Occupational exposure to welding fumes in the metalo-mechanic industries in Portugal

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OCCUPATIONAL EXPOSURE TO WELDING FUMES IN THE METALO-MECHANIC INDUSTRIES IN PORTUGAL

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INTRODUCTION

Some studies on occupational exposure to particulate have pointed out to hazardous effects to workers, in what regards inhalable and also respirable particulate. These occupational exposure scenarios are extremely complex as they involve components inherent to the individuals, working conditions and the developed activity itself [1].

This requires the application of an integrated approach comprising diagnostic, evaluation and risk management, adapted to each specific situation [2].

Regarding welding processes, several authors have shown the existence of asthma prevalence four time higher in welders in the USA than in other population [3]. Exposure to a specific type of welding depends from several factors such as the location of ventilation and exhaust equipment, the air flux, the amount of generated fumes, the workplace area, the distance from the welding front and the welding practices themselves [4].

Bearing in mind these considerations, the following research question arises: Which is the occupational exposure to welding fumes in the metalo-mechanic industries in Portugal?

This work aims to perform a characterization and environmental evaluation in a specific situation: welding processes in the metalo-mechanic industry, and identify eventual alterations on workers' health.

MATERIALS AND METHODS

A Nanoparticle Surface Area Monitor (TSI 3550 – Fig. 1 and 2), was used for assessing exposure to nanoparticles produced and manipulated in laboratory and industrial facilities. This equipment estimates the human lung-deposited surface area of particles (ADSA) expressed as square micrometers per cubic centimeter of air ($\mu m^2/cm^3$), corresponding to tracheobronchial (TB) and alveolar (A) regions of the lung.

Particles were sampled using a Nanometer Sampler Analyser, (TSI 3089 – Fig. 3) and observed further on using Transmission Electron Microscopy (TEM). The particles were subjected to chemical analysis, by Energy-dispersive X-ray spectroscopy (EDS).

Also, granulometry of particles was measured in the nanorange using a NanoScan SMPS Nanoparticle Sizer (TSI 3910 – Fig. 4) .

Fig. 1 - TSI Model 3550 - Nanoparticles Surface Area Monitor (NSAM) *, measures surface deposited area of nanoparticles in alveolar and tracheobronquial tracts of human lungs, based on diffusion charging.

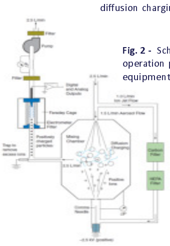

Fig. 2 - Schematic showing the operation principle of NSAM equipment.

Fig. 4 - TSI Model 3910- NanoScan SMPS anoparticle Sizer (SMPS) *

Fig. 3 - TSI Model 3089 - Nanometer Aerosol Sampler (NAS) *

RESULTS

Results clearly demonstrated the existence of nanoparticles with negative charge, as shown in figures 5 to 8, and also allowed the determination of lung-deposited surface area of nanoparticles, as well as the dose per unit lung mass and unit lung area (Table 1 and 2).

Outcomes showed that the amount of emitted nanoparticles is clearly dependent from the main welding parameters, namely the current intensity and the heat input of the welding process.

When comparing the shielding gas mixtures, higher emissions were observed for more oxidizing mixtures, that is, with higher CO_2 content, which means that these mixtures originate higher concentrations of ultrafine particles and higher values of alveolar deposited surface area of particles, thus resulting in a more hazardous condition regarding welders exposure.

The particles were subjected to chemical analysis, by EDS (Figs 9 and 10), regarding mild steel, the elements detected were iron, silicium and manganese (copper is also shown in the spectra but it is due to the grids used for collecting nanoparticles). For stainless steel, the detected elements were iron, cromium and nickel, which confirms the origin both from the base material and the consumable which are potentially carcinogenic elements.

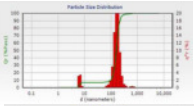

Fig. 5 – Size distribution of nanoparticles collected for welding with Arcal 21 (mild steel)

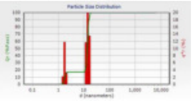

Fig. 6 – Size distribution of nanoparticles collected for welding with Arcal 129 (stainless steel).

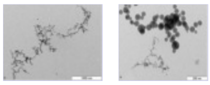

Fig. 7 - TEM images of collected nanoparticles during MAG welding for mild steel

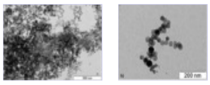

Fig. 8 - TEM images of collected nanoparticles during MAG welding for stainless steel

Table 1 – Average ADSA values obtained during welding tests for mild steel .

Gas mixture Metal transfer mode	Average ADSA ($\mu m^2/cm^3.s$)		
	Ar+10%CO_2	Ar+18%CO_2	100% CO_2
Short-circuit	8325	**22266**	12899
Globular	13306	**42896**	18292
Spray	17574		

Table 2 – Average ADSA values obtained during welding tests for stainless steel .

Gas mixture Metal transfer mode	Average ADSA ($\mu m^2/cm^3.s$)		
	Ar+5%CO_2	Ar+18%He+1%CO_2	Ar+5%He+2%CO_2+2%N_2
Short-circuit	23637	**75390**	33644
Globular	37054	**94136**	78361
Spray	39376	65829	**80861**

✓Mild Steel: Arcal 21=Ar+10% CO_2; Atal=Ar+18% CO_2; CO_2 puro

✓Stainless steel : Arcal12=Ar+5%CO2; Arcal121=81%Ar+18%He+1%CO2; Arcal 129=91%Ar+5%He+2%CO2+2%N2

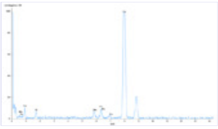

Fig 9 – Chemical composition of nanoparticles collected for welding with Arcal 21.

Fig. 10 – Chemical composition of nanoparticles collected for welding with Arcal 129.

CONCLUSIONS

Fusion welding processes are the most used in the metal working industry for joining materials.

These welding processes generate fumes that are a mixture of solid particles and toxic gases. More than 90% of the fumes are generated due to the vaporization of constituents present in consumables.

The smaller the size of these particles, the most dangerous to the health of people who are involved in the process of fusion welding. Tests were carried out varying the welding parameters for different welding gas mixtures, the surface area of nanoparticles deposited in the alveolar tract was determined. These particles were collected and characterized by transmission electron microscopy and energy-dispersive X-ray spectroscopy. Information on the size distribution of airborne nanoparticles can help differentiate between nanoparticles from emission sources and background airborne particulates.

The existence of nanoparticles with a high capacity of alveolar deposition was verified, and they can cause damage to the health of workers exposed to welding processes in the metalo-mechanic industry. It was also verified that the transfer modes and gaseous mixtures will have influence in the area of particle surface with ability to deposit in the alveolar region.

Define a methodology for risk assessment adapted to this situation and contribute to increase the knowledge on health effect on worker exposure to welding fume are planned to further, thus reducing risk for human health, defining how to evaluate, and improve air quality in welding environments.

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