Polymer-based nanocomposite for 3D printed patient-personalized boluses aimed at radiation therapy

The project seeks to develop innovative materials and processes to enhance the precision and safety of radiation therapy, a cornerstone treatment for cancer patients worldwide. Radiation therapy often relies on boluses—devices made from tissue-equivalent materials—placed on the patient's skin to optimize dose delivery to tumors while protecting healthy tissues. However, current bolus designs face limitations, particularly in minimizing radiation scattering at the interface between the bolus and the skin, which can lead to complications such as burns. This project addresses these challenges by creating a novel polymer-tungsten nanoparticle composite (PCTN) material optimized for use in 3D printing patient-specific boluses. The introduction of tungsten nanoparticles into the polymer matrix enables the material to scatter radiation internally, reducing the unintended dose delivered to healthy tissues and improving the overall effectiveness of therapy.

This multidisciplinary project, spanning medical physics, nanotechnology, and material science, aligns with RIS3 priorities in biomedicine, medical technologies, and pharmaceuticals. It also targets the NACE codes 26.6, 32.5, and 72.19, which correspond to the manufacture of irradiation and medical equipment, as well as research and development in natural sciences. The research objectives fall into three categories: fundamental research to characterize the radiation scattering and transmission properties of the bolus material; industrial research to develop and optimize the PCTN composite for radiation attenuation, flexibility, and compatibility with 3D printing; and experimental development to fabricate and test prototypes using both press-forming and additive manufacturing techniques. By combining these approaches, the project aims to deliver patient-specific solutions that are more effective, affordable, and environmentally sustainable than traditional bolus designs.

The project is led by Riga Technical University (RTU) with key contributions from Liepaja Regional Hospital (LRH) and Talisman LLC. RTU spearheads the material development and characterization processes, leveraging its expertise in polymer engineering and nanotechnology, while also optimizing the 3D printing processes for PCTN-based boluses. LRH provides the clinical infrastructure and expertise required for testing the prototypes under real-world conditions, using advanced equipment such as linear accelerators and phantoms to evaluate dose distribution and effectiveness. Talisman LLC contributes to the manufacturing aspects, producing molds, extruding PCTN filaments for 3D printing, and ensuring that the prototypes meet stringent quality standards. This collaborative approach ensures the project benefits from diverse expertise across the fields of science, healthcare, and manufacturing.

By implementing this project, significant advancements are expected in personalized radiation therapy. Traditional boluses are often labor-intensive and costly to produce, with limited adaptability to patient-specific needs. In contrast, the 3D-printed PCTN boluses can be produced with high precision at a fraction of the cost—current wax-based boluses cost around EUR 173 each, whereas 3D-printed versions

can be manufactured for as little as EUR 27. Furthermore, the ability to customize bolus designs using computer-aided design (CAD) software based on CT imaging allows for optimal dose distribution tailored to each patient's unique anatomy. This level of personalization reduces complications, enhances treatment outcomes, and significantly improves the overall patient experience.

In addition to improving patient care, the project offers considerable economic benefits. By positioning Latvia as a leader in high-value, patient-specific medical technologies, the project fosters new market opportunities, particularly in the export of advanced healthcare solutions. The production of these innovative boluses is expected to strengthen the biomedicine sector, contributing to the transformation of the Latvian economy in line with RIS3 goals. The environmental impact is also addressed through the use of recyclable thermoplastic materials, ensuring the sustainability of the manufacturing processes.

The project's scientific coordinator, Dr. habil. phys Yuri Dekhtyar, oversees the interdisciplinary collaboration between RTU, LRH, and Talisman LLC. The project is not related to economic activity and is fully aligned with the European Regional Development Fund (ERDF) funding priorities. Scheduled to run from Q3 2025, to Q3, 2028 (36 months) the project's total budget is EUR 600000. Key milestones include material development in the first part of the project, prototype fabrication in the latter part, and clinical validation in 2026-28. Dissemination activities, including scientific publications and conferences, will occur throughout the project, ensuring broad visibility and impact.

The planned outcomes are expected to improve the field of radiation therapy, not only by improving patient outcomes but also by reducing treatment costs and opening new avenues for commercial and clinical applications. By addressing a critical challenge in cancer treatment, the project demonstrates how cutting-edge research in nanotechnology and material science can be translated into practical healthcare solutions with global relevance.

Keywords: *radiation therapy, personalized medicine, nanotechnology, polymer composites, tungsten nanoparticles, 3D printing, medical technologies.*