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When nanoplastics meet neurons: the impact of functionalized polystyrene nanoplastics on human neuroblastoma cells

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INTRODUCTION & AIM

Nanoplastics (NPs) have emerged as a growing environmental and health concern due to their widespread presence in various environmental matrices, including food, water and air[1,2]. They are inadvertently ingested, inhaled, or absorbed through the skin, raising concerns about their potential to interact with cellular systems, including the nervous system[3-5]. Despite increasing awareness, the neurotoxic potential of NPs, particularly the effects of functionalized NPs, remains poorly understood.

This study provides novel insights into the neurotoxicity of four types of polystyrene nanoplastic (PS-NPs) – plain PS-NPs (50 nm and 100 nm) and amine- and carboxyl-functionalized PS-NPs (100 nm) — on human SH-SY5Y neuroblastoma cells.

METHOD

- **Nanoplastics**: Plain PS-NPs (50 nm, 100 nm), carboxyl- (100 nm) and amine-functionalized (100 nm)
- **Cell model**: Human neuroblastoma SH-SY5Y cells
- **Exposure**: 1–500 µg/mL for 24 and 48 h
- **Assays**:
  - Cell viability (MTT assay)
  - ROS/RNS production
  - NP internalization (TEM)
  - Ultrastructural alterations (TEM)

RESULTS

Functionalized NPs, particularly amine-modified ones, induced greater cytotoxicity than their plain counterparts in a concentration- and time-dependent manner (Fig.1).

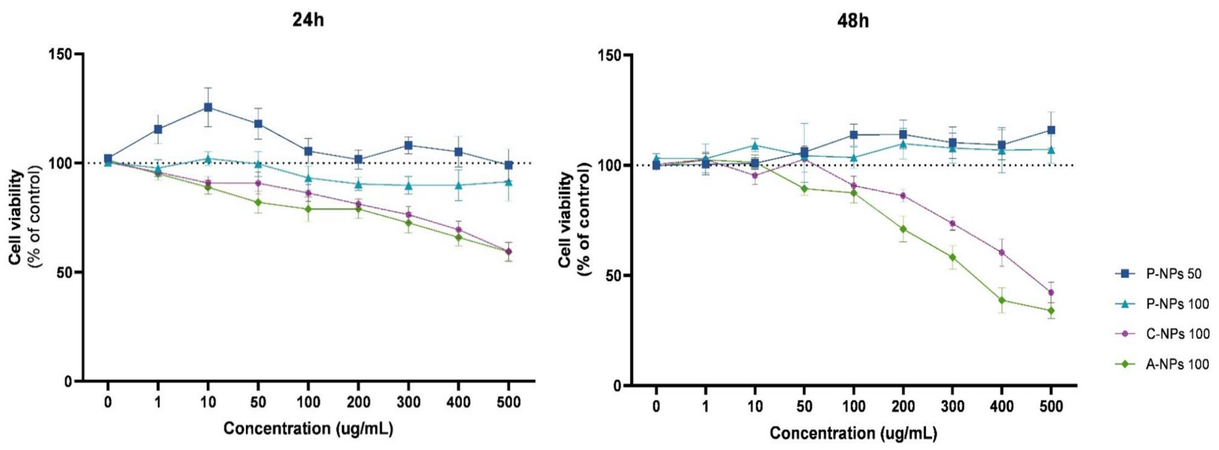

Figure 1. Cytotoxicity induced by PS-NPs in SH-SY5Y cells following 24- and 48-hours exposure. Cell viability after 48 hours exposure to 1–500 µg/mL of plain polystyrene nanoplastics (50 and 100 nm, P-NPs 50 and P-NPs 100) and carboxyl- or amine-functionalized PS-NPs (100 nm, C-NPs 100 and A-NPs 100). Data are presented as mean ± SEM.

ROS/RNS production was markedly elevated in plain 100 nm and amine-functionalized NPs, with oxidative stress intensifying over time (Fig. 2).

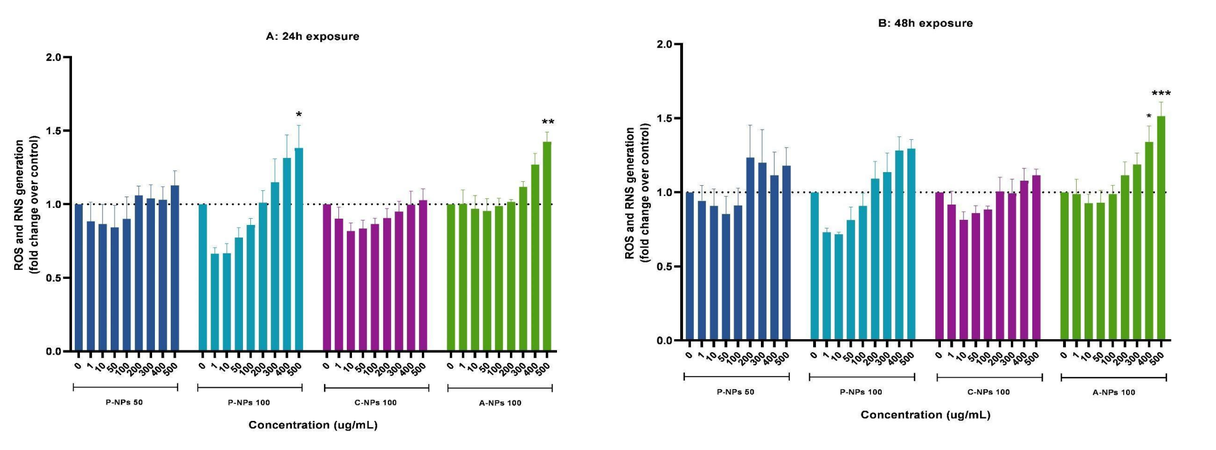

Figure 2. Generation of ROS and RNS in SH-SY5Y cells following exposure to four types of NPs. SH-SY5Y cells were treated with increasing concentrations of 50 nm plain NPs (dark blue), 100 nm plain NPs (light blue), 100 nm carboxyl-functionalized NPs (purple), 100 nm amine-functionalized NPs (green)) for (A) 24 and (B) 48 hours. Data are presented as mean ± standard error of the mean (SEM) (n=5, except n=4 for 50 nm and 100 nm plain NPs). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ vs. control.

TEM uncovered distinct subcellular damage patterns, including endoplasmic reticulum dilation, mitochondrial impairment, and Golgi fragmentation, correlating with NP size, concentration and surface chemistry. Notably, functionalized NPs exhibited greater cellular uptake, with amine-modified NPs showing the highest internalization (Fig. 3).

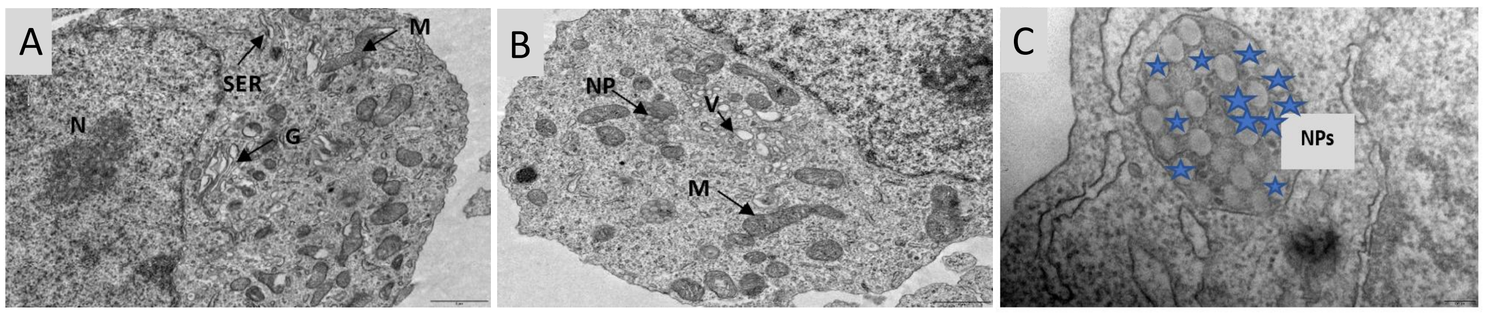

Figure 3. TEM images of neuronal SH-SY5Y cells: (A) control (untreated) cells, (B) cells exposed to 100 nm amine functionalized PS-NPs (200 µg/mL), and (C) representative vesicles containing internalized NPs (indicated by blue stars). Images were acquired using a JEOL JEM 1400 transmission electron microscope. N nucleus, M mitochondria, SER smooth endoplasmic reticulum, G golgi apparatus, V vacuole, NP nanoplastics.

CONCLUSION

- **Surface functionalization** of PS-NPs plays a critical role in modulating neurotoxicity.
- PS-NPs induce **multifactorial cytotoxicity**, including loss of cell viability and membrane integrity; oxidative stress and mitochondrial dysfunction; lipid homeostasis disturbances.
- Findings highlight the **urgent need for further investigation** into health implications, especially regarding human exposure and potential links to **neurodegenerative disease risk**.

References: 1. Patil SM, Rane NR, Bankole PO, Krishnaiah P, Ahn Y, Park Y-K, et al. An assessment of micro-and nanoplastics in the biosphere: A review of detection, monitoring, and remediation technology. Chemical Engineering Journal. 2022;430:132913.; 2. Pironti C, Ricciardi M, Motta O, Miele Y, Proto A, Montano L. Microplastics in the environment: intake through the food web, human exposure and toxicological effects. Toxics. 2021;9(9):224.; 3. Kadac-Czapska K, Knez E, Grembecka M. Food and human safety: The impact of microplastics. Critical Reviews in Food Science and Nutrition. 2024;64(11):3502-21.; 4. Jin M, Wang X, Ren T, Wang J, Shan J. Microplastics contamination in food and beverages: Direct exposure to humans. Journal of Food Science. 2021;86(7):2816-37.; 5. Liu Q, Chen Z, Chen Y, Yang F, Yao W, Xie Y. Microplastics and nanoplastics: emerging contaminants in food. Journal of Agricultural and Food Chemistry. 2021;69(36):10450-68.