BIOMONITORING OF VIETNAMESE RURAL HOME-BASED WOMEN ELECTRONIC WASTE RECYCLING WORKERS

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Introduction

The worldwide increase in demand for new electronics and the rapid obsolescence of personal electronics has caused increasing volumes of electronic waste (e-waste) to be generated each year. E-waste is the fastest growing portion of the waste stream[1]. In 2005, the United Nations Environmental Programestimated the volume of e-waste generated to be about 20 to 50 million metric tons per year[2]. E-waste is being exported from industrial countries in increasing quantities to less developed countries including China, India and Vietnam for recycling, salvaging and, when recycling is not possible, for disposal in landfills[3]. For some developing countries, recycling is an important industry that can both salvage reusablee-waste components and provide income for workers and their families. However, e-waste recycling practices and industries are often crude and do not safeguard the environment or human health. Additionally, e-waste dismantling sites are sometimes situated in rural areas where crops are grown, potentially leading to the contamination of soil, crops, and livestock.

E-waste recycling workers,who can dismantle, heat or incinerate e-waste,can be exposed to pollutants and other endocrine disruptors including polychlorinated dibenzo-p-dioxins and furans (PCDD/F), polybrominateddiphenyl ethers (PBDEs), and metals[4]. Potential health effects that have been associated with such exposure have been reported to include endocrine disruption, reproductive and developmental perturbation, nervous system pathology, immune system disruption, cardiovascular disease, and cancer in animals or humans[5]. Pregnant women and children living in proximity to e-waste sites are especially at risk for adverse reproductive and developmental outcomes[6]. Polychlorinated naphthalenes (PCNs) have been used in, for example, casting material for many electronics, including cable insulation[7]. Even though production of PCNmaterials have been halted, they might still be present in older electronics being dismantled in developing countries. Major sources of PCNs released into the environment are likely from waste incineration and disposal of items[7]. E-waste recycling in Vietnam frequently takes place in the home; consequently, there are few safety measures in place to reduce potentially unsafe exposures. This pilot biomonitoring study compares women working as home based e-waste recyclers in rural Vietnam with other women of similar age from the same region who are not knowingly exposed to chemicals from industrial sources.

Materials and methods

Field and Laboratory Methods: Ten women 18-52 years old home-based e-wasterecyclers in rural Vietnam and ten matched comparisonswere chosen. Matching was done by work status (chemical contamination known or not), age (plus or minus five years), childbirth (yes or no), history of nursing after delivery, sources of water supply (deep-water wells, drilled wells or rain water), dietary intake (fish, rice, chicken), and smoking and drinking habits.Whole blood, serum, and urine specimens were collected from each person. PCDD/F activity wasestimated in whole blood by the CALUX (Chemical Activated Luciferase Gene Expression) biological screening test and in serum by gas chromatography-mass spectroscopy (GC-MS). Hiyoshi Laboratory in Shiga, Japan performed the CALUX biological screening testing and Centers for Disease Control and Prevention in Atlanta (CDC) performed the GC-MS analyses. Analyses were also performed at CDC to measure PBDEs, dioxin like and non-dioxin like PCBs, PBBs, PCNs and persistent halogenated pesticides. Metal analyses were performed at CDC in whole blood or urine using inductively coupled plasma-dynamic reaction cell-mass spectrometry (ICP-DRC-MS). Inorganic and organic forms of arsenic and mercury were measured by high-performance liquid chromatography (HPLC) coupled to GC-ICP-DRC-MS.
Statistical Methods: Because the study utilized a matched design and the sample size was small (n=10 e-waste recyclers and n=10 comparisons), a one-sample Wilcoxon signed-rank test was applied to determine whether

paired differences between e-waste recyclersand comparisons were greater than zero in terms of PCDD/F, PBDEs, PCBs, PCNs and pesticides.For PCDD/Fand dioxin-like chemicals, statistical analyses were performed on both CALUX and GC-MS median toxic equivalency (TEQ) data.

Results and Discussion
The CALUX assay is a rapid and sensitive technique in assessing the total dioxin equivalency (TEQ) concentration, that is the total dioxin like activity of a mixture of dioxins and dioxin like (DL) compounds[8,9].The moderately higher TEQ reported with CALUX compared to GC-MS TEQ is consistent with the presence of other chemicals, for example PCNs in addition to PCDD/F and DL PCBs. These are detected in the CALUX screening test, but not all are measured in congener specific GC-MS analyses. The CALUX results warrant further investigation with a larger sample size given the *p*-value of 0.08 comparing e-waste recyclers to a matched unexposed comparisongroup.The somewhat higher TEQ medians reported with CALUX (14 pg/g) compared to GC-MS TEQ (10.9 pg/g) for workers is consistent with the presence of other chemicals, for example, PCNs in addition to dioxins, dibenzofurans and DL PCBs being detected in the CALUX testing.

PBDE data is provided in Table 1. Overall, eleven PBDE congeners were measured. Of the three PBDEs (BDEs 153, 183 and 209) with detectable levels in 30% or more of the study participants, only BDE 153 was found to be present at a concentration that was statistically significantly higher (p=0.04) in the e-waste recyclers (median 3.7 ng/g lipid) than the comparison group(1.1 ng/g lipid). The p-value for BDE 183 was 0.053 suggesting the need of a larger sample size. The congener pattern is consistent with exposure to commercial products OctaBDE and DecaBDE, but not the PentaBDE.

Table 1. Median and range concentration (ng/g lipid) of PBDEs in e-waste recyclers and comparisons (non-detected results set to zero)

Group / Analyte	Median (Range)	% Detect	Median LOD	p-Value[a]
E-waste Recyclers (n=10)				
PBDE-153	3.7 (1.4 - 21.5)	100	0.8	0.04*
PBDE-183	3.0 (0.9 - 13.5)	100	0.8	0.05
PBDE-209	4.3 (0 - 43.1)	50	8.2	0.16
$\sum_3$PBDE[a]	12.1 (2.4 - 70.5)	n/a	n/a	0.16
Comparison Group (n=10)				
PBDE-153	1.1 (0 - 10.7)	90	0.9	Ref
PBDE-183	0 (0 - 48.3)	30	0.9	Ref
PBDE-209	0 (0 - 32.7)	10	9.0	Ref
$\sum_3$PBDE[a]	1.45 (0 - 59)	n/a	n/a	Ref

a. One-tailedWilcoxon signed rank test comparing two groups, *: p-value less than 0.05

GC-MS congener specific analysis was performed for PBDD/F and PCDD/F, DL PCBs, non-DL PCBs, and PCNs. Table 2 presents the results associated with the Wilcoxon signed-rank test. 2,3,4,7,8,-PentaCDF and 1,2,3,6,7,8-HexaCDF were found to be present at a significantly higher concentration in e-waste recyclersthan comparisons. There were also significant p-values (0.043 and 0.043) for two of the DL PCBs: 3,3,4,4-PCB and 3,4,4,5-PCB. However, of the 35 non-DL PCBs measured, there were no significant differences observed between e-waste recyclers and comparisons.

Table 2. Detectable Congeners of Dioxins, Dibenzofurans and DL PCBs (ng/g lipid)

Congener	Median (Range) workers	Median (range) comparison	p-Value
123467D	6.4 (0.7- 11.8)	4.6 (0.75- 42.2)	0.237

OCDD	63.25 (35.3-131)	51.1 (28.1- 124)	0.157
23478F	7.75 (3.4-11.2)	6.5 (0.55- 8.1)	0.033*
123478F	3.9 (3- 5.1)	3.5 (0.4- 4.2)	0.061
1234678F	5.25 (0.55- 7.7)	5.0 (2.3-18.7)	0.171
123678F	5.1 (0.45- 7.9)	3.7 (0.35- 6.1)	0.043*
3344PCB	33.1 (13- 99.7)	40.8 (21- 164)	0.043*
3445PCB	4.55 (3-7.7)	6.3 (3.5-11.1)	0.043*
33445PCB	20.15 (10.1-27.8)	18.6 (13.5-37.4)	0.157
334455PCB	13.2 (6-17.1)	12.9 (6.5-24.4)	0.339

*: Significant result based on one-tailed Wilcoxon signed-rank test.

SixPCN congeners were measured and Table 3 shows PCNs 52-60 and PCNs 66-67 that had detectable levels in 30% or more of the study participants. The p-value for congeners 52-60 was 0.389. The p-value for 66-67 was 0.019, showing significantly higher exposure for these congeners in these e-waste recyclers.

Table 3. Wilcoxon signed-rank test for PCN 52-60 and PCN 66-67 (ng/g lipid)

PCN Congeners	Group/Parameter	Mean	Median	P-Value
52-60	E-waste recycler	49.9	55	
	Comparison	49.4	50.4	
	Difference	0.4	13.5	0.389
66-67	E-waste recycler	45.5	45.9	
	Comparison	35.9	35.5	
	Difference	9.5	3.4	0.019*

*: Significant result based on one-tailed Wilcoxon signed-rank test.

DDT and its persistent DDE metabolite were also measured and, although not associated with e-waste recyclers, the median concentrations found were higher (4.1 ng/g and 4.3 ng/g respectively)than those of the US general population(3.16 ng/g)[10].As expected, most of the pesticides that were measured show no difference between e-waste recyclers and comparisons. But β–Hexachlorocyclohexane (B-HCCH) differs significantly between the two groups (p = 0.017). For reasons not known to us the median level of B-HCCH in the control cohort is much higher than that in the case cohort (5.4 vs. 0). This is comparably higher than the levels measured by the National Health and Nutrition Examination Survey (NHANES) in the United States that measured the 50thpercentile as lower than the detection limit[11].

Median urine concentrations were significantly higher in e-waste recyclers than comparisons for arsenous acid, monomethylarsonic acid, cobalt and mercury (3.5 v 2.5, 7.0v 5.1, 0.6 v 0.4, 1.0 v 0.4 ug/g creatinine,respectively). Serum metals median levels were significantly higher in e-waste recyclers than comparisons for copper and zinc with medians 91.9 v 85.2 and 72.8 v 60.3 ug/dL, respectively. The remainder of the metals (i.e. cadium, lead, arsenobetaine, cadmium, dimethylarsinic acid, molybdenum, antimony, strontium, total arsenic, tungsten) were detected at higher levels in the e-waste recyclers than the comparisons but were not statistically significant. Lack in statistical significance may possibly be due to the small sample size. In our next study, we plan to also study e-waste recyclers who also have exposure to heated products (not dismantling only, as in this study); this mightexpose e-waste recyclers to greater or different patterns and levels of metals and organics.

The results of this pilot study indicate that these workers involved in electronics recycling in home based workplaces have elevated levels of some PBDEs, some metals and some dioxin-like compounds. We feel it is important to continue this research with a larger sample size to better assess Vietnamese women e-waste workers exposures to PBDEs, PCDD/F. PBDD/F, DL PCBs, PCNs, metals and other toxic chemicals to which they have been exposed.

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