Mobile Toxic Waste:

Recent Findings on the Toxicity of End-of-Life Cell Phones

A Report by
Basel Action Network (BAN)

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Introduction

The Basel Convention, which first and foremost is the world's only legally binding global instrument on hazardous wastes that deals with their definition, and the general and specific obligations of country Parties regarding their disposal and transboundary movement, has recently taken a special interest in end-of-life mobile phones through a partnership program with industry known as the Mobile Phones Partnership Initiative.

Remarkably however, that Basel initiative seems to be going out of its way to avoid addressing the obvious questions of whether or not discarded mobile or cellular phones (cell phones) qualify as hazardous waste and are thus subject to the Basel Convention's obligations. For this reason the Basel Action Network (BAN) felt compelled to publish this short report to fill the surprising vacuum in clarifying this matter of concern to all parties.

While it is generally known that electronic and electrical equipment contain hazardous materials, until very recently there have not been scientifically valid test results, which provide specific data on the toxicity of mobile or cellular phones in particular.

The Toxicity Characteristic Leaching Procedure (TCLP) test, a globally accepted test for determining hazardousness from leachate sources of solid wastes, is but one standard used to determine whether wastes possess the hazardous characteristic of being able to leach harmful substances from soil to groundwater resources that qualifies the waste as hazardous.

The propensity to leach harmful substances into the environment is considered widely as a determiner of hazardousness and indeed has been instated in the Basel Convention's Annex III (H13 characteristic) as being one of the defining hazardous characteristics.[1]

Cell phones, despite their relatively small size are experiencing an unprecedented rate of increased usage globally. That fact, combined with the rapid obsolescence due either to malfunction or to rapid development of new, desired features, will create very significant volumes of wastes, posing a very serious global pollution concern both from the standpoint of disposal and recycling as well as from the possibility of transboundary movements of such wastes.

In the United States alone, experts estimate that 130 million cell phones will be discarded by the year 2005, resulting in 65,000 tons of cell phone waste.[2] The sheer volume of discarded cell phones, as well as the unanswered question of their toxicity has created an impetus for two US institutions to conduct TCLPs on cell phones and other electronic wastes.
In early 2004, the University of Florida's Solid and Hazardous Waste Engineering Program completed and announced a United States EPA-

funded study entitled “RCRA Toxicity Characterization of Computer CPUs and Other Discarded Electronic Devices” (University of Florida Study).[3]

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At almost the same time, the California Environmental Protection Agency’s Department of Toxic Substances Control performed a series of tests, including the TCLP test, on cell phones and six other types of electrical and electronic equipment. (Cal EPA Study). The results of these two studies will be the focus of this report.

Toxic Mobile Components

According to the University of Florida Study, the average composition of the cell phones tested contain 45% plastics, 40% printed wiring (or circuit) board, 4% liquid crystal display (LCD), 0% solar cell, 3% magnesium plate, and 8% metals.[4] These figures do not include cell phone batteries, which are discussed below.

Found in these materials are the following toxic substances: lead, brominated flame-retardants, beryllium, hexavalent chromium, arsenic, cadmium, and antimony.

Persistent Bioaccumulative Toxins

Many of the materials found in cell phones are also on the United States EPA’s list of persistent bioaccumulative toxins (PBTs), for which the United States EPA has set a national goal of reducing the quantity of PBTs present in waste by at least half, by the year 2005.[5] Although the United States has banned some products that contain PBTs, such as leaded paint, many PBTs continue to be used in electronics manufactured today.

PBTs are particularly dangerous because they do not degrade over long periods of time, and can easily spread and move between air, water, and soil, resulting in the accumulation of toxins far from the original point source of pollution. Because PBTs accumulate in fatty tissue of humans and animals, the toxins are gradually concentrated, putting those at the top of the food chain at the greatest risk.

According to the United States EPA, “PBTs are associated with a range of adverse human health effects, including damage to the nervous system, reproductive and developmental problems, cancer and genetic impacts.”[6] Children are a particularly sensitive population adversely impacted by PBTs.

Of the above substances, all are listed in the Basel Convention’s Annex I. Significantly, the European Union has passed the Restriction on Hazardous Substances (RoHS) Directive phasing out lead, cadmium, hexavalent chromium, and PBB and PBDE flame-retardants in electrical and electronic equipment by July 1, 2006.

Cell Phone Batteries

Rechargeable batteries, the portable power source for cell phones, are rapidly changing as technological advances improve new power sources. Already sixty percent of rechargeable batteries sold worldwide are used in cell phones.[7] However, rechargeables currently have toxic constituents such as cadmium, as well as brominated flame-retardants. Total environmental impact from cell phone batteries not only depends on a battery’s material composition, but is also a function of the length of time cell phones are used before they are discarded. Many cell phone users replace their batteries at least once before retiring their phones.

Lead

Lead, ranked as number one priority on the United States EPA’s original list of PBTs of concern,[8] has been widely used in electronics as the primary method of attaching components to the printed wiring boards, and to other components through the use of leaded solders. Lead has long been known as a toxin to both humans and the environment. It is a common contaminant and can adversely impact entire ecosystems. In humans, it affects the central nervous system, immune and vascular systems, kidneys, and the endocrine system, with serious effects on the development of children's brains and resulting intelligence quotients. Lead is also a possible carcinogen. It accumulates in the environment and has very high chronic and acute effects on microorganisms, plants, and animals.

…the printed wiring boards of the 130 million US cell phone estimated to be retired in 2005 will generate approximately 40.6 tons (81,250 lbs.) of lead waste.

Brominated Flame Retardants

Brominated flame retardants (BFRs) are primarily found in the plastic housing and printed wiring boards of cell phones to prevent flammability. A number of different types of brominated flame retardants are currently used in electronics, some of which are known to be damaging to human health and the environment, and while others are still being tested. The following are brominated flame-retardants in use:

1. Hexabromocyclododecane (HBCD)
2. Polybrominated biphenyls (PBBs)
3. Polybrominated diphenyl ethers (PBDEs)
    - Decabromodiphenyl ether (Deca-BDE)
    - Octabromodiphenyl ether (Octa-a -BDE)
4. Tetrabromobisphenol (TBBP-A)[9]

Research has demonstrated that BFRs can be persistent bioaccumulative toxins, and can leach from landfills.[10] Polybrominated diphenyl ethers (PBDEs) are associated with cancer, liver damage, neurological and immune system problems, thyroid dysfunction and endocrine disruption.[11] To make matters worse, during incineration, if copper is present (as it is in printed wiring boards), it increases the risk that BFRs will create highly toxic brominated dioxins and furans. Furthermore, if this incineration occurs at low temperatures, as is commonly found in e-waste recycling operations in developing nations, the incomplete combustion generates even higher amounts of dioxins and furans. It is important to note that any brominated compound will have this effect and thus replacing one brominated compound with another (e.g. to comply with the ROHS directive) cannot be seen as an environmental solution.

A number of body-burden studies have been done in Sweden, Japan, and North America, quantifying the level of BFRs in human breast milk. In December 2001, Environment Canada released a study showing levels of PBDEs in the breast milk of North American women that were forty times higher than the highest levels found in Sweden.[12]

Beryllium

Another troubling toxin in cell phones is beryllium, usually used in beryllium-copper alloys to increase flexibility and strength in components that need to be capable of flexing, such as contacts and springs. Some of the greatest risks from beryllium occur in manufacturing and recycling facilities, where dust or fumes expose workers to one of the most toxic metals if inhaled. Beryllicosis can cause a permanent scarring of the lungs, sometimes years after initial exposure, and can be fatal.

Toxicity of Cell Phones

Although there is now new urgency in phasing out lead in electronics, the lead solder contained in the printed wiring boards of the 130 million US cell phone estimated to be retired in 2005 alone, will generate approximately 40.6 tons (81,250 lbs.) of lead waste.[13]

Because of these concerns, the United States Environmental Protection Agency funded TCLP studies that included testing for lead in twelve different types of electronic devices. Although the investigators at the University of Florida tested for eight metals, only lead, iron, copper and zinc results are listed below. In the near future, additional test results will be available from the University of Florida indicating levels of other metals they found in the leachate from cell phones and other electronic devices.

The University of Florida Study used both the standard TCLP and a modified TCLP procedure[14] in assessing leachate results for various electronic devices, including cell phones. Using the standard TCLP, the University of Florida Study tested 43 cell phones (without batteries), using samples reduced in size to less than 0.95 cm. These are designated as (True) in the Table below.

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The University of Florida Study shows that the average concentration of lead in the resulting leachate was 20 mg/L, with 33 of the 43 samples exceeding the toxicity characteristic limit for lead, which is 5 mg/L, under US regulations – a level which has been widely accepted outside the US as well.

When the University of Florida investigators conducted a modified TCLP on 20 cell phones, the resulting average lead leachate concentration is 32 mg/L, with 15 out of 20 samples once again exceeding US concentration limits for lead.

[Note: (M.S.) indicates a modified TCLP was used, and (True) indicates a standard TCLP was used.]

Table 1: University of Florida's TCLP Test Results for Cell Phones

Sample Number	Make	Model/Year	Method	pH	Metal Concentration in Leachate (mg/L)			
					Cu	**Fe**	**Pb**	**Zn**
1	Motorola	SWF4018DF J 160017B	(M.S.)	4.9	0.01	43.	141.	6.
2	Motorola	80148WNBEA	(M.S.)	5.0	0.11	87.	115.	0.4
3	Sprint	QCP-2700	(M.S.)	5.0	0.00	5.	1.5	17.3
4	Motorola	SWF2049A H7 41843A4C	(M.S.)	4.9	0.01	6.	1.6	3.0
5	Texas Inst	TI-36X Calculator	(M.S.)	5.0	0.04	11.	0.8	1.0
6	Ericsson	CR768	(M.S.)	5.0	1.16	44.	115.	19.0
7	Nokia	2120	(M.S.)	6.3	0.00	2.	0.1	12.0
8	Nokia (b)	5160	(M.S.)	4.9	0.03	9.	11.	20.3
9	Nokia (p)	5160	(M.S.)	5.0	0.01	2.	2.	18.3
10	Motorola	Piper 34106NNDPA/1996	(M.S.)	4.9	0.00	107.	14.	4.5
11	Motorola	Piper 34106NNDPA/1996	(M.S.)	4.9	0.00	93.	15.	4.0
12	Motorola	Piper 34106NNDPA/1996	(M.S.)	4.9	0.00	119.	17.	4.1
13	Motorola	Piper 34106NNDPA/1996	(M.S.)	4.9	0.00	113.	17.	2.7
14	Motorola	Piper 34106NNDPA/1996	(M.S.)	4.9	0.00	125.	15.	3.1
15	Motorola	Piper 34106NNDPA/1996	(M.S.)	4.9	0.00	111.	16.	0.3
16	Motorola	Piper 34106NNDPA/1996	(True)	4.9	0.00	109.	20.	3.5
17	Motorola	Piper 34106NNDPA/1996	(True)	4.9	0.01	109.	21.	4.1
18	Motorola	Piper 34106NNDPA/1996	(True)	4.9	0.01	97.	16.	3.1
19	Motorola	Piper 34106NNDPA/1996	(True)	4.9	0.01	94.	17.	3.1
20	Motorola	Piper 34106NNDPA/1996	(True)	4.9	0.00	105.	20.	3.3
21	Motorola	Piper 34106NNDPA/1996	(True)	4.9	0.00	83.	18.	2.5

22	Ericsson	DF688/1997	(True)	5.5	0.01	7.	4.	4.0
23	NEC	MP5G1A-1A/1996	(True)	5.4	0.02	4.	3.	7.0
24	Nokia	2160 EFR	(True)	8.8	0.00	0.1	0.0	0.2
25	Ericsson	KH668(2)/1997	(True)	5.6	0.08	14.	16.	7.7
26	Nokia	3390	(True)	5.0	0.82	56.	60.	18.9
27	NEC	DM2100 MP5G1B1-1A	(True)	8.4	0.01	0.1	0.0	0.0
28	Nokia	5120i	(True)	5.0	0.08	56.	16.	16.0
29	Motorola	Piper 76362NNDBA/1995	(True)	5.1	0.00	121.	30.	3.1
30	Mitsubishi	G100e/1996	(True)	5.1	0.00	20.	21.	15.4
31	Qualcomm	QCP-820(2)	(True)	5.2	0.03	147.	12.	25.1
32	Ericsson	KH688/1997	(True)	5.4	0.01	17.	1.1	7.3
33	Qualcomm	QCP-820(1)	(True)	5.0	0.00	0.6	1.5	20.5
34	Nokia	6160/1997	(True)	5.0	0.22	0.3	32.	12.8
35	Nokia	2180/1995	(True)	9.0	0.00	0.0	0.	0.1
36	NEC	TR5E800-26B Portable	(True)	5.0	0.02	0.1	65.	2.4
37	Motorola	FR50/2001	(True)	5.0	0.01	0.3	6.	85.0
38	Nokia	918+	(True)	8.4	0.00	0.0	0.0	0.1
39	LGIC	LGP-2300W	(True)	5.0	0.13	0.2	23.	5.4
40	Nokia	6160i	(True)	5.0	0.17	0.3	31.	13.4
41	Nokia	6160(2)/1997	(True)	5.0	0.06	0.4	16.	19.6
42	NEC	MP5AF4-1APortable/1995	(True)	5.0	0.10	0.1	61.	15.1
43	Motorola	Micro Elite TAC Lite II	(True)	5.0	0.00	21.	21.	8.3
44	Motorola	Ultra Classic	(True)	5.0	0.00	0.1	24.	1.6
45	Motorola	Profile 300	(True)	5.0	0.09	69.	35.	0.7
46	Motorola	76254NNFDA/1991	(True)	4.9	0.35	6.	47.	1.5
47	Motorola	Micro TAC Elite(2)	(True)	5.0	0.03	59.	13.	6.8
48	Motorola	Micro TAC Elite	(True)	5.0	0.05	78.	18.	5.8
49	Qualcomm	QCP-820(3)	(True)	5.0	0.00	74.	1.4	10.7
50	Motorola	F09HLD8415BG/1991	(True)	5.0	0.00	23.	48.	15.7
51	Motorola	F09HGD8467CG/1989	(True)	5.0	0.06	20.	40.	1.5
52	Motorola	34106NNRSA/1995	(True)	5.0	0.01	66.	19.	6.0
53	Nokia	2160EFR(2)/1994	(True)	4.9	0.00	1.7	0.3	7.8

The Cal EPA Study, on the other hand, conducted two additional tests over the TCLP test, as required by California regulations, with a smaller sample size, and tested for 14 materials, including lead, copper, beryllium, and arsenic.[15] The Cal EPA utilized three testing methodologies, the Totals Test[16], the Wet Extraction Test[17], and the TCLP (see Table 2 for TCLP Results).

All three Cal EPA Study reveals that in all the tests, lead in cell phones has consistently exceeded allowable concentration limits set by both federal and state regulators. The results derived by the Cal EPA Study, thus, greatly supports the findings of the University Florida Study with regard to lead.

Table 2 Cal EPA Test Results
(in mg/kg)

	TCLP LIMIT=	**5**	**100**	**1**	**5**	**5**	**1**	**5**
ID	**e-Waste Type**	**As**	**Ba**	**Cd**	**Cr**	**Pb**	**Se**	**Ag**
17	Cell	ND	ND	0.01	ND	**52**	ND	ND
18	Cell	NA	NA	NA	NA	**NA**	NA	NA
19	Cell	ND	ND	ND	ND	**52**	ND	ND
21	Cell	ND	ND	ND	ND	**51**	ND	ND

The Basel Convention Hazardous Waste Definitions

The Basel Convention broadly defines hazardous waste as wastes that are enumerated in Annex I of the Convention, unless they do not possess a hazardous characteristic found on Annex III. Lead is included in the enumeration on Annex I and also on Annex III, the H13 characteristic (leachable at hazardous levels as demonstrated by the University of Florida and Cal EPA tests) qualifies cell-phones, even without the batteries as hazardous waste under the Convention.

Utilizing the hazardous wastes list of Annex VIII, derived from Annex I and III, we find entry number A1180 that clearly encompasses cell phones that fail the TCLP test as hazardous.

Conclusions and Recommendations

Cell-Phones at End-of-Life are Basel Hazardous Wastes

Now that Toxicity Characteristic Leaching Procedures (TCLP), and other leachate tests have been performed on a number of cell phones, there is no longer any doubt that, currently, under the Basel Convention and numerous national laws, end-of-life cell phones are hazardous wastes.

As it is likely that other toxic substances, such as brominated flame retardants, or other hazardous characteristics – such as toxicity, or ecotoxicity would make even those phones that fell below the accepted lead levels, qualify as hazardous, a wise policy would be to accept on principle that all cell phones as currently manufactured, are in fact hazardous waste as defined in the Basel Convention and numerous national laws.

Although there is progress being made to decrease or eliminate lead from cell phones and other electronic devices, lead and other toxins remain in most of the cell phones being disposed of today. Multiply these toxins by the millions of cell phones that are being disposed of, recycled, or sent into the reuse market around the globe, and the magnitude of the hazardous waste and its impact on the planet starts to become conceivable.

These impacts will likely be far greater in developing nations. Currently many second-hand cell phones are being sent to developing countries where they will reach their end-of-life. Additionally, non-working cell-phone wastes are expected follow the path of other e-wastes around the world, which are exported, often illegally and in contravention of the Basel Convention, to developing countries, where the processing of the hazardous wastes is having an immediate and profound impact on entire regions and its peoples.

Currently the Mobile Phone Partnership Initiative is failing to consider the legal obligations with respect to transboundary movements and disposal of hazardous waste – an obvious Convention responsibility.

Basel Convention Role

Due to the serious global environmental implications with regard to the transboundary movement and disposal of toxic cell phone wastes, it is imperative that the Basel Convention take an active role in clarifying the legal obligations with respect to end-of-life phones under the Convention.

The Basel Convention's Mobile Phone Partnership Initiative would provide the obvious opportunity to clarify and educate stakeholders and consumers about these legal obligations.

This oversight must be rectified at once, as there remains much ignorance with respect to manufacturers, customs officials, service providers, and recyclers about the existence and obligations of the Basel Convention. Before collection and recycling schemes are developed that the legal implications be loudly articulated and broadcast, to avoid widespread non-compliance with the Basel Convention and its decisions.

Finally, it is hoped that the partnership will make recommendations that call for Extended Producer Responsibility for mobile phones which will not only require producers to take responsibility for mobile phones, but will also set mandated re-use and longevity targets. These strategies are vital if we are to move toward the global and Basel Convention goals of preventing wastes and hazardous characteristics at source.

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[10] Commission of the European Communities, *Proposal for a Directive of the European Parliament and of the Council on Waste electrical and Electronic Equipment* and *Proposal for a Directive of the European Parliament and of the Council on the Restriction of the use of certain hazardous substances in electrical and electronic equipment,* "Explanatory Memorandum", Brussels, June 13, 2000.
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[12] *Id*.
[13] FISHBEIN, *supra* note 6, at 32.
[14] TOWNSEND, s*upra* note 1, at 3.2.3. Note that because of the size of some of the electronic devises, the University of Florida utilized the modified TCLP test to overcome the difficulties of reducing the large electronic devices to small homogenous sizes. Because of the size of cell phones, the modified TCLP was not used in evaluating these electronic devices. Also, the components for sampling were completely disassembled and placed into the extraction fluid, maintaining the same 20:1 liquid to solid ration as in the standard TCLP, then rotated for 18 hours. The resulting leachate was drained and tested.
[15] State of California Environmental Protection Agency, *Draft E-Waste Report: Determination of Regulated Elements in Seven Types of Consumer Products*, (forthcoming July 2004).
[16] The Totals Test is a chemical digestion test developed by the Department of Toxic Substances Control (DTSC) of the State of California Environmental Protection Agency to determine the total amount of a specific constituent in the soil. A sample is digested chemically to obtain its soluble and insoluble fractions. The total of the soluble and insoluble fractions of the sample is then compared to the total threshold limit concentration (TTLC) established by California regulators.
[17] The Waste Extraction Test (WET) is a leaching test developed by Department of Toxic Substances Control of the. Results of the WET are compared to the Soluble Threshold Limit Concentration (STLC). The WET determines the amount of a specific constituent that can be leached from the soil using a solution designed to simulate landfill leaching. It is therefore a useful test for situations where a soil would be exposed to landfill leachate, such as disposal of ash together with uncombusted organic wastes in a solid waste landfill.