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# Characterization of Silicon Quantum Dots' Properties and Kidney Toxicity in Mice †

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**Abstract:** Due to their various optical and electronic features that offer advantages for medical purposes compared to traditional nanoparticles (NPs), quantum dots (QDs) represent an emerging tool for in vivo imaging, tumor biology investigation, and cancer treatment. Notwithstanding, QDs can also trigger toxicity effects in healthy cells, as previously reviewed by Zhu et al. [1]. Given that, we further aimed herein to characterize the silicon-based QDs obtained by laser ablation and evaluate their in vivo kidney toxicity. The studied NPs exhibited at transmission electronic microscope a core-shell structure with a crystalline silicon core and an amorphous silica shell with a diameter ranging between 6 and 10 nm. Their tendency to aggregate led to the formation of aggregates with sizes of hundreds of nanometers. QDs dispersion in water revealed a hydrodynamic diameter around 200 nm and a negative zeta potential of −14 mV. To test their in vivo toxicity, different doses of QDs (0, 1 10 and 100 mg QDs/kg body weight) prepared in 0.9% saline were injected in the caudal vein of the Swiss mice. The animals were sacrificed at 1, 6, 24 and 72 h, and the kidney tissue was harvested. The effects of silicon QDs on the antioxidant defense of kidney cells were investigated throughout the assessment of antioxidant enzymes' activities (catalase, superoxide dismutase, glutathione peroxidase, glutathione reductase and glutathione S-transferase). The administration of the highest dose of QDs induced a significant reduction in catalase activity, the level being half of the control after all periods of exposure. A time-dependent decrease in glutathione reductase activity was noticed for all doses administered compared to control animals. After 24 and 72 h, glutathione peroxidase and glutathione S-transferase were diminished in the kidney cells of mice that received 10 and 100 mg/kg b.w. compared to control, revealing that these enzymes were vulnerable to oxidative damage of high doses of silicon QDs. Yet, no significant changes were observed regarding the activity of superoxide dismutase in the kidney of treated mice compared to control, suggesting that the QDs administration would not generate superoxide anions inside kidney cells. This study highlighted the possible damaging effects of high doses of silicon-based QDs (>10 mg QDs/kg b.w.) on kidney cells, providing useful information for further clinical studies on humans.

**Keywords:** nanoparticles; quantum dots; toxicity

## 1. Introduction

Silicon-based Quantum Dots (Si QDs) are a special class of nanoparticles, due to the special properties they have: low toxicity and easily modifiable surface properties. For this reason, they are used in applications such as bioimaging, fluorescent labeling, drug administration, protein detection techniques, tissue engineering. In this context, we aimed to test the renal toxicity of silicone-based QDs obtained by laser ablation, in vivo.

## 2. Materials and Methods

In this study, adult male mice from the Swiss line were injected into the tail vein with different doses of QD (0, 1 10, and 100 mg QD/kg body weight) prepared in 0.9% saline. The injected nanoparticles were synthesized by the laser ablation method. After the expiration of the time periods after the injection of the nanoparticles (1 h, 6 h, 24 h, 72 h), the mice were sacrificed by cervical dislocation. The renal tissue was taken and cryogenized to be used later in the oxidative stress experiments (evaluating antioxidant enzymes: catalase, superoxide dismutase, glutathione peroxidase, glutathione reductase, and glutathione S-transferase).

## 3. Results

Evaluation of antioxidant enzyme activity (Figure 1) indicates a significant decrease in catalase levels at all periods of exposure. Both glutathione peroxidase and glutathione S-transferase exhibited a decrease in enzymatic activity at the highest concentrations (10 and 100 mg/kg). Glutathione reductase activity decreased relative to the control unit per unit time after all periods of exposure. No significant changes were observed in superoxide dismutase activity.

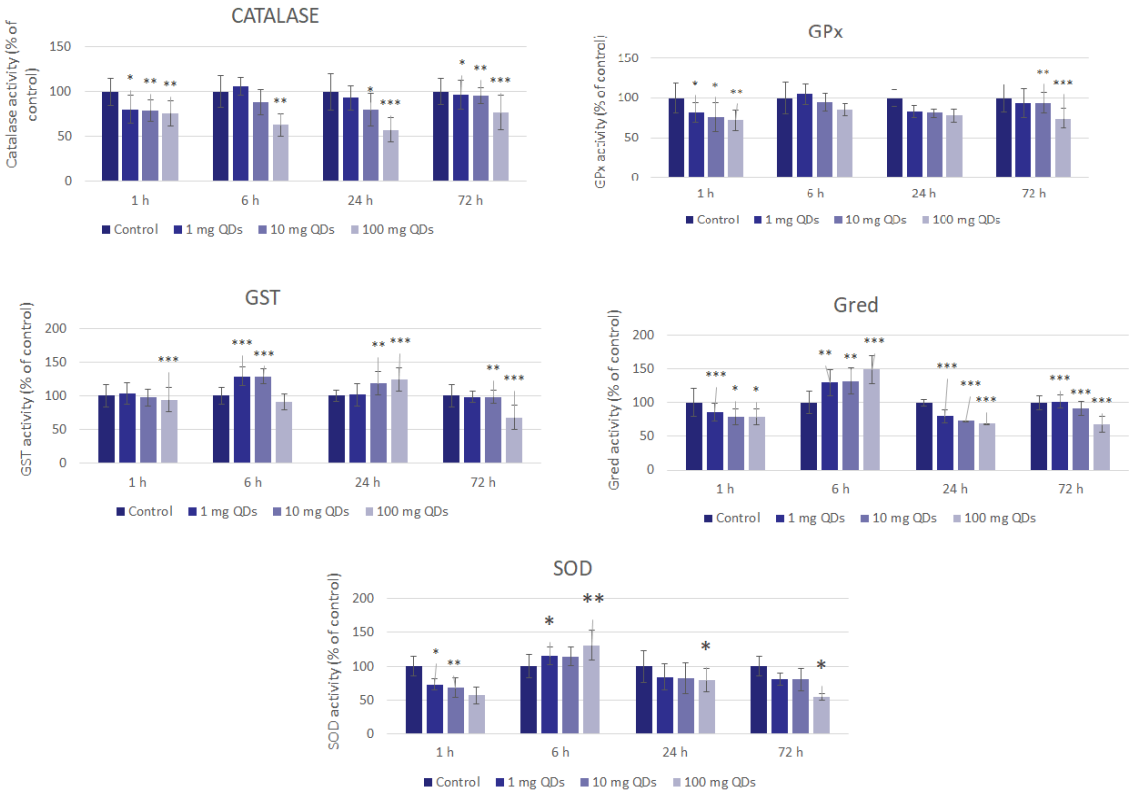


**Figure 1.** The evaluation of the activity of the antioxidant enzymes.

## 4. Conclusions

The experiments showed that nanoparticles of SiQDs synthesized by laser ablation could cause harmful effects on kidney tissue when administered in high doses (> 10 mg QDs/kg body weight). Understanding how Si QDs nanoparticles act biologically and identifying the mechanisms by which

they cause toxicity favors finding ways to design safer nanoparticles for the body and the environment.

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