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Domestic Sewage treatment using Batch Stirred Tank Electrochemical Reactor

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Abstract: The present investigation endeavor to study the domestic sewage treatment using an electrochemical technique. Experiments were carried out at different current densities and different volume in a batch electrochemical reactor using Ti/RuO₂ as anode and stainless steel as cathode. The characteristic such as pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Phosphorous and colour of the domestic sewage before and after treatment has been critically examined. The results showed that electrochemical chloride mediated indirect oxidation is a relevant, neat and possible solution for the treatment of domestic sewage water. The maximum COD reduction and colour removal efficiencies were 97.8% and 100%, respectively. Further a critical review is made on the various treatment methodologies and a note on their advantages and disadvantages are highlighted.

Keywords: Indirect electrochemical oxidation; Electro-coagulation; Current density; Domestic sewage; COD.

Introduction

Sewage is a major carrier of disease (from human wastes) and toxins (from industrial wastes). It is a mixture of domestic and industrial wastes. It is more than 99% water, but the remainder contains some ions, suspended solids and harmful bacteria that must be removed before the water is released into the sea. The composition of sewage varies depending upon the source of waste water. This also causes variation in the microbial flora of sewage. Several work activities bring workers into contact with sewage and sewage products. Each year, some workers will suffer from at least one episode of work-related illness. The majority of illnesses are relatively mild cases of gastroenteritis, but potentially fatal diseases, such as leptospirosis (Weil's disease) and hepatitis. They cannot be simply disposed off into water bodies or landscapes because of the oxygen demand they exert and also due to the presence of pathogenic microbes in them. The safe treatment of sewage is thus crucial to the health of any community.

Treatment of sewage is accomplished by adopting various treatment schemes, each incorporating one or several different treatment units such as Screens, Grit chambers, Plain Sedimentation, Chemical Precipitation, Trickling Filter, Activated Sludge, Anaerobic digestion, Up flow Anaerobic Sludge Blanket (UASB) reactor, Waste Stabilization Pond and Maturation Pond. As the environmental

regulations becoming more stringent day by day, new and novel processes for efficient treatment of sewage at low operating cost are needed. In this perspective, researchers are focusing on advanced oxidation processes such as electrochemical technique, wet air oxidation, ozonation, and a photo catalytic method for the degradation of organic compounds present in the these advanced wastewater. Among oxidation processes, electrochemical oxidation/treatment has been receiving greater attention due to its unique features such as complete degradation without generation of solid sludge, energy efficiency, automation and cost effectiveness ^{1,2}. The first detailed account has been given in ³. Their effectiveness results from the fact that the generated hydroxyl radicals (OH) are highly reactive and non-selective such that they are able to degrade many organic pollutants ^{4,5,6}. On the other hand, if chloride is present in the electrolyte⁷ an indirect oxidation via active chlorine can be operative, which has been successfully adopted for treatment of several industrial waste water.

electrochemical In oxidation technique, electron is used to degrade all the organics present in the effluent without generating any secondary pollutant or byproduct/sludge. The advantage of the electrochemical technique is high removal efficiencies with low temperature requirements compared to non electrochemical treatment. In addition to the operating parameters, the pollutant degradation rate depends on the anode material choice. High corrosion resistances, physical and chemical stability under high positive potentials are the main requests. When properties as above are required, dimensionally stable anodes (DSA), as those discovered by Beer in the 1970s are the natural candidates⁸. This designation denotes a class of thermally prepared oxide electrodes where a titanium substrate is covered by metallic oxides. Coatings onto titanium include TiO₂, IrO₂, RuO₂ and

 Ta_2O_5 . Combinations such as TiO_2/RuO_2 are indicated for alkaline medium, while IrO_2/Ta_2O_5 usually shows longer service life in acidic electrolytes.

Researchers also investigated electrocoagulation methods for industrial wastes ^{9,10,11,12,13}. Electro-coagulation has been proposed for the treatment of various effluents such as wastewater containing food and protein wastes ¹⁴, textile wastewater ¹⁵, aqueous suspensions containing kaolinite, bentonite and ultra fine particles ^{16,17} fluoride containing water ¹⁸, restaurant wastewater ^{19,20} textile dye solution ²¹⁻²² and smelter wastewater containing has full arsenic ²³.

In this paper, an attempt has been made to study the treatment efficiency of electrochemical oxidation and electro-coagulation processes for the removal of colour and COD of the domestic sewage, followed by indirect oxidation to augment the overall efficiency of the process. The effect of experimental parameters such as current density and reactor volume has been studied. The result showed that 98% removal efficiency can be achieved by indirect electrochemical oxidation techniques.

Materials and Methods

All the reagents used were of analytical grade. Synthetic sewage was prepared from the house hold waste materials were used after filtration for the experimental study. The characteristics of the domestic sewage before and after treatment (Indirect electrochemical oxidation: current density 5amp/dm²) is present in Table 1. This resembles the domestic sewage that found in the actual sewage treatment plant. NaCl and HCl were used as supporting electrolyte for the indirect electrochemical oxidation in the present study.

Table 1. Characteristics of the sewage before and after treatment

	Domestic sewage		
Parameters	Before Treatment After Treatment ^a		
pН	7.8	5.5	
COD (mg/l)	1100	24	
BOD (mg/l)	260	120	
TDS (mg/l)	600	110	
TSS (mg/l)	200	100	
Phosphorus (mg/l)	10	-	

^a Indirect electrochemical oxidation with current density 5 amp/dm² for 9 hours.



Fig. 1. Schematic of continuous stirred tank electrochemical reactor experimental setup: (1) Overhead tank; (2) DC power supply; (3) Anode; (4) Cathode; (5) Magnetic stirrer.

Electrochemical oxidation

The schematic diagram of the experimental setup given in Fig. 1 consists of a glass beaker with PVC lid having provision to fit a cathode and an anode. Salt bridge with reference electrode was inserted through provided in the lid. Proper provisions are also made for periodic sampling. The cathode was stainless steel plate and the anode taken was commercially available Ti/TiO₂, RuO₂ coated expanded mesh. Experiments were carried out under galvanostatic conditions using a DC-regulated power source. Stirring was done with a magnetic stirrer. Electrolysis was carried out at different current densities, viz. 1, 2, 3, 4 and 5 amp/dm^2 . Current corresponding to the current density is passed for 9 hours. During the experiment the cell voltage, electrode potentials were measured. A sample of 1ml was collected at every 1 hour and subjected to the COD analysis.

Electro-coagulation

Electro-coagulation is the modification of electro floatation where the coagulation agent is produced in situ at the respective electrodes. The anode was mild steel (sacrificial) available in commercial market. The cathode was stainless plate. The effective surface area of anode and cathode were 7 cm \times 7 cm. The

generation of metallic cations takes place at the anode, whereas at the cathode, typically a H_2 production occurs. The generated gas helps the flotation of flocculated particles, and therefore the process sometimes is named as electro flocculation²⁴.

A DC power supply was used as the source of constant electric current for the experiments. To maintain the uniform concentration of the electrolyte, the reactor solution was constantly stirred using a magnetic stirrer. Experiments were carried out at different current densities, viz. 1, 2, 3, 4 and 5 amp/dm². Current corresponding to the current density is passed for 9 hours. During the experiment the cell voltage, electrode potentials were measured. A sample of 1ml was collected at every 1 hour and subjected to the COD analysis.

Analytical measurements

COD is the amount of oxygen required for the chemical oxidation of organic matter with the help of strong chemical oxidants. It means measuring the strength (in terms of pollution) of waste water. By using this method, most oxidizable organic compounds present in the waste water sample may be measured. The COD of all samples were determined by the dichromate reflux method ²⁵.



Fig. 2. Scheme of electrochemical oxidation of organic pollutants in presence of chloride ion.

Results and Discussion

Theoretical description

The electrochemical reactions that take place during the electrochemical oxidation are complicated and not entirely known. For time being assumptions can only be made, based on the products that can be measured. A brief explanation of reaction mechanism taking place at metal oxide electrode is enumerated below.

The reactions of anodic oxidation of chloride ions to form chlorine is given as,

 $2CI^{-} \xrightarrow{k_{1}} Cl_{2} + 2e^{-}$ (1) The liberated chlorine form hypochlorous acid is given as

$$Cl_2 + H_2O \xrightarrow{k_2} H^+ + Cl^- + HOCl (2)$$

and further dissociated to give hypochlorite ion is given as

HOC1
$$\xleftarrow{k_3}{k'_3}$$
 H⁺ + OC1⁻ (3)

The generated hypochlorite ions act as main oxidizing agent in the pollutant degradation. A schematic diagram of indirect oxidation of pollutant ²⁶ is shown in Figure 2. It shows a generalized scheme of the electrochemical conversion/combustion of organics on noble oxide coated catalytic anode (MO_x). In the first

step, H_2O is discharged at the anode to produce adsorbed hydroxyl radicals according to the reaction.

 $MO_x + H_2O \rightarrow MO_x(OH) + H^+ + e^-$ (4)

In the second step, generally the adsorbed hydroxyl radicals may interact with the oxygen already present in the oxide anode with possible transition of oxygen from the adsorbed hydroxyl radical to the oxide forming the higher oxide MO_{x+1} .

$$MO_x(OH) \rightarrow MO_{x+1} + H^+ + e^-$$
 (5)

At the anode surface, the "active oxygen" can be present in two states. Either as physisorbed (adsorbed hydroxyl radicals ('OH) or/and as chemisorbed (oxygen in the lattice, MO_{x+1}). In the absence of any oxidizable organics, the "active oxygen" produces dioxygen according to the following reactions:

 $MO_x(OH) \rightarrow MO_x + 1/2O_2 + H^+ + e^-$ (6) $MO_{x+1} \rightarrow MO_x + 1/2O_2$ (7)

When NaCl is used as supporting electrolyte Cl ion may react with MO_x ('OH) to form adsorbed OCl radicals according to the following ²⁷:

$$MO_x(OH) + Cl^- \rightarrow MO_x(OCl) + H^+ + 2e^-$$
 (8)

Further, in presence of Cl ion, the adsorbed hypochlorite radicals may interact with the oxygen already present in the oxide anode with possible transition of oxygen from the adsorbed hypochlorite radical to the oxide forming the higher oxide MO_{x+1} according to the following reaction and also MO_x (OCl) simultaneously react with chloride ion to generate active oxygen (dioxygen) and chlorine according to the following reactions:

$$\begin{array}{l} \text{MO}_{x}(\text{OCl}) + \text{Cl}^{-} \rightarrow \text{MO}_{x+1} + \text{Cl}_{2} + \text{e}^{-} (9) \\ \text{MO}_{x}(\text{OCl}) + \text{Cl}^{-} \rightarrow \text{MO}_{x} + (1/2)\text{O}_{2} + (1/2) \text{Cl}_{2} + \text{e}^{-} \\ (10) \end{array}$$

In the presence of oxidizable organics the physisorbed "active oxygen" (OH) should cause predominantly the complete combustion of organics and chemisorbed will participate in the formation of selective oxidation products ²⁸ according to the following reactions:

$$(1/2)R + MO_x(OH) \rightarrow (1/2)ROO + H^+ + e^- + MO_x$$

(11)

$$R + MO_{x+1} \rightarrow RO + MO_x$$
(12)

The physisorbed route of oxidation is the preferable way for waste treatment. It is probable that dioxygen participates also in the combustion of organics according to the reactions, such as formation of organic radicals by a hydrogen abstraction mechanism: $RH+ OH \rightarrow R+H_2O$; reaction of organic radical with dioxygen formed at the anode: $R' + O_2 \rightarrow ROO'$ and further abstraction of a hydrogen atom with formation of an organic hydrogen peroxide (ROOH) and another radical; ROO' $+R'H \rightarrow ROOH + R'$. Since the organic hydrogen peroxides formed are relatively unstable, decomposition of such intermediates leads to molecular breakdown and formation of subsequent intermediates with lower carbon numbers. These sequential reactions continue until the formation of carbon dioxide and water.

The role of hypochlorite in electrochemical treatment of sewage effluent via chlorine generation is

Organic + OCl⁻
$$\xrightarrow{k_4}$$
 CO₂ + H₂O + Cl⁻ + P
(13)

Since domestic waste are electrochemically inactive, the reaction occurs at the anodes is chloride ion oxidation with the liberation of Cl_2 , which is a robust oxidizing agent. As regards to the reactions in the bulk, gaseous Cl_2 dissolves in the aqueous solutions due to ionization as indicated in Eq. (2). The rate reaction is less in acidic solution due to OH⁻ instability and considerably more in basic solution due to ready formation of OCI⁻ (pKa 7.44) ion in Eq. (3) implying that the basic or neutral pH conditions are more favorable for conducting reactions involving Cl₂. A cycle of chloride–chlorine–hypochlorite–chloride takes place, which produces OCl⁻. The pseudo steady state theory can be applied to each of the intermediates products (HOCl and OCl⁻) taking part in the bulk solution. Taking all other reactions are irreversible processes, the rates of reactions r_i specifically for the sequence are (Eqs. (1)–(3) and (13))

$$-r_{cl_2} = k_2 [Cl_2]$$
(14)

$$r_{HOCl} = k_2[Cl_2] - k_3[HOCl] + k'_3[H^+][OCl^-] = 0$$
 (15)

 $r_{ocl^{-}} = k_3[\text{HOCl}] - k'_3[\text{H}^+][\text{OCl}^-] - k_4[\text{sewage}][\text{OCl}^-] = 0$ (16)

$$-r_{\text{Sewage}} = K_4[\text{sewage}][\text{OCl}^-]$$
(17)

Then using Eqs. (15) and (16) we can easily deduce the following expression:

$$-r_{cl_{\gamma}} = -r_{\text{Sewage}} = k_4 [\text{sewage}][\text{OCI}^-]$$
(18)

Finally, as regard to bulk solution, it is also to be noted that $-r_{cl_2} = r_{cl^-}$ from material balance of Eq. (13), that is

$$-r_{cl_2} = r_{cl^-} = k_2[Cl_2] = -r_{Sewage} = k_4[sewage][OCl^-]$$

(19)

where the rate of reaction r_i and the rate constants k_i (*i*=2, 3 and 4) are defined with respect to bulk and the rate expression for main electrode reaction as per the Eq. (1) can be written as.

$$-r'_{cl^{-}} = -r'_{cl_2} = k_1 [Cl^{-}].$$
(20)

where k_1 is heterogeneous electrochemical rate constant. Hence, in the following section an attempt has been made to establish a relation between the reacting species in bulk and at the electrode surfaces. The basic relationship applicable to all electrochemical reactions is Faraday's law that relates to the amount of substance reacted at the surface to the charge $(I_A t)$ passed is $M_A I_A t/nF$ (assuming 100% current efficiency) and the characteristic measurable parameter is current density, i_A , which is I_A/A_e . Thus, the electrochemical reaction rate (for the disappearance of reactant A) can be expressed as,

$$-\left(\frac{V_R}{Ae}\right)\frac{d[A]}{dt} = \frac{i_A}{nF}$$
(21)

where I_A is the current passed in time t, M_A the molecular weight, n the number of electrons transferred per mole of reaction, A_e the electrode area, V_R the reactor volume and F is the Faraday (96,500C or A s/mol). It has to be noted $-r_A = -d[A]/dt = i_A a/nF$, where a is specific electrode area (A_e/V_R) . Assuming the main electrode reaction is governed by a simple Tafel type expression, then

$$-\left(\frac{V_R}{Ae}\right)\frac{d[A]}{dt} = \frac{i_A}{zF} = k'[A]\exp(bE) \quad (22)$$

Or
$$-r'_{cl^-} = -r'_{cl_2} = k_1[Cl^-] = k_l'a[Cl^-]\exp(bE) \quad (23)$$

The reaction may be assumed to be under diffusion control as the reacting species, CI^- in the electrolyte is dilute. The reactant CI^- is transported for the bulk to electrode surface where it under goes electrochemical oxidation to Cl_2 and it may be transported back to bulk by diffusion reaction in the bulk. Then,

$$\frac{i_A}{zF} = \mathbf{k}_{\mathrm{L}}([\mathrm{Cl}^{-}] - [\mathrm{Cl}^{-}]_{\mathrm{s}})$$
(24)

Elimination of [CI⁻]s using Eqs. (23) and (24), results can be written as

$$\frac{i_A}{zF} = \mathbf{k}_1[\mathrm{Cl}^-] \tag{25}$$

Where

$$\frac{1}{k_1} = \frac{1}{k_L} + \frac{1}{k' a \exp(bE)}$$
(26)

From a material balance of species CI^{-} by taking note of Eqs. (12) and (13) we can write

$$\frac{i_A}{zF} = \mathbf{k}'[\mathrm{Cl}_2]$$
(27)
$$\frac{i_A}{zF} = \mathbf{k}''[\mathrm{Sewage}][\mathrm{OCl}^{-}]$$
(28)

During electrolysis, since the constant current is applied, the rate of generation of [OCl⁻] will remain

constant under a given set of experimental condition, but it varies as the applied current is altered. Then

$$\frac{l_A}{zF} = k_{obs}[Sewage] = k[COD]$$
(29)

Adopting the same classification for the reactors as for conventional reactors, thus the electrochemical reaction rate (for removal of COD) can be expressed as

$$-\left(\frac{V_R}{Ae}\right)\frac{d[COD]}{dt} = \frac{i_A}{nF} = k[COD]$$
(30) or,
$$\ln\left(\frac{[COD]_0}{[COD]}\right) = kat$$
(31)

Electro-coagulation

Electro-coagulation has been successfully employed in industrial effluents for removal of organic contaminants, oil and greases. In this process, a potential is applied to the metal anodes, typically fabricated from either iron or aluminum, which causes two separate reactions. Iron upon oxidation in an electrolytic system produces iron hydroxide, Fe (OH)_n, where n = 2 or 3. Mechanisms^{29,30,31} that were proposed for the production of Fe(OH)_n are:

Anode: Fe \to Fe³⁺ +3e⁻ E° = -0.04V (32)

$$Fe \to Fe^{2+} + 2e^- E^\circ = -0.04V$$
 (33)

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-} E^{\circ} = -0.77V$$
 (34)

$$4Fe^{2+} + 2H_2O + O_2 \rightarrow 4Fe_3^+ + 4OH^- pH > 7$$
(35)

$$4Fe^{2+} + 4H^+ + O_2 \rightarrow 4Fe^{3+} + 4H_2O \text{ pH} < 7$$
 (36)

Cathode: $2H_3O+2e^- \rightarrow H_2+2H_2O \text{ pH} > 7$ (37)

$$2H_{3}O + 2e^{-} \rightarrow 4OH^{-} pH < 7$$
(38)

The Fe (OH) $_n$ formed remains in the aqueous stream as a gelatinous suspension, which can remove the pollutants from wastewater either by complexation or by electrostatic attraction, followed by coagulation ³².

consumption in Electrochemical oxidation process.						
Current			Percentage	Energy		
density	Volume	Voltage	COD	Consumption		
(amp/dm^2)	(liter)	(Volts)	Removal	(kwhr/kg COD)		
1	0.2	3.6	67.6364	5.225806		
	0.3	4.7	65.4545	7.05		
	0.4	4.9	64.0909	6.255319		
2	0.2	4.1	71.6364	11.23858		
	0.3	5.3	68.7273	15.14286		
	0.4	5.4	68.1818	12.96		
3	0.2	4.3	79.6364	15.90411		
	0.3	5.5	75.9091	21.34132		
	0.4	5.8	73.0000	19.50187		
4	0.2	5.2	87.8182	23.25466		
	0.3	6.3	83.6364	29.58261		
	0.4	6.7	84.1818	26.04752		
5	0.2	5.9	94.00	30.81238		
	0.3	6.9	89.0909	38.02041		
	0.4	7.3	88.3636	33.7963		

 Table 2. Effect of current density on percentage COD removal and power consumption in Electrochemical oxidation process.

 Table 3. Effect of current density on percentage COD removal and power consumption in Electro-coagulation process

Current				Energy
density	Volume	Voltage	Percentage	Consumption
(amp/dm^2)	(liter)	(Volts)	COD Removal	(kwhr/kg COD)
1	0.2	10.98	49.09	21.96
2	0.2	11.35	51.82	43.01
3	0.2	12.56	56.82	65.11
4	0.2	12.89	59.54	85.01
5	0.2	13.68	60.91	110.26

Electrochemical oxidation and electrocoagulation

The experimental results of the electrochemical oxidation (EO) as well as of electro-coagulation processes are presented in Table 2 and Table 3. The experiments were conducted at five different current densities of 1.0, 2.0, 3.0, 4.0 and 5.0 amp/dm². In respect of electrooxidation process in the batch reactor, at 1 amp/dm^2 it was observed that the percentage COD removal was 67.6% increased to 94% at 5 amp/dm² for the reactor capacity of 200 ml in 9 hours of operation. The percentage COD removal was increased with increase in current density. This might be due to the fact that the rate of generation of hypochlorite (OCI) increased with increase in current density, which eventually increased the pollutant degradation. In 9 hour of operation of the cell the maximum COD reduction was found to be 94% at 5 amp/dm^2 . As seen from the Table, the same trends of the COD reduction were observed in higher volumes also.

Electro-coagulation is a process consisting of creating metallic hydroxide flocs within the wastewater by electrodissolution of soluble anodes, usually made of iron or aluminum. This method has been practiced for most of the 20th century with limited success. In respect of electro-coagulation process in the batch reactor, it was observed that the percentage COD removal was maximum of 60.9% at 5 amp/dm² for the reactor capacity of 200 ml in 9 hours of operation and with the average cell voltage of 12.29 V, the specific energy consumption on average of 65.07 kWhr/kg of COD. The high amount of energy consumption and low percentage COD removal make them unfit for the electro-coagulation process in the domestic sewage treatment.

Electrochemical oxidation with supporting electrolyte

The reactions of anodic oxidation of chloride ions to form chlorine in bulk of solution is given as $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$ (39)

 $HOCI \leftrightarrow H^{+} + OCI^{-}$ (40) Organic + OCI^{-} $\rightarrow CO_{2} + H_{2}O + CI^{-} + P$ (41)

The results of the electrochemical oxidation with supporting electrolyte experiments at various current densities between 1 and 5 amp/dm² were shown in Figure 3 and Figure 4. As the current density increases, percentage COD removal increases. It is to be noted that maximum of 97.8% COD removal achieved with this indirect electrochemical oxidation method. It is due to the fact that, in indirect electro-oxidation, sodium or hydrogen forms of chloride are added to the wastewater for better conductivity and generation of hypochlorite ions. This generated hypochlorite ions act as oxidizing agent in the pollutant degradation in addition to the hypochlorite ions generated by the electrochemical reactions.

Comparison among various processes

Fig. 5. Shows the performance of the treatment process such as electrochemical oxidation, indirect

electrochemical oxidation and electrochemical coagulation with respect to percentage COD removal at various current densities. It can be seen in Fig. 5 that the electrochemical oxidation assisted with NaCl and HCl treatment process indicates 98% COD reduction within 7 hours of operation. The objective of this comparison is not to show which process is more efficient since they are different process and the yields are not comparable. However, it is useful to show that when both treatments are simultaneously applied the resulting COD reduction is more effective than a single process. The synergic aspect observed by assisting electrochemical oxidation with supporting electrolyte NaCl and HCl is important when one considers the need for degradation of some organic pollutants that usually are recalcitrant to conventional treatments.



Fig. 3. Effect of current densities on percentage COD removal in an electrochemical oxidation with supporting electrolyte NaCl



Fig. 4. Effect of current densities on percentage COD removal in an electrochemical oxidation with supporting electrolyte HCl



Fig. 5. Comparison between various electrochemical techniques

Energy consumption

The energy consumption was very important to study in the electrochemical process. The advantages claimed for Ti/RuO2/IrO2 (DSA) anodes over a graphite electrode are (i) lower cell voltage (3.90 V compared to 4.97 V for graphite), (ii) lower power consumption (2740 kWh per ton of Cl2 compared to 3580 kWh per ton of Cl₂) and (iii) electrode erosion taking place only at graphite electrode, not in DSA ³³ The results, which are presented in Table 1 and Table 2, show that the operational current density significantly influences the power consumption. Only a few percent of the total energy requirement of the electrochemical step is needed for pumping the electrolyte around the electrolyte cycle and a small fraction of the energy is necessary to maintain a sufficiently fast flow through the electrodes. The specific energy consumption for electrolysis, E, kWhr/kg COD, is computed using the following expression:

$E = [V_{cell}It/10^3] / [(Co-Ct)V/10^6]$

Where the numerator represents the power input in kWhr. V_{cell} is the cell voltage in volts, I is the current applied in amperes in the circuit, and t is the duration of electrolysis in hours for bringing the initial concentration, C_o (mg/l), of effluent to final concentration, C_t (mg/l), in the volume of the reservoir, V, in liters.

At 5.0 amp/dm² with the reactor volume 200 ml the energy consumption was 30.81 kWhr/kg COD for 9 hours with 94% COD removal, whereas 67.63% COD reduction was obtained at 1.0 amp/dm² with the energy consumption about 5.22 kWhr/ kg COD. The

maximum removal of COD was found to be 97.81% at 5.0 amp/dm² with an energy consumption of 24.20 kWhr / kg COD.

Conclusions

The present investigation reports on domestic sewage treatment method in а batch stirred tank electrochemical reactor. The experimental results showed that the electrochemical oxidation process could effectively remove color, COD, and odour from the domestic sewage. The maximum COD reduction of about 97.81% was obtained in indirect electrochemical oxidation process at a current density of about 5 amp/dm². Specific power consumption obtained for the treatment is 24.20074 kWhr/kg COD. The additives such as sodium chloride and hydrochloric acid are used to enhance the rate of COD removal. In the present investigation completely degraded organic compounds. without formation of chlorinated intermediate compounds, were identified at high current density. According to these results, the electrochemical oxidation could be a strong alternative to conventional physicochemical methods for the treatment of domestic sewage with further research.

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