibly Safe | Hazardous |
|---|---|---|---|---|
| EC (µmho/cm) | 650 ± 10 | <1000 | 1000 – 2500 | >25000 |
| SAR | 3.6 ± 0.2 | <4 | 4 - 9 | >9 |

### Effect of Inter-electrode Spacing

Inter-electrode spacing is a vital parameter in EC process for the removal of pollutant from effluent. Increasing the electrodes spacing will reduce the capital cost of treatment but may reduce the treatment efficiency.

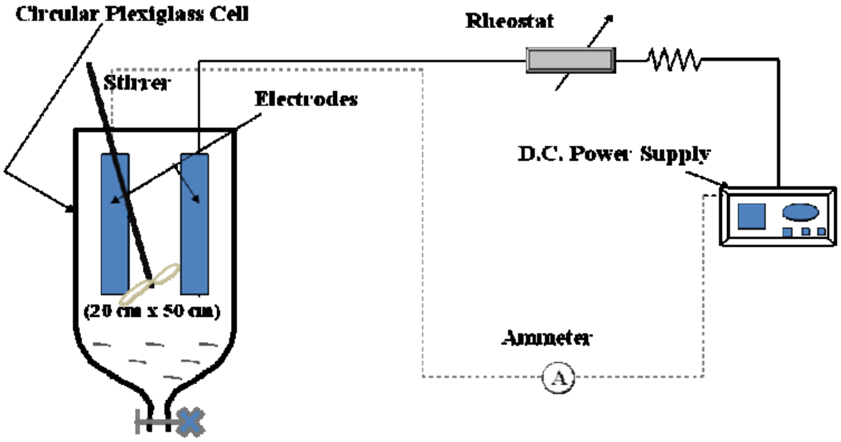


Fig. 1. Schematic of Electrocoagulation Set-up.

Hence, an optimization of this parameter is critical (Bukhari, 2008). Removal of TSS and turbidity at interelectrode spacing of 3, 5, 7 and 8 cm was studied. In each EC run the treatment time was kept constant at 30 minutes. Variation of TSS and turbidity removal as a function of inter-electrode spacing is presented in **Figure 5**. The analysis reveals that the removal efficiency of EC process for TSS and turbidity increased as the interelectrode spacing decreased from 8 cm to 5 cm. Maximum removal efficiency observed at an interelectrode spacing of 5 cm. However, further reduction in inter electrode spacing does not increase the process efficiency. The experimental states that a shorter gap would favor the minimization of the potential drop, which lead to a higher current density. However, after an optimum spacing surface charge double layer dominates and suppresses the removal efficiency (Mattenson *et al*., 1995). Furthermore, that the formation of scale on cathode surface may also passivate the electrode (Belmont *et al*., 1998, Virkutyte *et al*., 2010; Reyter *et al*., 2009, 2010). It concludes that for the studied operational conditions, an inter-electrode spacing of 5 cm is feasible for the removal of TSS and turbidity using EC process.

## Comparison of Treated Wastewater Quality with Available Standards

After determining the optimum values of aforesaid operating parameters, the treated wastewater quality was compared with various international wastewater reuse quality standards (Table 2). Comparison allows to judge the effectiveness of EC process for the treatment of wastewater to be utilized for landscape irrigation and plantation at KNPC. The analysis shows that TDS, TSS and turbidity are within the allowable limits of various countries. However, TSS and turbidity slightly exceed the limits of Saudi Arabian standards, since these standards are relatively stringent compared to other countries. These standards are specific for unrestricted (uncooked eaten crops) irrigation. The final pH value of treated wastewater is basic (8.2 ± 0.2) which is within the allowable limits. Similarly conductivity, O & G, COD, BOD, NH3-N, NO3-N, sulfate and chloride are below allowable limits. Value of total phosphate exceeds the Saudi Arabian standards. However, values are far below the standards of other countries. In case of metals, only the concentration of Zn (2.3 ± 0.2 mg/l) exceeds the limits of USA (2.0 mg/l), Taiwan (2.0 mg/l), Kuwait (2.0 mg/l) and China (2.0 mg/l).

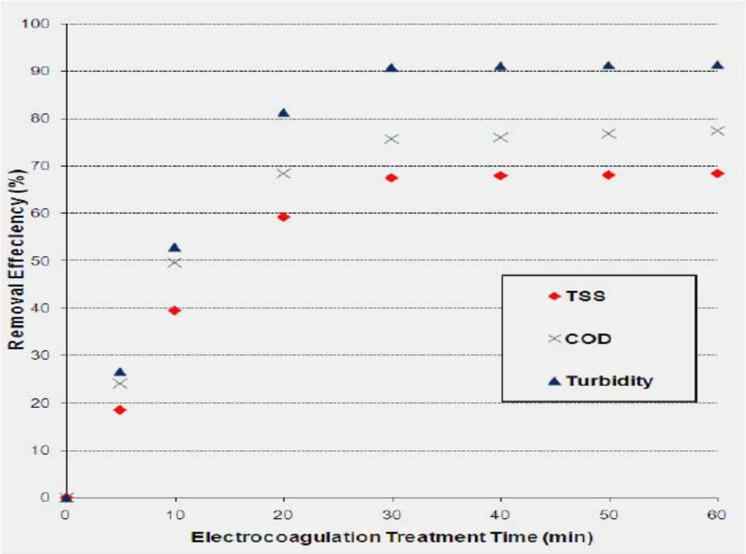


Fig. 2. Effect of EC treatment time on the pollutant removal efficiency

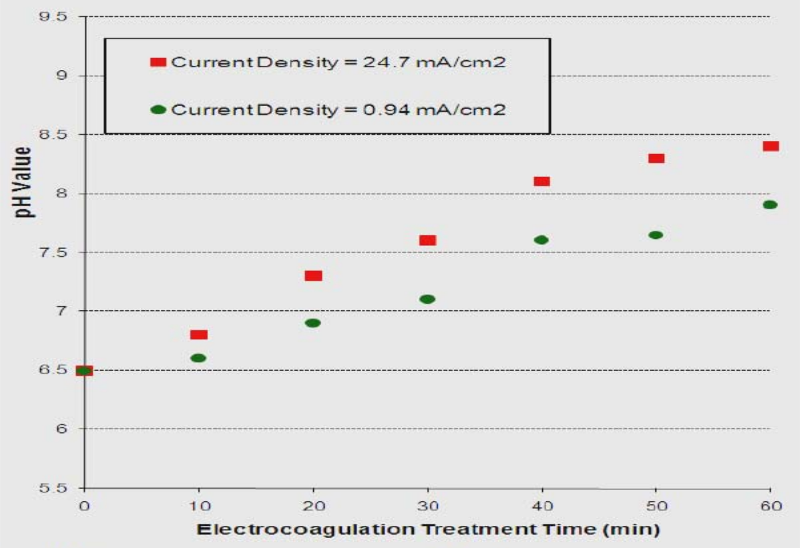


Fig. 3. Variation of pH with EC treatment time at two current densities

Microbiologically important indicator the total coliform shows that after EC treatment their count became zero. This ensures that the treated wastewater microbiologically safe. Electrical conductivity and TDS has great importance in irrigation business. Higher EC and TDS may damage the soil and become a potential irrigation problem. The conductivity and TDS values of studied wastewater are coming under 'Good' class (Class 2) of irrigation water (Table 3). Result shows that the quality of treated wastewater is safe for landscape irrigation and plantation. Furthermore, SAR is another important parameter which determines the extent to which sodium ion is adsorbed by the soil. If irrigation water with a high SAR is applied to a soil for years, the sodium can displace the calcium and magnesium in the soil. This will decrease the soil ability to form stable aggregates. This will also lead to a decrease in infiltration and permeability of the soil leading to problems with crop production (Dontsova, 2002). Therefore, SAR are calculated for the treated wastewater and compared with the allowable limits of Canadian Standards (Table 4). This shows that the values of EC and SAR of the treated wastewater are within the safe range.

## 4. Conclusions

Raw wastewater generated was characterized for possible reuse in landscape irrigation and plantation. Analysis of the wastewater shows that it is of weak to medium strength compared to the typical domestic wastewater (MetCalf & Eddy, 2003). However, raw wastewater is not suitable for direct. Since their various parameters (solids, turbidity, BOD, COD, metals and total Coliform) were above international standards. A laboratory scale EC process was utilized to treat the raw wastewater in order to bring the quality up to the required level. Effect of various parameters such as operating time, current density and inter-electrode spacing was evaluated. It was found that 91.8%, 77.2% and 68.5% removal in turbidity, COD and TSS were achieved within 30 minutes of EC treatment. Further increase in treatment time did not improve their removal efficiency. Change in pH value during EC treatment was also noted and maximum value of 8.4 was observed at the end of treatment which is within allowable limits. Applied current density has significant effect on the removal efficiency of EC process. It was found that the current density of 24.7 mA/cm2 has the highest removal efficiency for studied. Further increase in current density showed insignificant improvement in removal efficiency. The effect of inter-electrode spacing on the removal of TSS and turbidity reveals that their removal efficiency increases as the inter-electrode spacing decreases from 8 cm to 5 cm. Maximum removal efficiency is observed at an inter-electrode spacing of 5 cm. However, further reduction in inter electrode spacing does not increase the process efficiency. This states that a shorter gap favors the minimization of the potential drop that leads to a higher current density. However, after an optimum spacing surface charge double layer dominates and suppresses the removal efficiency (Virkutyte *et al*., 2010; Reyter *et al*., 2010). After EC treatment, the wastewater quality was compared with various international wastewater quality standards. It was found that the studied parameters were within the allowable limits except TSS and turbidity of Saudi Arabian standards. Saudi Arabian standards are relatively stringent these are specific for unrestricted (uncooked eaten crops) irrigation. Electrical conductivity, TDS and Sodium Absorption ration (SAR) are important to determine the suitability of wastewater for safe irrigation. Their values are within safe range. Finally, study shows that the raw wastewater generated after EC treatment is safe for landscape irrigation and plantation. It can be stated that the study may help to conserve municipal water and alleviate the water shortage problem in the study area.

## 5. Acknowledgements

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