Novel Particle Accelerator Applications – Are Particle Accelerators the Hygiene Systems of the future?

Abstract – The range of industrial uses for particle accelerators is constantly increasing. This review will focus on how particle accelerators, and the radiation produced, can be used in sterilisation, sanitation, and hygiene systems.

1 *Introduction*

Particle accelerators are some of the most complex systems ever produced and have facilitated fundamental physics research with ever increasing depth. Institutes such as CERN are continuously advancing the field of accelerator science for research purposes. However, only a tiny percentage (3%) of the world's particle accelerators are used for high level science. Many accelerators are used within Medical (33%) or Industrial (64%) fields [1] [2]. The industrial uses for accelerators continue to increase, this paper will explore particle accelerators as a solution to issues surrounding food and water treatment for environmental and hygiene purposes.

2 *Radiation in Sterilisation*

The role of particle accelerators in hygiene systems is to produce radiation in the form of x-rays, beta-rays (electron beams), or gamma-rays. The chosen beam energies are low enough not to cause long-term radioactivity, but sufficiently ionising to enable the generation of ions and free radicals. For instance in water hydrated electrons, hydroxyl radicals and hydrogen atoms are produced [3] [4] [5]. These highly reactive substances lead to chemical reactions which breakdown the complex molecules of pathogens, biological matter, and insects/ larvae. Due to their complexity only a small quantity of radiation is required to cause enough damage to neutralise these contaminates.

Synthetic radioactive isotopes, such as Co (60) and Cs (137), have been used in the sterilisation of food and medical equipment due to the energies of the beta and gamma radiation emitted. [3] [6] [7]. However, particle accelerators can also be used to generate ionising radiation.

Use of a particle accelerator instead of isotope-based source can provide a safer working environment as the requirement for handling and transporting radioactive materials is removed. This is most apparent as a particle accelerator can be turned off when not required [1]. Particle accelerators allow more accurate control of the radiation dosage received by the target substance compared to isotope sources. Manually setting the beam intensity allows better control regarding constancy of the radiation received and therefore a higher quality service. A particle accelerator also allows seamless adjustment of radiation dosage levels. This cannot be done for isotope-based sources without interaction with the source [1]. There are long-term cost benefits of particle accelerator usage as the replacement and disposal of radioactive isotopes is no longer required [1].The amount of energy absorbed by an object from a radiation source is measured in Grays (Gy), where 1 Gy is equal to 1 Joule of absorbed energy per kg of matter [8]. This dosage acts as a measure of sterility assurance [9]

3 *Food treatment*

The use of radiation in food production has been studied since the 1920s. 1950/60s US military research regarding the use of radiation to improve the longevity of ration packs brought the method into the public eye [10]. Benefits of food irradiation include reducing spoilage, and removing micro-organisms and insects, with minimal affects to the taste or smell [7] [11] [12]. Following the irradiation process food "cools down" returning to a safe to consumption state.

An advantage of a particle accelerator is that this process can be used to sterilise packaged goods [7]. Therefore, food may be processed as normal before being transferred to a specialist irradiation facility. Thus, the feasibility of the technology is increased as not every packaging plant would require an onsite radiation source

The International Atomic Energy Agency (IAEA) categorises the safe levels of radiation which food may be permitted to be exposed to be between 3-50kGy this is further defined into three categories [7].

Table 1: Table of Food approved Radiation Levels based on [7] [13]

Classification	Dosage	Description
Radicidation	4–6 kGy	Application of a dose of ionizing radiation sufficient to reduce the number of viable specific non-spore-forming pathogenic bacteria to such a level that none are detectable. Often referred to for the specific removal of Salmonella.
Radurization	6–10 kGy	Application of a radiation dose to cause a substantial decrease in the numbers of viable spoilage inducing microorganisms.
Radappertization	10–50 kGy	The application radiation sufficient to reduce the number of viable microorganisms to such an extent that no microbial spoilage or toxicity should become detectable, regardless of the length or conditions of storage providing that the packaging integrity is maintained

4 Water treatment

Radiation in wastewater treatment has been experimented with in a range of countries including Brazil, South Korea, Hungary, and the USA [5]. Conventional water purification involves the application of disinfectants and other chemicals to remove biological contaminants and organific molecules, namely from industrial waste [14]. The advantage of a particle accelerator is that a single dose of radiation can remove both types of contaminants, whilst reducing the usage of chemical additives [15]. Use of a particle accelerator can alleviate costs and logistical factors regarding chemical production and transportation, eg. chlorine.

The effectiveness of this method has been demonstrated through the treatment of wastewater and effluent from dye production. In Daegu, South Korea a pilot of processing 1000m^3/day with a dosage of 50kGy, removed 99% of tested organic pollutants [4]. US Department of Energy sponsorship for research into using linear accelerators for water purification at the Thomas Jefferson National Accelerator Facility, demonstrates demand and technological progression [15].

5 Limitations and developments

The main limitation of particle accelerators in hygiene relate to infrastructure size and cost [16]. These continue to decrease with technological advances; prototype RF cavities which remove the requirement for expensive liquid helium would enable higher beam energies at a reduced operational cost [15]. Whilst, accelerators lengths of 2m for water treatment provide space efficient solutions [15]. The development of other particle accelerator-based industries will generate a greater manufacture base for specialised components and therefore a decrease in cost [16].

Workforce interaction with particle accelerator installations is crucial. Mass usage will require control by non-specialist plant-operators. Therefore, particle accelerators must be “turn-key” systems and exhibit high reliability [14] [16].

Another barrier is public opinion as radiation is a word that often carries negative connotations, studies have shown a reduction in consumer concerns surrounding food irradiation. This is of importance when combined with increasing awareness regarding use of chemical disinfectants, pesticides and added preservatives [17].

6 Conclusion

It can be concluded that although particle accelerators are not currently sufficiently developed to be deployed for sterilisation purposes. The potential benefits regarding size, efficiency, chemical requirements, logistics, and system simplicity would favour the future utilisation of particle accelerator technologies. Applications relating to food and water treatment could vastly improve hygiene systems in developing countries. For instance, the installation of compact water purification solutions in remote locations [14].

7 *References*

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