OCCUPATIONAL EXPOSURE IN METAL 3D PRINTING

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Metal 3D printing is a growing industry that poses potential exposure risks to metal dust and nanosized particles with known toxic characteristics. Powder bed fusion (PBF) is an additive manufacturing (AM) technique in which metal particles similar to welding fumes are released due to the laser heating of a metal powder. Metal 3D printing workers are also exposed to nanosized metal dust, especially during powder handling and post-processing work activities.

Materials and methods

Metal exposure among 3D printing operators (n=18) and other AM workers (n=14) was studied during their work shifts at AM facilities using PBF. Mass and number concentrations of particulate matter were measured using personal and stationary instruments (DISCmini, NanoScan, Partector, P-Trak). Dermal wipe samples (Ghost Wipes, SKC Europe) were collected from the dominant hand of the AM workers and all participants provided urine samples and exhaled breath condensates (EBC) pre- and post-shift. Levels of various metals (e.g., Al, Fe, Co, Cr, and Ni) were determined using ICP-MS. Metal levels were compared to those of an unexposed control group (n=15, matched for age, sex and smoking) and to established guidance values.

Results

Air concentrations of metals were generally low, and occupational exposure limit values were exceeded only in individual samples. The highest concentrations of nanoparticles were detected during powder handling and post-processing (Figure 1). In the operators' breathing zones, the highest concentrations were measured for aluminum, cobalt, copper, and nickel. AM workers showed eleveted dermal metal concentrations post-shift (Figure 2). Metal levels in urine and EBC were generally comparable to those observed in the control group (Table 1). Health-based biomonitoring action threshold values in urine were not exceeded for any of the studied metals. The post-shift EBC samples of the 3D-printing operators showed significantly higher copper levels than controls.

Overall, based on the results, health risks in the examined work tasks can be considered low if good occupational hygiene practices and protective measures are maintained.

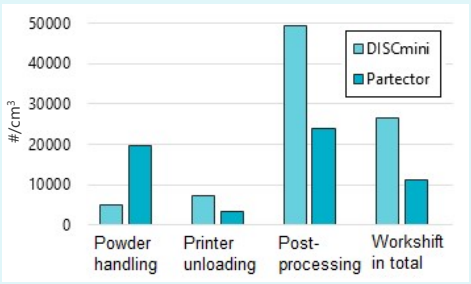

Figure 1. Particle number concentrations according to work tasks (mean #/cm³ in the breathing zone of 3D operators)

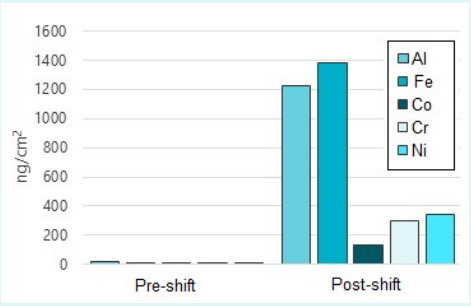

Figure 2. Metal concentrations in the dominant hand of AM workers (mean ng/cm²).

	Al	Cu	Co	Ni	Mn
Operators post-shift urine	1.83	7.19	0.16	0.74	0.05
Operators post-shift EBC	9.01	2.49*	0.04	1.97	0.52
Other workers post-shift urine	2.32	8.54	0.20	1.21	0.04
Other workers post-shift EBC	8.61	1.71	0.04	1.58	0.47
Controls urine	2.65	8.49	0.18	1.21	0.06
Controls EBC	6.32	1.53	0.04	1.70	0.43

Table 1. Metal concentrations in post-shift urine and EBC samples (median µg/l). Urine levels have been corrected according to the specific gravity. *p<0.05 compared to the control group

The results emphasize the importance of occupational hygiene and the need to implement exposure control measures in metal 3D printing work.

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