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'Electrocoagulation reactor interface in water treatment process for economy in water distribution'

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Abstract-

This paper provides an overview of electrocoagulation process when introduced in drinking water treatment plant working. The literature review shows that presently electrocoagulation process is followed to recycle domestic waste water, sewerage water, industrial waste water etc. Research study is carried out herein, to investigate the advantages of electrocoagulation method if used in water treatment process. Water samples after conventional water treatment process and electrocoagulation process are collected to conduct laboratory test and compare their water quality standards. The objective of proposed study is to develop economical water distribution system with water qualitative uses such as:

i) Standard drinking water quality as per norms set by WHO.

ii) Substandard water quality for following uses:

a) Domestic Uses: Carwash, Sanitary and floor clearing, Kitchen-garden maintenance etc.
b) Watering the agricultural fields
c) Industrial uses- Producing manure, detergents, heavy water

Heavy water is made by the prolonged electrolysis of water containing alkali. It is used as a neutron moderator in different types of nuclear reactors. It is also used in various laboratories and factories.

Key words-

Water treatment plant, Wastewater treatment; Electrochemical treatment; Electrocoagulation; Coagulation; Sacrificial anodes, Water distribution system

1. Introduction-

Water is precious element on earth. Although, it is available in abundance but it is contaminated with organic and in-organic impurities. Removal of impurities before it is used for drinking purpose is costly affair. The classical water treatment processes are filtration, air stripping, ion-exchange, chemical precipitation, chemical oxidation, carbon adsorption, ultrafiltration, reverse osmosis, electrolysis, volatilization, and gas stripping.

1.1 Water Treatment History (Tischler, 2007) [13]-

There are documented ways to improve water quality as early as 4000 BCE. Coagulation via alum was used in early 1500 BCE and is still a widely used treatment process today [13]. The first public water utility was built in Paisley, Scotland in 1804 which also gave birth to the concept of transport of pathogens in public water supply. Unfortunately, it was only in 1855 that the connection between microorganisms and waterborne diseases was made. By early 1900s water treatment moved beyond aesthetic problems and into the realm of pathogens. World's first drinking water standards were also established during this period. The US Public Health Service set standards for bacteriological quality of drinking water in 1914, but world's first usage of chlorine disinfection to address pathogen problems was in 1908 by Jersey city, New Jersey (United States) [13]

Chlorine is the most commonly used disinfectant in the world currently for its ease of usage, simple to dose, measure, and control, a reasonably prolonged residual, low capital installation costs, availability, affordability, and treatment efficiency (Poleneni and Inniss, 2013). According to a survey conducted about disinfectant use in US systems in 1997, 90% of the systems use chlorine as primary disinfectant (Poleneni, 2013). Though over the past decade number of utilities using chloramines as primary disinfectant has increased, chlorine still remains as the most preferred choice. Since its first usage as primary disinfectant in 1908, it has been used around the world in many forms to protect people against water-borne diseases such as diarrhea, cholera, Escherichia coli, Legionellosis, dysentery, etc. As with any chemical reaction, the reaction of chlorine with organics in water does produce some by-products and unfortunately, these disinfection by-products (DBPs) turned out to be carcinogenic in nature (Poleneni and Inniss, 2015). Since their discovery in drinking water in the 1970s and with increasing understanding of their occurrence and health effects, the control of DBP formation has become one of the major issues for the drinking water industry (Karanfil et al., 2008). Many countries around the world decided to regulate DBPs to protect public health, which in turn created a need for research and development of new treatment technologies to achieve compliance. Majority of the research focused on trihalomethanes (THMs) and haloacetic acids (HAAs), the two largest classes of DBPs on weight basis and also because they are regulated by many countries.

1.2 Water Treatment Plants-

Drinking water treatment is an ancient art, while establishing standards is relatively new. People have been drinking water and developing ways to make it safer to consume for a long time. Public drinking water systems use different water treatment methods to provide safe drinking water for their communities. Public water systems often use a series of water treatment steps that include coagulation, flocculation, sedimentation, filtration, and disinfection.

1.2.1 Water Treatment Steps-

Water treatment methods are classified as Primary, Secondary and Complete treatment.

Primary Treatment- There is four methods of primary treatment: chlorination; ozone treatment; ultraviolet treatment; and membrane filtration.

Secondary Treatment-

Secondary treatment of water consists of sedimentation and filtration followed by chlorination. Sedimentation can be carried out by holding the raw water in ponds or tanks. The four basic types of filtration methods are: cartridge filtration, rapid sand filtration, multimedia sand filtration, and up-flow filtration.

Complete Treatment-

Complete treatment consists of flocculation, coagulation, sedimentation and filtration followed by disinfection. Flocculation and coagulation will assist in removing contaminants in the water, causing turbidity, colour odour and taste which cannot be removed by sedimentation alone. This can be achieved by the addition of lime to make the water slightly alkaline, followed by the addition of coagulants like Alum (aluminium sulphate), ferric sulphate or ferric chloride. The resultant precipitate can be removed by sedimentation and filtration.

Chemical treatment may be required to reduce excessive levels of iron, manganese, chalk, and organic matter. Such treatment is usually followed by clarification. Iron may be removed by aeration or chlorination to produce a flocculant which can be removed by filtration. Manganese may be removed by aeration followed by adjustment of pH and up-flow filtration. Most colours can be removed by treatment with ferric sulphate to precipitate the colours.

2. Working Principle of Electrocoagulation-

Electrocoagulation (EC) [8] is advanced electrochemical based technology, to remove contaminants from water by passing electric current through water. In EC reactor, anode and cathode in the form of plates, balls, wire mesh rod and tubes are used. At present, electrocoagulation process is used for the treatment of wastewater containing foodstuff, organic matter, synthetic detergent effluents, mine wastes and heavy metal containing solution. EC removes metals, colloidal solids and particles and soluble inorganic pollutants from aqueous media by introducing highly charged polymeric metal hydroxide species. Working principle of electrocoagulation reaction taking place inside the chamber and the construction of EC reactor [9] is explained Fig. 1 (a and b). The requirements to operate electrocoagulation are a Direct current power source, Resistance Box, a multimeter etc.

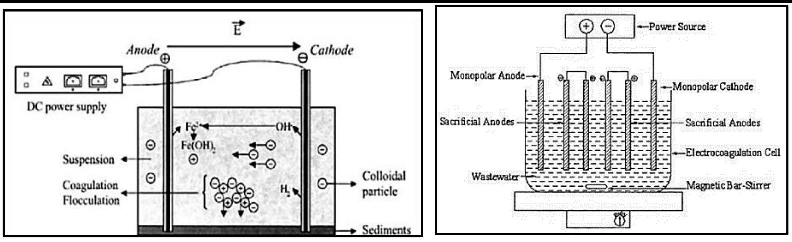


Fig. 1 (a) EC Reaction Reactor chamber, (b) EC Reaction inside the Reactor

Coagulation process is initiated by neutralizing the charges of the particles by released ions. The released ions remove undesirable contaminants by chemical reaction and precipitation. Water containing colloidal particles, oils or other contaminants are destroyed or become less soluble in the applied electric field.

Traditionally, the electrochemical process electrolytically oxidizes a sacrificial anode to release metal ions that form coagulants, destabilizing contaminants, and breaking emulsions. This coagulation forms flocculants that float to the surface for removal. An electrochemical process offers outstanding benefits when compared to other technologies:

- Can treat both process and waste water
- Treats a wide range of contaminants
- Operation uses safe, simple equipment
- Typically, no need for chemical treatment
- Can reuse electrocoagulation-treated waters, to minimize waste

The electrochemical process is complex, but well understood. It involves following distinct stages that incorporate chemical and physical phenomena. Electrocoagulation is a versatile process able to treat drinking and waste waters. The pros and cons of electrocoagulation [10] (EC) are compared to alternative processes. There are many brands of electrocoagulation devices available and they can range in complexity from a simple anode and cathode to much more complex devices.

Photo 1 – EC reactor used as domestic waste water recycler

In Photo 1 – a simple electrocoagulation plant is shown, which is used as domestic waste water recycler in a residential colony. The water coming out the electrocoagulation reactor is use for carwash and maintaining lawn in the colony.

3. Water Treatment Plant working-

The case study presented herein refers to water treatment and distribution in a residential colony, where electro-coagulation reactor is used as waste water recycler to make consumptive use of water. The water from a bore-well is pumped into overhead tank. It is then subject to primary and secondary treatment to bring it up to the quality standard laid down by World Health organization [13]. After its use in domestic purposes, the waste water is collected and passed through the electro-coagulation reactor, where it is treated to make its use for car-wash, floor cleaning and sanitary purposes other than drinking. Thus, electro-coagulation reactor is used as waste water recycler. The working is illustrated in Fig. 2

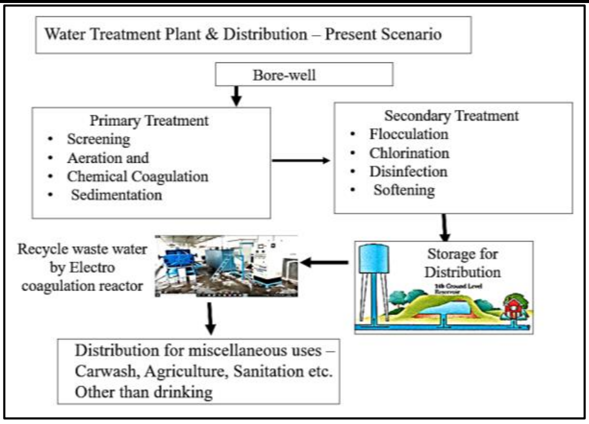


Fig. 2 – EC reactor used as domestic waste water recycler

3.1 Modified Water Treatment Approach-

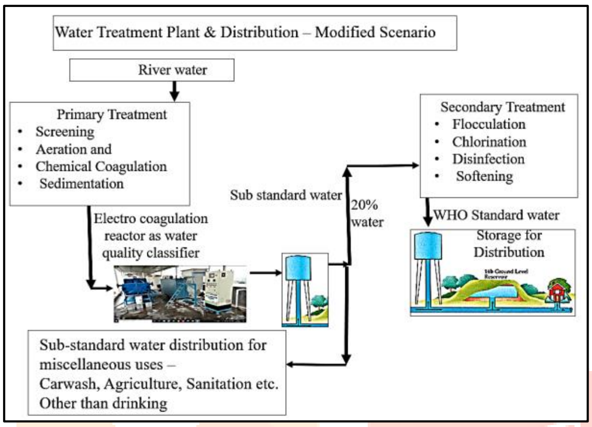


Fig. 3 – EC reactor used as water quality classifier

In modified method to make consumptive use of water from the treatment plant, electro-coagulation reactor is used as interface between primary and secondary treatment process as shown in Fig. 3. Thus, the reactor acts as a classifier between sub-standard and standard water quality.

4 Laboratory Tests for Modified Treatment Approach-

Following water samples have been collected from a residential colony in which electrocoagulation reactor is used as domestic waste water recycler:

1. The bore-water is collected in an overhead tank after the primary treatment and Secondary treatment for supply to the residential flats. After the domestic use the waste water is passed through Electrocoagulation Reactor. Let this EC reactor treated water sample be denoted as S1.
2. In modified treatment process electrocoagulation reactor is used as interface between primary and secondary treatment process. It is proposed to send only 20% water for secondary treatment. Let this water sample be denoted as S2.
3. The bore-water supplies water after primary, secondary and complete treatment into an overhead tank. Let this water sample be denoted as S3.

4.1 Lab Test Results-

Table 1 Water Samples - Physical Variants Test Report of water samples

No	Parameter	Standard Value	Sample S1	Sample S2	Sample S3
1	pH	7	11	7	8
2	Turbidity	5	18	16	12
3	Temp.	30	37	37	37

Table 2 Water Samples - Oxygen Variation Test Report of water samples

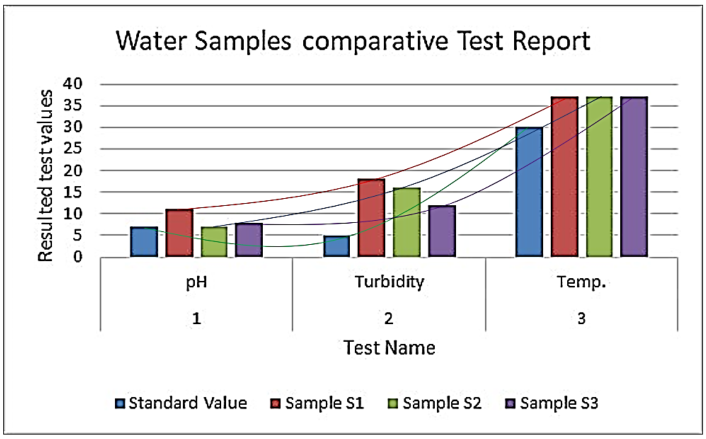
1	DOi	8.8	10	12	13
2	DOr	6	8	10	11
3	DO_d	2.4	3	2	2.8

Table 3 Water Samples -Chemical Variants Test Report of water samples

1	Calcium	7.5	25	37	29
2	Magnesium	50	44	38	43
3	Nitrates	45	51	56	47
4	Sulphates	200	298	168	157
5	Hardness-	500	380	412	350

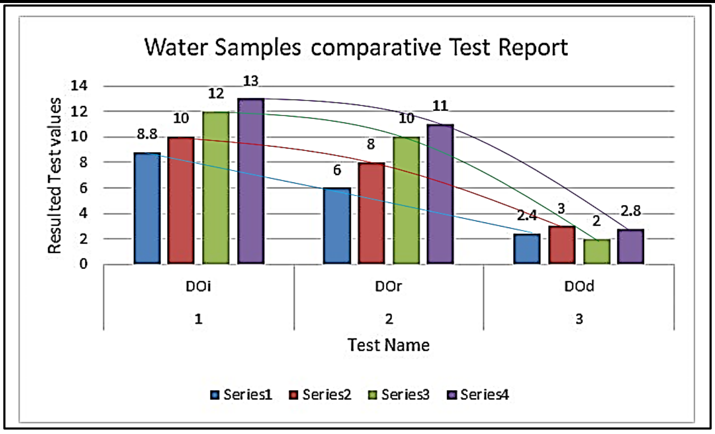
4.2 Graphical Interpretation of Results-

Graph 1 the blue bar and curve represent the standard curve S, having physical properties pH, turbidity and the temperature values laid down by WHO. The water sample curve S1 shown in red colour represent deviation for pH, turbidity and the temperature, from the standard curve S. Similarly, S2 in green colour and S3 in purple colour represent deviation for pH, turbidity and the temperature, from the standard curve S.



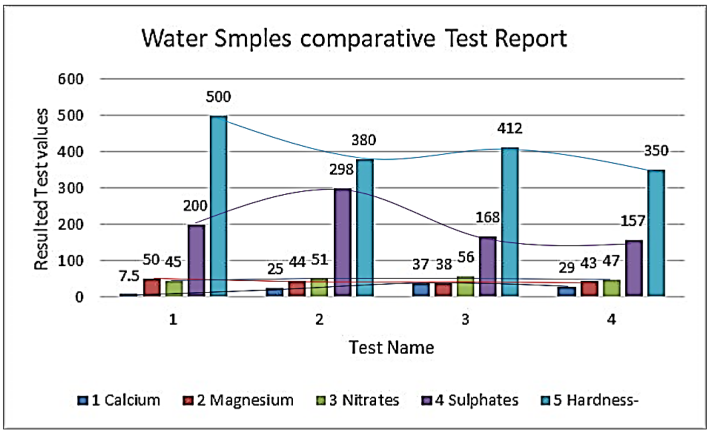
Graph 1- Physical Properties deviation of water samples with standard curve

Graph 2 the blue bar and curve represent the standard curve S, having DO_i. DO_r and DO_d (Dissolved Oxygen, initial, deficit after 2 days and re-aeration after 5 days) by DO test method of water samples. The water sample curve S1 shown in red colour represents deviation from S. Similarly, S2 in green colour and S3 in purple colour represent deviation from the standard curve S.



Graph 2- Dissolved Oxygen variation in water samples with standard curve

Graph 3 the blue bar and curve represent the standard curve S, calcium, nitrate, sulphate and hardness caused due to them by lab test. The water sample curve S1 shown in red colour represents deviation from S. Similarly, S2 in green colour and S3 in purple colour and S4 the hardness in light blue colour represent deviation from the standard curve S.



Graph 3- Chemical contents deviation in water samples from standard curve

5 Conclusion-

Three types of water samples S1- domestic waste water after EC reactor treatment, S2 – EC reactor used as interface in water treatment process and S3- the water after given primary and secondary treatment, without EC reactor as interface, have been considered in water quality analysis. The lab test results have been compared with standard quality curve S. It is found that water samples S1 and S3 closely match the standard curve S. Therefore, it is concluded that EC reactor as interface in water treatment process is better option to classify substandard water for uses other than drinking purposes instead of using it as waste water recycler. The water sample S2 from EC reactor is of substandard quality. Thus, EC reactor can be used as classifier between standard and substandard water. It is a useful finding to plan and manage suitable water supply system by municipal corporation authorities. The modified water treatment process will reduce the power load on the water treatment plant.

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