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Electrocoagulation of Waste Water and Treatment of Rice Mill Waste Water: A Review

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Abstract: ***Electrocoagulation is a process used for removal of waste from water. With growing concern about the impact of human activities are having on environment different processes are being developed for treatment of different types of wastes. Generally iron and aluminum are used as electrodes for electrocoagulation but different workers have used other electrodes as well. The shape and number of electrodes along with the spacing affects the process. The process is fast and generally removes all the waste material which can be coagulated under the influence of electric current. Effluents from vast range of industries using organic and inorganic processes can be treated using this simple but efficient process.***

Keywords: Electrocoagulation, wastewater, electrodes, environment, COD

1. Introduction

Environment has become focus of concern after it has been realized that most of the problems plaguing environment is either man-made or due to one or other reasons related to anthropogenic activity. The deterioration of environment has taken place in last 2 centuries due to rapid urbanization and industrial growth. Due to the industrialization the activities which were not harmful till few decades ago have also become a menace to the environment.

The effluents of many industries are toxic and therefore cannot be treated at biological treatment units. For treatment of such toxic wastes electrocoagulation has become a standard practice. Various wastes from industries, agriculture and urban areas can be effectively treated with electrocoagulation. The process of electrocoagulation forms metal hydroxide flocks by electro dissolution of soluble anode. When the pH is near acidic or neutral (4-7), the metal electrodes dissolve in the solution under the influence of electric current in their cationic form and react with water to form diverse complexes. The complexes of metals and water then act as coagulant and thus forming aggregates of particles which settle down due to their weight. The colloidal particles move under the influence of electricity towards the anode. This movement of particles towards one electrode increases the chances of encounter between the coagulants and pollutants thus making the process of settling of pollutants fast (Zongo et al., 2012).

Electrocoagulation is a process by which wastewater is treated by passing of electricity in the water using different electrodes. The type of electrodes, shape and spacing along with the size of electrodes determine the degree of treatment of wastewater. The process of electrocoagulation is based on the fact of formation of large colloids containing pollutants and the metal hydroxides which are released from electrodes when electricity is passed through them.

For chemical coagulation different coagulant like Alum, FeSo4, Ferric chloride, lime, poly aluminum chloride etc have been used to treat wastewater. These chemicals form large complexes with the impurities present in the wastewater and using centrifugation or gravity assisted precipitation these large complexes settle down which can be removed by decantation (Asati, 2013). To remove impurities from wastewater different concentrations of such coagulants have been tested and in general higher the concentration of coagulants larger the amount of impurities removed. But there are cases like where the coagulant itself adds to the undesirable qualities of water like Ferrous and ferric salts tend to impart characteristic color to the water in which they are added to remove impurities. Such coagulants also tend to add undesirable chemicals even though in small quantities which may result in higher concentration of harmful chemicals in water making in unfit for drinking or other purposes. Bazrafshan et al. (2013) were able to remove more than 50% COD and BOD from dairy wastewater with 15 minutes of effective voltage supply.

Electrocoagulation has become a major treatment method for different effluents released from industries. The ease of the process and its high ability to remove the pollutants from water has made it a useful method. The various parameters of electrocoagulation which affects the treatment process are electrodes types, shape and size, pH at which electrocoagulation is taking place and current density. These parameters have large influence on the effectiveness of the electrocoagulation. Linares-Hernández et al. (2009) have stated that electrocoagulation process is fast and very effective in removing colloidal and suspended particles which can be seen in changes in number of coliforms, turbidity and color of the effluents but have noted that the process has drawback in removal of organic compounds present in effluents as only low significant BOD and COD were removed in their study.

Electrocoagulation is a complex process occurring via series steps. When current is passed through electrochemical reactor, it must overcome the equilibrium potential difference, anode over potential, cathode over potential and potential drop of the solution. The anode over potential includes the activation over potential and concentration potential, as well as the possible passive over potential resulted from the passive film at the anode surface, while the cathode over potential is principally composed of the activation over potential and concentration over potential. In case of iron electrodes due to oxidation in an electrolyte system, iron produces form of monomeric ions, Fe $(OH)_3$ and polymeric hydroxy complexes depending upon the pH of the aqueous medium while in case of aluminum electrodes $Al^{3+=}$ (aq) ions will immediately undergo further spontaneous reaction to generate corresponding hydroxides and polyhydroxides (Chaturvedi, 2013)

2. Electrode Types

Different types and shapes of electrodes have been used by different workers for effective electrocoagulation. The process of electrocoagulation is totally dependent on the electrodes and the shape and size of it influences the process. Most common electrode types are iron and aluminum while steel and other metals have also been used by some. The electrodes dissolve at anode and produce metal hydroxides which form large complexes with the pollutants and helps in settling the pollutants.

Srivastava and Soni (2012) have used aluminum plates and glass cylinders as containers for electrocoagulation. Thirugnanasambandham et al. (2013a) used stainless steel plates as anode and cathode with effective surface area of each plate as 108 cm^2. Kumar and Gidde (2014) used two aluminum plates of dimensions 15.5 cm x 1.8 cm x 3mm as electrodes in cylindrical glass breaker. They found different parameters like COD, TSS, TS, TVS and TDS were removed in different current densities and different pH. Bazrafshan et al. (2013) used six aluminum electrodes in parallel with active area of each electrode 14 cm X 20 cm and total area od 280 cm^2. They kept the distance between the electrodes as 2 cm. They also determined that with increase of electric current supplied there is increase in electrode consumption. For removal of cadmium from industrial wastes Bazrafshan et al. (2006) used four iron electrodes acting in parallel and they found that at 40V the consumption of electrodes was maximum. Al-Fe, Al-Al and Fe-Fe plates (100mm×50mm×0.5mm) plates were used by Daniel and Prabhakara Rao (2012) in electrocoagulation process for removal of arsenic from industrial wastes. They found that Fe-Fe electrodes were best suited for removal of arsenic from effluents with nearly 99% removal of arsenic at all pH tested and for all electrolysis time. The formation of sludge was also highest with Fe-Fe electrode pair and they had the minimum operating cost at pH 10. Aluminum electrodes of (5.5cm×3.8cm×0.1cm) with a distance of 4 cm and reaction area of about (3.8×2.9×0.1) cm were used by Islam et al. (2011) for removal of turbidity from textile effluents using electrocoagulation. Iron electrode was used for removal of two organic dyes from real and synthetic industrial effluents using solar energy for electrocoagulation (Pirkarami et al., 2013).

Kobya et al. (2003) used iron and aluminum electrodes for treatment of textile mill effluents for removal of hazardous wastes. The electrodes were of 46 mm×55 mm×3 mm in dimension and the total effective area was 78 cm^2. Consumption of 3g/kg of COD was found for iron while it was 20% lower in the case of aluminum in all pH range. Aluminum electrodes of 14×24 cm2 dimensions and 2 and 4 cm spacing were used for treatment of industrial effluent treatment plant for removal of algae and TSS and it was found that 2 cm spacing with three electrodes was optimum for removal of TSS and algae from the treatment plant water (Azarian et al., 2007). Iron or aluminum as anode or cathode (6×6 cm^2) were used for treatment of simulated textile effluents for removal of color using electrocoagulation (Keshmirizadeh et al., 2013). Iron sheets (33 cm×6 cm×0.2 cm) as the electrode were used by Thirugnanasambandham et al., (2013b) for bagasse effluent treatment with effective surface area of each electrode as 108 cm^2. Praveen et al. (2011) used six pairs of mild steel as anode and stainless steel as cathode (10cm×3cm each) for electrocoagulation of plating effluents. Bazrafshan et al. (2012) have used four aluminum electrodes in parallel for electrocoagulation of wastewater of slaughter houses. In this study they were able to remove TSS, BOD, COD and TKN with efficiency but the study also highlighted the use of fat separator and effective settling time of 24 hours prior to electrocoagulation. Arslan-Alaton et al. (2008) have used aluminum as well as steel electrodes for treatment of simulated acid dyebath effluent. They found that steel electrodes are better in removal of COD and color of the effluent as they achieve same level of efficiency at half time. Dermentzis et al. (2011a) have used four aluminum electrodes size 10cm x 5cm x 0.5cm and effective surface area of 20 cm^2 each for removal of nickel from sewage wastewater. Akyol (2012) had used aluminum as well as iron electrodes for treatment of wastewater of paint manufacturing unit. Shakir and Husein (2009) have used aluminum electrode as anode and stainless steel electrode as cathode for treatment of battery industry wastewater and achieved 100% removal of lead through electrocoagulation process.

Mahvi and Bazrafshan (2007) worked on removal of cadmium from industrial wastewater using four aluminum electrodes of size 10×10 cm and spacing of 1.5 cm. Tchamango et al. (2010) used a pair aluminium electrodes of size 10 cm× 4 cm × 0.5 cm for removal of COD, phosphorus, nitrogen contents, and turbidity from artificial dairy wastewater made from solutions of milk powder with removal rate of 61, 89, 81 and 100% respectively. Dermentzis et al., (2011b) used a pair of aluminum electrodes of size 10cm x 5cm x 0.5cm and an effective area of 30 cm^2 each and 1.5 cm spacing for removal of copper, nickel zinc and chromium from industrial wastewater. For removal of hexavalent chromium from synthetic wastewater Dermentzis et al., (2011c) used a pair of iron electrodes of size 10cm x 5cm x 0.2cm with effective area of 30 cm^2 each and interspacing between the electrodes as 1.5 cm. Lakshmanan et al. (2010) used rod-shaped iron anodes (22 cm long, 5 mm diameter, effective surface area of 110 cm^2) and porous cylindrical stainless steel cathode for removal of arsenic from artificial wastewater. Sugumaran et al. (2014) used iron electrode and aluminium (anode) electrode of 10.4cm×2.5cm×0.6cm each for electrocoagulation of leather processing industry effluent. Maghanga et al. (2009) used two steel plate electrodes of size 137.5 mm x 3.13 mm x 50 mm as anode and cathode with interspacing of electrodes as 0.2, 0.5, 0.7 and 1 cm for treatment of tea factory effluent through electrocoagulation for removal of color. Through this they were able to reduce BOD and COD up to 84% and 96.6% respectively. Gengec et al. (2012) used four aluminum electrodes with effective dimensions 80 mm× 50 mm× 3 mm and total effective surface area of 240 cm^2 to remove color, COD and TOC from baker's yeast manufacturing unit effluent. They achieved color, COD and TOC removal of 88%, 48% and 49% at 80 A/m^2 , pH 4 and 30 min for aerobic effluents and 86%, 49% and 43% at 12.5 A/m^2, pH 5 and 30 min for anaerobic effluents. Deniel et al. (2009) used aluminum, iron and hybrid Al/Fe plates of 100mm x 50mm x 0.5mm size as electrodes for removal of arsenic from wastewater. Olanipekun Giwa et al. (2012) used three aluminum electrodes of size 45 mm x 53 mm x 3 mm and effective surface area of 56.7 cm^2 for treatment of effluents from petrochemical factory for turbidity removal. Aluminum plates, Cast Iron Plates, Mild Steel Plates were used for electrocoagulation of dairy effluent by Shah and Patel (2012). Aluminum plate gave highest percentage removal of COD (75%) after 30 minutes of electrocoagulation while mild steel showed negative response in COD reduction. Four electrodes with iron as anode and titanium as cathode with interspacing of 2 cm and of s 8×8×0.2 cm size were used to treat olive oil mill wastewater (Yazdanbakhsh et al., 2013). Sarala (2012) used iron electrodes with effective surface area of 72 cm^2 to treat domestic wastes using electrocoagulation. Dalvand et al. (2011) used four electrodes made up of aluminum of size 11.2 cm x 10.8 cm x 0.2 cm with effective surface area of electrodes was 484 cm^2 for removal of dye from textile mill wastewater through electrocoagulation. They found that with less distance between the electrodes the efficiency of the process to remove dyes from effluents increase. Rodriguez et a. (2007) used two different types of electrode i.e. aluminum and iron for electrocoagulation process study of treatment of wastewater of a mining and smelting complex stream in Serbia, Sakara. Shivayogimath and Jahagirdar (2013) used four iron electrodes of size 5cm x 5cm x 1mm with spacing of 1 cm for treatment of sugar industry wastewater. They achieved considerable removal of turbidity and COD. El-Ashtoukhy et al. (2013) removed phenolic compounds from petrochemical oil refinery wastewater using electrocoagulation process involving an aluminum plate insulated on the back by epoxy as cathode and anode as raschig rings connected together with a thin wire of aluminum placed in a perforated plastic basket and the cathode-anode distance was kept at 0.5 cm. Bhaskar Raju et al. (2008) tested mild steel and aluminum as electrodes for treatment of wastewater from synthetic textile industry and they found that aluminum was more effective in removing COD and suspended solids. Chaudhary and Sahu (2013) used aluminum electrodes as anode (3 in numbers with 1 cm spacing, 66 cm height and 1.25 diameter) and the cylindrical electrochemical reactor of height 73 cm and internal diameter of 3.5 cm working itself as cathode for treatment of sugar industry effluents by electrocoagulation process. Al Anbari et al. (2008) used carbon steel as anode and stainless steel as cathodes in twelve electrolyte cells for electrocoagulation of wastewater for removal of heavy metals. Tyagi et al. (2014) used a pair of iron plates with 4 cm spacing to study the treatment of synthetic wastewater through electrocoagulation. Gajjar and Patel (2013) used a pair of aluminum, MS and SS plates for electrocoagulation of paint industry wastewater. Aluminum showed higher efficiency in removal of COD from paint effluents. A-Mohammed (2007) used aluminum as anode and iron as cathode of different sizes for electrocoagulation process for removal of phenol from wastewater and found that the larger plates produced better results in terms of removal of phenol from wastewater He also showed that with decrease in spacing between electrodes the efficiency of the electrocoagulation process in terms of phenol removal increases. Cerqueira et al. (2009) used beehive like electrodes made of aluminum and iron plates of size 10 cm x 5 cm x 0.15 cm for electrocoagulation of wastewater textile industry effluents. Demirci (2014) used four monopolar aluminum plates of size 60mm x 60mm x 3mm for treatment of effluents of textile industry and found that COD removal efficiencies was around 94%.

3. pH

In electrocoagulation pH provides an important parameter for efficient treatment performance. It has been well established that the initial pH (Chen et al., 2000 and Do et al., 1994) is an important factor and has a considerable influence on the performance of electrocoagulation process. Different pollutants settle at different pH depending upon their chemical as well as electrical natures. Metals are generally removed at acidic pH while some like Cadmium are removed at alkaline pH. Most of the pollutants are more effectively removed at neutral pH. With increase in pH from 6-7 the effective removal of COD and TSS increased and after this the relationship becomes negative in nature (Thirugnanasambandham et al., 2013a). Kumar and Gidde (2011) found that pH 5 and 6 were more efficient in removing solids while pH 7 was more effective in removing COD. Bazrafshan et al. (2006) used pH 3, 7 and 10 for removal of cadmium from wastes. They found that for all pH and current densities pH 10 was most effective in removing cadmium from wastewater. Mahvi and Bazrafshan (2007) also showed that for removal of cadmium from industrial wastewater pH 10 was more effective and around 99.99% removal was achieved at this pH when the electrocoagulation process was continued for 60 minutes. Daniel and Prabhakara Rao (2012) found that at alkaline pH of 8 and 10 removal of arsenic was maximum with least electrolysis time. For removal of phosphates from industrial effluents pH 7 was found to be most effective (El-Shazly and Daous, 2013). Similar results were obtained by Kobya et al. (2003) for removal of COD and turbidity from textile mill effluents. At pH 10 they found highest removal of COD and turbidity. 98% of dye removal through electrocoagulation was achieved at pH 5.5 while at increased or decreased pH this efficiency went down around 20% (Keshmirizadeh et al., 2013). Hussain et al. (2013) found that at pH 3.5 copper and at pH 4.5 cobalt were removed with most efficiency i.e. 98.8% and 97.9% respectively from textile, electroplating and tannery effluents. For removal of COD and color from plating effluents pH 7 was found to optimum in the conditions tested by Praveen et al. (2011) as any increase in pH further causes hydroxide of iron to become soluble and therefore render it useless for coagulation. Arslan-Alaton et al. (2008) showed at with steel electrodes the removal of color and COD was highest at pH 7.5 while with aluminum electrodes it was best around acidic pH for treatment of simulated acid dyebath effluent.

Dermentzis et al. (2011a) have shown that for removal of nickel from sewage wastewater the effective pH was from 4-10. At pH less than 4 and greater than 10 the effective removal of nickel was significantly less. For removal of COD and TOC using iron electrodes Akyol (2012) found that pH 4 (91% and 89% removal respectively) was better suited while for aluminum electrode pH 3 for COD removal (94%) and pH 4 for TOC removal (92%) were found to be more suitable. To remove lead pH 10 was found to be more suitable even though it was removed effectively from pH range 6-10 (Shakir and Husein, 2009). Yazdanbakhsh et al. (2013) showed that for removal of turbidity, COD and phenolic compounds from olive oil mill effluents optimum pH is 5.2. Rodriguez et a. (2007) were able to get neutral pH from initial pH 4.2 of wastewater from mining and smelting stream and were also able to remove metal ions from the wastewater. At pH 5 Shivayogimath and Jahagirdar (2013) were able to get highest removal of turbidity and Cod from sugar industry effluent. At pH 7 the removal of phenolic compounds from oil refinery wastewater iun 180 mintues was 88% as reported by El-Ashtoukhy et al. (2013).

Al Anbari et al. (2008) studied the effect of different pH on removal of heavy metals from wastewater and found that at initial pH 7 the removal of cadmium and cobal was maximum around 83% and 80% respectively. Zinc, nickel, copper and Cr (IV) were removed at 99% efficiency at pH 7 and their removal efficiency was not affected even up to 12 pH. The removal of COD from paint effluents was higher at pH 7 as shown by Gajjar and Patel (2013). A-Mohammed (2007) showed that for removal of phenol from wastewater pH 6-8 gave better results. Cerqueira et al. (2009) showed that at pH 6-5 the removal efficiency the removal of COD was low but the turbidity and color removal was high at current density of 15 A/m^2 for 30 min for aluminum electrodes while iron electrodes the values of removal of color, turbidity and COD was less than aluminum electrodes.

4. Current Density

Increase in current density in electrocoagulation causes production of metal hydroxides which shows strong affinity for dispersed and colloidal particles present in wastewater and helps in their coagulation and therefore removing COD and TSS. Thirugnanasambandham et al. (2013a) found that this effective removal of COD and TSS was evident up to 15 mA cm^2. At 200 A COD was removed with 71.65% efficiency in the process developed ny Kumar and Gidde (2011). Bazrafshan et al. (2006) found that at 40V cadmium was best removed at all pH tested in the experiments. El-Shazly and Daous (2013) determined that for removal of phosphates from industrial effluents 4 mA/cm^2 was best. 50 mA/ cm^2 was found to be the optimum current density for removal of hexavalent Chromium from effluent of electroplating industry using iron as electrodes (Verma et al., 2013). Acid Orange 2 and Reactive blue 9 are organic chemicals in industrial effluents and for their removal optimum current density of 45 A/m^2 was found to be best (Pirkarami et al., 2013). Algae and other TSS were removed at optimum current density of 100W/dm^3 (Azarian et al., 2007). An increase in the efficiency of color removal from 98 to 99% was obtained by increasing in current density from 100 to 120 A/m^2 but this value can not be considered significant and therefore according to Keshmirizadeh et al. (2013) 100 A/m^2 should be considered optimum for color removal from textile effluents. Optimum current density of 10 mA cm^{-2} was established by Thirugnanasambandham et al., (2013b) for COD and TSS removal from bagasse effluents. The optimum current density for removal of COD and color from plating effluents was found to 4 A/m^2 by Praveen et al. (2013). Arslan-Alaton et al. (2008) found that at 20 A current the removal of color from acid dyebath effluent was 1005 with steel electrodes while with aluminum electrodes it was 94% and similarly the COD removal was 58% with steel electrodes. At 30 mA/cm^2 current density nickel was effectively removed from the sewage wastewater at about 99% with just 20 minutes of electrocoagulation (Dermentzis et al., 2011). They showed that even at lesser current density the removal of nickel was as good as 30 mA/cm^2 but it took more time than required at higher current density. 1.2 mA/cm^2 current density for 120 minutes was necessary to remove 100% lead from battery industry wastewater (Shakir and Husein, 2009). At current density of 20 mA/cm^2 removal of >97% for Cu^{2+} , Ni^{2+} , Zn^{2+} and >80% for Cr^{6+} respectively was achieved in the pH range 4-10 from synthetic wastewater while with industrial wastewater this removal percentage was lower due to the presence of organic materials in it which competed with the coagulant and lowered the percentage of metal removal. During this process the COD removal from industrial wastewater was found to be more than 80% along with the removal of metal ions (Dermentzis et al., 2011b). Similarly Dermentzis et al. (2011c) found that for removal of hexavalent chromium 40 mA cm^{-2} was best. The significant removal of turbidity was achieved at 0.8 A from effluents of petrochemical factory and with higher current the efficiency of the process decreased. This according to Olanipekun Giwa et al. (2012) was due to insufficient formation of metal hydroxides from the aluminum anode at higher current density causing less coagulant for removal of turbidity. At current density of 117.187 A/m^2 the removal of turbidity, COD and phenolic compounds was optimum at pH 5.2 which was the natural pH of the olive oil mill effluent when the electrocoagulation process was done for 60 minutes (Yazdanbakhsh et al., 2013). Sarala (2012) showed that at 0.25A current the removal of COD, TDS and TSS was maximum in domestic wastes effluents. Shivayogimath and Jahagirdar (2013) got highest removal of COD and turbidity at 12V from sugar industry effluents. At 9.82 mA/cm^2 current density El-Ashtoukhy et al. (2013) were able to remove around 88% of phenolic compounds from oil refinery wastewater in about 180 minutes time. Chaudhary and Sahu (2013) were able to remove the COD about 79.5% from sugar industry wastewater when they applied current density of 40 mA/cm^2. At current density of 1.35 mA/cm^2 zinc, copper and chromium were removed with 99% efficiency in 6.4 minutes while it took 9 minutes for nickel and for cadmium and cobalt it took 30 minutes to be removed at 87% and 80% efficiency respectively (Al Anbari et al., 2008). Tyagi et al. (2014) showed at up to current density of 17 mA/cm^2, there was increase in removal of COD but beyond this current density there was decrease in efficiency of COD removal. A-Mohammed (2007) reported that at 221 A/m^2 the removal of phenol from wastewater was highest. Cerqueira et al. (2009) showed at with increase in current density from 25 to 125 A/m^2 the operation time decreased from 30 minutes to 10 minutes. At the higher current densities the efficiency of iron electrode was found to be better for COD, color and turbidity removal.

Electrocoagulation process has numerous advantages over other wastewater treatment processes.

1) If there is no pretreatment of the wastewater before electrocoagulation then there is not added chemicals which can increase the chemical load of the coagulants. This does not allow any increase in pollutants.
2) As the infrastructural requirement of the process is not huge the process is relatively cheap as compared to other treatment methods.
3) The process requires less civil works and other constructions.
4) In most of the cases the process is able to remove color from the effluents up to 95%.
5) Without any biological treatment the removal of BOD through electrocoagulation is generally 60%.
6) Without any treatment of the effluents the removal of COD by electrocoagulation is nearly 70% in many cases while in general studies in the laboratories it is as high as 95%.
7) As it does not require any addition of chemicals it causes very less amount of sludge development during the process. The amount of sludge is equal to the colloidal and suspended particles present in the wastewater and the amount of metal hydroxides formed at the anode.

Along with these advantages the process is relatively simple and easy to operate and maintain.

Rice is staple food for more than half of human population and the process of converting paddy in to eatable rice has become more industrialized resulting in various problems mostly related to water pollution. Due to rapid growth in different sectors the household activity of rice processing has been converted into major industrial activity and the processing of par boiled rice has become a major cause of concern due to the wastewater it generates (Srivastava and Soni, 2012). It has been effectively shown by the studies on earthworm population dynamics that the rice mill waste water is not good for many life forms and it has been studied that the population of earthworms in fields are major sufferers from the polluting effects of rice mill wastewater. As the earthworm population is affected adversely by rice mill effluents it has negative effect on soil which reduces its production capacity. This in turn causes problem in agriculture practices on the land polluted by rice mill effluents as the fertility of the soil goes down due non availability of various organisms which directly or indirectly help in increasing the fertility of soil (Pradhan and Sahu, 2011).

Different methods have been applied by workers throughout the world to treat wastewater generated because of industrial activities. Rice mill effluents have been known to cause environmental problems due to high contents in total dissolved and total suspended solids. Various other parameters like high COD, oil and grease content, low pH also increase the harmful nature of the rice mill effluents. The rice mill effluents also have high contents of organic matter which results in growing of microorganisms like bacteria and fungus which can be harmful to plant, animal and human life in general. To treat such wastewater electrocoagulation, chemical coagulation, flocculation etc have been tried by different workers.

To remove various pollutants different techniques have been tried and tested. Malik et al. (2011) used different microorganisms to treat rice mill effluents and they found that in absence of nutrients the BOD, COD, pH and starch content decreased slightly but in presence of nutrients the growth of microorganisms was better and the decrease in all the parameters was significant. Similarly Krishnan and Neera (2013) used fresh water algae like Oedogonium and Chara for treatment of rice mill wastewater. They found that with use of algae different parameters like COD, turbity, TDS, BOD, TDS etc were removed more effectively than compared to system where algae was not used. Chitosan has also been tried for removal of COD and TSS from rice mill wastewater, which has been used in many wastewater treatment designs due to its better adsorption quality, and it has been found that at the dose of 600mg/l with 20 min settling time 98% COD and 95% TSS were removed (Thirugnanasambandham et al., 2013a).

Apart from these methods the rice mill wastewaters have been also tested for its use in different fields. Its use for production of electricity as a substrate has been tried and it was found that when earthen pot was used as container the production of electricity was higher than the production of electricity when microbial fuel cell (MFC) was made by incorporating proton exchange membrane (Behera et al., 2010). In the same study it was also found that with this MFC set up, the effective treatment of wastewater was better and the MFC also removed phenols which become a problem in standard effluent treatment. At pH 8 the maximum output was achieved of 6.25 mA and 0.772 V. The treatment of rice mill wastewater has also been tried using bacterial cells. Different microorganisms like bacteria and fungi are present in rice mill effluents. The bacteria were cultured from the rice mill effluent and the efficiency of these bacteria especially *Pseudomonas* sp. were tested for their degradation capacity of pollutants in rice mill wastewater using free as well as immobilized cells. The treatment of rice mill wastewater was found to be best in packed bed reactor having immobilized cells (Manogari et al., 2008). Even though the rice mill wastewater has been shown to be detrimental for growth of many life forms like earthworms but it has been shown to be good medium for mass production of Spirulina which is used as an excellent source of protein (Amala and Ramanathan, 2013).

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