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Treatment of powder coating industry wastewater by Electrocoagulation Process

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Abstract—This paper is the extended study of previous paper "Powder coating industry: Wastewater Characteristics and its effect on environment". This paper explains about the treatment of Powder Coating Industry waste water and the best possible treatment method and its parameters. Electrocoagulation method or technique is one of the promising techniques available for the treatment of this type of wastewater. The experiments were conducted with aluminium electrodes with various combinations of connections. Parameters such as pH, TDS, Colour, Turbidity, Phosphate and Chromate removal is showed using Aluminium electrode with the efficiency of 95.5% is found out. The electrical usage power required has also been calculated for the designed test treatment unit.

Keywords—Treatment, Electrocoagulation, Powder Coating Industry, Case study.

I. INTRODUCTION

Powder Coating Industry and other chromate and phosphate wastewater producing industries will be always having the issues regarding Generation of wastewater, Handling, Disposal and Treatment. There are several Advancement in the field of water treatment process yet the question is which type of treatment and how much of it is to be applied. In spite of having method of Zero disposal and closed system, less frequently yet large amount of polluted water is produced , thus to handle and treat such waste for powder coating Industry wastewater this study is carried out and Electrocoagulation method is chosen for study.

II. LITERATURE STUDY

Ahmed Samir Naje1 et, al., (2015) Contemplated Treatment Performance of Textile Wastewater Using Electrocoagulation (EC) Process under Combined Electrical Connection of Electrodes .In this paper The effect of a few working parameters, for example, bipolar anode component (Fe or Al), electrolysis time (RT), momentum power (I), pH, concoction bolster, between terminal separation (IED), and mixing speed (Mrpm) were analyzed.

B.Lekhlif, J. Mater et, al.,(2014) [12] here the studies were conducted on electrocoagulation on wastewaters of electroplating industry charged by nickel (II) and chromium (VI) The principle goal of this investigation was the observing of some physicochemical parameters under 6 and 12V and the assessment of the immediate electric potential impacts on the electrocoagulation exhibitions in the treatment of wastewaters charged by substantial metals like nickel and chromium and COD.

Fernando B. Mainier, et, al., (2016) Chromate and dichromate sodium as an element of oxidizer qualities are utilized as a part of a few modern regions; for instance, in surface security of covered parts of cadmium, zinc and aluminum (chromate covered treated), consumption inhibitors, the treatment of calfskin, the fabricate of shades, and so on. Be that as it may, the utilization of such items has been addressed because of the issues of poisonous quality and contamination that can be caused in the natural. The Brazilian ecological office has set up that the convergences of chromate in water courses are under 0.5 ppm.

Yavuz Demirci, et, al., (2015) This paper shows the aftereffects of the treatment of a genuine material wastewater by electrocoagulation (EC) process. The material profluent utilized as a part of the trials was acquired from a material industry in Malatya/Turkey. The profluent was wastewater taken from kicking the bucket procedure of the business. Aluminum cathodes were associated with an EC reactor in three distinct writes: monopolar-parallel (MP-P), monopolar-serial (MP-S), and bipolar-parallel (BP-P).

III. CASE STUDY

"Primo Coats" is the small startup firm or an Industry which is located in Doddannavar Compound, Udyambag, Belagavi. Which does metal finishing of the parts of the Ships Engine such as Air Filters, and many other basic components with the technology called "Powder Coating". It also does the pretreatment process of the same.

The jobs prepared are dipped in these baths as mentioned above and further taken for a quick drying and then it is painted or coated with powder. According to the study and as told by the workers, water will be disposed at a very rare frequency. Water from the rinsing baths are disposed once in a month , half of the volume of Degreasing and Derusting units are disposed after the deposited sludge especially in the derusting bath is removed and the Phosphating and Passivation Solutions are used until they lose their strength.(again 1 year on an Average).

Fig. 1 Powder Coated Products in Primo Coats.

Fig.2 Manual Pre-Treatment process at Primo Coats.

TABLE I
CHARACTERIZATION OF SOLUTION AND THEIR BASIC PARAMETERS.

Bath no.	Name of baths	Colour	pH	TDS	Turbidity (NTU)	BOD_5 (mg/L)	COD (mg/L)	Conductivity mS/cm
1	Degreasing tank	Brownish, Clay coloured	11.12	2421.3	103.1	997	2978	87
2	Rinsing Tank	Light Whitish	10.3	2113.2	106.3	750	1876	3.7
3	De-rusting Tank	Dark Green	0.54	1457	28.6	1174	5461	113
4	Rinsing Tank	Milky colour	1.34	1714	27.4	913	3943	33
5	Phosphating	Whitish	2.6	2038.7	84	974	4153	13.2
6	Rinsing Tank	Milky colour	4.4	2733.1	26.7	786	3171	2.4
7	Passivation	Bright Yellow	2.07	1921.5	6.7	817	2981	2.2

*all the values are noted through experimental study.

IV. MATERIALS AND METHODOLOGY

In this Chapter technical specification, details regarding experimental setup, process methodology and Method used for analysis of wastewater as per standard have been discussed.

A. *Collection Of Sample &Characteristics*

The wastewater samples were collected from (Primo Coat) A powder coating industry; the samples were collected separately from different water disposal unit and tested. The wastewater was analysed for physic-chemical parameters by using standard analytical methods.

Fig; 3 Water Sample Collected from the Industry and Placed for Mixing.

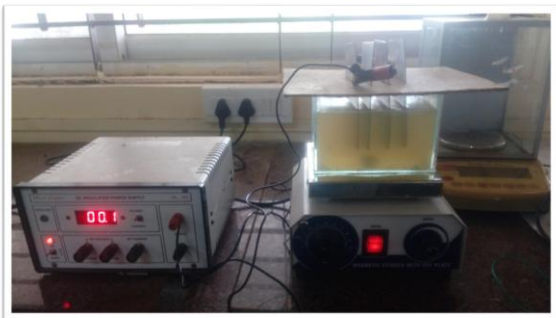
All these samples were mixed together to make a combined waste water sample for analysis. These samples were mixed such as to make a sample of 1 litre for every test, so depending upon the Disposal Frequency the mix has been prepared it is , the rinse water are taken 250 ml ,250 ml and 260 ml respectively and Degreasing sample of 50ml , Derusting 50 ml, Phosphating 50 ml of water to make a mix of 1L batch sample for analysis (Fig: 5).

Fig; 4 Water Sample Collected from the Industry Mixed to make a sample for analysis.

B. *Technical Specifications Of The Experimental Setup*

A batch electrocoagulation (EC) reactor was designed and fabricated for the treatment of powder coating industry effluents. The details are :

- Material used : Acrylic material
- Total working volume: 1 L
- Dimensions: 15cmx10cmx10cm.
- Power specification : DC source of 30V and 0-2A
- Material for electrode : aluminum electrodes
- Dimensions of electrode: 10cmx5cmx0.1cm.
- Electrode immersion depth : 5 cm
- Distance between each electrode : 2 cm (conductivity of water is too high)
- A magnetic Stirrer.



Fig; 5 Electrocoagulation set up for Experiment on Treatment of Powder Coating Wastewater.

C. *Brief Methodology:*

` The experimental electrocoagulation technique was used for the batch treatment of dairy wastewater.

- The wastewater sample collected from the Powder Coating industry was stored and was analyzed for various parameters as per standard analytical methods.
- After the initial characterization of waste water batch experiments were conducted to regulate the various working conditions such as pH, Voltage and duration of electrolysis.
- The sample solution was prepared as required by mixing it as specified earlier.
- The total submerged surface area of individual electrode is 50cm2.thus the space across the electrodes was maintained at 1.0 or 2.0 cm throughout the experiment, and 2cm gap was maintained from the base of the reactor.
- Electrode plates were weighed before and after each run.
- For each experiment conducted varied voltage of experiment conducted varied voltage of 10 and 15 volts.
- The magnetic stirring unit was used to maintain homogenous mixing of the reactor content at 200rpm.
- The concentration of Waste water was halved to its strength throughout the experiments to minimize current expending, duration and achieving better efficiency.
- At start of each experiment the electrodes were scraped with sand paper to detach the scales and were revised by 15 – 20 % HCl, followed by a detergent wash for the removal of impurities from the electrode surface.
- The EC experiments were performed for optimum electrolysis time of 45 minutes and in each run.
- Necessary investigation the samples after the treatment were enabled to get settled for minimum of an hour before any chemical analysis.
- The sludge produced was collected for further analysis. And froth was filtered and removed.
- The experiments were performed with electrodes connected to the DC power supply in following configuration,

1. Al/Al bipolar electrode in parallel mode with spacing.
2. Monopolar Electrodes in Parallel Connection.
3. Monopolar Electrodes in Series.

V. RESULTS

A. General

This chapter discusses the treatment results of mixed effluent sample using electrocoagulation by aluminum electrodes in monopolar parallel and series connection system and bipolar parallel system. The electrolysis was conducted in batch setup to investigate the effect of various optimal operational parameters such as pH, electrolysis time (ET), voltage (V) for the removal of various physio-chemical parameters during the electrocoagulation (EC) process.

TABLE III
PHYSIO-CHEMICAL CHARACTERISTICS OF COMBINED WASTEWATER SAMPLE FOR ANALYSIS

Sl No.	Parameters	Values obtained	CPCB standards
01	pH	3.36	6.5 to 8.5
02	Colour	Greenish-Grey	Colourless
03	Conductivity	2481 µs/cm	-
04	Turbidity	385 NTU	40
05	COD	4573 mg/L	250
06	BOD 5	1667 mg/L	50
07	Total dissolved solids	2361.3 mg/L	1500
08	Oil and grease	113.5 mg/L	10
09	Suspended solids	1950 mg/L	150
10	Acidity	1180 mg/L	-
11	Alkalinity	34.45 mg/L	-
12	Phosphate	217.9 mg/L	2
13	Chromate	84.7 mg/L	2

So with the initial Physio-Chemical parameters of the combined waste effluent taken for testing and analysis. The samples were treated by EC reactor with different connections and based on the literature study the voltage supply should be around 10-25 V for most efficient functioning. The analysis results for different connections with different voltages have been noted and tabulated below even the graphs plotted for different parameters have been given below.

B. *Tabulated Readings of Electro-coagulation with Aluminium electrodes in Monopolar Series connections.*

These set of readings are taken during the batch treatment at a specified interval of time for basic analysis.

TABLE IIIII
BASIC ANALYTICAL OUTCOMES OF WASTE WATER SAMPLE IN MONOPOLAR PARALLEL CONNECTION.

Sl .no	Volts	parameters	5 mins	10 mins	15 mins
1	10	pH	3.4	3.7	4.0
2		Conductivity	2359	2309	2260
3		Turbidity	379	373	360
4		TDS	2241	2101	2021
5		COD	3474	2987	2134
1	15	pH	3.6	4.1	4.5
2		Conductivity	2341	2210	2102
3		Turbidity	376	361	350
4		TDS	2115	1913.4	1778.4
5		COD	3614	2812	1783

After the complete treatment of 45 mins floc was carefully removed and the sludge was also filtered and the water was taken for final Analysis and outcomes are given in table IV.

TABLE IV
DETAILED ANALYTICAL OUTCOMES OF WASTE WATER SAMPLE IN MONOPOLAR PARALLEL CONNECTION.

Sl No.	Parameters	Values (10 V)	Values (15 V)
01	pH	5.96	6.5
02	Colour	Greyish	Greenish
03	Conductivity	780 µs/cm	737 µs/cm
04	Turbidity	129 NTU	57 NTU
05	COD	570 mg/L	173 mg/L
06	BOD5	187 mg/L	67 mg/L
07	Total dissolved solids	1328 mg/L	961 mg/L
08	Oil and grease	34 mg/L	9 mg/L
09	Suspended solids	154.5 mg/L	112.13 mg/L
10	Acidity	117.8 mg/L	109 mg/L
11	Alkalinity	25.7 mg/L	12.6 mg/L
12	Phosphate	15.3 mg/L	9.7 mg/L
13	Chromate	8.4 mg/L	3.1 mg/L

C. *Electro-coagulation with Aluminum electrodes in Monopolar Series connections.*

These set of readings are taken during the batch treatment at a specified interval of time for basic analysis.

TABLE V
BASIC ANALYTICAL OUTCOMES OF WASTE WATER SAMPLE IN MONOPOLAR SERIES CONNECTION.

Sl .no	Volts	parameters	5 mins	10 mins	15 mins
1	10	pH	3.1	3.5	4.0
2		Conductivity	2389	2329	2291
3		Turbidity	385	379	373
4		TDS	2290	2101	2021
5		COD	3767	2987	2134
1	15	pH	3.3	4.0	4.1
2		Conductivity	2301	2197	2004
3		Turbidity	380	378	367
4		TDS	2210	2198	2103
5		COD	3971	3104	2948

After the complete treatment of 45 mins floc was carefully removed and the sludge was also filtered and the water was taken for final Analysis and outcomes are given in TABLE VI.

TABLE VI
DETAILED ANALYTICAL OUTCOMES OF WASTE WATER SAMPLE IN MONOPOLAR SERIES CONNECTION.

Sl No.	Parameters	Values (10 V)	Values (15 V)
01	pH	5.6	6.2
02	Colour	Greyish	Greyish
03	Conductivity	843.4 µs/cm	762.3 µs/cm
04	Turbidity	243 NTU	159.7 NTU
05	COD	980 mg/L	830.2 mg/L
06	BOD5	247 mg/L	178.2 mg/L
07	Total dissolved solids	1418 mg/L	1195 mg/L
08	Oil and grease	67 mg/L	21 mg/L
09	Suspended solids	195.5 mg/L	132.13 mg/L
10	Acidity	136.7 mg/L	109 mg/L
11	Alkalinity	29.4 mg/L	18.9 mg/L
12	Phosphate	12.5 mg/L	9.1 mg/L
13	Chromate	9.7 mg/L	7.2 mg/L

D. *Electro-coagulation with Aluminum electrodes in Bipolar Parallel connections.*

These set of readings are taken during the batch treatment at a specified interval of time for basic analysis.

TABLE VII
BASIC ANALYTICAL OUTCOMES OF WASTE WATER SAMPLE IN BIPOLAR PARALLEL CONNECTION.

Sl .no	Volts	parameters	5 mins	10 mins	15 mins
1	10	pH	3.5	3.8	4.2
2		Conductivity	2379	2351	2295
3		Turbidity	371	361	354
4		TDS	2201	2127	2008
5		COD	3411	2931	2438
1	15	pH	3.5	4.0	4.3
2		Conductivity	2320	2109	1986
3		Turbidity	377	369	357
4		TDS	2180	1973.6	1791
5		COD	3614	3125	2901

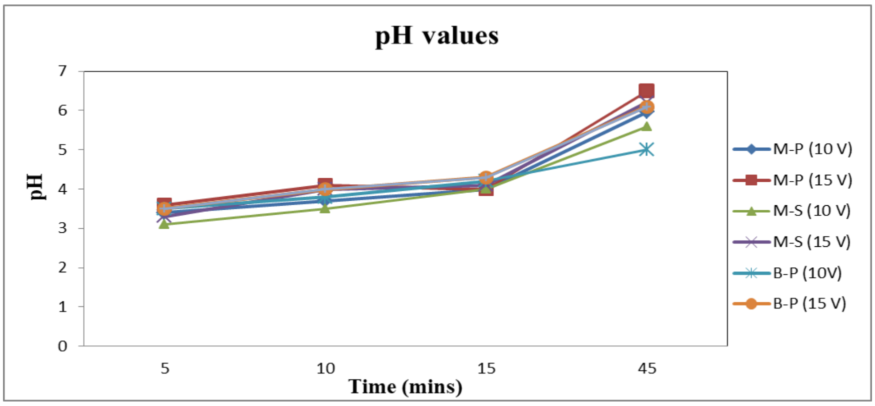
After the complete treatment of 45 mins floc was carefully removed and the sludge was also filtered and the water was taken for final Analysis and outcomes are given in Table VIII.

TABLE VIII
DETAILED ANALYTICAL OUTCOMES OF WASTE WATER SAMPLE IN BIPOLAR PARALLEL CONNECTION.

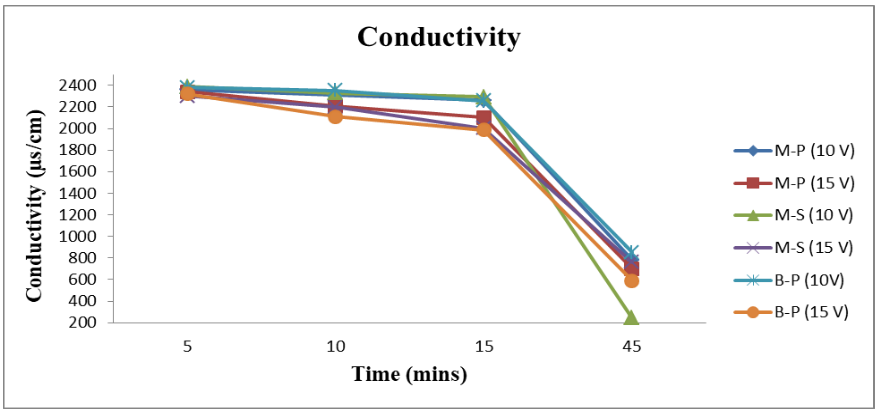
Sl No.	Parameters	Values (10 V)	Values (15 V)
01	pH	5	6.1
02	Colour	Greyish	Greyish
03	Conductivity	853.4 µs/cm	789.3 µs/cm
04	Turbidity	278 NTU	171.7 NTU
05	COD	610 mg/L	181 mg/L
06	BOD5	195 mg/L	71 mg/L
07	Total dissolved solids	1418 mg/L	1195 mg/L
08	Oil and grease	51 mg/L	11 mg/L
09	Suspended solids	167.8 mg/L	121.13 mg/L
10	Acidity	121.7 mg/L	117 mg/L
11	Alkalinity	23.4 mg/L	11.9 mg/L
12	Phosphate	16.5 mg/L	11.1 mg/L
13	Chromate	9.1 mg/L	4.2 mg/L

E. *Graphs And Calculations*

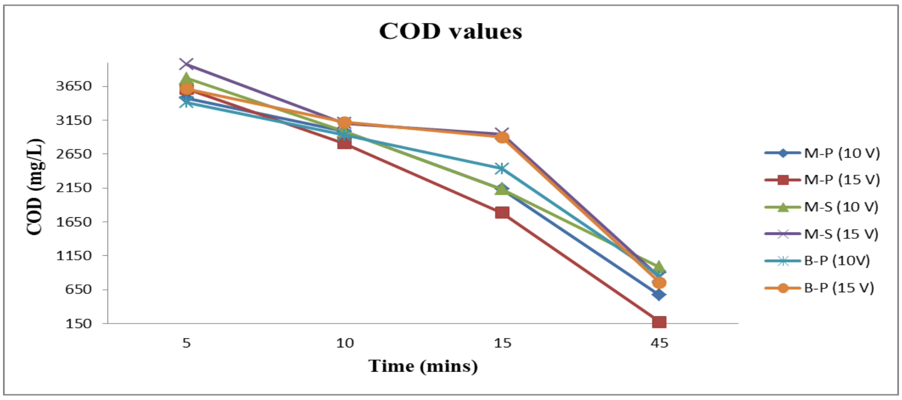
1. Graphs showing trend of the parameters responding to the treatment with respect to time.



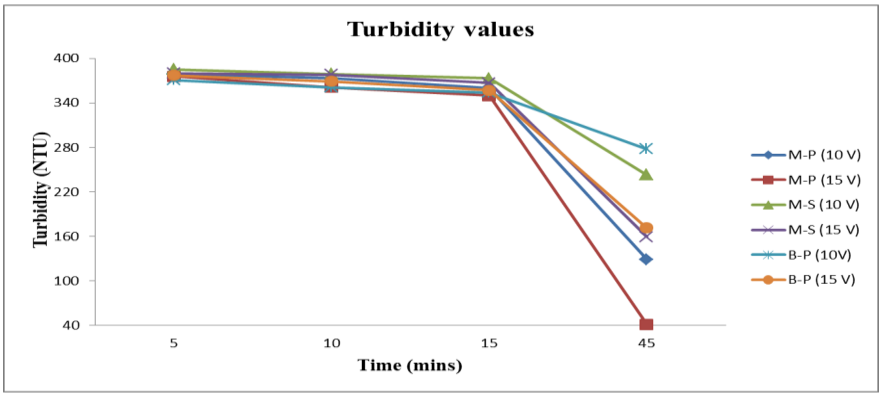
Fig; 6 Graph showing pH values for different Variables.



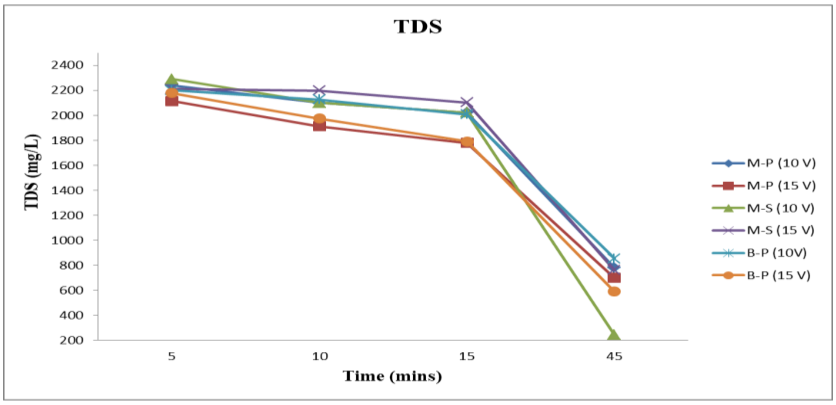
Fig; 7 Graph showing Conductivity values for different Variables.



Fig; 8 Graph showing COD values for different Variables

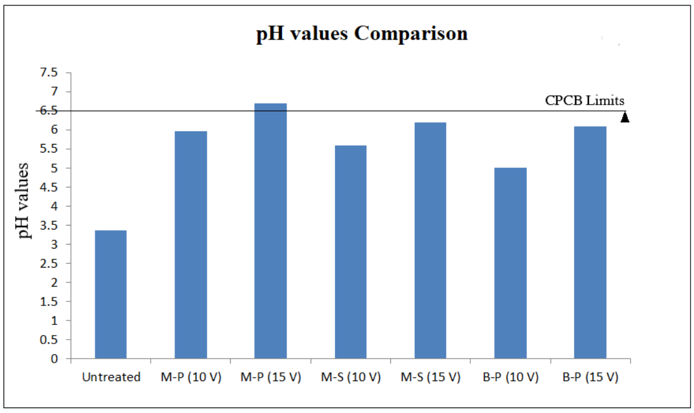


Fig; 9 Graph showing Turbidity values for different Variables.

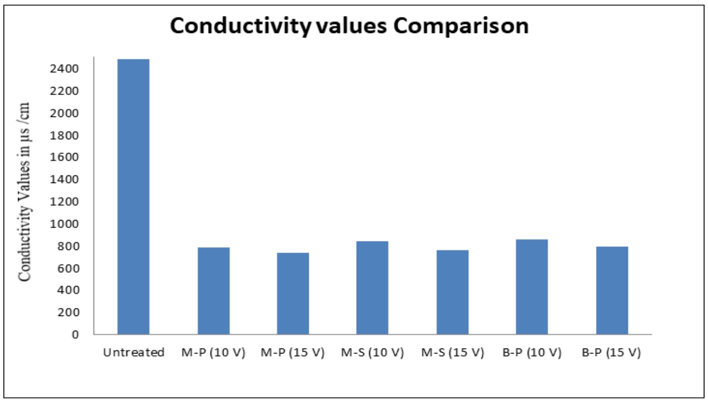


Fig; 10 Graph showing TDS values for different Variables.

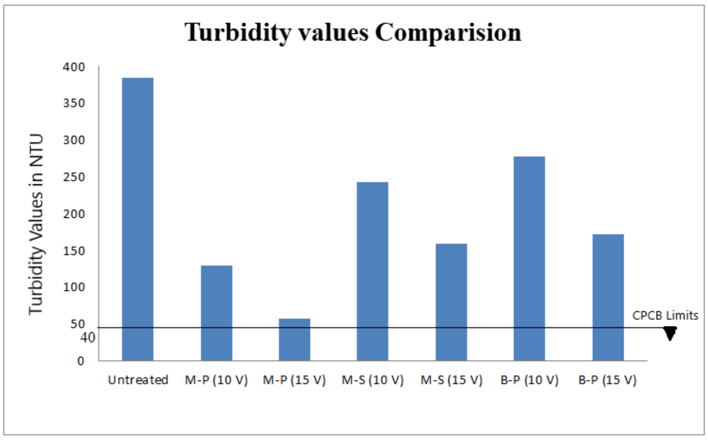
2. *Graphs showing comparison of different parameters with untreated and treated with different connections.*



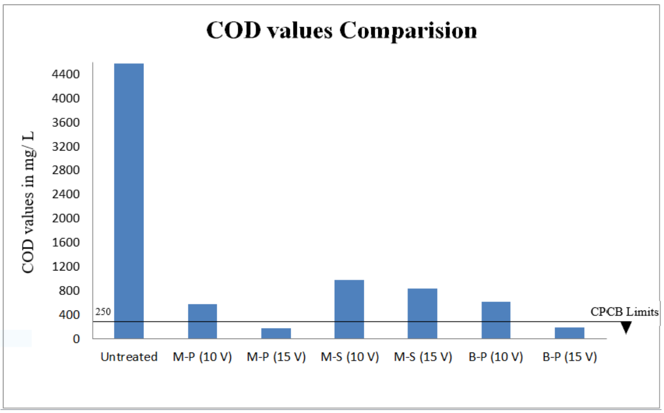
Fig; 11 Graph showing pH value comparison.



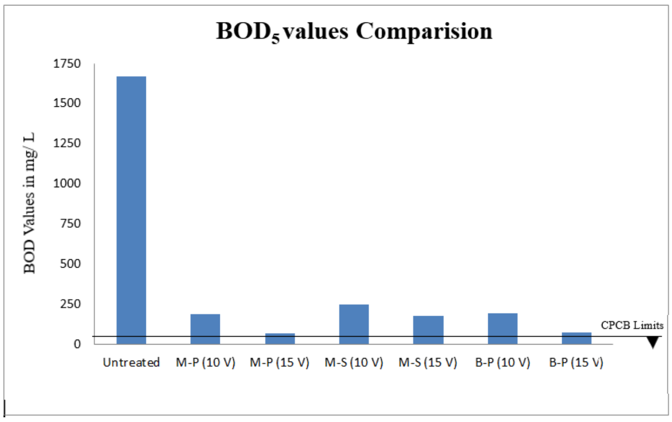
Fig; 12 Graph showing Conductivity value comparison.



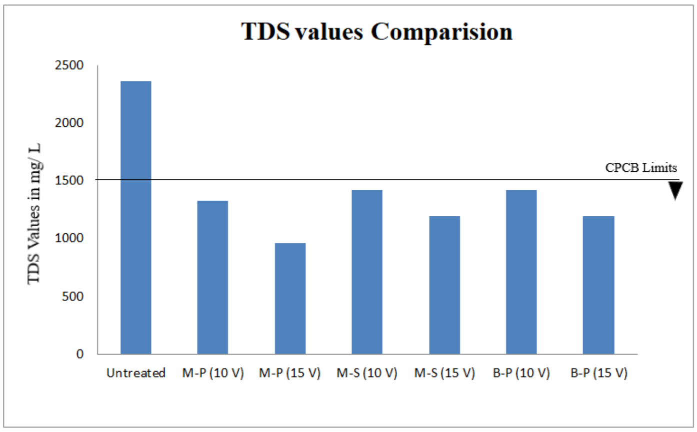
Fig; 13 Graph showing Turbidity value comparison.



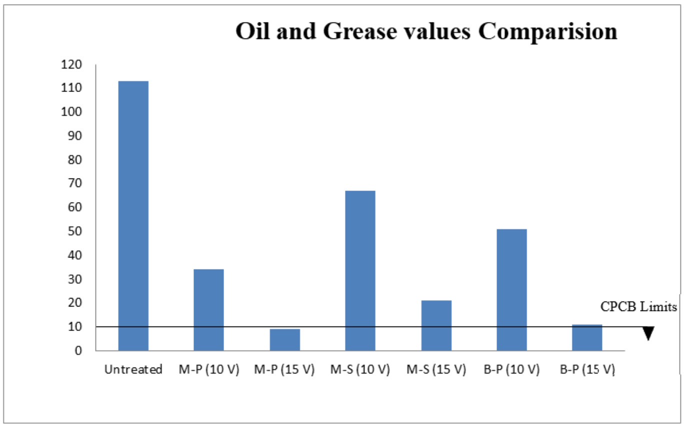
Fig; 14 Graph showing COD value comparison.



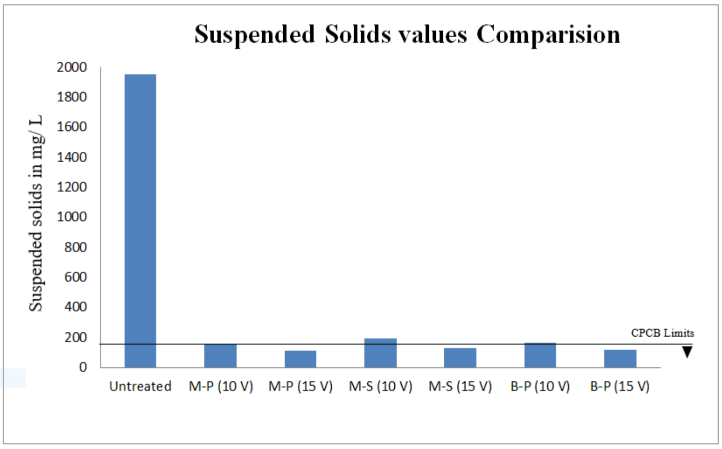
Fig; 15 Graph showing BOD_5 value comparison.



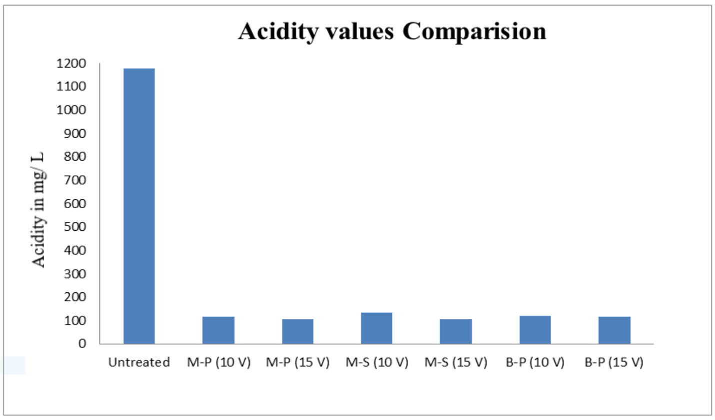
Fig; 16 Graph showing TDS value comparison.



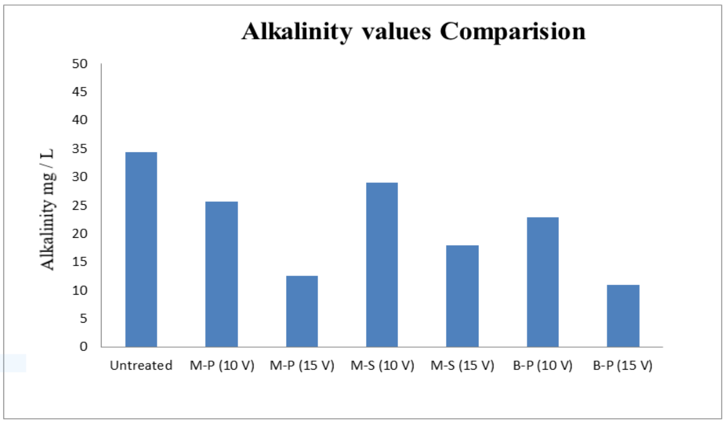
Fig; 17 Graph showing Oil and Grease value comparison.



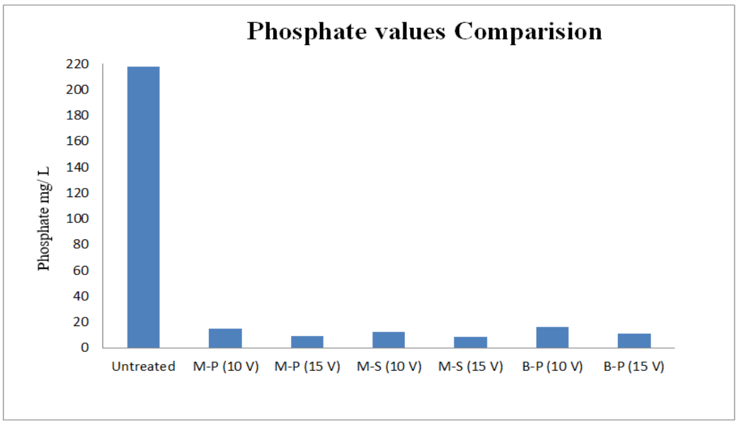
Fig; 18 Graph showing Suspended solids value comparison.



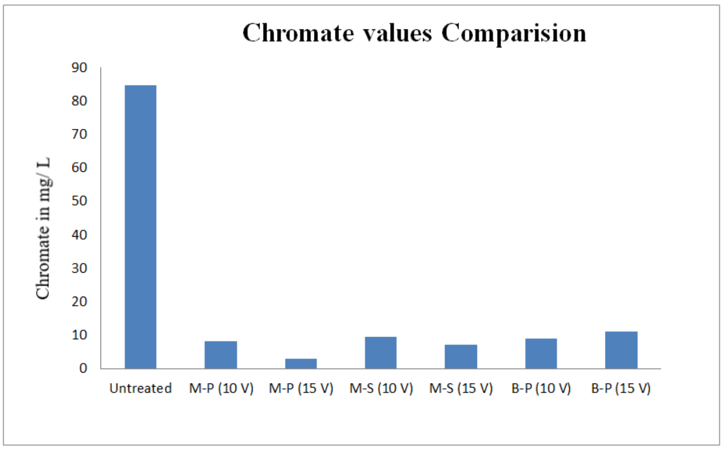
Fig; 19 Graph showing Acidity value comparison.



Fig; 20 Graph showing pH value comparison.



Fig; 21 Graph showing phosphate value comparison.



Fig; 22 Graph showing Chromate value comparison.

From the graphs above we can see that there is drastic change in the treated and untreated water sample parameters. Although there is change in parameters and reduction in the amount of pollutants following CPCB standards is the most important factor. When comparison is done Monopolar connection with 15V supply is found to be the efficient one in treating. Phosphate reduction is near to CPCB standards but not under permissible limits. So a bit focus should be given on phosphate reduction.

F. *Electrical Efficiency Calculation for 45 mins of treatment of a sample collected*

The treatment unit was designed and fabricated for treatment of 1 liter of sample wastewater and for 45 mins as a time considered. When it comes to treatment, Efficiency plays a vital role, thus calculation of Electrical efficiency, Power consumed per treatment process is important to know.
Formula for calculation of Power consumed per hour is:

$$\text{Power Consumed} = \frac{(\text{Volts}) \times (\text{Current}) \times (\text{Usage hour})}{1000} \ldots\ldots\ldots\ldots\ldots \text{KWh}$$

Case 1: Voltage : 10 V , Current : 0.2 A , Duration : 45 mins ,
Cost per unit (as per current rate): Rs. 50 per unit

.

$$P = \frac{10 \times 0.2 \times (45/60)}{1000} = 0.0015 \text{ KWh}$$

Cost per Treatment process for 1 L of wastewater sample.= 0.0015 x 50 = <u>Rs 0.075 per hour</u>

Case 2 : Voltage : 15 V , Current : 0.2 A , Duration : 45 mins ,
Cost per unit (as per current rate) : Rs. 50 per unit.

$$P = \frac{15 \times 0.2 \times (45/60)}{1000} = 0.00225 \text{ KWh}$$

Cost per Treatment process for 1 L of wastewater sample. = 0.00225 x 50 = <u>Rs 0.1125 per hour</u>

Note: The above calculated values are for treatment of 1L of sample and thus the design current supply is in accordance with that. According to the requirement of the industry wastewater quantity the unit can be designed.

VI. CONCLUSIONS

The following conclusions were drawn from the study conducted on treatment of Powder Coating Industry wastewater using the method of Electro Coagulation with different Electrode Combination.

1. *In Monopolar Parallel Electrode combination the test was conducted for 10V and 15V in that 15V is observed to be efficient for the treatment period of 45 mins as almost all parameters were found out to be under the limits except phosphate and Chromate value but with additional 10 mins of treatment they were also under limits.*
2. *For monopolar series connection there were six electrodes and the current density increased and for every 10 to 15 min interval of treatment the supply would short as the wastewater sample taken for experimentation was high in conductivity the current started to expand , however the concentration was reduced and the values were interpolated*

and readings were noted according to Dilution. Pollutants were however reduced but they were not under the standard limits.

3. *For Bipolar connection parameters such as pH , BOD , COD were found out to be under limits whereas rest were not. However this type of connection can be tried with increases duration for better results*

4. *Electrical usage per treatment process for 1 liter test sample was for 10V it was Rs. 0.075 per hour and for 15V Rs. 0.1125 / hour. This is very less. However for greater amount of sample it may vary but it won't be expensive enough.*

5. *For industrial purpose the initial cost may be bit high but the treatment and operating cost is less and also the treatment efficiency is good.*

6. *By observing the above conducted Experiment Monopolar Parallel connection with 15V supply has been observed as the most efficient one in reducing impurities of all parameters for the Test sample of 1 Liter with operating cost of Rs.0.1125.*

VII. **SCOPE FOR FUTURE STUDY**

1. The Electro coagulation being one of the effective method of treatment can be used for many other type of chromate and phosphate waste.
2. Powder coating industry wastewater has High conductivity value thus in few conditions Electro coagulation method was problematic. Thus focus should be given on the selection of mix.
3. The same study can be conducted using different electrodes and different variables
4. Fe electrode can be also used or combination on Fe-Al electrodes can be used.

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