ANS Control: Electron Beam Irradiation

Targeted Species: Electron beam irradiation has been used to effectively control a variety of microorganisms in aquatic pathways. Specific ANS of Concern – CAWS[1] that may be controlled include bloody red shrimp (*Hemimysis anomala),* European amphipod (*Echinogammarus ischnus),* fish-hook water flea (*Cercopagis pengoi),* harpacticoid copepod (*Schizopera borutzkyi),* parasitic copepod *(Neoergasilus japonicas),* scud (*Apocorophium lacustre*), spiny water flea (*Bythotrephes longimanus),* testate amoebas *(Psammonobiotus communis, Psammonobiotus dziwnowi,* and *Psammonobiotus linearis),* and water flea (*Daphnia galeata galeata).*

Selectivity: Electron beam irradiation is designed to control microbial ANS. It is a non-selective Control.

Developer/Manufacturer/Researcher: Dr. Michael Fisch of Kent State University is a researcher and developer of this technology for aquatic pest control/aquatic species management.

Brief Description: Irradiation involves water treatment by exposing contaminated water to low doses of radiation from gamma-sterilizers or electron accelerators (Woods & Pikaev 1994). Electron beam irradiation can break down DNA in living organisms, resulting in microbial sterilization or death. Electrons penetrate through the cell wall and cytoplasmic membrane, causing a molecular rearrangement of the microorganism's DNA, which prevents it from reproducing. Electrons are an effective agent for irradiation because they are not strongly scattered by turbidity, can penetrate deeply into organic materials, and are more ionizing than ultraviolet (UV)[2] light (an alternative form of irradiation) (Fisch 2010). The radiation sensitivity of a microorganism generally depends on the amount of DNA in the nucleus. The lethal dose depends on how well the organism is protected from electron penetration.

Prior Applications: Electron beam irradiation has a well-documented history of use in irradiation of food (Diehl 1990), environmental waste (Cooper et al. 1998), medical sterilization (Woods and Pikaev 1994), and water treatment (Cleland et al. 1984).

General Effectiveness: Overall, electron beam irradiation can be an effective technology to treat water for possible aquatic microbial nuisance species. It is impossible to achieve total destruction of all microorganisms in a sample via irradiation, but the number of viable organisms can be greatly reduced. The primary advantages of this technology are that it adds no chemicals to the water supply, creates no by-products, and has no specialized storage requirements.

Operating Constraints: Electron beam irradiation works in contained areas such as pipes and flowing troughs; it is ineffective in large, open, or turbid systems such as marshes, lakes, rivers, and canals. Irradiations can target specific organisms using constant water flow and varying the beam current for dose adjustment (Gehringer et al. 2003).

[1] For a complete list of the 39 specific ANS of Concern – CAWS, please see Table 1 of the main report.
[2] For more information on the use of this control technology, please see the fact sheet titled "Ultraviolet Light (UV)."

Irradiation is most effective after solids have been removed from untreated water. Suspended solids or particulate matter can cause shielding, which may allow microbes to pass through the filter without undergoing direct penetration by the electron beam. Current pretreatment requirements and the ability to treat only a constant-flow stream of water make using this technology to treat natural or urban water sources problematic. This Control is less effective when high concentrations of suspended solids exist, therefore it would be less effective during storm events.

Cost Considerations:

Implementation: Implementation costs may include the construction of a piping system and electron beam irradiation treatment facility. Facility construction costs would consist of the primary facility and supporting systems, such as access, equipment, and power supply infrastructure.

Planning and design activities in the implementation phase may include research and development of this Control, modeling, site selection, site-specific regulatory approval, plans and specifications, and real estate acquisition. Design will also include analysis of this Control's impact to existing waterway uses including, but not limited to, flood risk management, natural resources, navigation, recreation, water users and dischargers, and required mitigation measures.

Operations and Maintenance: Operations and maintenance costs would include electricity to operate the system, regular inspections, repair of mechanical parts, site safety and security, and an effective monitoring program.

Mitigation: Design and cost for mitigation measures required to address impacts as a result of implementation of this Control cannot be determined at this time. Mitigation factors will be based on site-specific and project-specific requirements that will be addressed in subsequent, more detailed evaluations.

Citations:

Cleland, M.R., R.A. Fernald, & S.R. Maloof. 1984. Electron beam process design for the treatment of wastes and economic feasibility of the process. *Radiation Physics and Chemistry*, vol. b24, p. 179

Cooper, W.J., R.D. Curry, & K.E. O'Shea. 1998. Environmental Applications of Ionizing Radiation. John Wiley & Sons, NY. 722 pp

Diehl, J.F. 1990. Safety of Irradiated Foods. Marcel Dekker, NY. 345 pp

Fisch, M. 2010. Study of electron beam mitigation of ballast water. *Proposal to the US PA*

Gehringer, P., H. Eschweiler, H. Leth, W. Pribil, S. Pfleger, A. Cabaj, T. Haider, & R.Sommer. 2003. Bacteriophages as viral indicators for radiation processing of water: a chemical approach. *Applied Radiation and Isotopes*, vol. 58, pp. 651–656

Woods, R.J. & A.K. Pikaev. 1994. Applied Radiation Chemistry: Radiation Processing. Wiley-Interscience, NY. 535 pp