MediZap

Advanced Sterilization

Unlocking the Power of X-Rays: A Critical Examination of Terminal Sterilization Techniques for Pharmaceutical Drug Products

Several emerging methods of terminal sterilization hold promise to become established techniques that adhere to pharmaceutical drug products over time. These technologies encompass X-Rays, ultrasonication, supercritical gases, ultraviolet light, pulsed light, microwaves, infrared radiation, and plasma. This article specifically examines X-Rays.

Emerging sterilization technologies must satisfy several criteria to be considered suitable for product sterilization:

- The technology must achieve a Sterility Assurance Level of 10^{-6} or higher.
- Products must withstand the terminal sterilization conditions.
- Terminal sterilization within the final packaging must be attainable.
- Chemical residues as by-products of sterilization must not be produced.

Additionally, terminal sterilization technologies must:

- Be sufficiently advanced for practical scale use.
- Be capable to validate dose delivered for microbial elimination.
- Be affordable.
- Be safe to use.
- Have processing times meeting production requirements.

To facilitate the adoption of new sterilization technologies, the international standard ISO 14937: 2009 'Sterilization of health care products - General requirements for characterization of a sterilizing agent and the development, validation, and routine control of a sterilization process for medical devices' provides valuable guidance for the development and validation of alternative technologies.

X-radiation, comprised of X-Rays, represents a form of electromagnetic radiation originating from transitions in electron states within an atom. With wavelengths ranging from 0.01 to 10 nanometers and frequencies between 30 petahertz and 30 exahertz, X-Rays lie between ultraviolet and gamma rays in the electromagnetic spectrum. Often referred to as Röntgen radiation, X-Rays possess strong penetration capabilities, akin to gamma radiation, due to their photon nature. Requirements for employing X-Rays for sterilization purposes are outlined in the ISO 11137-2:2017 standard 'Sterilization of health care products – Radiation'.

Facilities offering X-Ray sterilization, termed X-Ray irradiators, operate similarly to E-Beam sterilization facilities, being electrically powered. X-Rays are generated via an X-Ray tube, akin to electron beam accelerators. The irradiation process typically involves either continuous conveyance through the X-Ray beam or a multi-pass approach using totes. The penetration depth achieved by X-Rays often surpasses that of both E-Beam and Gamma radiation.

The radiation dose received by the product from an X-Ray generator depends on various factors such as the irradiator's design, accelerator power, electron energy, beam width, X-Ray target design (vertical vs. horizontal), product density and thickness, and conveyor speed.

While X-Ray technology has long been utilized for decontamination in food processing, its application for sterilization purposes in pharmaceutical drug products remains less developed. Factors contributing to limited adoption include high costs, intricate material conversion settings, and the need for comprehensive product compatibility data. Nonetheless, advancements in accelerator technology and economic viability are making large-scale X-Ray sterilization facilities increasingly comparable to E-Beam and Gamma sterilization facilities.

Transitioning from established Gamma radiation processes to X-Rays necessitates considerations such as assessing physical effects of X-Ray sterilization on drug (primary and secondary) packaging and determining pre/post sterilization potency suitability for associated pharmaceutical drug products.

Despite challenges, X-Rays offer advantages like fast processing times, uniform treatment, flexibility in irradiation, and minimal material degradation compared to Gamma radiation. Interest in X-Ray sterilization has grown in recent years, driven by advancements in beam power ratings of industrial electron accelerators, potentially leading to increased adoption alongside E-Beam and Gamma radiation technologies.

MediZap is proud to have a new X-Ray capable facility in Lewisville, TX. Bulk raw materials and sterile drug products in formats such as large vials (30ml-100ml), mini IV bags, and IV bags.