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Experimental Study to Optimize the Treatment Efficacy of Pharmaceutical Effluents by Combining Electron Beam Irradiation

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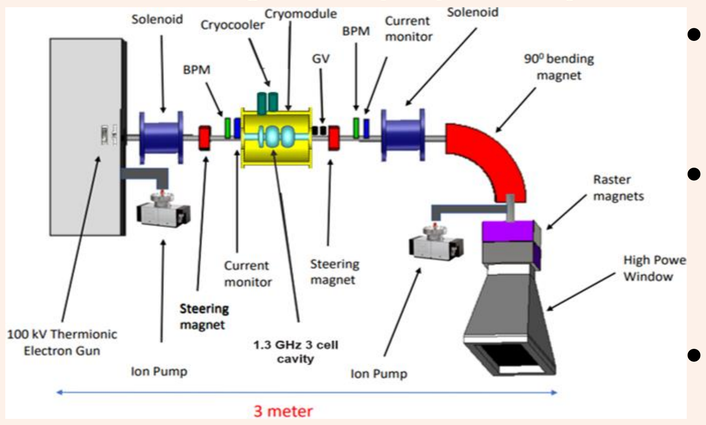
ABSTRACT

Here, we report our first step towards tackling this issue at the roots by irradiating the pharmaceutical effluents from a stages of their existing treatment plant with an Electron Beam (EB) with doses varying from **25 kGy to 200 kGy**. We have used a **normal conducting pulsed wave linear accelerator** developed by SAMEER. It produced a pencil beam of electrons of energy **6 MeV** with an average current of **16 micro-Ampere**. To ensure optimum dose delivery, Fluka-Flair Simulations have been used. We have successfully demonstrated that electron beam irradiation along with the use of conventional techniques like coagulation after the irradiation can further increase the efficacy of the process with a final reduction in Chemical Oxygen Demand (COD) to be as large as **65%** in some of the cases.

MOTIVATION

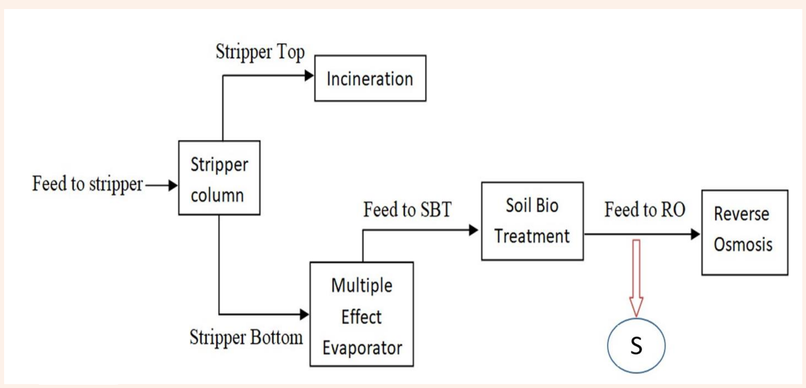
Schematic diagram of proposed system



- Wastewater treatment by electron beam is an effective method.
- Required a compact, high intensity SC electron accelerator that can be fit anywhere.
- Pharmaceutical effluents are the most difficult to treat

- Pharmaceutical effluents are irradiated by using an Electron Beam (EB).
- For best results, EB is combined with coagulation and scavengers (titanium dioxide (TiO_2), air, and ozone).

MATERIAL AND METHODES



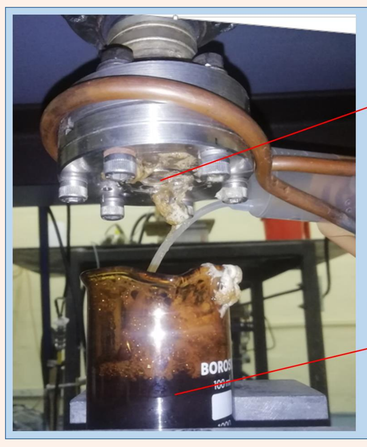
Sample S water quality parameters:

- COD = 704 ppm
- pH = 7.74
- TDS = 1421 ppm

Fig: Collection of sample S from industrial effluent treatment plant

- For quantitative COD analysis
  - The Titrimetric Method is used.
  - All required COD solutions are created using the APHA.
- For Coagulation, ferric sulphate ($Fe_2[SO_4]_3$) is used as a coagulant.
- TiO_2 powder is also used as a scavenger

EXPERIMENTAL SETUP



- 6 MeV and 16 μA, normal conducting pulsed LINAC from SAMEER is used.
- Samples are irradiated in a 100 mL standard cylindrical borosilicate glass beaker
- For absorbed dose calculations, Fluka-Flair simulation was performed.

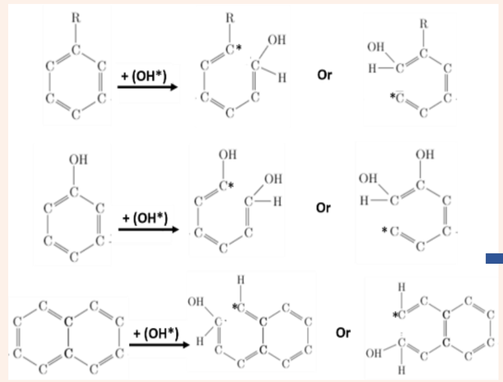
Irradiation time (s)	15	30	60	120	480
Associated dose (kGy)	25	50	100	200	800

Table: Absorbed dose as a function of irradiation time.

RESULTS & DISCUSSION

a) Electron beam and Electron beam with coagulation

- Coagulation aids in the extraction of insoluble compounds after irradiation.
- EB irradiation of water produced: OH*, H_3O+, e^-, H_2O_2, H_2, and H*
- These species interact with aromatic impurities as follows



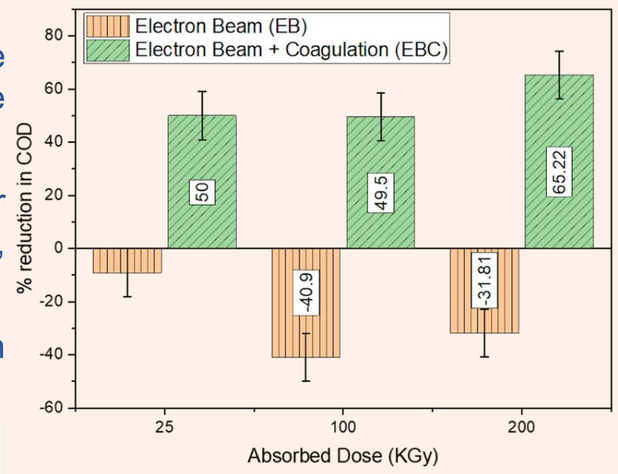
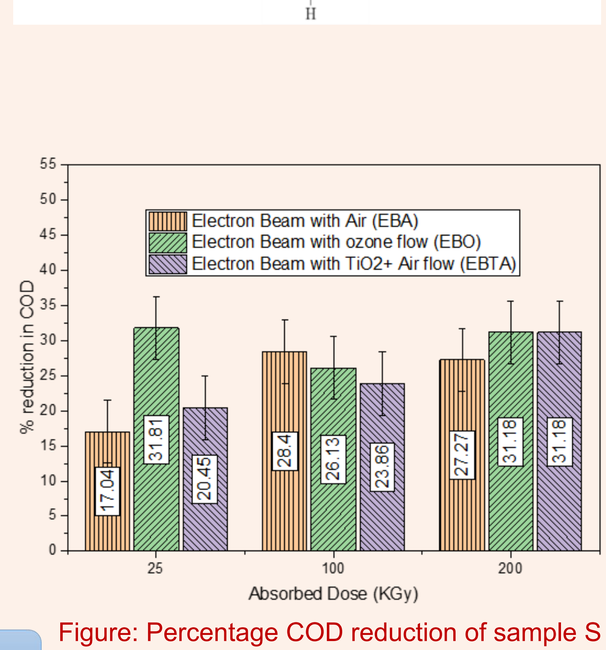


Figure: Percentage COD reduction of sample S for EB and EBC process with different absorbed dose.



b) The Scavengers effect

- Species like, NO_3^-, NO_2^-, O_2, CO^-, HCO_3, O_3, TiO_2 act as radical scavengers.
- TiO_2,O_2, and O_3 absorb reducing species and convert them to oxidizing species

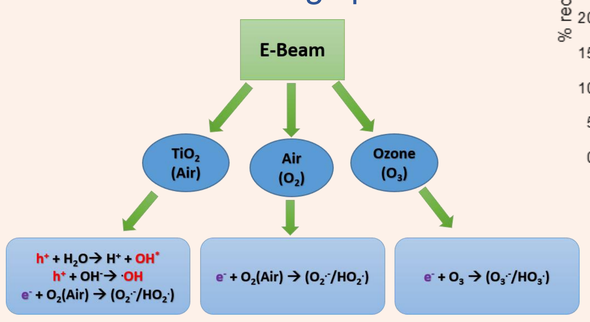


Figure: Percentage COD reduction of sample S for EBA, EBTA and EBO process with different absorbed dose

CONCLUSION

- We used a 6 MeV electron accelerator to irradiate a pharmaceutical wastewater sample,
- The aim of this study was to improve the EB treatment process by combining coagulation and scavengers.
- Electron Beam with coagulation (EBC) achieved a reduction of 66% in COD just after 200 kGy of radiation dose.
- This results clearly show that combining EB treatment with coagulation is more efficient than EB treatment alone.
- Moreover, the scavenging agents also help EB treatment to reduce COD efficiently (i.e. 27 to 30% of COD reduction).

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