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Health risks related to occupational exposure in WEEE management

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Abstract

The activity of recycling Waste of Electrical and Electronic Equipment (WEEE) includes various processes: manual dismantling, semi–automatic or manual separation, metallurgical and combustion processes, etc.

Workers engaged in these processes are potentially exposed to several toxic chemicals and other occupational risk factors as noise, vibrations, biomechanical overload of musculoskeletal system, manual loads handling, etc.

According to scientific literature, the occupational exposure to chemicals, mainly inhalatory, is relevant in all working phases. Among the main toxic chemicals there are metals (e.g.: copper, lead, cadmium, mercury, chromium, etc.) and other organic compounds (e.g. brominated flame retardants BFR, polychlorinated biphenyls PCBs, polycyclic aromatic hydrocarbons PAH, polychlorinated dibenzo–p–dioxins and furans PCDD/Fs, etc.).

To date knowledge on possible adverse health effects in these workers is largely insufficient.

Our aim is an estimate of the toxic and carcinogenic risk due to the occupational exposure to chemicals related to WEEE recycling activity. The human Health Risk Assessment will be applied. This method can esteem an Hazard Quotient (HQ) for toxic substances, defined as the ratio between the mean daily dose of the specific chemical and the maximum admittable dose without adverse effects; the same method can also esteem the carcinogenic risk, defined as the odd of increasing the lifetime number of cancer cases.

1. Working processes and occupational health risks in the activity of recycling WEEE

WEEEs are frequently treated as general municipal solid waste, and are incinerated in incineration facilities or put in landfills. In these cases all workers involved are exposed to the occupational risk related to both, e–

waste and other waste components, and the risk specifically due to WEEEs cannot be evaluated.

However this method for WEEEs end–of–life cannot be considered still adequate, and WEEEs recycling activities are increasingly applied.

In general, WEEEs recycling activities can be divided in two types: *informal* and *formal* (Grant et al, 2013). The former includes the mainly manual dismantling of the WEEEs and rudimental pyro–metallurgical technics to recover "precious" components. Formal WEEE recycling activities are less impacting, but require specific technical procedures to safely remove relevant materials from electric and electronic equipments.

Among the main electronic devices included in WEEEs there are the old computer cathode ray tube (CRT) screens and CRT televisions, containing a relevant amount of lead encapsulated in the glass. Old and new computers, but also cell phones and almost all electric and electronic devices have printed circuit boards containing various metals like copper, iron, tin, aluminum, gold, silver. To recover these metals, combustion processes are frequently applied, possibly causing the liberation of several very toxic organic compounds like dioxins and furans. An important proportion of WEEEs are big household appliances as fridges and air conditioning systems, containing toxic refrigerant fluids like chlorofluorocarbon (CFC). Other relevant WEEEs are batteries, containing acid substances and various toxic metals like lithium, nickel, cadmium and lead, and lamps; a recent relevant problem is related to the new fluorescent lamps, containing mercury (Hg), a well–known neurotoxic metal.

Considering specifically the working processes in the activity of recycling e–waste, the occupational health risks for WEEE workers are significantly different depending on the different procedures used in order to recover the materials, as pointed out in a recent review (Tsydenova & Bengtsson, 2011). The main occupational risks related to these activities are:

a) chemical exposure: it is usually the main risk for workers both in developed and developing countries. Chemical exposure can vary largely depending on the different substances and recycling process. The main exposure in workers is due to the inhalation of dusts and vapors, and possibly to dermal contact. Ingestion may occur only in cases of inadequate protective habits like eating and smoking during work without washing hands and using gloves. An exposure to metals is possible during the processes to recover the components of particular e–waste such as printed circuit boards or batteries; organic compounds may be generated during pyro–metallurgical processes, other diffused organic chemical are refrigerants in air conditioning systems and fridges; further organic chemicals can be generated in other specific e–waste recycling procedures. The risk related to occupational exposure to chemicals will be further developed in the next sections;

b) biomechanical overload of musculoskeletal system due to loads handling, repetitive movements of upper musculoskeletal districts and vibrations generated from different tools can be related to manual dismantling of large WEEEs and manual separation of small components;

c) high noise exposure e.g. during mechanical shredding and treatments for color or density separation and/or further grinding may be induced by both instruments used and parts treated;

d) injury risk: examples are the breakage of glass cathode ray tubes, and of the bulbs of fluorescent lamps, and the extraction of metals using strong acids or heating using flammable propellants such as propane and kerosene (mainly in developing countries), or the use of various cutting and breaking tools;

e) other possible occupational risks are exposure to biological agents related to the contamination of WEEEs from various microorganisms, adverse microclimatic conditions during treatments and other. Finally workers could be exposed to risk factors concerning work–organization, e.g. work–related stress and work–shifts (Lavoie et al, 2001).

2. Occupational exposure to chemicals in WEEE recycling activities

2.1. *Organic compounds*

a) Polybrominated diphenyl ethers (PBDEs) and other flame retardants (Frs). Occupational exposure to FRs has been recently evaluated in a Finnish study performed in four recycling sites for 2 consecutive years (Rosenberg C. et al, 2011). The mean concentrations of PBDEs cogeners in the air sample ranged from 3.5 to 2320 ng/m^3, suggesting a possible risk for workers, even if, to date, there is not an adequate knowledge of occupational limits for these compounds. In Sweden (Sjödin A et al, 1999) the exposure to PBDEs in a group of workers employed in an electronics dismantling plant resulted 37 pmol/g lipid weight (lw) and it was significantly higher compared to the exposure of a control group.

b) Dioxins and furans. A recent study from Ghana (Wittsiepe J et al, 2015) showed high exposure levels to dioxins and furans both in the workshops and in the closer areas, with potentially harmful effects to the health of e–waste workers and also local residents, including carcinogenic effects.

c) Polibrominated byphenils (PBBs) and polychlorinated biphenyls (PCBs). Workers exposure to PBBs and PCBs through inhalation or dermal contact in WEEEs dismantling and recycling facilities have been evaluated in Northern China (Yang et al, 2013). Serum concentration of several PBBs cogeners was measured: the mean concentration resulted 0.52 ng/g lipid, about 9 times higher than a control group. 20 PCBs congeners have been measured in the serum of workers and control group. PCBs were 44.1 ng/g lipid in workers, about 4 times higher than controls.

d) PAHs (Polycyclic Aromatic Hydrocarbons). Sixteen different PAHs have been measured in the air of a WEEEs recycling site in China (Zhang D et al, 2011), founding an air mean concentration of 744 ng/m^3.

2.2. *Metals*

In a big WEEE recycling site in Ghana, the collection of air samples showed high exposure levels to various metals, higher than the current occupational limits value proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) (Caravanos et al, 2012). In a recent Swedish study (Julander et al, 2014) WEEE workers' exposure to toxic metals has been measured. The highest air concentration was found for Iron (98 μg/m^3), followed by Zinc (14 μg/m^3) and Lead (7 μg/m^3). Significantly higher concentrations of Cadmium and Copper were found during dismantling than during outdoor activities. Also Chromium and Lead showed this tendency but the difference was not significant. For all the metals considered, the concentrations measured in the working area were significantly higher than in a control group. Considering blood, urine and/or plasma concentrations, Chromium (mean= 1.4 μg/l), Cobalt, Indium, Lead and Mercury were higher in recycling workers, compared with a control group of office workers.

Considering occupational exposure to Lead, the Hong Kong study (Lau et al, 2014) measured elevated environmental Pb levels in the dismantling and desoldering areas of the workshops, and estimated the blood Lead levels in workers in the range 10–39.5 μg/dl, possibly exceeding the current ACGIH Biological Exposure Index (BEI) of 30 μg/dl (ACGIH, 2014). A Chinese study (Wang et al, 2011) on Lead exposure of workers in an e–waste site reported the frequencies of lymphocytic micronucleated binucleated cells (MNBNCs) and the Pb blood levels in workers compared to a control group. Lead levels (median: 11.5 μg/dL) in workers were positively correlated with

MNBNCs frequency and they both were significantly higher than in control group. Xue et al estimated the health risk for Lead exposure, founding a Hazard Index of 1.45 for WEEE workers, suggesting the possible occurrence of adverse health effects related to Lead exposure, such as gastrointestinal disorders, hematologic effects like anemia and various others.

Regarding Mercury (Hg), another well–known neurotoxic metal, in a French study conducted in fluorescent lamps recycling facilities (Zimmermann F et al, 2014), the mean Hg indoor concentration was 15.4 $\mu g/m^3$, that is above the ACGIH occupational limits for exposure to Hg alkyl compounds.

Considering cancer risk, a recent study from Hong Kong (Lau et al, 2014) performed a *human Health Risk Assessments* and the cancer risk in WEEE workers for the exposure to Cadmium (Cd), Chromium (Cr) and Nickel (Ni) has been estimated. Authors found that in the workers of the dismantling area, for all these three carcinogens the cancer risk was above the acceptable level.

3. Estimating the adverse health effects for workers employed in WEEE recycling activity: a Health Risk assessment

To quantify the toxic and carcinogenic risk due to the occupational exposure to chemicals in workers during WEEE recycling activities, the *human Health Risk Assessment* (HRA) method can be applied. HRA is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future (Environmental Protection Agency, EPA). This method, internationally validated and widely used, can esteem the Hazard Quozient (HQ) for toxic substances, defined as the ratio between the mean daily dose of a specific chemical and the maximum admittable dose without adverse health effects (Reference Dose, RfD). The method enables also the calculation of the carcinogenic risk, defined as the odd of increasing the lifetime number of cancer cases, obtained multiplying the mean daily dose of the carcinogenic chemical for its carcinogenicity power (Cancer Slope Factor, CSP). Another way to esteem the health risk for WEEE workers is the calculation of the "Disability–Adjusted Life Years" (DALYs), that are a measure of the overall disease burden, representing the number of years lost due to ill–health, disability or early death.

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