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Covid 19 Pandemic Influence on the Presence of Micro and Nanoplastics in the Environment

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The presence of micro-and nano-plastics in the water and in the soil, is not any secret. The primary source of nanoplastics in the natural environment is the production and processing of plastics, and the secondary source of nanoplastics is the fragmentation of plastic products. The fragmentation of plastics is the result of a number of processes, which depend on both the composition of the plastics and environmental conditions. The 2020 COVID-19 pandemic has changed many aspects of daily life and has perhaps forever changed the way we live. The future certainly appears to be less urban and less global. The 2020 pandemic of the the COVID-19 has increased the demand for respiratory protective equipment, especially covid-19 face masks and respirators. Covid- 19 face masks include nanotextiles made of plastic nanofibers are especially popular and widely used. Due to the number of nanotextile-based masks and respirators used daily, their production, use and improper and unregulated disposal contribute to and will continue to contribute to increasing environmental pollution by micro- and nano-plastics. It is likely that there will be no return to normality. The global ecosystem upon which modern society has evolved will have to be redesigned.

1. Introduction

The occurrence of nano- and micro-plastics in the world's oceans and freshwaters, including potable water, has been demonstrated in a number of studies (Waymana and Niemann, 2021); (Gerritse et al., 2020) (Pirsaheb et al., 2020). Similarly, the presence of nano- and micro-plastics has also been confirmed in soil (Brewer et al., 2021). The primary source of nanoplastics for the environment is referred to as plastics production and processing, while the secondary source of nanoplastics is the fragmentation of plastic products (Barnes et al., 2009). Facilitated fragmentation is offered by non-woven textiles, which are fabrics containing fine fibres. Their specification is influenced by production technology, namely Spunbond, Meltblown, electrospinning.

1.1 Ecotoxicity of micro- and nanoplastics

Knowledge about the toxicity of nanoplastics is still very limited. Testing has so far concentrated mainly on aquatic tests that are internationally recognised (ISO standards, etc.) and easy to perform. The mechanisms of toxic effect and the factors that influence toxicity have not yet been fully clarified (Klaine et al., 2008) (Farré et al., 2009) (Bhatt and Tripathi et al., 2011). Different nanoplastics will have different action mechanisms, which is often linked to the purpose they serve. In addition, the same nanoplastic may also exhibit different action mechanisms depending on the ambient conditions. The following possible action mechanisms of nanoplastics are most often mentioned (Figure 1).

1.2 Toxicity of microplastics and nanoplastics – bacteria

Although to a lesser extent and due to the proven low toxicity of polymeric materials, the application of polymeric nanomaterials has also been studied. In a similar research work, Naha et al. (2016) tested the toxic effects of poly (N-isopropylacrylamide), (PNIPAM) and N isopropylacrylamide/N -tert-butylacrylamide (NIPAM/BAM) polymer nanoparticles in different ratios, using Vibrio fischeri as a model.

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Although they exhibited excellent properties as nanosystems for biomedical purposes, the results of tests performed by the authors on these bacteria led to a significant toxic effect after a short exposure time (5 min: EC50 = 40.5 mg/l for 65: 35 NIPAM/BAM ratio and 5 min: EC50 = 25.7 mg/l for a 50:50 NIPAM/BAM ratio). According to the results, reaching a general conclusion about the toxic effects of nanoparticles on microorganisms is by no means an easy task, as their inherent toxicity varies substantially from one another, between organisms, and between experimental conditions. In addition, the intrinsic characteristics of NPs, such as size, shape, solubility or surface charge, may suffer modification due to various conditions such as agglomeration of particles in the presence of aqueous solution. The presence of all these variables highlights the need for rigorous and standardised toxicity assessment protocols (Martinéz et al., 2021).

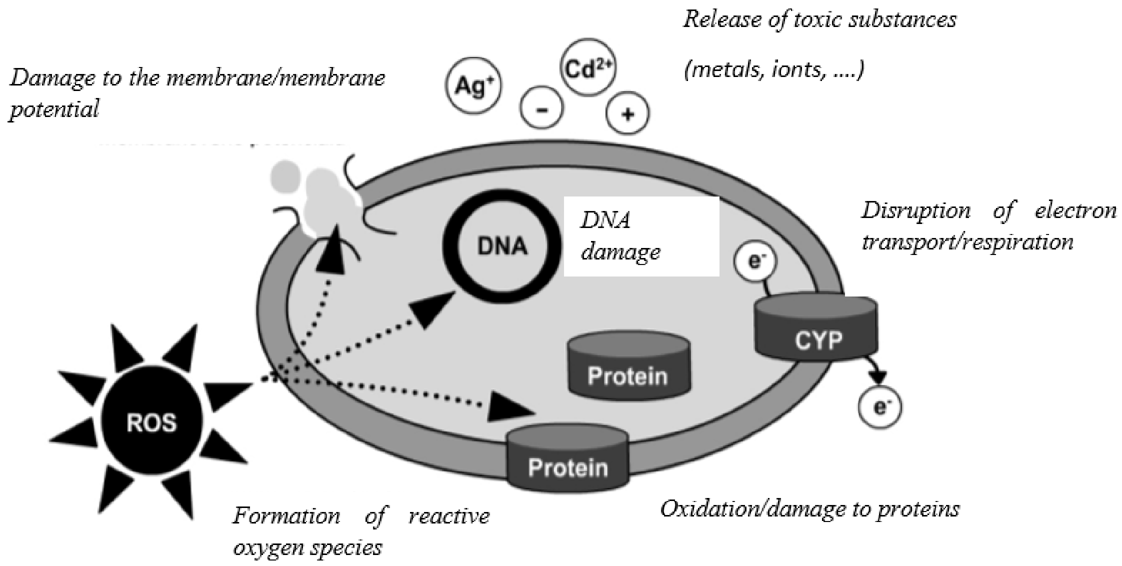

Figure 1: Possible action mechanisms of nanomaterials (CYP - cytochrome P) (Sovová and Kočí, 2012)

1.3 Toxicity of microplastics and nanoplastics – aquatic organisms

Several studies have investigated the toxic effects of polystyrene and polyethylene in the form of micro- and nanoplastics in invertebrates such as nematodes, bivalves, and crustaceans. Exposure of the nematode Caenorhabditis elegans to five different sizes of spherical polystyrene (PS) microplastics, (0.1 to 5 μm) with a concentration in the medium (1 mg/L) resulted in excitotoxicity on locomotion/motor behaviour, reduced survival rates and decreased life expectancy, particularly after exposure to 1.0 μm polystyrene particles. Furthermore, the expression of various neuronal genes was affected, which coincided with impaired cholinergic and GABAergic neurons and oxidative stress. Unfortunately, no evidence was found of the actual uptake of spherical polystyrene in the form of microplastic by C. elegans (Lei et al., 2018).

1.4 Toxicity of microplastics and nanoplastics – animals

To assess the human health risk posed by micro- and nanoplastics, there is a large body of evidence on the translocation of plastic particles from artificial substitutes to lymph nodes and other parts of the body. Exposure studies in mammalian model systems indicate potential absorption of micro- and nanoplastics in various organs. Micro- and nanoplastics are cytotoxic to human macrophages. In human brain and epithelial cell lines, a mixture of micro- and nanoparticles of 40-250 nm PS, 10 μm PS and 100-600 nm PE, and 3-16 μm PE, caused a dose-dependent increase in oxidative stress (ROS). Platelet activation (in vitro) was triggered by aminated PS (Kögel et al., 2020). In mice, daily oral doses administered by a probe with a 5 and 20 μm fluorescent polystyrene (PS) microparticles resulted in accumulation of both sizes in the liver and kidney. Very high doses (from 2 × 104 to 1.5 × 106 items/animal/day) induced liver inflammation and metabolic changes indicating effects on (energy) lipid metabolism, oxidative stress (ROS) and neurotoxic effects. Mice fed with 500 nm and 50 μm of PS particles at a concentration of 1 mg/l showed a decrease in body weight and changes in liver and lipid values after five weeks.

2. Production of nanofibres

Nanotextile-based protective equipment is usually made-up of non-woven fabrics onto where nanofibres created by electrospinning have been applied. The concentration measurements of nanoparticles released into the working environment were carried out at three workplaces where continuous production of nanofibre textiles takes place – at SPUR a.s., NAFIGATE Corporation a.s. and Nano Medical s.r.o. In these companies, a different technological set-up is used to produce nanotextiles. However, the area where the actual spinning of the input material takes place is always separated from the surrounding working environment. The air from the spinning chamber is exhausted and filtered through HEPA filters.

In NAFIGATE Corporation, a.s. and Nano Medical s.r.o., nanotextiles are produced on lines manufactured by ELMARCO s.r.o. These electrospinning lines contain two spinning segments with string electrodes. During our measurements, both companies were spinning polyvinylidene difluoride (PVDF) from dimethylacetamide solution. The resulting PVDF nanotextile was immediately laminated between 2 layers of non-woven fabric prepared by Spunbond technology. Measured nanoparticle concentrations were pulsatile at both workplaces. In the line service area at the Nano Medical s.r.o. workplace (Figure 2), values in the range of 4,000-7,000 #·cm^{-3} were measured with more pronounced peaks of 9,000 #·cm^{-3} and 16,000 #·cm^{-3}. Nanoparticle concentrations in the range of 2,000-#·cm^{-3} with an average of 4,000 #·cm^{-3} were measured at the NAFIGATE Corporation a.s. The mean diameter of the nanoparticles was approximately 30 nm. The fluctuations at low concentration were measured, namely the growth of the diameter at 60; 100; 180 nm.

Figure 2: High-capacity production line for continuous production of nanofibre textiles of Nano Medical s.r.o. The letter A indicates the location of the spinning units with polymer material containers

3. Ekotoxicity tests performed

According to the OECD methodology [20], seeds of white mustard *(Sinapis alba* L.) and oilseed rape *(Brassica napus*) meadow fescue *(Festuca pratensis)* and lettuce *(Lactuca sativa*) were plated against samples of non-laminated PVDF (seeds were placed on the exposed PVDF layer), laminated PP-PVDF, unworn mask Nanovia Mask 99.97 and worn mask Nanovia Mask. The germination and root growth inhibition of seeds placed on and off the tested fabric were investigated. The calculation of root growth inhibition when seeds are applied on/off the tested nanotextile is based on the measurement of root length (root elongation) after the test and follows the formula Eq(1):

$$\mathrm{I} = \frac{(L_c - L_V)}{L_c} \times 100 \tag{1}$$

where I is the inhibition or stimulation of root growth (%), L_c is the average root length in the control (mm), L_v is the average root length in the test specimen (mm). If the resulting value of $I > 0$, it equals to root growth inhibition, if $I < 0$, it equals to root growth stimulation.

In Figures. 3 and 4 are graphs comparing inhibition in mustard and rapeseed in direct contact with the specimen and out of the specimen. Separate columns represent: Mustard non-laminated PVDF and Rapeseed non-laminated PVDF, Mustard laminated PP-PVDF and Rapeseed laminated PP-PVDF, Mustard Mask Nanovia

Mask unworn and Rapeseed Mask Nanovia Mask unworn, Mustard Mask Nanovia Mask worn and Rapeseed Mask Nanovia Mask worn.

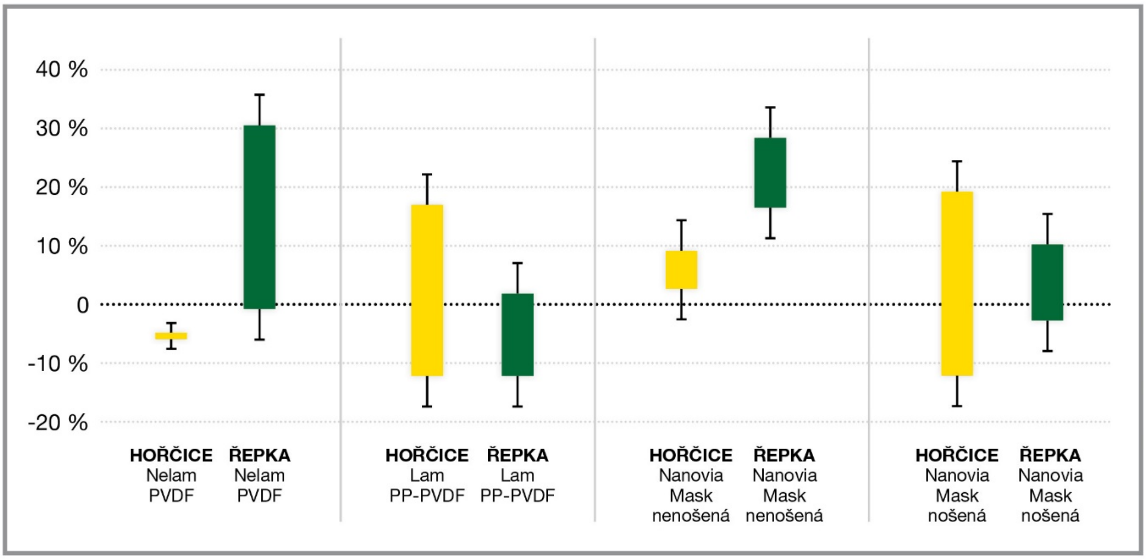

Figure 3 Graphical comparison of inhibition in mustard and rapeseed (seeds out of specimen)

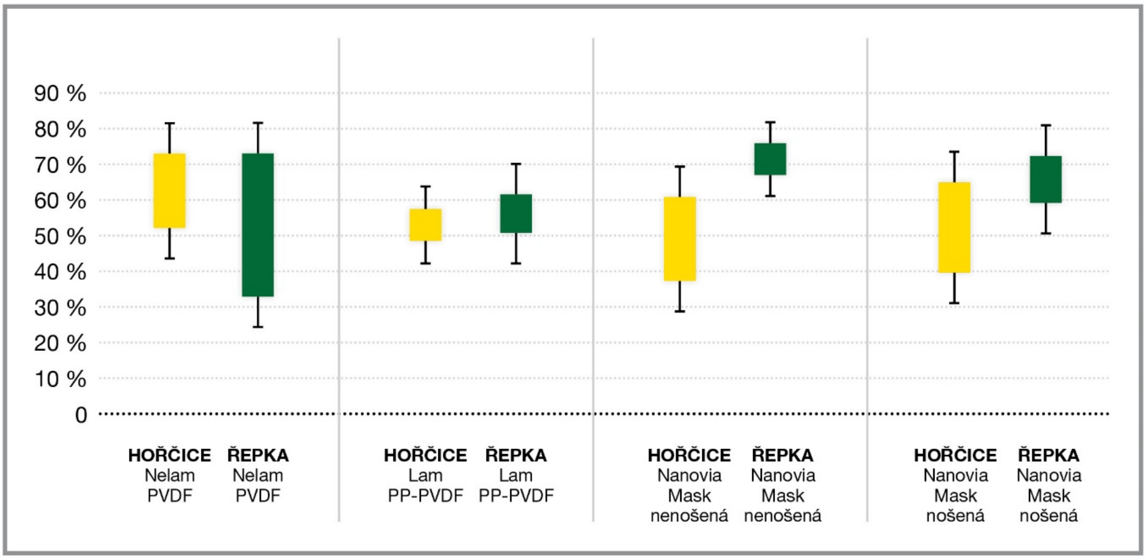

Figure 4 Graphical comparison of inhibition in mustard and rapeseed (seeds per specimen)

Figures 5 and 6 are graphs comparing inhibition in meadow fescue and lettuce in direct contact with the specimen and out of the specimen. Separate columns represent: Meadow grass non-laminated PVDF, Lettuce non-laminated PVDF, Meadow grass laminated PP-PVDF, Lettuce laminated PP-PVDF, Meadow grass Mask Nanovia Mask unworn, Lettuce Mask Nanovia Mask unworn, Meadow grass Mask Nanovia Mask worn, Lettuce Mask Nanovia Mask worn.

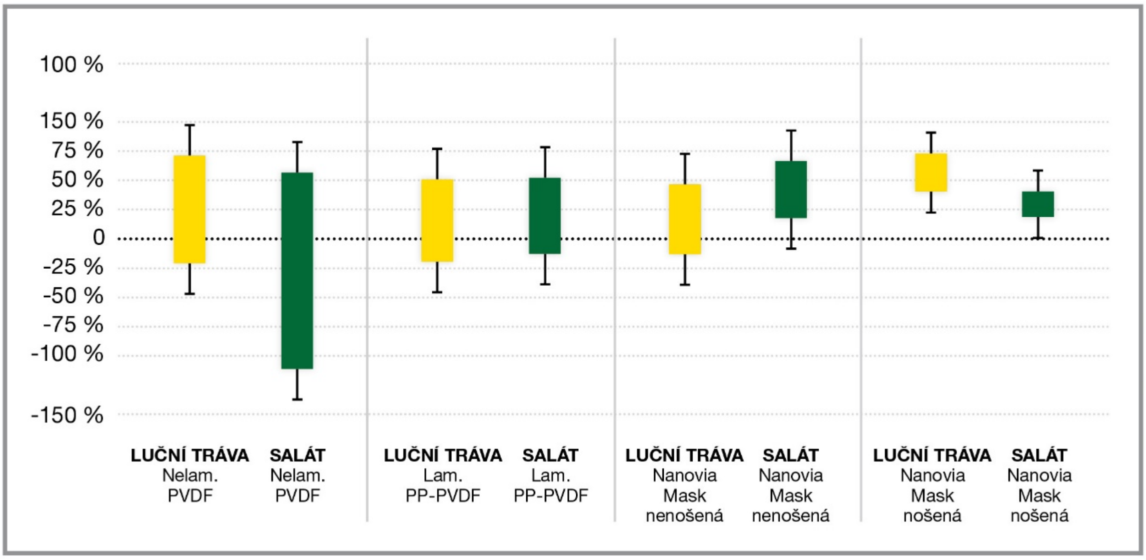

Figure 5 Graphical comparison of inhibition in meadow grass and lettuce (seeds per specimen)

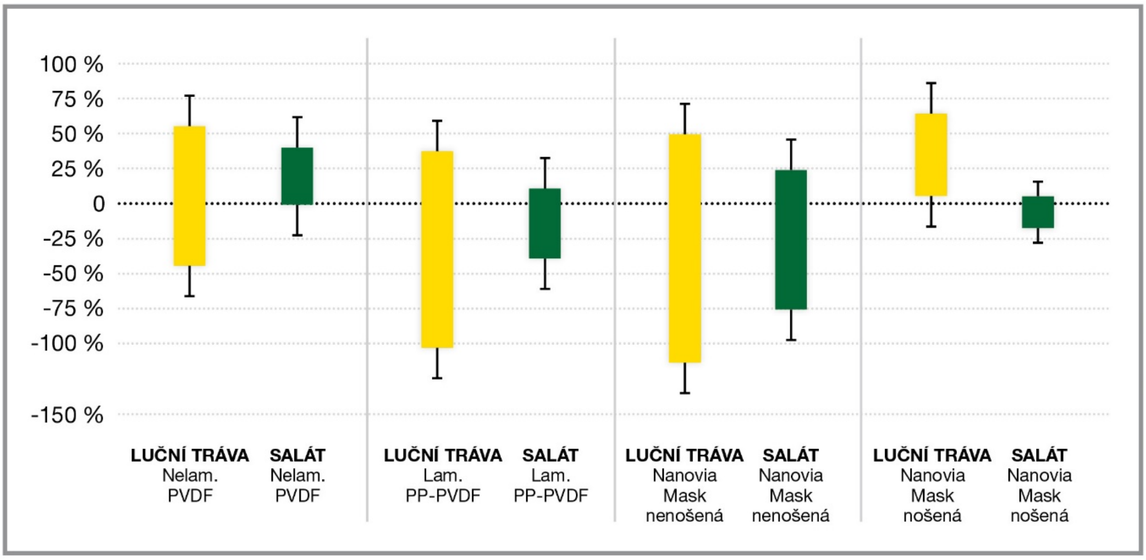

Figure 6 Graphical comparison of inhibition in meadow grass and lettuce (seeds out of specimen)

From Fig. 3, it is apparent that significantly higher root growth inhibition occurred in mustard and rapeseeds that were in direct contact with the nanotextile. The average inhibition reaches values of more than 50%. For lettuce, the highest inhibition was found for seeds placed on the Nanovia Mask specimen unworn (85.5%), while for seeds placed outside the fabric, the highest inhibition was found for the Nelam PVDF specimen (55.42%). In meadow fescue, on the other hand, root growth was stimulated, both in seeds that were in direct contact with the fabric and in specimen where the seeds were placed outside the fabric, e.g., in an unworn Nanovia Mask, the I value of -131% was determined.

4. Conclusion

One consequence of the COVID-19 pandemic has been an unprecedented increase in respiratory protective equipment production incorporating nanotextiles. As these protective agents are made of fibres and nanofibres of different plastics, they contribute to the increase of nano- and micro-plastics in the environment (Sullivan et al. 2021). On the basis of measurements carried out both in the material production for the production of nanomasks and nanorespirators and in the production of our own protective equipment, we have shown that if the production line (or its corresponding part) is separated from the rest of the working environment and the air exhausted from this separated area is filtered by HEPA filters, the filters will trap the nano- and micro-plastics formed. Therefore, a greater risk to the environment is posed by the actual use of protective equipment, particularly mechanical stress (abrasion). Semichronic toxicity tests performed on seeds of selected plants showed the effect of the protective equipment material on root growth. Direct contact of the fabric with mustard and rapeseeds showed root growth inhibition of more than 50%. In the case of meadow fescue seeds, on the contrary, its growth was stimulated.

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