Finnish Institute of Occupational Health

Genotoxicity in peripheral blood leukocytes and reticulocytes of e-waste management workers

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HBM4EU science and policy for a healthy future
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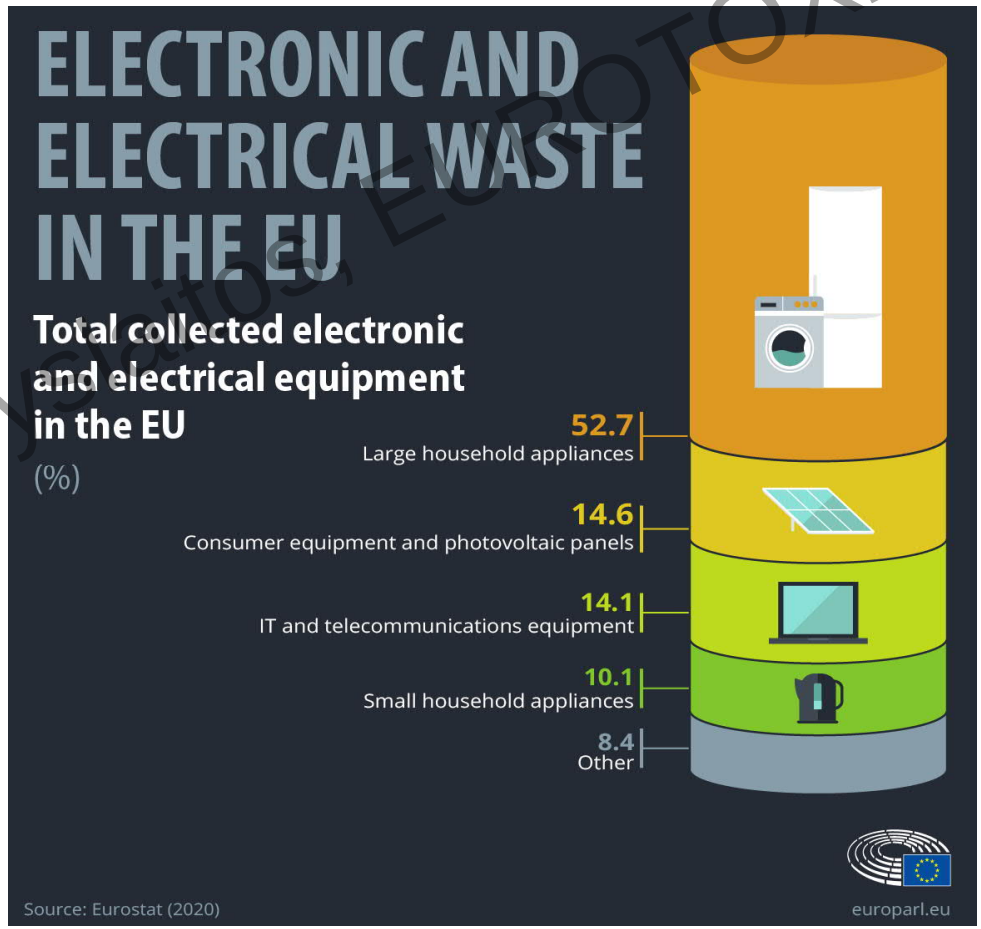
PARC
Partnership for the Assessment of Risks from Chemicals

E-waste

A variety of different electronic and electric products that are thrown away after use, including both “white goods” such as refrigerators, washing machines, and microwaves and “brown goods” such as televisions, radios, computers, and mobile phones.

Discarded electronic and electrical equipment contains harmful chemicals that can pollute the environment and increase the health risks for employees involved in e-waste recycling.



HBM4EU: E-waste study

Study objectives:

- Identify the most relevant compounds in e-waste processing
- Collaborate with employers and employees in the public and private sector
- Address questions and concerns that employers and employees might have
- Implement human biomonitoring with sufficient supportive measurements and contextual data to identify means for further improvement of occupational hygiene practices.

2021-2022

8 countries

195 e-waste workers

73 controls

Scheepers, et al. (2021) Int J Environ Res Public Health. 18(24):12987. doi: 10.3390/ijerph182412987

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Biomarkers

	Biomarkers	Matrix	Time of sampling
Exposure	Cadmium (Cd), Chromium (Cr), Lead (Pb) and Mercury (Hg)	Urine	Pre- and post-shift, end of the work-week
	Organophosphate flame retardants (OPFRs)	Urine	Pre- and post-shift, end of the work-week
	Phthalates and non-phthalate plasticizers	Urine	Pre- and post-shift, end of the work-week
	Cadmium (Cd), Chromium (Cr), Lead (Pb) and Mercury (Hg)	Blood	End of the workweek
	Brominated flame retardants (BFRs) and polychlorinated biphenyls (PCBs)	Blood	End of the workweek
	Cadmium (Cd), Chromium (Cr), Lead (Pb) and Mercury (Hg)	Hair	Before the workweek
Effect	Micronuclei in blood reticulocytes (MNRET)	Blood	End of the workweek
	Micronuclei in blood lymphocytes (MNPBL)	Blood	End of the workweek
	Telomere length (TL)	Blood	End of the workweek
	Epigenetics	Blood	End of the workweek
	Inflammatory markers	Blood	End of the workweek
	Micronuclei	Buccal	End of the workweek
	Metabolomics	Urine	Pre- and post-shift, end of the work-week

Exposure to metals in e-waste management

Mainly inhalation and skin exposure, also inadvertent ingestion exposure (hand to mouth).

Cadmium:

- Often CdO2 or CdS
- Alloyed with other metals in cables
- Ni-Cd batteries

Classified as human carcinogen (IARC, Group 1)

Chromium:

- Anti-corrosion agent
- Previously in floppy disks and data tapes
- Urinary Cr reflect recent exposure to both CrIII and CrVI
- Cr in red blood cells reflects long-term exposure to CrVI

CrVI classified as human carcinogen (IARC, Group 1)

Lead:

- In most electronics
- Lead-acid batteries
- Cables
- Cathode ray tubes

Inorganic Pb classified as probable carcinogen (IARC, Group 2A)

Mercury:

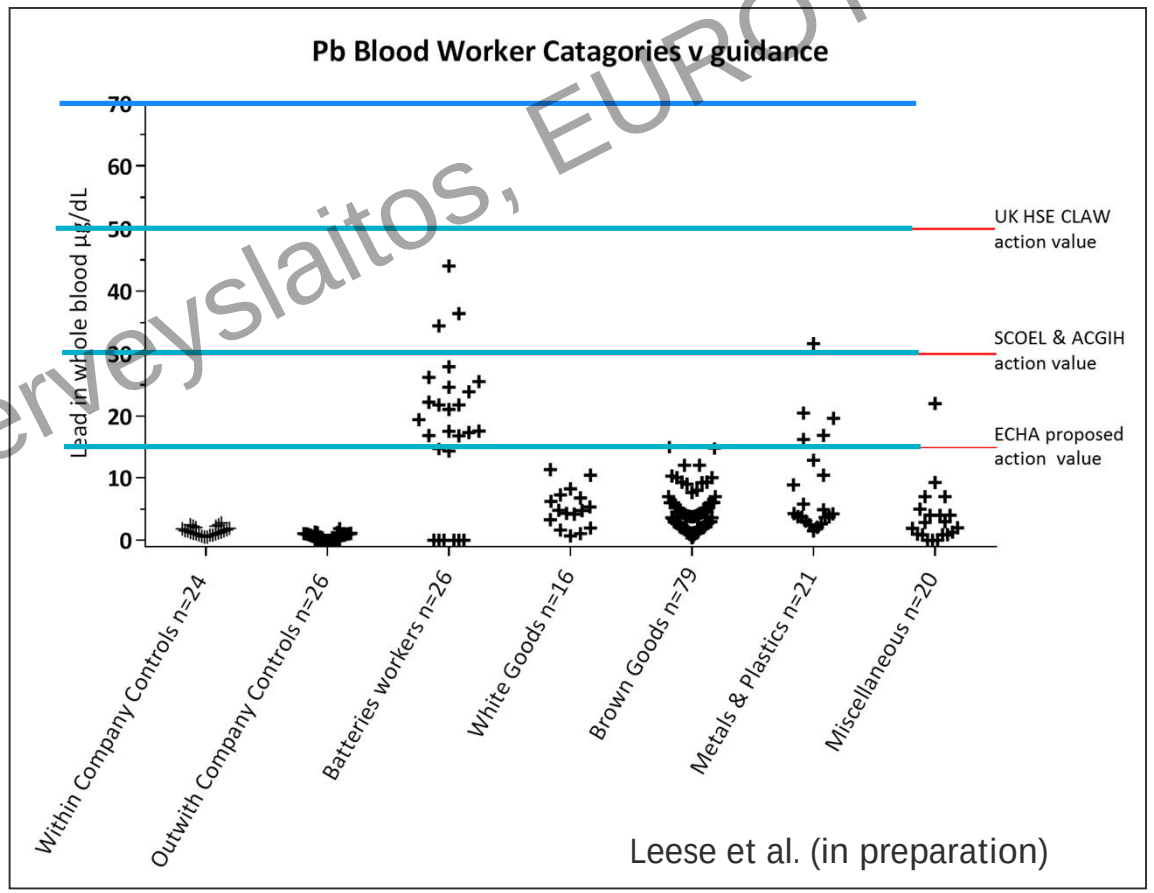
- In most electronics
- Highly in fluorescent lights and LCD screens
- Hg in urine reflects mainly exposure to inorganic mercury

Exposure to metals by work tasks

	Pre-shift urinary metals (gMean, µg/g creatinine)					Post-shift urinary metals (gMean, µg/g creatinine)					Blood metals (gMean, µg/l)			RBC Cr (gMean,µg/l)
	n	Cd	Cr	Pb	Hg	n	Cd	Cr	Pb	Hg	n	Cd	Pb	CrVI
Total E-waste workers	177	0.21	0.19	1.43	0.51	188	0.19	0.21	1.45	0.48	187	0.42	42.17	0.71
Batteries	25	0.31	0.20	7.53	0.54	22	0.23	0.18	8.59	0.43	26	0.29	157.37	0.45
White goods	46	0.21	0.28	0.77	0.26	45	0.19	0.35	0.68	0.30	41	0.45	24.34	0.98
Brown goods	55	0.18	0.16	1.36	0.63	80	0.19	0.17	1.22	0.70	79	0.42	35.44	0.73
Metals and plastics	20	0.19	0.15	1.68	0.51	21	0.20	0.17	2.38	0.39	21	0.55	60.53	0.69
Miscellaneous E-waste	15	0.23	0.14	1.07	0.38	20	0.17	0.20	1.39	0.47	20	0.41	31.94	0.46
Total controls	67	0.14	0.22	0.39	0.26						69	0.25	15.14	0.72
Within company controls	38	0.14	0.23	0.37	0.22						43	0.25	12.28	0.50
Outwith company controls	29	0.14	0.21	0.43	0.34						26	0.26	21.40	1.28

Blood lead and HBM guidance values

- Action values for Pb in blood
  - 70 µg/dL (current EU binding BLV)
  - 50 µg/dL (UK HSE CLAW)
  - 30 µg/dL (SCOEL and ACGIH)
  - 15 µg/dL (recommended by ECHA RAC)



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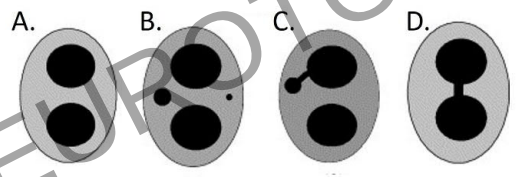
Genotoxicity biomarkers allow the detection of early effects that result from the interaction between the individual and the environment; they are therefore important tools in cancer epidemiology.

Ladeira C, Smajdova L; AIMS Genet. 2017

Biomarkers of Genotoxicity

Micronuclei in peripheral blood lymphocytes (MNPBL) INSA

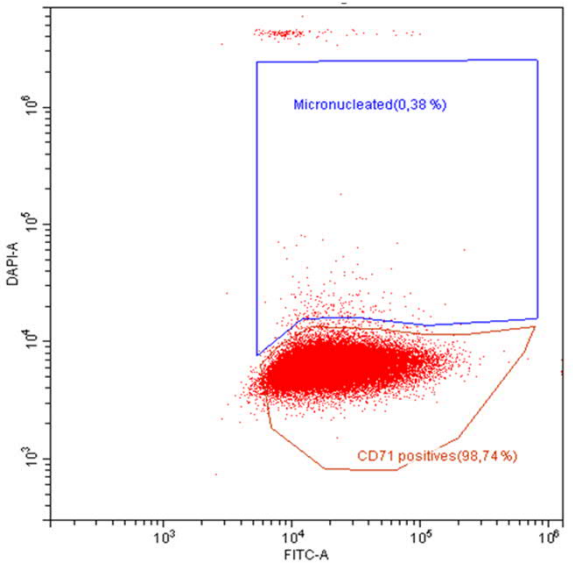
- Reflect long-term exposure and cumulative effects.
- Epidemiological studies have shown an association between elevated MNBPL frequencies and cancer risk.



A) Binucleated cell; B) Micronucleated cell; C) Nuclear bud; D) Nucleoplasmic bridge

Micronuclei in +CD71 reticulocytes (MNRET) FIOH

- Reflect recent genetic damage in bone marrow approximately three days prior to sample collection.
- One of the more recent tools in human biomonitoring.
- Flow cytometry allows rapid analysis of large number of reticulocytes (20 000 -100 000 cells, >1000 cells/second).



Telomere length (TL) NIOM

- Several factors can induce telomere instability, but molecular mechanism is still unclear.
- Both shortening and lengthening of telomeres has been reported in association with occupational and environmental exposures.

Study population

	MNPBL		MNRET		TL	
	Workers (n=95)	Controls (n=50)	Workers (n=82)	Controls (n=41)	Workers (n=131)	Controls (n=57)
Gender						
Male	87 (92%)	35 (70%)	76 (93%)	29 (71%)	114 (87%)	39 (68%)
Female	8 (8%)	15 (30%)	6 (7%)	12 (29%)	17 (13%)	18 (32%)
Age						
Mean (SD)	44.0 (9.9)	41.3 (9.4)	44.3 (9.8)	43.1 (9.2)	42.3 (9.6)	41.0 (9.4)
Min-Max	18-64	21-60	23-64	21-60	18-64	21-60
Smoking status						
Non smoker / former smoker	57 (60%)	42 (86%)	47 (57%)	35 (86%)	83 (64%)	48 (86%)
Current smoker	38 (40%)	7 (14%)	35 (43%)	6 (15%)	48 (37%)	8 (14%)
Alcohol consumption						
High	14 (15%)	1 (2%)	12 (15%)	1 (2%)	14 (11%)	1 (2%)
No / low	81 (85%)	48 (99%)	70 (85%)	40 (97%)	117 (90%)	55 (98%)
Home location						
Urban	63 (66%)	32 (64%)	53 (65%)	27 (66%)	99 (76%)	38 (67%)
Rural	32 (34%)	18 (36%)	29 (35%)	14 (34%)	32 (24%)	19 (33%)

Biomarkers of genotoxicity by work tasks

	MN PBL (Mean ± SD)						MN RET (Mean ± SD)			Telomere length (Mean ± SD)		
	n	MNBC (‰)	MN in BC (‰)	NBUD (‰)	NPB (‰)	CBPI	n	Mni (‰)	No. +CD71 RETs	n	kb pairs per genome	kb
Total E-waste workers	95	9.16 ± 5.71	10.10 ± 6.12	1.82 ± 1.59	0.39 ± 0.70	1.75 ± 0.20	82	5.05 ± 3.88	158462 ± 57324	134	25.85 ± 18.56	0.56 ± 0.4
Batteries	23	10.68 ± 4.23	11.72 ± 4.69	2.16 ± 1.93	0.67 ± 0.82	1.76 ± 0.19	18	4.66 ± 3.14	171812 ± 43768	23	40.49 ± 25.48	0.88 ± 0.55
White goods	38	8.71 ± 4.82	9.80 ± 5.57	2.19 ± 1.30	0.38 ± 0.76	1.72 ± 0.21	32	4.09 ± 2.70	146539 ± 64126	40	21.12 ± 13.07	0.46 ± 0.28
Brown goods	12	11.91 ± 10.94	12.51 ± 11.11	0.72 ± 1.32	0.25 ± 0.45	1.84 ± 0.20	10	8.32 ± 5.78	137375 ± 59397	47	26.99 ± 14.73	0.59 ± 0.32
Metals and plastics	18	6.89 ± 3.47	7.56 ± 3.77	1.56 ± 1.58	0.17 ± 0.49	1.75 ± 0.17	18	5.13 ± 4.40	179330 ± 51288	18	19.35 ± 8.87	0.40 ± 0.2
Miscellaneous E-waste	4	6.58 ± 2.62	7.79 ± 2.68	0.75 ± 0.96	0.42 ± 0.63	1.82 ± 0.09	4	6.07 ± 4.11	152585 ± 56198	6	30.40 ± 20.90	0.66 ± 0.45
Total controls	50	8.44 ± 4.93	9.31 ± 5.42	1.74 ± 1.50	0.67 ± 1.01	1.65 ± 0.24	41	5.69 ± 4.21	156387 ± 60094	57	25.38 ± 20.80	0.55 ± 0.45
Within company controls	28	8.60 ± 5.32	9.37 ± 5.92	1.34 ± 1.23	0.77 ± 1.14	1.73 ± 0.21	27	5.57 ± 4.09	144132 ± 64521	34	27.08 ± 21.20	0.59 ± 0.46
Outwith company controls	22	8.24 ± 4.50	9.25 ± 4.85	2.27 ± 1.66	0.56 ± 0.81	1.54 ± 0.22	14	5.92 ± 4.58	180023 ± 43269	23	23.08 ± 20.15	0.50 ± 0.44

In conclusion

- Workers in e-waste recycling are exposed to several heavy metals. Levels of Cd, Pb and Hg in urine and blood were higher in e-waste workers than in controls.
- In future studies the detected lead exposure of the battery workers deserves priority as their blood values exceeded the new action value proposed by ECHA RAC.
- Elevated levels of PBL micronuclei were measured in battery workers, who also had longer telomeres compared to the controls.
- No statistically significant differences were detected by the reticulocyte micronucleus assay.
- In some task groups the number of studied workers was too small for statistical analysis, more e-waste workers are recruited in the PARC-project.
- Rapid development and growth of the electronics industry calls for continuous exposure assessment also among the e-waste management workers.

PARC

Partnership FOR THE Assessment OF Risks FROM Chemicals

PARC supports further analysis HBM4EU data to generate more information on exposure sources and routes, exposure-effect and pathway analyses.

PARC T4.1.1.4 Occupational studies - Waste management survey

- A follow-up study in wider sector of waste management (e-waste and plastics recycling) and including a higher number of exposure and effect markers to be analysed

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Thank you!

Questions?

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IN COOPERATION WITH

the HBM4EU E-waste study team.

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