Potential Toxic Effects from Micro- and Nanoplastics: Insights from Occupational Studies

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Problem: Exposure & Effects are not Characterized

Microplastics are ubiquitous. Although studies report microplastics in our air, food, and water, more data is needed to evaluate their impact on human health. Size, shape, type, and properties to assess human health are lacking in many articles, and we know less about nano-plastics (explained in Zarus 2020). Animal studies indicate dose response, but they do not translate to human exposures (Porter et al. 1999).

Therefore, the challenge remains to design studies to best measure human exposures and assess health effects.

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Our Solution: Learn from Worker Exposure Studies

Studies of worker exposures in varying industries that produce plastic particles reported that workers can inhale nano-plastics or ingest microplastics. The industries include surface texture applications (flocking); synthetic textile manufacture, weaving, and cutting; and workplaces involved with producing, cutting, or applying polyvinyl chloride (PVC). The table below summarizes workplace exposures to micro and nano plastic by type and the measured health effects. Most studies find respiratory effects from all microplastic types, and some microplastics are associated with unique effects.

Worker Exposures to Microplastics and Nanoplastics

Microplastic Type	Industry	Study Details	Respiratory and Lung Effects	Health Endpoints and Heaalth Effects	Reference
Poly-acrylonitrile fibers vs. Natural fibers	Textile	Cohort, one exposed to only synthetic fibers; others to hemp or cotton dust prior to synthetic fibers exposure [TD =1.04 mg/m^3, RD =0.53 mg/m^3]	Lower prevalence of respiratory symptoms in synthetic workers compared to hemp and cotton; the synthetic-only cohort exposed to lower TD and RD levels.	None Studied	Valic & Zuskin (1977)
Synthetic fibers	Textile	Workers (7) and transfer of disease to guinea pigs. Textile fibers and dust examined.	Lung biopsies identified inflammation and damage in symptomatic workers. Only polyester antigens produced precipitins (not nylon, wool/polyester).	None Studied	Pimentel et al. (1975)
Synthetic fibers	Synthetic fiber manufacturing	Case-control study of colorectal cancers.	None studied	Colorectal cancers were higher in fiber drying areas: 44% of the cancer patients (n=43) worked in one of the three departments compared to 21% of the controls.	Vobecky et al. (1984)
Synthetic fibers	Textile	Retrospective cohort study	None Reported	Risk of all causes of death and colorectal cancers were low (when including all years worked); while not significant, the cases of liver & gallbladder, leukemia ,and non-Hodgkin's Lymphoma increased with years worked.	Goldberg & Theriault (1994)
Synthetic fibers	Synthetic fiber hosiery	Cohort study; exposures to unmeasured polyester dust. Industrial processes: spinning, weaving fibers; cutting, finishing stockings.	Chronic respiratory symptoms (dyspnea, sinusitis, nasal catarrh), acute symptoms (cough, throat dryness), decreased lung function highly prevalent in exposed vs unexposed.	None Studied	Zuskin et al. (1998)
Synthetic fibers	Textile	Case cohort analysis [EU only]	None Reported	>20 years of exposure associated with increased risk of colorectal cancers; dyes increased colon cancer.	De Roos et al. (2005)
PVC	PVC	PVC dust microscopy and [TD = 5–7 mg/m^3; RD>90%]	None Studied	None Studied	Casula et al. (1977)
PVC	PVC	Cohort study of 1216 workers [TD = 0.38–2.88 mg/m^3; RD =40.3%]	Pneumoconiosis in workers. Low risk of lung cancer, but study separated by job and not job area.	Low risk of lung cancer, but study separated by job and not job area.	Mastrangelo et al. (1979)
PVC	PVC	Lung function tests of 509 male workers in from different exposure groups. [TD =0.2–11.5 mg/m^3]	No statistical difference between population exposed to PVC dust (only); solvents; or mixture of dust and solvents.	None Studied	Chivers et al. (1980)
PVC	PVC	Correlations between 5498 workers by occupation (during 1940-1974) and cancer type [TD= 0.23–2.88 mg/m^3]	None Studied	Significant excess of non-secondary liver tumors with 11 deaths.	Jones et al. (1988)
PVC	PVC	Nested case reference study of workers [TD>10 mg/m^3, RD = 4.5–50%]	Increased risk of lung cancer associated with exposure to PVC dust	None Studied	Mastrangelo et al. (2003)
PVC	PVC	Meta-analysis of 6 worker studies.	None Studied	Increased cancer risk in PVC workers from 6 studies. Increased risk of hepatocellular carcinoma and soft-tissue sarcoma.	Boffetta et al. (2003)
PVC dust and vinyl chloride	Polyvinyl chloride & Vinyl chloride	Comparing death-rates depending on job four categories [TD = 0.23–2.88 mg/m^3 for PVC Baggers in Jones et al., 1988].	PVC Baggers had significant risks for all deaths	Autoclave workers had highest liver tumor risks; PVC Baggers had significant risks for all deaths and cardiovascular disease deaths.	Gennaro et al. (2008)
Nylon fibers and particles	Flock	Chest radiography, pulmonary function tests, high-resolution, computed tomography, and serologic testing of 8 patients. And bronchoalveolar lavage, lung biopsy, or both of 6 patients.	Peribronchovascular interstitial lymphoid nodules in 7 patients. Nylon fiber is the suspected cause of this condition.	None Studied	Kern et al. (1998)
Nylon fibers and particles	Flock	Worker questionnaire, chest X-ray, spirometry; and lung diffusing capacity tests; [RD =5–40 mg/m^3, EU, CFU]; in vivo toxicological studies to evaluate toxicity of the plant's dust.	Respiratory or systemic symptoms significantly associated flocking ranges and performing blowdowns with time worked/week. Tox studies on rats exposed to flock showed acute inflammation.	None Studied	Burkhart et al. (1999)
Nylon fibers and particles	Flock	Patient reports	Reduced lung volume in 13 of 20 patients; reduced lung capacity in 10 of 20 patients	None Studied	Eschenbacher et al. (1999)
Nylon fibers and particles	Flock	Lung biopsy review and questionnaire	Reduced lung volume among the 5 cases.	None Studied	Kern et al. (2000)
Polyethylene fibers and particles	Flock	Case study of symptomatic female flock workers	Reduced lung function and reduced lung volume over 4 years.	None Studied	Barroso et al. (2002)
Polyethylene fibers and particles	Flock	Case control study with respiratory questionnaire, physical examination, chest radiograph, and pulmonary function testing [TD =4.4 to <10mg/m^3, RD <0.2 to 5 mg/m^3]	Respiratory symptoms (e.g., dyspnea, cough, phlegm, wheezing, or chest tightness) increased 3.6 x in flock workers compared to controls. Serum interleukins were several times higher in flock workers (indicators of ongoing inflammation).	None Studied	Atis et al. (2005)
Aramid fibers	Aramid	Case study of workplace exposures in two departments [TD <.099 mg/m^3, F<0.053 fibers/cm^3, acids]	Upper-respiratory symptoms reported (56% Spinning workers, 27% Finishing workers) (infected gland, sore throats, and infections).	None Studied	NIOSH (2001)

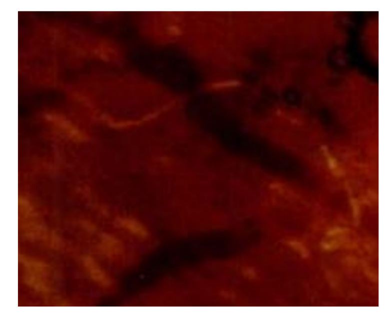
Abbreviations: PVC = Polyvinyl chloride; EU = endotoxin units; CFU = colony forming units; RD = respirable dust; TD = total (inhalable) dust; F = Fibers. Only dust and fiber measurements were included in the table.

Findings: Summary of Health Effects

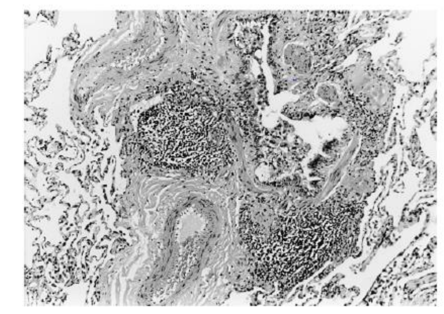
Numerous studies indicate respiratory effects from inhalation of plastic particles and fibers. However, there are some differing health effects associated plastic type and specific workplace duty within the facilities. The activities suggest that size, shape, type, and route of exposure play a role. Longer-term exposures and higher concentrations resulted in more severe health effects. Polyethylene, nylon, aramid, polypropylene, and PVC exposures showed differing effects.

All Plastic Exposures: Human studies showed respiratory effects, including restricted airways, pulmonary inflammation, reduced lung function, and abnormal lung X-rays. While measurements are lacking in most of these studies, effects have been reported with respirable particulate levels as low as 0.53 mg/m^3 in the flock industry. Loss of lung function increased with years worked, with dustier environments, and smaller particles. Findings from animal studies showed immediate inflammation and pointed to a dose response relationship (Porter et al. 1999). Reduced lung function was measured as reduction of forced expiratory volume (46–81%) and forced vital capacity (39–56%) in these studies (referenced on table).

Airborne Carpet Fiber x250 (A. Brockington 2020)



Inhaled fiber on lung blood capillary 50x scaled to left (Pauly et al., 1998)



Lung biopsy of synthetic worker x250 (Eschenbacher et al., 1999)

Some Plastics: Polyester used as flock appeared to have a greater effect on the lung than nylon flock. Colorectal cancers and other gastrointestinal effects were observed in workers who worked near dyed synthetics fibers. Protein markers indicated high strength synthetic fibers (aramid) nearly were as toxic as crocidolite and chrysotile asbestos to tracheal epithelia. Lung and liver cancers were identified as health outcomes among PVC workers. Study limitations include lack of standard measurement methods. Some authors measured total dust while others measured respirable dust and lung function challenges differed. Often the measurement detection levels were high, and the results were non-detects. Some studies included years worked and job classification.

Implications: Use Best Practices from these Studies for Workers and General Public

Although workers experience higher doses than the public, results from these occupational studies reveal endpoints and sampling methodology that should be targeted in environmental studies. Therefore, comprehensive human health risk studies will require that standardized measurement and sampling protocols (with greater volumes of air) are developed.

ATSDR & NCEH have proposed these (referenced) best practices along with added quality assurance to minimize sample contamination. These practices were shared with the Nanotechnology Environmental and Health Implications Working (NEHI) Group at Nano.gov to develop a multi-agency approach. Waterborne methods are available for review and air methods are still being developed at NEHI.

Draft method development site:

SCAN ME

Thanks to Ashaki Brockington initiating work into residential microplastic air sampling methods.

Airborne synthetic slip-cover fabric

References available at:

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