Chapter 13

Applications of Electron Beam Accelerators

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Particle accelerators are now widely used in variety of applications for scientific research, applied physics, medicine, industrial processing and for pollution control. Radiation sterilization was introduced as the first industrial process in mid 1950s. A wide range of radiation processing technologies have been developed and applied since then. Radiation processes are generally being applied to produce new or improved products than previously possible using conventional or more expensive traditional techniques. Different radiation technologies for environmental applications require different ranges of electron energy and high power electron beams.

13.1 Environmental Applications

13.1.1 Flue Gas Treatment

Electron beam accelerators are used for flue gas treatment, wastewater treatment and sludge purification. In the EB purification of Flue gas, flue gas from a boiler is cooled down to 65 ℃ in the spray cooler with water spray. The cooled flue gas is introduced into reaction vessel where the gas is irradiated in the presence of ammonia. Sulphur dioxide (SO_2) and Nitrogen Oxide (NO_x) are converted to powdery by products i.e. ammonium sulphate and ammonium nitrate by irradiation and the byproducts are collected by an electrostatic precipitator or a bag filter. When flue gas is irradiated by EB, the energy is absorbed in main components of gas, namely nitrogen, oxygen, water and carbon dioxide to form ionized and excited species. These species will form oxidising radicals like OH^* and HO_2 which will react with SO_2 and NO_x to form sulphuric acid and nitric acid aerosols. These will get neutralized with ammonia and form ammonium sulphate and ammonium nitrate which can be used as fertilizer. The main advantage of this radiation process is the simultaneous removal of SO_2 and NO_x with high removal efficiency. This process is a dry process, simple and easy plant operation. Byproducts of this process can be used as fertilizers.

13.1.2 Wastewater treatment

Electron Beam irradiation of water for both ground water remediation and wastewater treatment attracts increasing interest because of its capability to destruct variety of organic compounds. The economy of irradiation of water depends on the through put, which will be fulfilled by high power accelerators. The main purpose of wastewater treatment is to remove organic pollutants, to reduce COD, BOD and to remove e-coli, harmful microorganisms and pathogens. A large amount of waste water comes from chemical industries, textiles, food industries and others industries. Low biodegradability of organic compounds, color characteristics and presence of metallic ions results in low efficiency of conventional wastewater treatment plants, and allowing the discharge of dangerous products to environment.

Ionizing radiation is a promising tool for the treatment of textile dye effluents and attracted considerable attention in the recent years. The radiolysis of water is very well documented and it has been known that it produces primary free radicals like, hydroxyl radicals (OH^*), hydrated electrons (e^-_{aq}), hydrogen atom (H), and molecular products like, H_2, H_2O_2, HO_2, H_3O^+ in varying amounts depending upon the linear energy transfer (LET) value of a particular radiation. Hydroxyl radical is a strong oxidizing agent and aqueous electrons are strong reducing agents which can react with organic dyes and degrade to intermediate products. These intermediate or toxic groups can be more biodegradable and can be easily removed by biological treatment. pH of effluent have a strong relation in removal of pollutants using electron beam as G values can vary with pH of water. In highly alkaline medium OH^* transforms to less reactive O^{*-} resulting in lowering the pollution destruction efficiency. Similarly highly acidic medium ($pH < 2$) is also not favorable for removal of pollutants. Hence, for highly productive treatment of pollutants the pH should be adjusted in range of 4-9. If the contaminants are in high concentration, the radicals react with contaminants and produce transformation products. These transformation products may compete with pollutants in reacting with radicals as scavengers, resulting in the slowdown of reactions as treatment proceeds. As a result, after a particular dose the pollutants may not get degraded in faster rate and require higher dose. For effluent having concentration of ~100 ppm, a dose of 5-7 kGy is recommended as a pre-treatment to biological treatment. With 5 kGy dose most of the non biodegradable material present in the effluent will become biodegradable. Using e-beam as pre treatment the efficiency of biological treatment can be increased to ~30% which can increase the speed of treatment and hence decrease the Retention time in biological treatment facility. The main advantage of electron beam treatment is to reduce the load of chemicals used for effluent treatment.

13.2 Industrial Applications

13.2.1 Polymer Irradiation

Crosslinked polymers are used in variety of high-end applications ranging from lithography to organ transplant. For some applications, the purity and cytocompatibility of the polymer is desirable. Conventional crosslinking approaches involves different additives and thermal treatment, which might not only contaminate the polymer but can also affect its physic-mechanical properties. Radiation crosslinking, on the other hand, is an environment friendly, additive free, room temperature, efficient process which can be used for processing of wide range of polymers. Mechanical properties of polymers will increase with increase in the molecular weight, polymers with higher molecular weight will show better mechanical properties, radiation crosslinking will increase molecular weight by increasing extra bonds. Cross linking will increase with increasing dose, this type of polymers are called radiation resistant polymers. Some polymers will degrade with radiation dose; Teflon is one of the radiation degradation polymers. Radiation is used to make powder of scrap Teflon which is resistant to chemicals. Powder Teflon can be used in many applications like nonstick coating, cosmetics, lubricant, graft material in surgical equipment and coating in containers for reactive chemicals. Radiation induced grafting has been a way to functionalize the surface of existing polymer forms, so that they can be used in variety of applications, such as biomedical, environmental and industrial uses.

13.2.2 Food Irradiation

Radiation technology is gaining more attention in the world for irradiating food material. Irradiation is more effective and appropriate technology to destroy food borne pathogens. A few hundred Gy dose will render most insect pests sterile and lead to their death. Irradiation can prevent deterioration of food grains, vegetables and fruits. A dose of 200 Gy will arrest germination. Cooked food can be stored for a long time at room temperature if it is packed and irradiated with few hundred Gy dose. Spices can be stored for years with a dose of few kGy of dose.

13.2.3 Hydrogel

The term hydrogel describes three-dimensional network structures obtained from a class of synthetic or natural polymers which can absorb and retain significant amount of water. The hydrogel structure is created by the hydrophilic groups or domains present in a polymeric network upon the hydration in an aqueous environment. Hydrogels are made by dissolving certain polymers in low concentrations of water and then treating them with an electron beam. This weaves the inner structure of the hydrogel into a molecular net, allowing it to hold moisture while retaining its shape. Due to their high-water retaining capacity and biocompatibility they have been used in wound dressing, drug delivery, agriculture, dental materials, implants, inject able polymeric systems, ophthalmic applications, hybrid-type organs. Electron beam treated hydrogels (Fig. 13.1) are sterile and can be used to dress first

Figure 13.1: Radiation synthesized hydrogel.

and second degree burns and wounds, doctors can observe healing process of wounds without undressing as the hydrogels are transparent. The hydrogels can also absorb fluid that exudes from the wound. These provide ideal environment for healing of wound by acting as a pseudo blister. Hydrogels prepared by PVP/PVA using irradiation for medical applications especially wound dressings are evaluated for physico-chemical, mechanical, microbiological properties and toxicity. The hydrogel does not have allergic and sensitivity reactions to the skin. It is elastic, sterile, an efficient barrier for bacteria and also for excessive loss of body fluids, and allows the diffusion of oxygen towards the wound as well as is effective enough for treatment of open wound and infected burn wound. For preparing hydrogel 10% PVP (poly vinylpyrrolidone-900 kDa) and 1.5% PEG (polyethylene glycol-400 kDa) was mixed with 500 ml of water. 1% Agar mixed with 500 ml of water and heated for 2 min at 100 ℃. These two solutions were mixed and poured to moulds of desired shape. These moulds were irradiated using electron beam at a dose of 25 kGy.
The advantage of radiation synthesized hydrogel over conventional methods is very pure products are obtained since the present of chemical initiators are not required. The preparation of sample does not require special sterile production rooms but still enables to obtain a sterile product. The irradiation process is easily controlled.

13.3 Conclusion

This Chapter discusses the different application of electron beam accelerators for societal,industrial and environmental uses.

Suggestions for Further Reading

a) [59–62]