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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 a Hazard Quotient (HQ) for toxic substances, defined as the ratio between the mean daily dose of the specific chemical and the maximum admissible 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-

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

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

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

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

25 Considering specifically the working processes in the activity of recycling  
26 e-waste, the occupational health risks for WEEE workers are significantly  
27 different depending on the different procedures used in order to recover  
28 the materials, as pointed out in a recent review (Tsydenova & Bengtsson,  
29 2011). The main occupational risks related to these activities are:

30 a) chemical exposure: it is usually the main risk for workers both in  
31 developed and developing countries. Chemical exposure can vary  
32 largely depending on the different substances and recycling process.  
33 The main exposure in workers is due to the inhalation of dusts and  
34 vapors, and possibly to dermal contact. Ingestion may occur only in  
35 cases of inadequate protective habits like eating and smoking during  
36 work without washing hands and using gloves. An exposure to met-  
37 als is possible during the processes to recover the components of  
38 particular e-waste such as printed circuit boards or batteries; organic  
39 compounds may be generated during pyro-metallurgical processes,  
40 other diffused organic chemical are refrigerants in air conditioning  
41 systems and fridges; further organic chemicals can be generated

1 in other specific e-waste recycling procedures. The risk related to  
2 occupational exposure to chemicals will be further developed in the  
3 next sections;

- 4 b) biomechanical overload of musculoskeletal system due to loads  
5 handling, repetitive movements of upper musculoskeletal districts  
6 and vibrations generated from different tools can be related to  
7 manual dismantling of large WEEEs and manual separation of small  
8 components;
- 9 c) high noise exposure e.g. during mechanical shredding and treatments  
10 for color or density separation and/or further grinding may be  
11 induced by both instruments used and parts treated;
- 12 d) injury risk: examples are the breakage of glass cathode ray tubes, and  
13 of the bulbs of fluorescent lamps, and the extraction of metals using  
14 strong acids or heating using flammable propellants such as propane  
15 and kerosene (mainly in developing countries), or the use of various  
16 cutting and breaking tools;
- 17 e) other possible occupational risks are exposure to biological agents  
18 related to the contamination of WEEEs from various microorganisms,  
19 adverse microclimatic conditions during treatments and other.  
20 Finally workers could be exposed to risk factors concerning work-  
21 organization, e.g. work-related stress and work-shifts (Lavoie et al,  
22 2001).

## 23 2. Occupational exposure to chemicals in WEEE recycling activities

### 24 2.1. Organic compounds

- 25 a) Polybrominated diphenyl ethers (PBDEs) and other flame retardants  
26 (FRs). Occupational exposure to FRs has been recently evaluated in  
27 a Finnish study performed in four recycling sites for 2 consecutive  
28 years (Rosenberg C. et al, 2011). The mean concentrations of PBDEs  
29 congeners in the air sample ranged from 3.5 to 2320 ng/m<sup>3</sup>, suggesting  
30 a possible risk for workers, even if, to date, there is not an adequate  
31 knowledge of occupational limits for these compounds. In Sweden  
32 (Sjödín A et al, 1999) the exposure to PBDEs in a group of workers  
33 employed in an electronics dismantling plant resulted 37 pmol/g lipid  
34 weight (lw) and it was significantly higher compared to the exposure  
35 of a control group.
- 36 b) Dioxins and furans. A recent study from Ghana (Wittsiepe J et al,  
37 2015) showed high exposure levels to dioxins and furans both in the  
38 workshops and in the closer areas, with potentially harmful effects

- 1 to the health of e-waste workers and also local residents, including  
 2 carcinogenic effects.
- 3 c) Polibrominated byphenils (PBBs) and polychlorinated biphenyls (PCBs).  
 4 Workers exposure to PBBs and PCBs through inhalation or dermal  
 5 contact in WEEEs dismantling and recycling facilities have been eva-  
 6 luated in Northern China (Yang et al, 2013). Serum concentration  
 7 of several PBBs congeners was measured: the mean concentration  
 8 resulted 0.52 ng/g lipid, about 9 times higher than a control group.  
 9 20 PCBs congeners have been measured in the serum of workers  
 10 and control group. PCBs were 44.1 ng/g lipid in workers, about 4  
 11 times higher than controls.
- 12 d) PAHs (Polycyclic Aromatic Hydrocarbons). Sixteen different PAHs  
 13 have been measured in the air of a WEEEs recycling site in China  
 14 (Zhang D et al, 2011), founding an air mean concentration of 744  
 15 ng/m<sup>3</sup>.

## 16 2.2. Metals

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

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

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

6 Regarding Mercury (Hg), another well-known neurotoxic metal, in a  
7 French study conducted in fluorescent lamps recycling facilities (Zimmer-  
8 mann F et al, 2014), the mean Hg indoor concentration was 15.4  $\mu\text{g}/\text{m}^3$ ,  
9 that is above the ACGIH occupational limits for exposure to Hg alkyl  
10 compounds.

11 Considering cancer risk, a recent study from Hong Kong (Lau et al,  
12 2014) performed a *human Health Risk Assessments* and the cancer risk in  
13 WEEE workers for the exposure to Cadmium (Cd), Chromium (Cr) and  
14 Nickel (Ni) has been estimated. Authors found that in the workers of the  
15 dismantling area, for all these three carcinogens the cancer risk was above  
16 the acceptable level.

### 17 **3. Estimating the adverse health effects for workers employed in WEEE** 18 **recycling activity: a Health Risk assessment**

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

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