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Effluent Treatment Plant (ETP): A Comparative Study between Electro-Coagulation and Chemical Coagulation Techniques of Dyeing and Washing Industries in Bangladesh

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Abstract

This is a comparative study with the effluent treatment plant using electro-coagulation EC) and chemical coagulation (CC). The study was conducted at Gazipur district and Savarupazila of Bangladesh to find out the water chemistry of effluent and treated water and makes a comparison with the DOE standard for surface and irrigation water. Find out of sludge characteristics was one of the other objectives of this study. Sample collection was done within the month of October to November, 2013 and general lab test of water and sludge were done at Asia Arsenic Network (AAN) in Jessore. In water analysis part it was observed that the electric conductivity, TDS, color and turbidity was better for the chemical coagulation process and sulfate, DO, BOD, COD, TSS, sulfide, chloride condition was better in electro-coagulation process. Bacteria removal efficiency was noticeable in the electro-coagulation process than the chemical coagulation process. In sludge the pH, conductivity, TDS was slightly higher in CC process than the EC process. The water analysis part will be helpful to give a suggestion that effluent treatment plant (ETP) using EC process is better than the ETP using CC process in the perspective of treated water quality and environmental issue.

Keywords: Effluent, ETP, Electro-coagulation, Chemical coagulation, Sludge, Water chemistry.

Introduction

Industry makes an evaluation in the economic sector of a developed or developing country. Bangladesh although an agricultural country but at the modern civilization industry is the main part for earning foreign currency. According to the calculation at 2013 Bangladesh has 5600 garments industry only and their create a job opportunity for 4.4 million people especially for women. Bangladesh earned 27018.26 million US$ at2012-13 from different foreign country[1]. At present the garment sector earns about 77% of the country's foreign currency, and industrial work force earning about 50%[2] (European Commission). For the Garments industry there also need huge amount of dyeing and washing industry to color and wash the garment products. In Bangladesh, already there have established more than thousand of dyeing and washing industries in large or small scale. The textile dyeing and washing industries are the industries that consume huge amount of water and chemical products. Textile-manufacturing industries such as Dyeing and washing are the most used in the garment sector. Dyeing and washing industries both processes generate high amount of wastewater. This waste water generally contain suspended solids (SS), high color, suspended solids (SS), temperature, pH, chemical oxygen demand (COD), biological oxygen demand (BOD) other organic matters[3-5]. General study showed that waste water carries huge amount of pathogenic organisms, in where may have a risk for the agriculture related workers, the persons who control crop and for the consumers[6-9].

Due to the reason of dyeing industries of Gazipur and Savar there generate huge amount of effluent and solid sludge. The river Turag and Dhalessori are polluting in every moment for the discharge into the surrounding agricultural fields, irrigation bodies, surface flowing water. At March 2014 Department of Environment of Gazipur district has given information that only Gazipur district has 324 effluent treatment plant (ETP) for waste water treatment. These polluted effluents change the general properties of surrounding water bodies. Here highly change the physical, chemical, and biological properties of water bodies. The changes within the water bodies are odor, noise, temperature, turbidity. Public health, livestock, wildlife, fish, and other biodiversity may fallen in danger for this type of change in the water body. Procedure for issuing Environmental Clearance Certificate the red category industry must submit the Layout Plan (showing location of Effluent Treatment Plant), process flow diagram, design of the ETP[10].

Coagulation is an exigent part of the effluent treatment plant. Chemical coagulation predominantly used in physic-chemical treatment. These include electro coagulation, electro flotation[11], electro decantation[12] and others. Electro-coagulation has

received a small attention as profitable issue of the treatment system. There had several tries to improve this system literally but there was little success to improve this process. But at present different countries trying to apply this system practically and they are successful in their attempt. This process we usually know as electro-coagulation[13]. On the other hand Chemical coagulation is a preliminary process where need to use additional chemical. Chemical coagulation is one of the most common and practical methods which using rapidly in different industries of Bangladesh. This process is standard for chemical oxygen demand (COD) and for removal of colloidal forms of pollution from wastewater and abatement. Destabilization is used to make flocculants in the waste water. This process enlarges the ionic strength which helps in double-layer compression. By adsorbing counter anions neutralization of the particle using the addition of chemicals called coagulants and flocculants. These generally adjust with pH of effluent[14]. About hundred years the electro-coagulation is known to the chemist. But there was not enough systematic research to improve their actions and mechanisms, chemical behavior, design and operation site of the system[15]. From these types of coagulation which is more compatible and which is more commercially and environmentally beneficial for the industry is an important issue. This study has discussed this issue with in a precise way. In the study there generally find out the water chemistry of effluent and treated water of electro-coagulation and chemical coagulation process used in ETP. Determining the criteria of acceptable limit of treated water for the purposes of surface and irrigation water with The Department of Environment (DoE) standard which help us to know about the water chemistry of effluent treatment plants.

Materials and Methods

The experience was conducted in the month of July 2014 to April 2015. The effluents and solid samples were collected in the month of February from the specific industries and were processed for subsequent experiments and for physic-chemical analysis.

Study Area: The study has been conducted in Gazipursadar and Sripurupazila of Gazipur district of Bangladesh which located in from 23°53´ to 24°21´ north latitudes and in the east longitudes from 90°09´ato 92°39´. On the other side, Savarupazila (Dhaka District) is situated in north latitudes from 23°44´ to 24°02´ and in east longitudes from 90°11´ to 90°22´.

Selection criteria and GPS points of the industries from where the samples were collected: Selection of Water and Soil Quality Parameters: To measure the quality of the collected samples the following tests were performed in respect to the impact of climate change and plantation on embankment and local livelihood of the study area.

Table-1
Identification effluent treatment plants of the industries with GPS points

Sample Category	Name of the Industry		Location	GPS readings	
				Latitude	Longitude
Industries which use electro-coagulation technique for the effluent treatment plant					
EC-1	Concept Knitting Ltd.	Dyeing industries	Tongi, Gazipur	23°54'32.08" N	90°22'25.92" E
EC-2	Obony Dyeing Ind. Ltd		Hemayetput, Savar	23°47'34.27"N	90°15'36.53"E
EC-3	Evience Textile Ltd.		Sripur, Gazipur	24°10'5.25"N	90°26'9.20"E
EC-4	Azim and Sons Pvt. Ltd. (Washing industry)		Board Bazar, Gazipur	23°56'12.18"N	90°22'31.97"E
Industries which use chemical coagulation technique for the effluent treatment plant					
CC-1	Sajid Washing and Dyeing Ltd.	Dyeing industries	Tongi, Gazipur	23°53'43.77"N	90°23'24.27"E
CC-2	Masco Dyeing Ind. Ltd.		Gazipura, Gazipur	23°55'15.43"N	90°23'11.02"E
CC-3	Viyellatex Dyeing Ind. Ltd.		Gazipura, Gazipur	23°55'15.82"N	90°23'14.87"E
CC-4	Raz Washing Plant (Washing Industry)		Saignboard, Gazipur	23°57'15.16"N	90°22'25.94"E

Table-2
Selected Physical and Chemical Parameters of water test with their Units, Methods and Instruments Name

	Parameters	Unit	Method	Instrument Name
Physical	EC (Electrical Conductivity)	µS/cm	Whinstone Bridge	HACH-156 sension meter 156, Made in USA
	TDS (Total Dissolve Solid)	mg/l	Conductivity	HACH-156 sension meter 156, Made in USA
	TSS (Total Suspended Solid)	mg/l	Filtration	Whatman® Glass Microfibre filter (47mm Ø Circles, Cat No 1822-047)
	Salinity	g/l	Conductivity	HACH-156 sension meter 156, Made in USA
	Turbidity	NTU	Attenuated Radiation Method	UV-VIS HACH DR/2010, Made in USA
	Color	Pt-Co	Attenuated Radiation Method	UV-VIS HACH DR/2010, Made in USA
Chemical	pH		Membrane Electrode	TOA pH METER HM-12P, Made in Japan
	DO	mg/l	Mohr's Titration	-
	BOD	mg/l	Mohr's Titration	-
	COD	mg/l	Mohr's Titration	-
	Sulphide (S^{2-})	mg/l	Nesslar	UV-VIS HACH DR/2010, Made in USA
	Chloride (Cl)	mg/l	Mohr's Titration	-
	Sulphate (SO_4)	mg/l	Turbidity Metric Method or Sulfa Ver 4 Method	UV-VIS HACH DR/2010, Made in USA
Biological	Bacteria (Total Coliform)	CFU/ 100ml	Membrane Filtration Method	Incubator-DSO-270 D/2011

Figure-1
Glass fiber membrane filter after filtration (Dry)

Technologies: There have different types of ETP in Bangladesh whose are using two types of coagulation i. Electro-coagulation ii. Chemical coagulation. These coagulation is completely separate from each other. In the chemical coagulation (CC) system coagulants are added directly in wastewater where mainly use chemical such as $FeSO_4$, $Al_2(SO_4)_3$ etc. On the other side anodes (aluminium or iron electrodes) is used to release active coagulants into solution of electro-coagulation system. This process is another technology for wastewater treatment and recovery of dangerous chemicals from wastewater[16].

Process flow-diagram for effluent treatment plant using electro-coagulation technique.

Results and Discussion

Water analysis: Physical Parameters.

The highest and lowest pH value of electro-coagulation effluent (ECE) water samples were 8.83 and 7.98 with mean 8.36(±0.36). In case of electro-coagulation treated (ECT) water sample the highest pH value was 7.47 and the lowest value was 7.15 with mean 7.13(±0.15). Within the chemical coagulation effluent (CCE) water samples the highest value was 9.78 and the lowest value was 7.80 with means 8.70(±0.86). Whereas the pH value of chemical coagulation treated (CCT) water samples range from 7.28 to 6.56 with mean 6.98(±0.33). According to DOE standard the pH value for industrial water discharge is 6-9. In Figure the pH ranges of Chemical Coagulation was more efficient than Electro-coagulation but both of them maintained the DOE level.

Figure-4 showed the conductivity the highest conductivity of ECE and CCE water samples were 3210 µs/cm and 2664.25 µs/cm and the average conductivity were 2664.25 (±963.922) µs/cm and 2244.75 (±877.52) µs/cm. On the other side the ECT and CCT water sample's the mean value were 1790 (±701.28) µs/cm and 1178 µs/cm. From the average conductivity value it is consider that the CCT is better but all processes maintain the DoE standard.

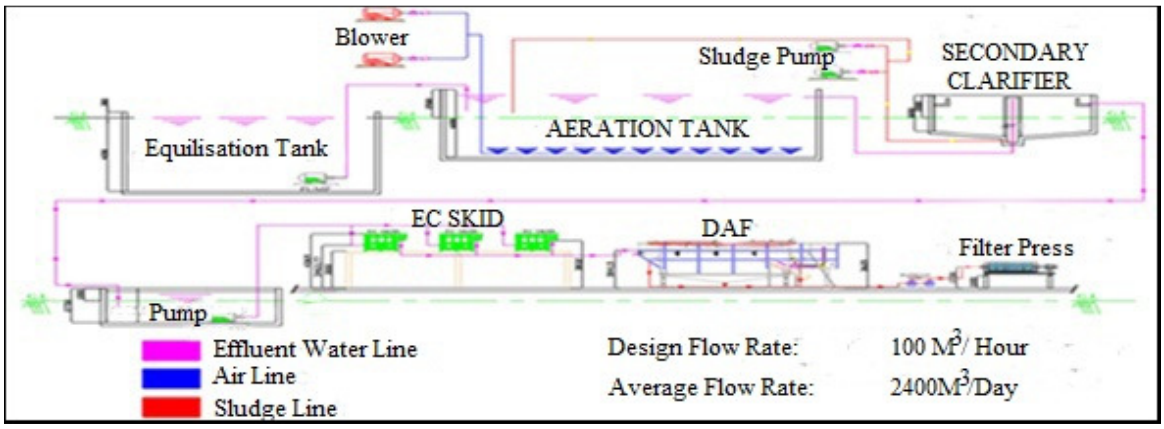

Figure-2
Process flow-diagram of Effluent Treatment Plant (ETP) with electro-coagulation technique (Drawn by Autocad-2007)

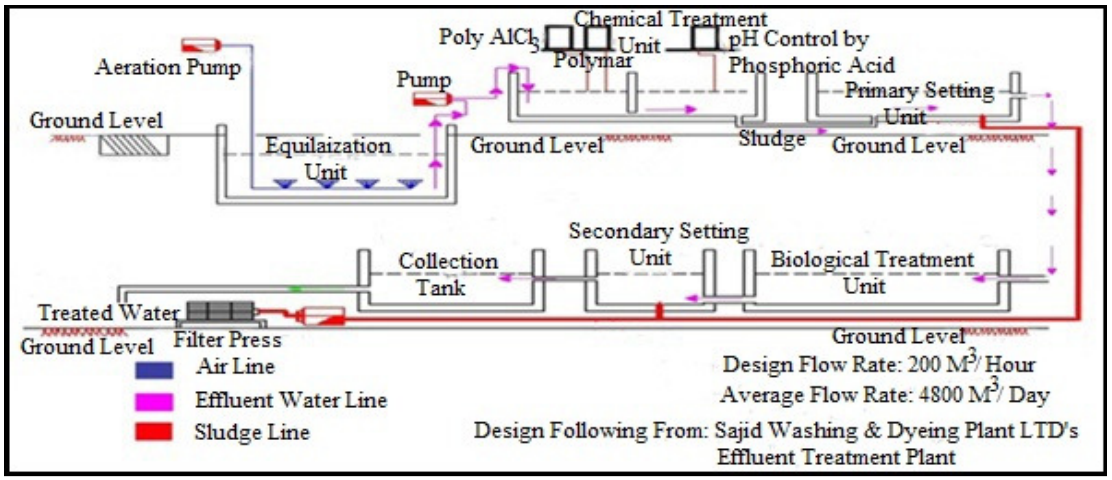

Figure-3
Process flow-diagram of Effluent Treatment Plant (ETP) with chemical coagulation technique (Drawn by Autocad-2007)

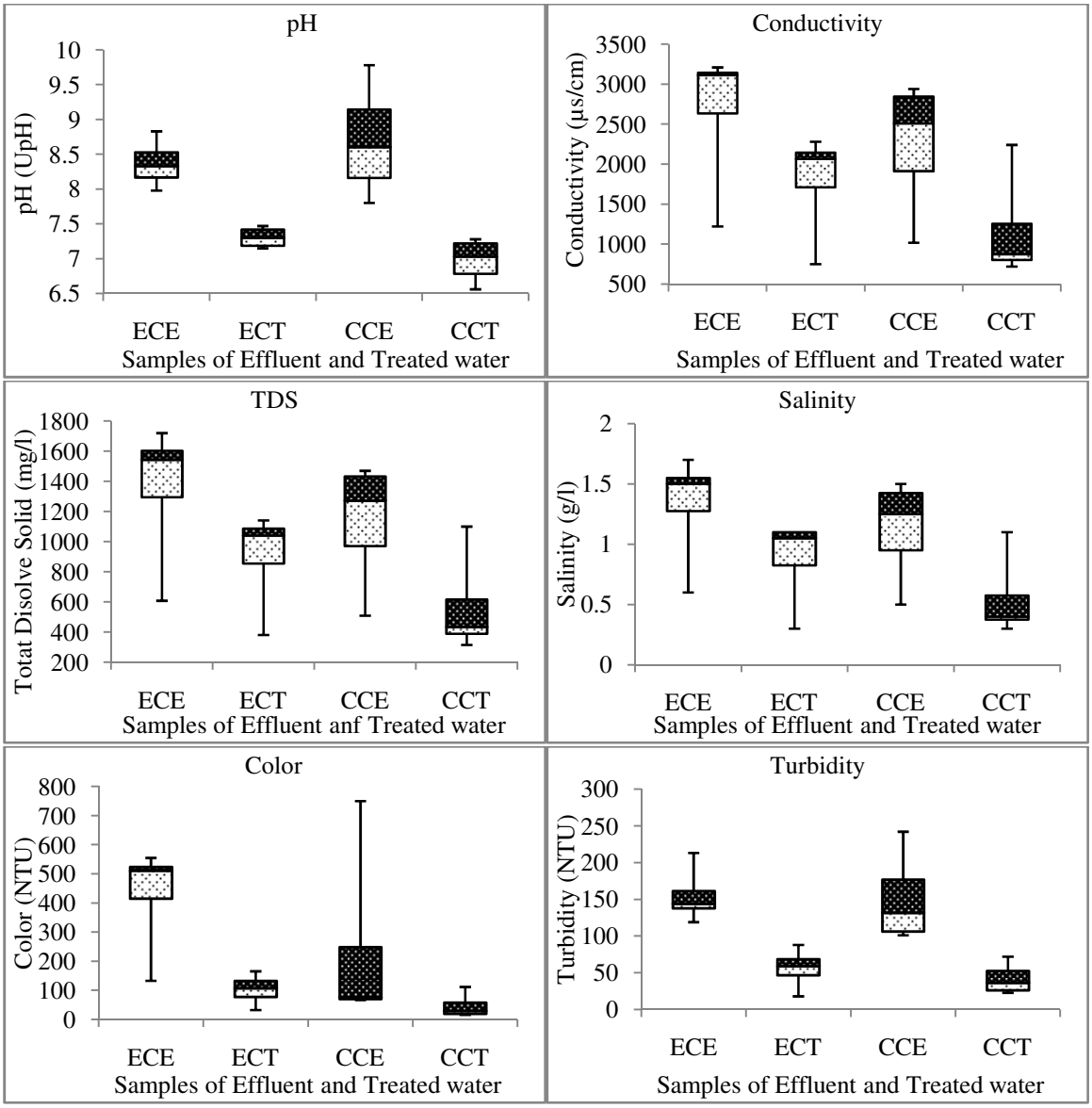

Figure-4
Box plot for pH value, electrical conductivity, TDS, Salinity, Color and Turbidity of effluent and treated water sample of various ETPs

From-4 the figure the highest concentration of total dissolved solids of ECT was 1141 mg/l and the lowest concentration was 380 mg/l where the mean value was 900 (±350.93) mg/l. In CCT the highest TDS concentration was 1100 mg/l and the lowest was 315 mg/l where as the mean TDS value was 570.64 (±357.64) mg/l. In this figure showed that the mean value of ECT (900 mg/l) was higher than the CCT (570 mg/l). The total dissolved solid of effluent and treated water was maintained with the DOE standard. Here highest TDS was 1720 mg/l in EC-2 which was a dyeing industry used electro-coagulation. The TDS of treated water was maintained with the DOE standard. The experiment of figure shows that, the mean value of salinity in the ECE sample was 1.33(±0.49) g/l and CCE sample it was 1.13(±0.45)g/l. after the treatment the salinity decrease. The average salinity removal efficiency of electro-coagulation using ETP plant was 33.96% and chemical coagulation using ETP plant was 51.11%.

The Figure-4 represented the highest concentration of color in ECE sample water was 555 Pt-Co and the mean value was 427(±197.57) Pt-Co. For ECT water sample the mean value was 103.50(±55.76) Pt-Co. On the other side for the CCE water sample the highest value was 750 Pt-Co. For the CCT water sample the mean value was 47.25(±44.39) Pt-Co. Among the electro-coagulation using ETP plant the color removal efficiency was 75.80% and chemical coagulation using ETP plant was 80.52%.

Figure-4 shows the concentration range of turbidity in ECE water sample was 213 NTU to 119 NTU where the mean value was 155(±40.42) NTU and the range for the ECT water sample was 88 NTU to 18 NTU where the mean value was 56(±28.89) NTU. For the chemical coagulation system the value of CCE water sample was 242 NTU to value was 101 NTU where the mean value was 151.50(±64.92) NTU and in CCT water sample the value was 72 NTU to value was 23 NTU where the mean value was 42(±22.38) NTU. The figure shows that for electro-coagulation using ETP plant the turbidity removal efficiency was 63.87% and for the chemical coagulation using ETP plant was 72.28%.

Chemical Parameters: In Figure-5 there didn't have any DO level in effluent (ECE and CCE) water sample. The mean value of DO was 5.27(±1.07) in electro-coagulation process. For chemical coagulation the mean value was 3.59 (±0.55) mg/l. The DO level was higher in electro-coagulation treated water than the chemical coagulation treated water that means water quality is better in electro-coagulation process. For DOE the standard value DO range is 4.5-8 mg/l. The DO level was ok in the electro-coagulation process but lower in chemical coagulation process.

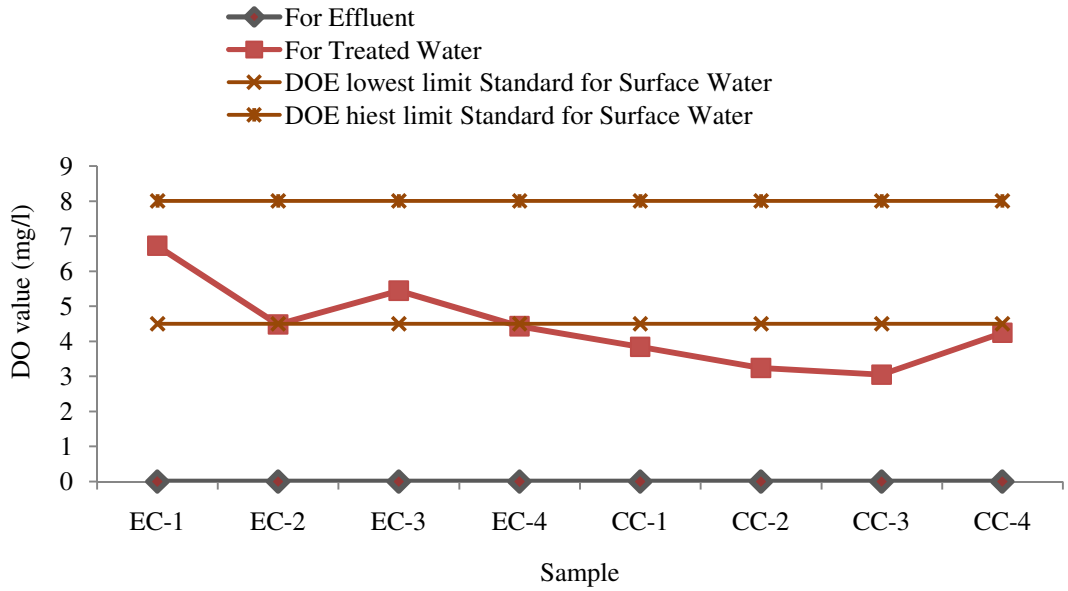

Figure-5
DO value of effluent and treated water sample at different ETPs with DOE standard

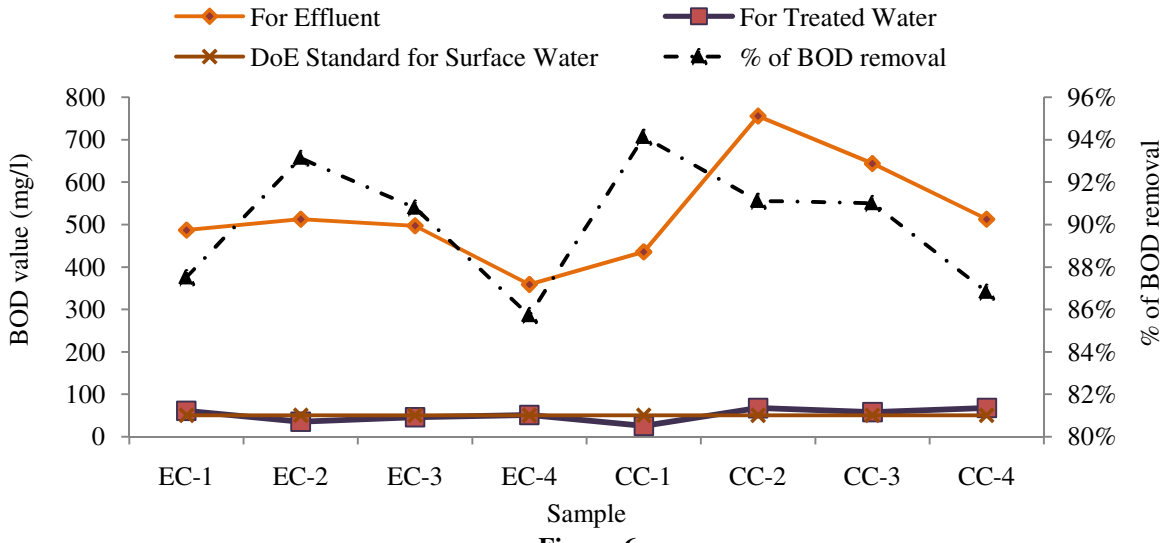

Figure-6
BOD value of effluent and treated water sample at different ETPs with DOE standard

The mean concentration of Biological Oxygen Demand (BOD) in electro-coagulation effluent sample water was 463.38 (±70.77) mg/l and in chemical coagulation sample water was 586.40(±141.55) mg/l. For the treated water in electro-coagulation the BOD level was 48.25(±10.69) mg/l. and in chemical coagulation the value was 54.55(±19.80)mg/l. From the mean value of ECT and CCT, it was found that CCT is slightly higher than the ECT that means that the water quality of electro-coagulation is better than the chemical treatment. According to WHO level (200 mg/l) all treated water quality is so better in both process but according to DoE level (Inland surface water- 50 mg/l) this trested water have slightly problem. On the other side DoE level (Public sewer- 250 mg/l and in Irrigation land 100 mg/l) all treated water are suitable for irrigation in both process. Here the figure shows that both electric and chemical coagulation process removed BOD more than 85.7%.

In Figure-7 shows COD range of ECE water sample was 1648 mg/l to 1136 mg/l and for the CCE water sample was 1808 mg/l to 1408 mg/l. For the treated water in ECT water sample range of COD value was 152 mg/l to 96 mg/l and in CCT the range was 232 mg/l to 42 mg/l. From the mean value of ECT and CCT it was shown that COD in CCT mean value (129.50 mg/l) was slightly higher than the ECT mean value (120.50 mg/l) so why it can be said that electro-coagulation is better than the chemical coagulation. The figure also shows that all EC processes had a good COD removal capacity within 90-91% and the chemical coagulation had COD removal capacity of 87-97%. According to WHO COD standard level (500 mg/l) all treated water is quite good for the environment. On the other side DoE level (Public sewer- 400 mg/l and in Irrigation land 400 mg/l) all treated water are suitable for irrigation in both process.

In Figure the TSS value in EC water sample decreased from 91.25 (±31.85) mg/l to 15.75(±7.10) mg/l. On the other side for the chemical coagulation process the value in CC water sample decreased from 108.50 (±25.488) mg/l to 35.13(±7.261) mg/l. Here from the mean value of ECT and CCT the TSS condition was good in the electro-coagulation process. The DOE standard of TSS is 150 mg/l for surface water and 200 mg/l for the irrigation activities. All samples showed less amount of TSS than the DOE standard. For these samples it was observed that the average TSS removal efficiency of EC process was 80.37% and for CC process it was 65.04%.

The Figure-8 shows that the concentration of sulfate and sulfide in ECE water sample was 62.50 (±28.86) mg/l and 52.50(±14.54) mg/l. For ECT water the value it decreased to the mean value 28.75(±18.43) mg/l and 14.83 (±11.36) mg/l. For the chemical coagulation the sulfate and sulfide value of CCE water sample was 71.75 (±28.62) mg/l and 29.50(±16.29) mg/l. In CCT water sample the value decreased to 69.75 (±7.632) mg/l and 30.86(±36.07) mg/l. From the average value of ECT and CCT water showed that the sulfate and sulfide value of CCT was higher than the ECT water sample. In some Chemical coagulation the amount of sulfate and sulfide increased. The average sulfate removal efficiency in EC process was 54% on other side in CC process it was only 2.79%. It was observed that sulfate and sulfide removal efficiency was better in EC process than the CC process.

Figure-8 shows that chloride value decreased in EC process water sample from 615.48(±291.90) mg/l to 573.33(±235.27) mg/l. For the chemical coagulation the value increased from 463.72(±725.08) mg/l to 514.31(±804.87) mg/l. The increase of chloride in chemical coagulation may be for the reason of additional chloride adds in the treatment. For this observation it was observed that for Chloride all samples did not maintained the DOE standard. In EC process it was observed that first three samples were closely to the DOE standard value.

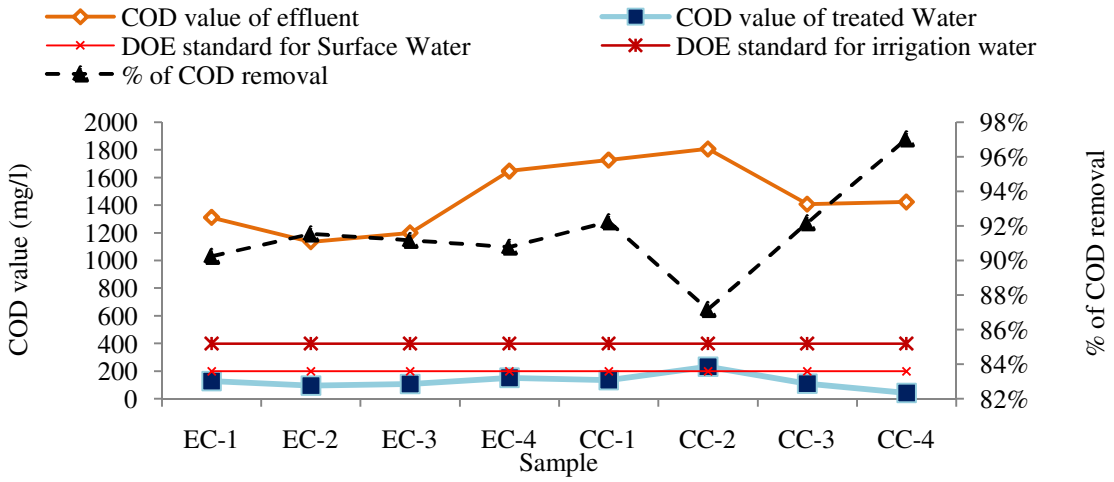

Figure-7

COD value of effluent and treated water sample at different ETPs with DOE standard

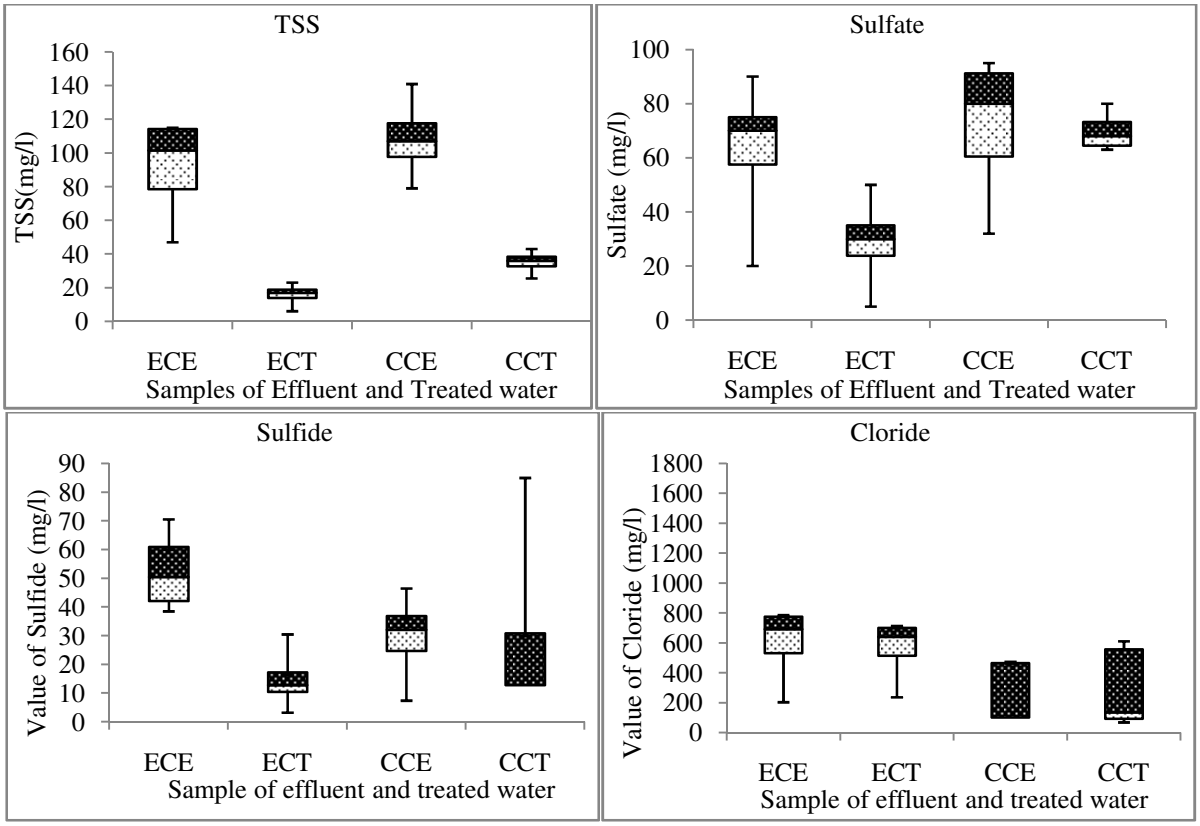

Figure-8
Box plot of TSS, sulfate, sulfide and chloride for effluent and treated water sample of different ETPs

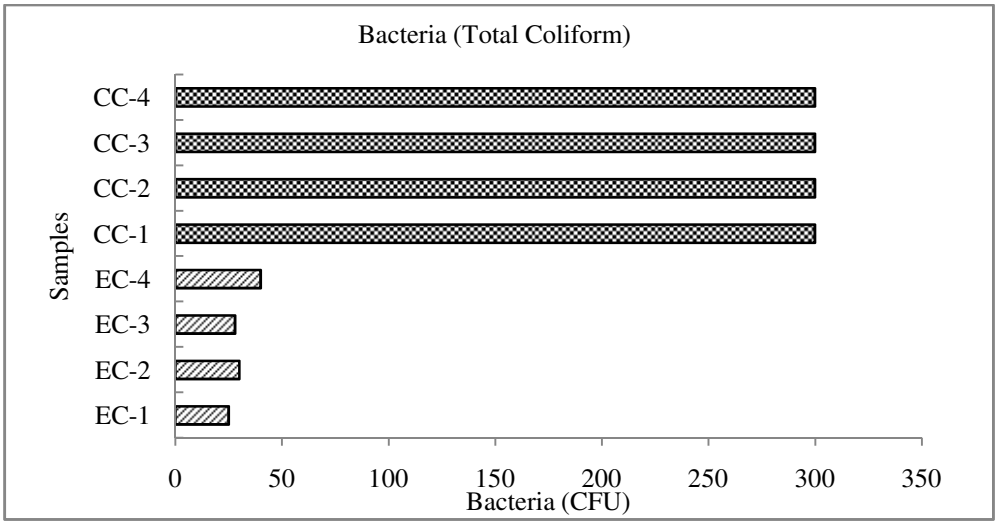

Figure-9
Bacteria (total coliform) amount in the treated water sample in EC and CC process

Bacteria (Total coliform): In the treated water of EC process it was observed that the bacteria (total coliform) amount was in the lowest level where only one sample had highest bacteria (total coliform) 7 CFU/100 ml and other three samples had 0 CFU/100 ml. For CC process bacteria content was non-countable for 50 ml sample water. When the colony for bacteria observed more than 300 CFU then it is considered as non-countable. For the use of 200-400 V DC current in EC process there would have no or less amount total coliform in the sample which amount considered as no harmful for the surface water even in other uses. But in CC process there was observed huge amount of bacteria (total coliform) for the reason of biological treatment.

Conclusion

This study was investigated to find out the performance of electro-coagulation and chemical coagulation with cost benefit analysis of different ETP plant. The study focused that the efficiency of pH removal process was high in CCT (chemical coagulation) process than the ECT (electro-coagulation) process whose were very nearly value of the neutral pH value 7.00. The value TDS in the studied water sample was observed the higher range in EC process than the CC process. But after completing the treatment the removal efficiency was stronger in the CC process than the EC process where as the concentration was within the range of DOE standard. The present observation the salinity level was found as same as the result of TDS. Color and Turbidity are associated with each other. The present study showed the higher average value of color and turbidity concentration in EC process were 427 Pt-Co and 155 NTU respectively where as the average value of color and turbidity in CC process were 47 Pt-Co and 42 NTU respectively. For these parametric treatments the CC process was better than the EC process. DO is an important parameter of any water bodies. There was no DO value in the effluent water in both EC and CC process. After completing the treatment procedure the higher of DO value was observed in EC process (5.27 mg/l) than CC process (3.59 mg/l) where as the DOE standard of DO is 4.5-8 mg/l. BOD and COD both are associated with each other and for treated water it was observed that in EC process the average BOD and COD were 48.25 and 120.50 mg/l respectively and in CC process average BOD and COD were 54.55 and 129.50 mg/l respectively. If make a comparison between EC and CC process then EC process is better than CC process for this perspective. In spite of having higher quantity there also found less removal efficiency of Sulfate observed the quantity 58.43% and -13.34% in EC process and CC process respectively. That means the Sulfate content was increased in some sample. TSS removal efficiency was better in EC process (80.38 %) and CC process (65.05 %). In Chloride test after treatment it was observed that the removal efficiency was higher in EC process (2.30%) than the CC process (-11%) which indicated that in CC process there had increased the Chloride for additional chemical use. Bacteria (total coli-form) content in the studied treated water sample was no or so much lower in the EC technique but in CC process bacteria was un-countable. For the reason of high voltage in EC process had destroyed all the bacteria, virus and cysts.

Recommendation: For color, TDS, conductivity and pH removal chemical coagulation (CC) was better but electro-coagulation was also in the range of std. value so why any kind of coagulation process may be used for water treatment. Performance of DO increasing efficiency was better in electro-coagulation process than chemical coagulation so, electro-coagulation is better for this parameter. BOD, COD, TSS, sulfate, sulfide, chloride, bacteria, virus and cysts removal efficiency was better in electro-coagulation process than the chemical coagulation and there need to choice the electro-coagulation in waste water treatment.

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