Ecological Questions 34 (2023) 1: 99–107 http://dx.doi.org/10.12775/EQ.2023.008

Application of copper and aluminium electrode in electro coagulation process for municipal wastewater treatment: A case study at Karachi

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Received: 7 September 2022 / Accepted: 3 October 2022

Abstract. The reuse of treated domestic wastewater is an imperative source of water for numerous purposes. The treatment of municipal wastewater can be process by utilizing the technique for electrocoagulation. Electrocoagulation (EC) is an eco-friendly technique that combines the functions and advantages of conventional coagulation, flotation, and electrochemistry in water and wastewater treatment. The aim of present study was to assess the potential of electrocoagulation process in removing COD, BOD, TSS, turbidity, sulphate, nitrate, chloride and TDS from municipal wastewater. This experimental study was carried out at a batch system by using copper and aluminium electrodes aiming to treat the municipal wastewater at (0, 7, 14, and 21 volts, 50mamp for 60minutes) from Sample Baloch Colony (SBC), Sample Rind Goth (SRG), Sample Cattle Colony (SCC), Sample Pakistan Machine Tool Factory (SPMTF) and Sample Mehran Highway (SMH). The results revealed that the maximum removal efficiency of COD 96% for SPMTF, BOD 38.5% for SPMTF, TSS 98.14% for SMH, Turbidity 95.7% for SPMTF, Sulphate 95.9% for SRG, Nitrate 95.23% for SMH, Chloride 97.92% for SMH and TDS 96.9% for SRG at 21 volt. The present study suggested that the treated wastewater could be safely reuse for lawns, parks, tree plantation and recreation purpose.

Key words: electro-coagulation; municipal wastewater treatment; physico-chemical parameters.

1. Introduction

Water is essential to sustain life on the biosphere (Zobeidi et al., 2022; Khan et al., 2020) However, with the increasing population and industrial growth, its resources are becoming limited and/or contaminated (Han & Currell, 2022; Ziarati et al., 2022). Boretti and Rosa (2019) reported that one third of the world's population would experience severe water scarcity within the next 20 years. Many industries consume fresh water and exhaust as a wastewater (Ziarati et al., 2021). It should be treated properly to reduce or eradicate the pollutants and achieve the permissible limit for its reutilization in the industrial/agriculture process to promote sustainability (Roopashree & Lokesh, 2014).

Treated metropolitan wastewater is an important source of water for dissimilar drives viz., irrigating agricultural farms and parks, fish farming, and artificially refilling underground wastewater (Yengejeh et al., 2017; Wang et al., 2022). Wastewater transmits several contaminants that can be identified in groups based on their properties viz., total suspended solids (TSS), non-organic particles, organic particles, and microbes. To understand the difference between studied parameters that are important for assessing the performance of wastewater abilities are the chemical oxygen demand (COD) and nitrogen and phosphorus mixes in the waste of such treatment units. Living decomposable materials are always tested according to biological oxygen demand (BOD) and COD. If these resources come in the atmosphere untreated, their biological constancy can prime to reduced oxygen properties, anaerobic situations, and the distribution of bad odors as from hydrogen sulphide (Paul et al., 2013). Electrolytic treatment of wastewater presents an innovative technology in which a sacrificial metal anode and cathode produce electrically active coagulants and tiny bubbles of hydrogen and oxygen in water (Chopra et al., 2011; Sarala, 2012; Al-Othman et al., 2022). Recently, there has been considerable interest in identifying new technologies that are capable of meeting more stringent treatment standards (Kobya et al., 2008). Yang et al. (2008) studied the electrocoagulation electro-flotation processes and noted that high COD removal could be achieved; however, suspended solids and colour removal was not conducive for secondary sewage treatment; nevertheless, electrocoagulation could be used for small scale, decentralized municipal domestic sewage treatment. Zaleska-Chrost et al. (2008) determined that laboratory conditions for electrocoagulation was a better treatment than chemical coagulation, having identified COD, turbidity, suspended solids, and colour, where crude sewage is contingent on the pollutant removal efficiency. Linarez-Hernandez et al. (2010) observed that the combination of electrocoagulation and electroxidation was capable of successful at completing treatment electrocoagulation coagulates and removes particulates, while electrocoagulation oxidizes what remains. Overall, the process is capable of reducing COD, BOD, colour, turbidity, and coliforms in 2 hours. Belkacem et al. (2008) concluded that BOD removal was 93.5%, COD 90.3%, turbidity 78.7%, suspended solids, and colour greater than 93% using electro-filtration with aluminium electrodes, where parameters involved electrical potential of 20 V, distance of 1 cm, and electrolysis time less than 20 minutes. In addition, the kinetics was less than 5 minutes with a removal of 99%. Nouri et al. (2010) concluded that electrocoagulation had a treatment time between 20 and 60 minutes, 40 V electrical potential for the removal of Cr(VI) ions by using iron electrodes, and a pH of 3. Recently there has been growing interest towards electrochemical techniques for the treatment of wastewater containing organic pollutants. Two important features of the electrochemical process are converting non-biocompatible organics in to biocompatible compounds and oxidation of organics into carbon dioxide and water. A typical electrochemical treatment process consists of electrolytic cell, which uses electrical energy to affect a chemical change. In simplest forms, we can say that, an electrolytic cell consists of two electrodes, anode and cathode, Immersed in an electrical conducting solution (the electrolyte), and are connected together, external to the solution, via an electrical circuit which includes a current source and control device (Murthy et al., 2011). During the last years, the electrochemical methods have been developed and used as alternative options for the remediation of water and wastewaters mainly due to their advantages, e.g., environmental compatibility, versatility, high-energy efficiency, the amenability of automation and safety, and cost effectiveness. The main objective of present study was to assess the efficacy of electrocoagulation process by using copper and aluminium electrodes along with different volts (0, 7, 14, and 21 volts, 50 amp and 60 minutes for removal of COD, BOD, TSS, Turbidity, Sulphate, Nitrate, Chloride and TDS from SBC, SRG, SCC, SPMTF and SMH at Landhi-34 area Karachi.

2. Methodology

2.1. Study area

Present study area is comprised of Baloch's Colony (SBC) Labour square area, Cattle Colony (SCC), Mehran Highway (SMH), Pakistan Machine tool factory (SPMTF) and Rind Goth (Fig. 1). These five locations of the study area lies in district Malir that is geographically located at 24° 45' to 25° 37' N and 67° 06' to 67° 34' E. The area of Malir district is approximately 2268 km^2 kilometres. The establishment of industrial unit in rural parts of this district causing devastated effects by throwing their untreated toxic wastes into surface water bodies. In addition, the waste from other different sources like agricultural, domestic and municipal are also being dumped into surface water due to unsafe disposal systems which makes surface water highly polluted (Azizullah et al., 2011).

2.2. Materials collection

For holding a sample, the electrochemical cell consists of a borosil glass beaker of 5 lit capacity. Commercially available aluminium and copper plate was cut into required sizes [150×50×3 mm] followed by Kuokkanen et al. (2013). In order to minimize the deposition on electrodes polarity of current was inverted at conventional intervals provisions

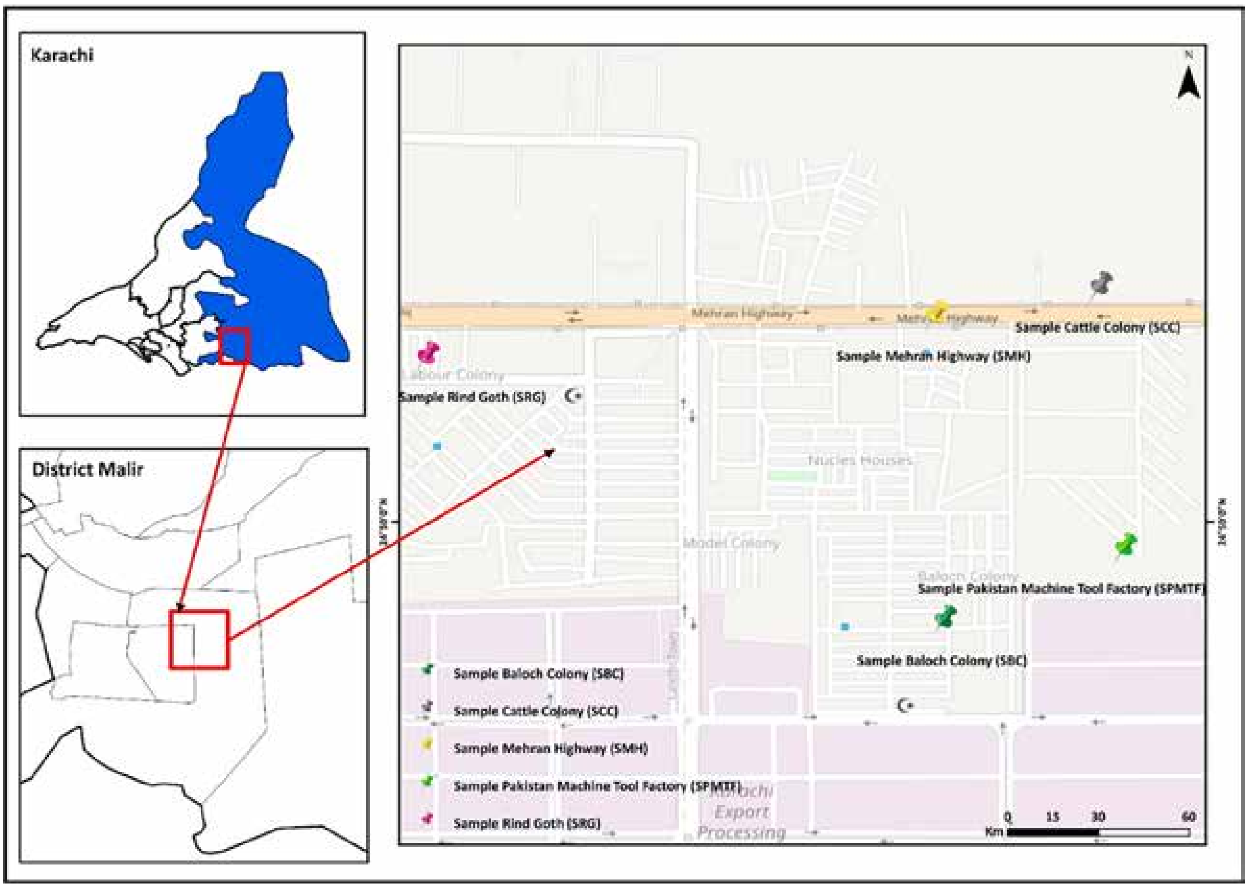

Figure 1. Map location of study area

were made in the reactor for the transmutation of electrodes. The electrolytic cell was equipped with a magnetic stirrer in order to keep the electrolyte well commixed. In this study, an individual effect of cell voltage was quantified. The electrolysis was carried out under galvanostatic conditions covering a wide range of operating conditions. In addition, provisions for electrical connections were made by making holes at the top of the plates.

2.3. Experimental set-up

The efficiency of the electrolytic cell was studied with different voltages such as (0, 7, 14, 21 volt) at the fixed electrolysis Time. Each experiment of batch operation for 60 minute samples has been drawn and operating parameters such as pH, COD, BOD, TSS, nitrates, turbidity, Oil & Grease, sulphate Pb, Cd and TDS measured (Bazrafshan et al., 2011). Before each run, the impurities in the surfaces of electrodes were removed by dipping in HCl solution (15% W/V) for 1–2 min and then washed with distilled water.

At the end of each experiment (i.e. after electrocoagulation) runs, the sample was transferred into another beaker and kept undisturbed for 20 minutes in order to allow the flocs that formed during electrocoagulation to settle down.

2.4. Analysis of samples

All the reagents were used of analytical grade and solutions were prepared by using distilled water. The studied parameters such as COD, BOD, TSS, turbidity, sulphate, nitrate, chloride and TDS were determined using standard analytical methods and procedures followed by (Federation and Aph Association, 2005; Yengejeh et al., 2017). The calibrated instruments was used for observing readings. The repeated measurements were made up to ensure precision and accuracy of results before and after the treatment.

2.5. Statistical analysis

The mean data of studied parameters was used in this present work by using Excel. All the graphs were prepared by using OriginPro16.

3. Result and Discussion

Data show that pH of untreated domestic wastewater samples is basic (6.8–8.1) and within the standard limit of Sindh Environmental Quality Standards (SEQS 6–9). The

COD concentration in wastewater samples of the study area was found higher (200–25900 mg/L) than SEQS (150 mg/L) standards (Table 1). Similarly, higher values (80–10142 mg/L) of BOD was found in wastewater samples than recommended limit of SEQS (80 mg/L). Data revealed that extremely high concentration of COD and BOD were found in wastewater of SCC area than other parts of the study area. The 8.8 times higher and 0.58 times lower TSS content was noted in SCC and PMTF areas respectively than SEQS limit (200 mg/L). The Oil & Grease concentrations were found 5 times lower in SBC and PMTF samples as compared with SEQS 10 mg/L) values. The maximum turbidity (NTU) was observed by 830 (NTU) in SCC, but the lowest was observed by 23 (NTU) in PMTF domestic wastewater samples. The sulphate (mg/L) concentration in all studied domestic wastewater samples ranges between 10–128 mg/L and found within the SEQS (600mg/L) values. The sulphate (mg/L) content in SCC studied wastewater sample was observed 60 times lower than SEQS (600 mg/L) values. The nitrate (mg/L) content was found lower 1.8 (mg/L) in PMTF samples as compared with other domestic wastewater samples. The cadmium (Cd) and lead (Pb) content was not observed in SBC, SRG, SCC, PMTF and SMH studied areas samples as compared with SEQS values such as 0.1 mg/L for Cd and 0.5 mg/L for Pb. The chloride (mg/L) concentration was noted by 0.21 times higher in SRG, whereas chloride (mg/L) in the PMTF wastewater samples was found 7.69 times lower as compared with (SEQS 1000 mg/L). The TDS (mg/L) content was found lower in SBC, SRG, SCC, PMTF and SMH studied areas samples as compared with SEQS 3500 mg/L standards. However, the concentration of TDS (mg/L) in PMTF studied area was received by 4.6 times lower than SEQS 3500 mg/L values.

The data revealed that to understand the response of 0 volt, 7 volt, 14 volt and 21 volt along with 50 m amp, 60 minutes on pH value in SBC, SRG, SCC, PMTF and SMH studied domestic wastewater samples (Fig. 2). It was observed that the lowest pH value observed by 7.01. at 14 volt in SBC studied samples as compared with 7.05. 0 volt. The minimum pH value in SRG, SCC, PMTF and SMH was observed by 6.85, 6.8, 7.76 and 7.08 at 21 volt as compared with 6.92, 6.82, 8.13 and 7.17 at 0 volt. The maximum removal efficiency of COD in treated domestic wastewater samples was received by 65, 220, 950, 8 and 170 mg/L at 21 volt and compared to 1338 for SBC, 5820 for SRG, 25900 for SCC, 200 for PMTF and 4800 mg/L for SMH at 0 volt. It was observed that the maximum removal of COD concentration in treated domestic wastewater sample was found to be with an increase of volt. The maximum removal of BOD was observed by 37 for SBC, 82 SRG, 380 for SCC, 3 for PMTF and 66 mg/L for SMH at 21 volt as compared with 732, 2140, 10142, 80 and 1877 mg/L at 0 volt, respectively. The results of present study revealed that the recovery of COD and BOD was observed with increasing voltage. Similarly, Zaied and Bellahkal (2009) found the removal of 98% COD with application of electrocoagulation method at 14 mA/cm^2 and 50 minutes. Khansorthong and Hunsom (2009) observed the reduced of COD by 77% after wastewater treating with pulp and paper mill by electrocoagulation in batch mode with 6 iron mate pieces. Furthermore, Meas et al. (2010) noted that removal of COD (95%) and turbidity (99%) by using sacrificial electrodes. Rahmani and Samarghandi (2007) noted the reduction of COD in wastewater with application of electrocoagulation method. In addition, Arbabi et al. (2014) found the maximum removal efficiency of COD with rising of current density. Saleem et al. (2011) found the allowable limits of BOD in the wastewater at 24.7 mA/cm^2 current density.

Table 1. Physicochemical properties of pre-treated studied wastewater samples

Parameters	Unit	SEQS values	SBC	SRG	SCC	PMTF	SMH
pH		6–9	7.05	6.92	6.82	8.13	7.17
COD	mg/L	150	1338	5820	25900	200	4800
BOD	mg/L	80	732	2140	10142	80	1877
TSS	mg/L	200	89	46	1760	38	54
Oil & Grease	mg/L	10	2	4	5	2	4
Turbidity	NTU	-	106	148	830	23	58
Sulphate	mg/L	600	128	24	10	21	72
Nitrate	mg/L	-	8.8	3.8	4	1.8	2.1
Cd	mg/L	0.1	ND	ND	ND	ND	ND
Pb	mg/L	0.5	ND	ND	ND	ND	ND
Chloride	mg/L	1000	147.22	214.14	187.40	130	192.72
TDS	mg/L	3500	819	944	1372	761	1316

Note: SEQS = Sindh Environmental Quality Standards; 0, 7, 14, 21 volt, 50mamp, 60minutes; SBC = Sample Baloch colony; SRG = Sample Rind Goth; SCC = Sample Cattle Colony; PMTF = Pakistan Machine Tool Factory; SMH = Sample of Mehran Highway; pH = Power of hydrogen; COD = Chemical oxygen demand; BOD= Biological oxygen demand; TSS = Total suspended solids; Cd = Cadmium; Pb = Lead; TDS = Total dissolved solilds; - = Not available and ND = Not detected.

Idusuyi et al. (2022) noted that optimum COD and BOD removal efficacy of 90.7% and 97.67% were found at 10 V.

Data showed that the greatest removal of TSS was received by <3 for SBC, 1 SRG, 80 for SCC, 1 for PMTF and 1 mg/L for SMH at 21 volt as compared with 89, 46, 1760, 38 and 54 mg/L at 0 volt, respectively. It was observed that the highest removal of turbidity (NTU) was observed up to <1 for SBC, 5 SRG, 55 for SCC, <1 for PMTF and 2 NTU for SMH at 21 volt as compared to 106, 148, 830, 23 and 58 NTU at 0 volt, respectively (Fig. 3). It has been noted that the maximum removal of sulphate (mg/L) was observed by 6 for SBC, <1 SRG, <1 for SCC, <1 for PMTF and 3 mg/L for SMH

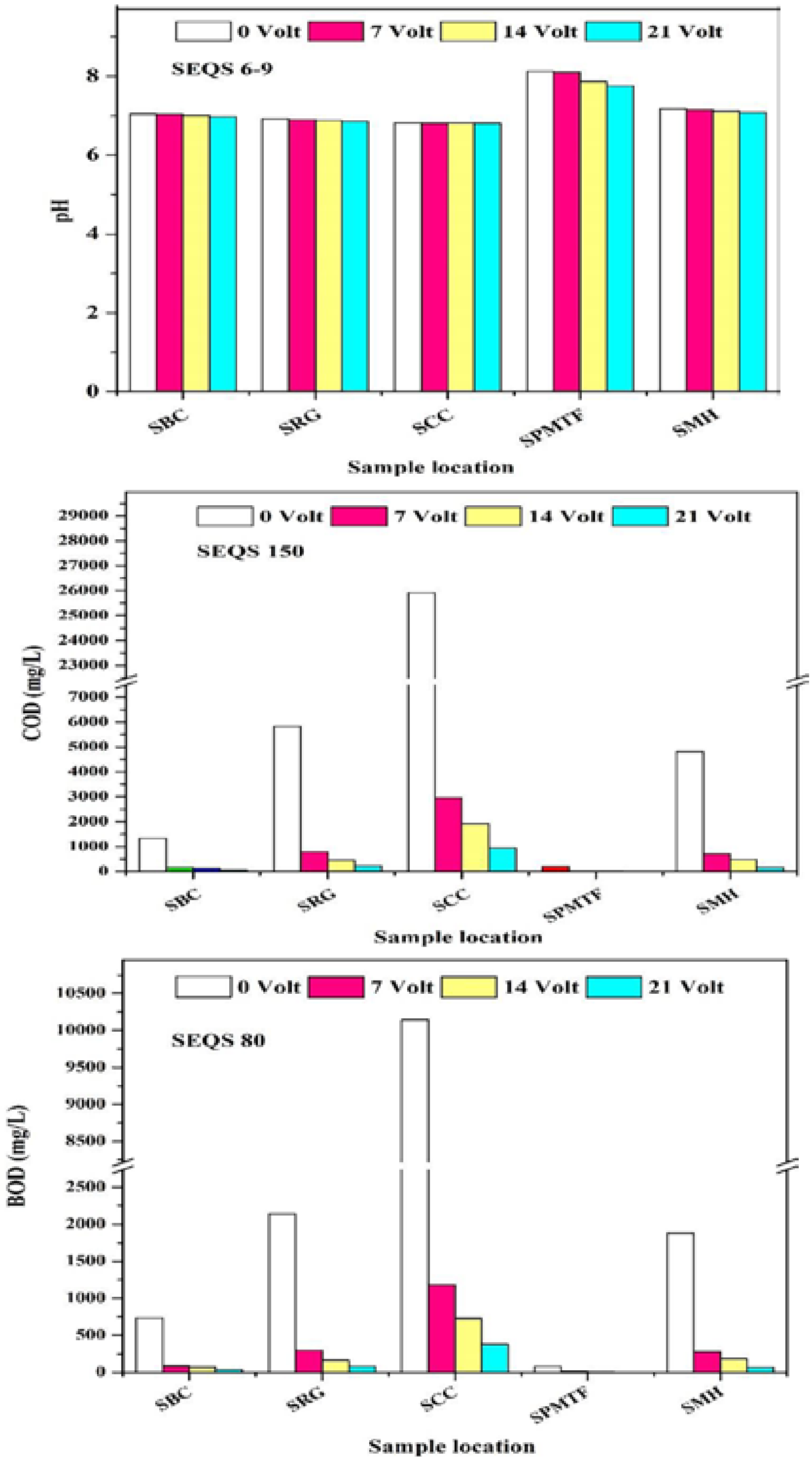

Figure 2. Response of voltage on pH, COD and BOD in wastewater samples collected from SBC, SRG, SCC, PMTF and SMH areas at Landhi-34

at 21 volt in comparison with 128, 24, 10, 21 and 72 mg/L at 0 volt, respectively. The above results revealed that the maximum removal of TSS, turbidity and sulphate was noted at 21volt due to dispersion of solid particles and changes in water molecules. The efficacy degrees of eliminating COD, TSS, nitrate and turbidity from urban wastewater using electrocoagulation with aluminium electrodes at 30 V and 30 minutes of contact time were 88.43%, 87.39%, 100% and 80.52%, respectively (Yengejeh et al., 2017). Arbabi et al. (2014) stated that that turbidity removal efficiency rates were augmented with an enhance of current density. Malakootian et al. (2010) reported an accumulative current density manufactured greater and denser flocs. The number of bubbles reduced, nonetheless their thickness amplified.

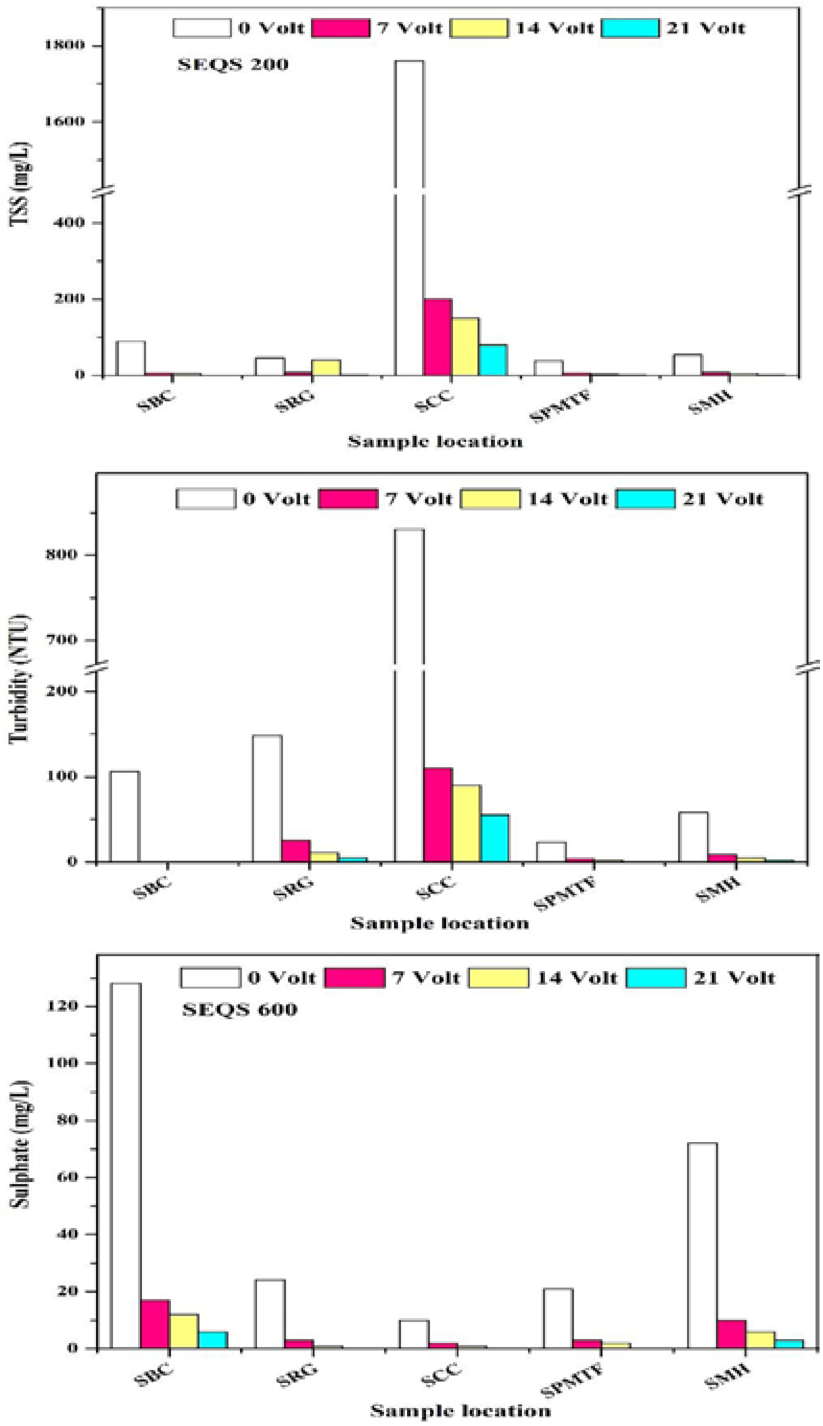

Figure 3. Response of voltage on TSS, Turbidity and Sulphate in wastewater samples collected from SBC, SRG, SCC, PMTF and SMH areas at Landhi-34

Consequently, insubstantial particles were detached by the bubbles. Mahvi et al. (2010) stated that electrocoagulation technology can be successfully introduced as a suitable and capable method to eliminate sulphate ion from aqueous settings by using plate aluminium electrodes.

Data explored that the highest removal of nitrate was detected by 0.1 for SBC, 0.1 SRG, 0.1 for SCC, <0.1 for PMTF and <0.1 mg/L for SMH at 21 volt as compared with 8.8, 3.8, 4, 1.8 and 2.1 mg/L at 0 volt, respectively. It was seemed that the uppermost removal of chlorine mg/L was observed up to 7 for SBC, 6 SRG, 4 for SCC, 6 for PMTF and 4 mg/L for SMH at 21 volt as compared to 147.22, 214.14, 187.4, 130 and 192.72 mg/L at 0 volt, respectively (Fig. 4). The maximum removal of TDS (mg/L) was received by 40 for SBC, 30

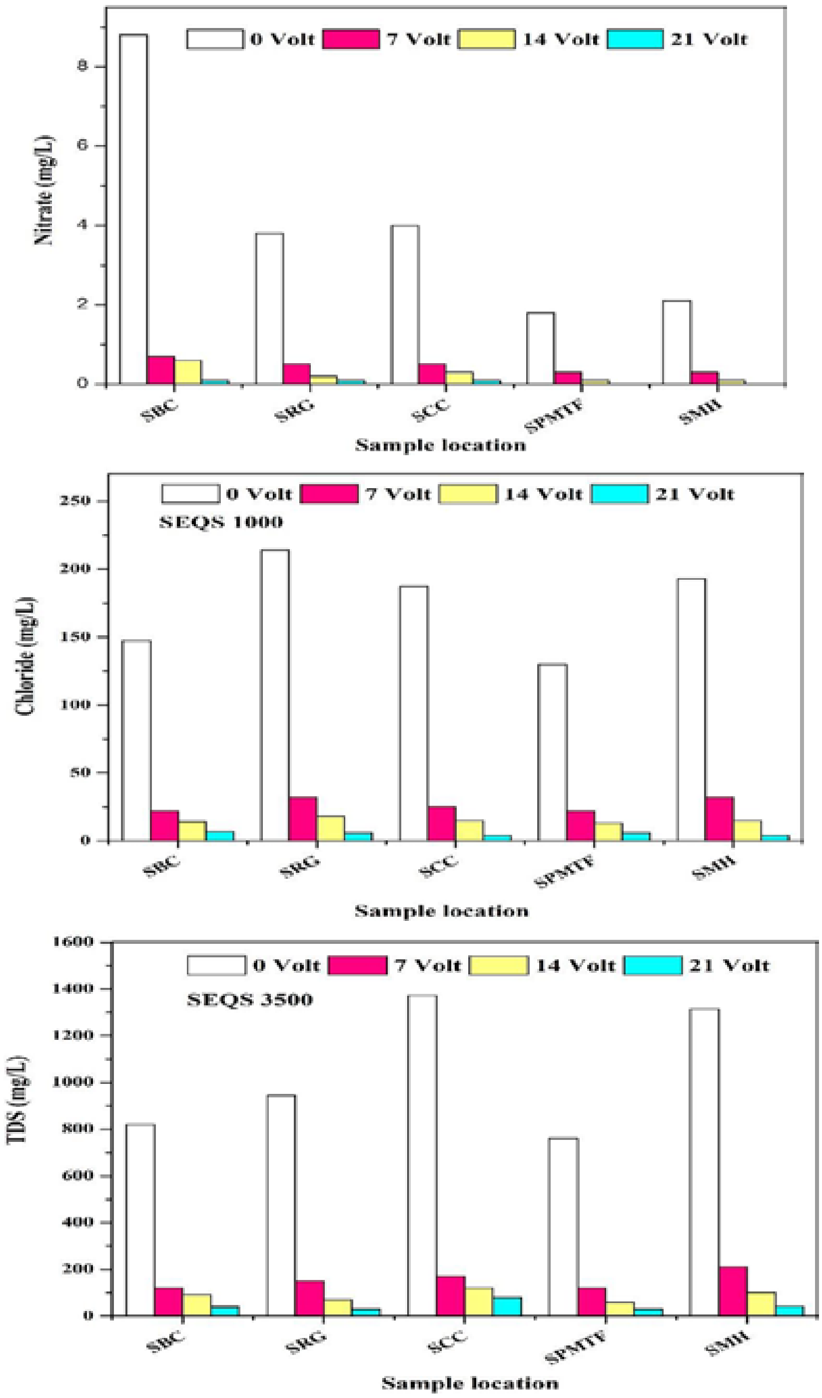

Figure 4. Response of voltage on Nitrate, Chloride and TDS in wastewater samples collected from SBC, SRG, SCC, PMTF and SMH areas at Landhi-34

SRG, 80 for SCC, 30 for PMTF and 41 mg/L for SMH at 21 volt as compared to 819, 944, 1372, 761 and 1316 mg/L at 0 volt, respectively. It was assumed that the maximum removal of nitrate, chlorine, and TDS at 21volt, because of changes in water chemistry. Bazrafshan et al. (2011) found that the maximum removal of nitrate from the solution by iron electrodes (96%) at 40 volts, 60 minutes of contact time, and an initial concentration of 5 mg/L. Saleem et al. (2011) reported that the chlorides and TDS were found allowable limits in the wastewater at 24.7 mA/cm^2 current density as compared with various international values for wastewater reprocess.

4. Conclusion

The study investigated the removal efficacy of COD, BOD, TSS, turbidity, sulphate, nitrate, chloride and TDS from municipal wastewater samples from SBC, SRG, SCC, SPMTF and SMH at Landhi-34 Karachi area using electrocoagulation method. The pH range of municipal wastewater sample was observed under SEQS limits. It was established that the lowest pH value observed by neutral in the SBC studied samples. The maximum removal efficiency of COD for SPMTF, BOD for SPMTF, TSS for SMH, Turbidity for SPMTF, Sulphate for SRG, Nitrate for SMH, Chloride for SMH and TDS for SRG was observed at 21volt as compared with 0 volt. The results showed that COD, BOD, TSS, turbidity, sulphate, nitrate, chloride and TDS parameters removal efficiency was directly proportional with increasing of voltage. Finally, the results of study indicated that, EC technology integrated with other environmental friendly and easily available techniques could be applied for the cost effective treatment of municipal wastewater.

Acknowledgement

We are grateful to Mr. Aneeq Mahmood Abbasi, Assistant Manager, working as GIS Analyst for help in to make GIS map location of study area.

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