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Advance Oxidation of Sewage Water, Reclamation and Hygienization by Radiation Technology: A Novel Approach

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Abstract

First time in India, the present study was investigated the efficiency of electron beam to hygienise and oxidise the wastewater and focus on new technologies and processes. The use of electron beam accelerator to disinfect sewage water is gaining a great importance. The current emphasis on environmental health and water pollution issue are that, there is an increasing awareness in the process of disposing the waste water supply as well as beneficially. EB treatment of the waste water has found to be very effective in reducing the pathogens as well as BOD and COD load, indicating an increased in bio-degradability of waste water. EB dose of 1.5 kGy was sufficient for complete elimination of total coli forms. The experimental results elucidated that the percentage of reduction of BOD was 14 more as well as 32 % of reduction in COD with respect to increasing of irradiation doses(0.45 -6 kGy). So the irradiated sewage water can find its application either in agriculture for irrigation or in industry sector for cooling purpose or in both the sectors after flocculation treatment. Irradiation with electron beam is an unconventional to chlorination of municipal sewage water to provide disinfection.

Keywords: Sewage water; Oxidation; Hygienization; Electron beam irradiation

Introduction

Water is one of the critical inputs for the sustenance of mankind. India will face water crisis within the next two decades and will have neither the money to build new infrastructure nor the water needed by its growing economy and rising population. Water is becoming an increasingly scarce resource, so the planners are forced to consider any sources of water which might be used economically and effectively in developing agriculture programs. Whenever fresh water is limited in its supply then water with marginal quality is the best alternate for agriculture. During recent years the methodology of wastewater management has shifted from conventional disposal strategies into value added products [1].

Expansion of urban population increased the coverage of domestic water supply and sewerage which gave large quantities of municipal wastewater. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of this wastewater safely and beneficially. Use of wastewater in agriculture could be an important consideration when its disposal is being planned in arid as well as semi-arid regions [2]. Municipal Sewage water is mainly of 99.9% water together with relatively small concentration of suspended and dissolved organic and inorganic solids. Sewage is rich with bio-molecules(Carbohydrates, Proteins and Lipids) and their decomposition products as well as various natural and synthetic organic chemicals generated due to different industrial processes [2]. The sewage contains numerous pathogens, even after the treatment with conventional methods. *E. coli*, *Salmonella sp*, viruses (Eg. Poliovirus) and parasites in sewage causing types of diseases especially of faecal oral route [3].

Radiation Chemistry

Two basic concepts are fundamentally important in aqueous radiation chemistry. One is absorbed dose, which describes the amount of energy deposited in the material exposed to an ionizing radiation field. Formally, the absorbed dose can be defined as the amount of energy absorbed divided by the mass of material irradiated. SI unit used to describe the absorbed dose is Gy. and 1 Gy is equivalent to 1 J/kg.

The other important concept in radiation chemistry is G-value, which measures the radiochemical yield by the number of specified chemicals species in an irradiated substance produced per 100 eV of energy absorbed from ionizing radiation.

In water as well as wastewater, the principal component is water. Therefore, it would be expected that the effect of ionizing radiation may be dominated by interaction of radiation and water [4]. As far as pure water is concerned, when exposed to ionizing radiation, the radiolysis of water can be presented as following equation [5].

$$H_2O \rightarrow [2.7]\,OH^* + [2.6]e_{aq}^- + [0.6]H^* + [2.6]H_3O^+ + [0.7]H_2O_2 + [0.45]H_2$$

So if we consider pure water, each 100eV absorbed by water will result in the generation of 2.7 radical OH^*, 2.6e_{aq}^-, 0.6 radical H^*, 2.6H_3O^+, 0.7 molecule of H_2O_2 and 0.45 molecule of H_2 [12].

In aqueous media, the oxidizing hydroxyl radical OH^*, the reducing hydrated electron e_{aq}^- and the hydrogen radical H^* are the predominant products, all of which are highly reactive transient species and are responsible for the various effects including the reduction of pathogens, the oxidation of hazardous organic pollutants and the destruction of molecular structure of targeted pollutants. The ionizing

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radiation is fast emerging as a alternate technology for disinfection. It is more eco-friendly as it is non-polluting, energy efficient and does not leave toxic residue behind [6]. Various wastewater treatment plants are operating based on gamma and electron beam technology in the world. In India, sludge hygienization plant (SHRI) using Gamma radiation technology is at Baroda, Gujarat. In our present study, we are investigating the efficiency of electron beam to hygienise and to oxidise the wastewater and focusing on new technologies and processes. The EB treatment has better public acceptance as it is non nuclear and safe to use.

Materials and Methods

The water samples were collected from sewage treatment plants and great care was taken during collection of the samples. The samples were brought to the laboratory with necessary precautions and those were analyzed for Physico–chemical parameters (Temperature, pH, Electrical Conductivity, Total Dissolved Solid, Dissolved oxygen, Biochemical Oxygen Demand (mg/l), Chemical Oxygen Demand (mg/l)) and microbiological parameters (coli forms and other enteric bacteria) were carried out by adopting standard procedures [7] .Then the samples were irradiated with Electron Beam using ILU-6 Electron Beam Accelerator (Electron Beam Facility at the Radiation Technology Development Division, Bhabha Atomic Research Centre -BARC, Mumbai) at different doses (0.45kGy, 0.75kGy, 1.5kGy, 3kGy, 4.5kGy &6 kGy) under room temperature. All irradiated samples were again analysed for above cited physico-chemical and microbiological parameters.

ILU-6 (pulse) accelerator parameters

Energy	2 MeV
Average Beam Current	1.2mA
Pulse repetition frequency	10 Hz
Conveyor Speed	~10 cm/sec
Pulse current	250 mA
Pulse accelerator duration	~500 µS

The dosimetry study was carried out by using FWT60 radio chromic films calibrated by Graphite Calorimeter.

The observed data was subjected to statistical analysis.

Results and Discussion

The effectiveness of EB treatment was evaluated by analyzing Physico- chemical and Biological parameters of both pre and post irradiated water samples. The effect of EB on Physico-chemical parameters was summarized in Table 1 and Table 2. In the present study it was observed that EB treatment does not increase the wastewater temperature significantly, it may be due to short span of exposure period (Fraction of second).Results elucidates that pH value was reduced gradually with respect to increase in dose(8.5 to 7.6 with dose range from 0.45 to 6.0 kGy) as shown in Figure 1. Similar results were observed by [8,9] on irradiation of wastewater with high doses. The change in pH was due to the formation of organic acids. The formation of organic acids revealed that the complex organic compounds were broke down into simpler forms with respective higher doses [10]. In this study it was observed that there was an increase in both Electrical Conductivity and Total dissolved Solids with increased doses (EC- from 4242±15 micromhos/cm. to 4545±20 and TDS- 2800 mg/l to 3000 mg/l), represented in Figure 2 and Figure 3. No significant change was noticed in case of dissolved oxygen before and after EB treatment. The BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) values indicates the amount of oxygen needed for complete degradation or oxidation of organic as well as in inorganic compounds, therefore, BOD and COD values represents the content of all the organic and inorganic compound in waste water [11]. The oxidation effect of radiation on organic as well as inorganic pollutants in waste water was determined by measurement of BOD and COD with irradiation [12]. The BOD and COD values were observed to decrease with increase in irradiation doses. The percentage BOD removal increased from 7% to 14.5% for the dose 0.45 to 6.0 kGy and percentage COD removal increased from 18% to 37% with increase in dose from 0.45 to 6.0 kGy (Figure 4). Similar result was observed by Ali et al. [10]. The BOD/COD ratio was increased with the increase in EB doses from 0.45 to 6.0 kGy

		Irradiation Doses in kGy						
S.No	Parameters	**Control**	**0.45**	**0.75**	**1.5**	**3**	**4.5**	**6**
1	Temperature	25 °C	25 °C	25 °C	25 °C	25.2 °C	25.2 °C	25 .3 °C
2	PH	8.5±0.5	8.4±0.5	8.4±0.5	8.2±0.5	8.1±0.5	7.9±0.5	7.6±0.5
3	Conductivity	4242±15	4242±15	4242±15	4393±15	4393±15	4545±20	4545±20
4	TDS	2800±25	2800±25	2800±25	2900±25	2900±25	3000±25	3000±25
5	Dissolved Oxygen	0.48	0.46	0.48	0.46	0.44	0.48	0.48
6	BOD	819.5±5	728.5±5	726±5	701±5	760±5	745.5±5	800±5
7	COD	106010	920±10	866±10	718±10	750±10	662±10	662±10

Electrical conductivity is in micromhos/cm. Except Temperature and PH all is in mg/l. And all value have haven the mean value

Table 1: Effect of EB treatment on physico-chemical characteristic of sewage water.

		Irradiation Doses in kGy				
S.No	Irradiation doses in KGy	BOD value in mg/l	BOD removal (%)	COD value in mg/l	COD removal (%)	BOD/COD Ratio
1	0 Control	819.5	0	1060	00	0.77
2	0.45	728.5	11.10	920	13.20	0.74
3	0.75	726	11.40	866	18.3	0.83
4	1.5	701	14.46	718	32.26	0.97
5	3	760	7.26	750	29.24	1.01
6	4.5	745.5	9.02	662	37.54	1.02
7	6	800	7.37	662	37.54	1.20

Table 2: Effect of EB treatment for removal of BOD and COD with respective doses in percentage.

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indicating increase in biodegradable fraction of the wastewater after EB treatment (Figure 5). Both TDS and BOD/COD ratio were increased indicating the biodegradability of waste water.

The high concentration of pathogens presents a major obstacle of the practical application of sewage water in agriculture. So the effect of radiation on pathogens is of primary concern when applying the radiation technology on the processing of sewage water.

Radiation effects on microorganisms are mainly associated with the chemical changes but also depended on physical and physiological factors Dose rate, dose distribution, radiation quality, radiation type and exposure pattern are important physical parameters and also depends on physiological factors like growth phase, sensitivity and number of microorganism etc. The action of radiation on a living organism can be divided into direct and indirect effect. If the radiation interacts with the atoms of the DNA molecule or some other cellular component critical to the survival of the cell, it is a direct effect, which will eventually affect the ability of the cell to reproduce and survive. The formation of major radiolysis products from water and their subsequent interactions with waste particles are described as indirect effect, which is generally caused by energy deposition in the medium resulting in the formation of secondary reactants generated through free radicals production, sensitizer and secondary ionization [13]. EB treatment was found to be very effective in reducing the bacterial count, especially total coli form

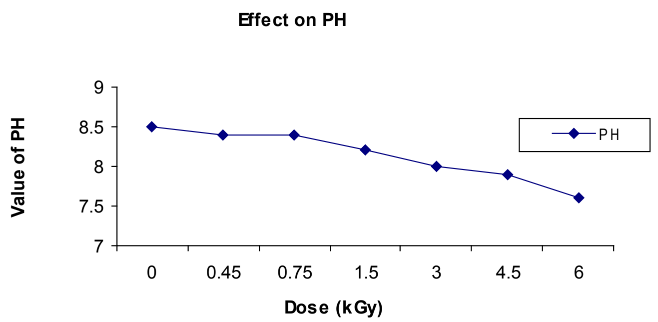

Figure 1: Effect of radiation on PH.

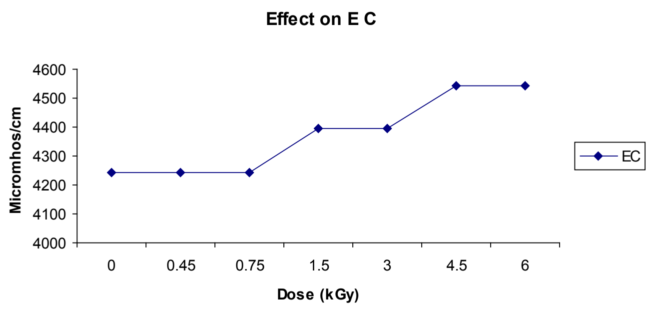

Figure 2: Effect of radiation on **EC**.

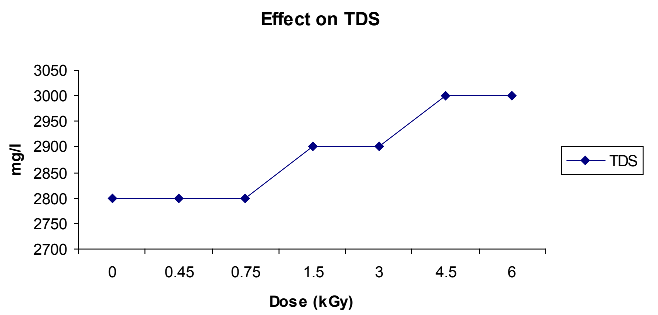

Figure 3: Effect of radiation on TDS.

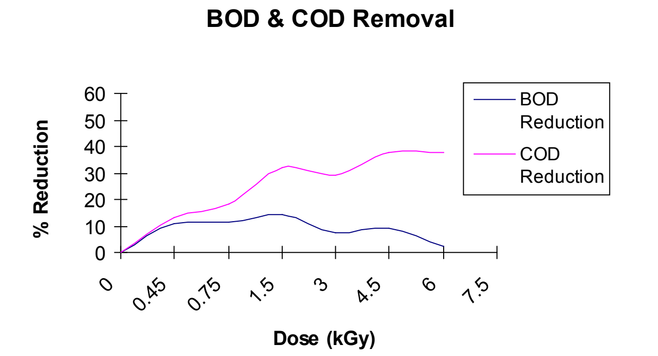

Figure 4: Reduction of BOD &COD after irradiation.

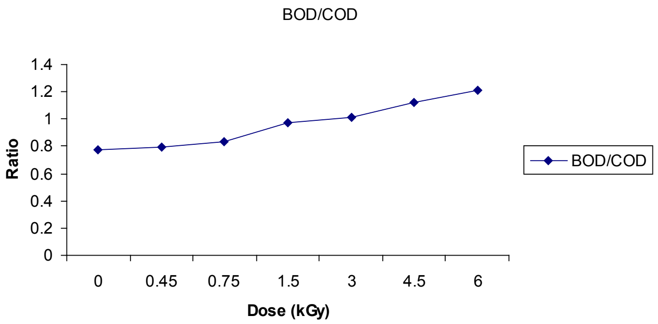

Figure 5: Ratio of BOD & COD (Biological degradability) .

S.No	Irradiation doses in kGy	Total Bacterial Count	Total Coliform	Total Salmonella-Shigella
1	0 Control	610000	96000	4000
2	0.45	3500	310	160
3	0.75	330	3	0
4	1.5	22	0	0
5	3	0	0	0
6	4.5	0	0	0
7	6	0	0	0

Table 3: Effect of EB treatment on microorganisms with respective doses.

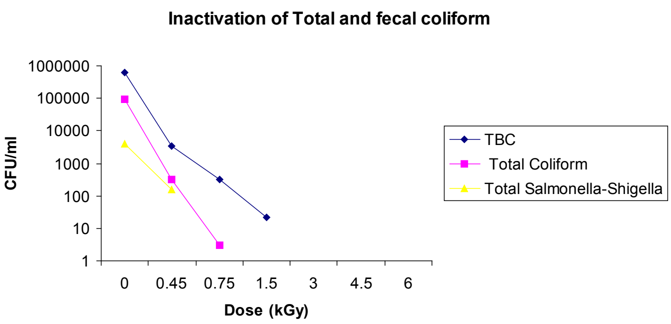

Figure 6: Effect of radiation on bacterial load.

S.No	Organisms	D_{10} Value
1	Total Bacterial Count	≤ 0.4
2	Total Coliform	≤ 0.4
3	Total Salmonella- Shigella	≤ 0.4

Table 4: D_{10} Value for total bacterial count, total coliform and total salmonella-shigella.

count to a safe level. The total bacterial count reduced from 6.1× 10^5 to 0 at 3.0 kGy, total coli from count was reduced from 9.6× 10^4 to 3 at 0.75 kGy and total Salmnella-shigella count reduced from 4 × 10^2 to 0 at 0.75 kGy (Table 3 & Figure 6). The D_{10} values of the Total Bacterial Count, Total Coliform and Total Salmonella-Shigella was found to be ≤ 0.4 kGy (Table 4).The effectiveness of gamma and EB in eliminating bacterial load is also reported by Sampa et al. and Rawat et al. [9,14].

Conclusion

The organic and inorganic contents were reduced due to the reaction with oxidative species formed due to water radiolysis. In conventional method, the chlorination of water results in the formation of toxic organo-chlorine products, which are mutagenic and carcinogenic in nature. This experiment shows the effectiveness of EB treatment in reducing pathogenic bacterial load to a safe level. The BOD and COD were also reduced after EB treatment. Some of the non biodegradable fraction got converted into biodegradable fraction as indicated by increase in BOD/COD with an increased in treatment dose. The EB treated waste water can be effectively used in irrigation as well as in industries as it does not contain any pathogens only after biological treatment. In future, treating of sewage by combination of both EB treatment with bio flocculation (TDS will be removed), can be make treated waste water fit for both industrial and agricultural purposes.

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