# Enhanced Therapeutic Efficacy of P-32 using Silica Microparticle Carriers

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***Keywords :*** $^{32}$P, Silica Microparticle, Intratumoral, Radionuclide Therapy, Geant4

## 1. Introduction

$^{32}$P is a pure beta-emitting radionuclide utilized in therapeutic nuclear medicine [1,2]. However, when administered directly into a tumor, its rapid clearance from the target site can lead to suboptimal therapeutic efficacy and unnecessary radiation exposure to adjacent healthy tissues [3]. This study aims to overcome this limitation by employing ~1 μm diameter silica microparticles (SMPs) as a stable carrier for $^{32}$P. We hypothesized that $^{32}$P-labeled silica microparticles ($^{32}$P-SMPs), would enhance intratumoral retention, thereby localizing the radiation dose and augmenting the overall therapeutic effect on solid tumors.

## 2. Methods and Results

This section covers the procedures and findings of our study, from the initial synthesis and characterization of $^{32}$P-SMPs to their comprehensive evaluation in cellular and animal models, and concluding with a dosimetric analysis.

### *2.1 Synthesis and Characterization*

$^{32}$P-SMPs were successfully synthesized. Their morphology and size were characterized using Transmission Electron Microscopy (TEM), which confirmed a uniform, spherical morphology with a consistent particle diameter of approximately 1 μm.

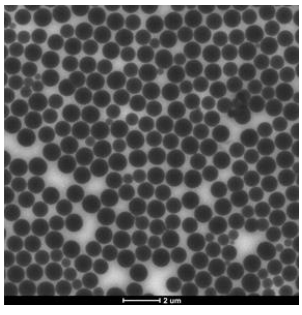


Fig. 1. Transmssion Electron Microscopy (TEM) image of a synthesized silica microparticles (SMPs), showing its uniform spherical morphology and ~1 μm diameter. The scale bar represents 2 μm.

### *2.2 In Vitro Stability and Efficacy*

The radiochemical stability of $^{32}$P-SMPs was evaluated in PBS, cell culture media, and murine serum, demonstrating excellent stability in biological environments with minimal $^{32}$P leaching. In vitro studies using the CT26 murine colon carcinoma cell line revealed that $^{32}$P-SMPs had significantly higher cellular uptake and induced enhanced cytotoxicity compared to a free $^{32}$P control group, as confirmed by CCK-8 and clonogenic assays.

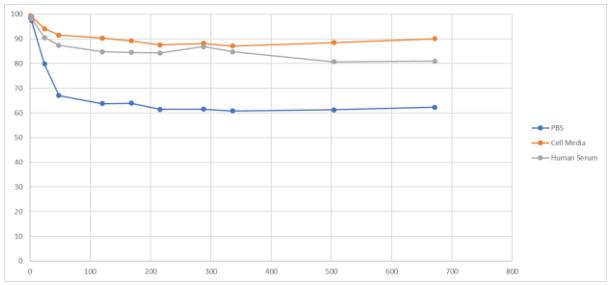


Fig. 2. Radiochemical stability of $^{32}$P labeled silica microparticles ($^{32}$P-SMPs) over 1 month, evaluated by radio-TLC

### *2.3 Geant4 Simulation*

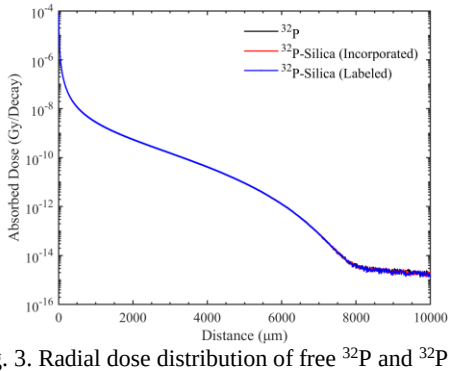


Fig. 3. Radial dose distribution of free $^{32}$P and $^{32}$P synthesized with a silica microparticle (SMP) calculated using a Geant4 toolkit

To quantify the dosimetric advantage of enhanced retention, a Geant4 Monte Carlo simulation was performed. Using the activity distribution data obtained from the in vivo study, the simulation verified that $^{32}$P SMPs deliver a higher and more concentrated absorbed

dose to the tumor, while substantially sparing surrounding healthy tissues.

## 3. Conclusions

The synthesized $^{32}$P-SMPs have proven to be a robust and stable platform for localized radionuclide therapy. Exhibiting enhanced cellular uptake, superior cytotoxicity, and most importantly, prolonged intratumoral retention, $^{32}$P-SMPs effectively concentrate the therapeutic radiation dose where it is most needed. These promising experimental results, supported by dosimetric simulations, strongly suggest that $^{32}$P-SMPs represent a highly effective strategy to improve the therapeutic index of intratumoral $^{32}$P treatment and hold significant potential for clinical translation.

## REFERENCES

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