



A photograph showing representative exhausted batteries uncontrolled dumped in the city of Yaounde, Cameroon

A preliminary inventory of pollutants entering into the local environment from the label on exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon: a potential source of zinc recycling

*This is a report within the framework of an Initiative undertaken by **CREPD** to Assess, Collect and Recycle exhausted batteries in the main cities of Cameroon*

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NOTE DE PRÉSENTATION

En Afrique Sub-Saharienne en général et plus particulièrement au Cameroun, l'exode rural, corollaire du déclin des conditions d'existence dans les campagnes, entraîne des taux de croissance assez élevés de la population dans les villes. La ville de Yaoundé à titre d'exemple a vu sa population passer de 1.000.000 d'habitants en 1990 à environ 1.800.000 habitants en 2005. Cette croissance de la population n'est pas suivie par l'amélioration des infrastructures et mentalités en matière de gestion des déchets ménagers et industriels. Là où quelques efforts sont faits, un manque d'éducation populaire vis à vis d'une mauvaise gestion des déchets sur la santé et l'environnement anéantit ceux-ci. Les tas d'ordures jonchent les carrefours, les marchés et les cours d'eau des quartiers populaires et résidentiels. Ces tas d'ordures contiennent des déchets de toutes sortes allant des matières organiques biodégradables aux emballages et bouteilles en plastiques en passant par des boites de conserves, piles usées et objets électroniques qui sont source de pollution en métaux lourds. De plus en plus, la combustion active est pratiquée sur ces tas d'ordures comme moyen d'élimination. Cette technique génère des fumées contenant des polluants ayant de graves répercussions sur la santé des populations et l'environnement. Malheureusement, ce problème de pollution urbaine risque de poser un problème de santé publique et de sécurité qui nuira au développement si des actions concrètes ne sont pas enclenchées.

Le Centre de Recherche et d'Éducation pour le Développement (CREPD), conscient de la menace de la pollution urbaine sur le développement, a mis sur pied un programme de recherche qui permettra d'obtenir des données, résultats et interprétations permettant de sensibiliser les décideurs et la population sur ce problème. L'un des axes majeurs de ce programme est de pouvoir inventorier tous les déchets toxiques qui se trouvent dans les ordures ménagers et industriels dans les grandes villes du Cameroun. Sur le terrain déjà, le CREPD mène des actions de collecte des piles et batteries usagées dans la ville de Yaoundé. Ces objets sont bien connus pour leur grande capacité à polluer une fois abandonnés dans la nature au terme de leur cycle de vie. Les recherches scientifiques montrent que certains des métaux lourds qu'ils contiennent baissent la défense immunitaire de l'organisme une fois ingérés. Dans un pays où le VIH/Sida est déjà un problème de santé publique, mieux gérer les ordures source de métaux lourds toxiques contribuerait aussi à combattre cette pandémie.

Le CREPD reconnaît l'importance à travailler en étroite collaboration avec les partenaires et les populations en vue de changer les comportements en matière de gestion des ordures en général et des piles et batteries en particulier. Sachant que des tonnes de piles et batteries entrent dans le marché de la consommation au Cameroun par an, et que si rien n'est fait pour empêcher

aux métaux qu'ils contiennent d'entrer dans le cycle biologique et l'environnement, quelle sera la situation sanitaire et environnemental de notre pays d'ici 15 ans? C'est la grande interrogation qui guide la démarche du CREPD qui entend œuvrer à l'extension de cette vision au niveau sous-régional.

La reconnaissance en la justesse de cette cause que nous défendons est venue au niveau du Programme des Nations Unies pour l'Environnement à travers le Groupe de travail pour le Plomb et Cadmium dont le CREPD est membre. Les bonnes volontés au-delà du Cameroun, tel le Docteur Toru OUCHI de l'Université de Kobe au Japon appuient financièrement ce projet. Les premiers résultats sont édifiants. Des piles usées collectées dans quatre quartiers de la ville de Yaoundé, près de 66% proviennent de la Chine et 26% seulement de PILCAM, l'unique entreprise Camerounaise fabriquant des piles. Ces piles sont à 98% de type carbone zinc qui est reconnu très toxique car contenant du mercure et des acides comme les chlorures d'ammonium et de zinc. Seul 1% de ces piles est de type alcalin moins toxiques et à recyclage facile.

Nous entendons poursuivre dans cette lancée guidés par la ferme conviction que la cause est juste bien que peu comprise par beaucoup de nos concitoyens.

Le Coordinateur

Dr. Gilbert KUEPOUO

RÉSUMÉ

Les résultats d'analyses portant sur un total de 2607 unités de piles usées collectées dans la ville de Yaoundé montre qu'elles sont composées des piles non rechargeables de types D, AA, AAA avec une présence mineure de pile de types C, 123 et 9-volt. Les piles rechargeables de type AAA ont aussi été collectées. 98,12% de ces piles usées collectées appartiennent au système chimique à carbone et zinc. 1 %, 0,53 % et 0,35 % appartiennent aux systèmes chimiques alcalin/manganèse, NiMH et lithium, respectivement. Quatre vingt trois (83) noms de commerce ont été identifiés sur les étiquettes que portent ces piles. L'analyse de ces étiquettes montre que 66 % de ces piles sont fabriqués en Chine. Le seul nom de fabrication domestique de piles sèches représente 26% des piles collectées. Bien que l'étiquetage sur certaines de ces piles ne montre aucune mention sur la quantité de mercure ajoutée, d'autres montrent le taux de mercure ajouté lors de la fabrication. Celle-ci varie entre 0,01 % et 0,025 % de mercure.

L'étiquetage de 52 % de toutes ces piles indique le taux de mercure ajouté alors que 45 % ne présentent aucune information sur la quantité de mercure présente dans ces piles. L'étiquetage indique aussi que 3% de ces piles sont totalement dépourvus de mercure. D'autre part, 3% de ces piles portent des étiquettes indiquant l'absence totale de cadmium et 97 % ne présentent aucune information sur la quantité de cadmium ajoutée lors de la fabrication.

La collecte et la décharge des déchets à Yaoundé se font sans séparation sélective. Les piles usées présentes dans les tas d'ordures sont pour la plupart du temps brûlées à ciel ouvert par les populations comme moyen de destruction. Une autre partie des piles usées ramassées avec les autres ordures par la municipalité (HYSACAM) va finir enterrées ou rejetées dans les sites de décharges des ordures. La combustion à ciel ouvert régulièrement pratiquée par les populations va à l'encontre de notes de caution que portent les étiquettes de ces piles. Mais aucun étiquetage ne précise la meilleure manière de mieux disposer les piles en fin de cycle de vie. Ainsi par la combustion non seulement le mercure très toxique est émis ou rejeté dans l'environnement local, mais les acides comme le chlorure d'ammonium et le chlorure de zinc aggravent la pollution. Le zinc est jeté dans la nature malgré son potentiel de récupération et de recyclage.

Mots clés : piles, Yaoundé, Chine, mercure, cadmium, recyclage, zinc

ABSTRACT

Exhausted portable batteries collected from the uncontrolled dumping in Yaounde are mostly composed of non-rechargeable batteries of type D, type AA, type AAA with minor contribution of type C, type 123 and type 9-volt batteries. Rechargeable battery units of type AAA are also present. These non-rechargeable exhausted batteries belong to the carbon zinc chemical system with 98.12 %; the alkaline manganese (1.00 %), NiMH (0.53 %) and Lithium (0.35 %) chemical systems. 83 trademarks are labeled on these exhausted batteries. Trademarks with label says coming from China contribute for about 66 %. The sole domestic trademark is labeled on 26 % of these exhausted portable batteries. Of these exhausted portable batteries, 52 % are labeled as containing 0.01 to 0.025% of mercury, and 3 % marked as mercury-free. 45 % of these batteries have no labelling notes indicating the added content of mercury. For cadmium, 3 % of these batteries are marked cadmium-free, and 97 % do not show any labelling notes indicating the added content of cadmium. These exhausted batteries will mostly end up in fire by the uncontrolled burning process despite the cautionary notes warning against such practices, and the potential of recovering zinc in cans of these batteries. Then, mercury will be released into the local urban environment, as well as acid compounds such as ammonium chloride and zinc chloride.

Keywords: labelling, batteries, uncontrolled dumping, carbon zinc, China, mercury, cadmium, zinc.

1 – Introduction

Cameroon is located in the Gulf of Guinea between Gabon, Guinea Republic and Nigeria with 15.7 millions of inhabitants (Human Development Report, 2005). Douala and Yaounde are the main cities. Douala is the coastal city and hosts the main seaport of Cameroon. Yaounde is the capital city of Cameroon with about 1 million of inhabitants in 1990 and 1.8 millions in 2005. This increase of the population in Yaounde is not being followed by the significant change of the waste disposal practice. However, the municipal waste collection system does exist, but it is very poor and inefficient, not covering the entire city. Then, the uncontrolled dumping of household waste is a common practice. Some streets are being littered with waste. Used plastics and exhausted portable batteries are the main hazardous materials persistent in uncontrolled dumping of household waste in Yaounde, Cameroon. This study focuses on exhausted portable batteries.

In fact the composition study of exhausted portable batteries is essential to the proper management of these batteries at the end of their life cycle by taking into account the recovery potential of certain metals in it, and the assessment of the health and environmental impacts.

According to Panero et al. (1995), heavy metals, which are toxic and thus liable to produce serious problems for the health and for the maintenance of the biosphere are present at different levels in all the household dry batteries. Then the uncontrolled dumping of exhausted portable batteries in household waste would release hazardous substances into the lowlands, river, water and soil. This can create several environmental and health issues. The uncontrolled burning of waste containing these batteries will exacerbate this harmful effect releasing some pollutants into the air. However, the impact of the waste mismanagement on the air, health and the biosphere is poorly assessed and hard to evaluate in Cameroon. This was stressed out during the UNEP Regional Workshop on Better Air Quality in Sub-Saharan cities in July 2006 in Nairobi by pointing out that air pollution quality is emerging as major health and environmental problem in Sub-Saharan African cities (Urban Environment Newsletter, September 2006).

This work is carried out to determine from the label, chemical systems, potential pollutants and potential recovered materials contained in exhausted portable batteries, which

are uncontrolled-dumped in the city of Yaounde. These labeled notes inform also on the countries of origin and cautionary notes marked on these exhausted portable batteries.

2 - Collection methodology

Two approaches are basically taken to commonly analyze waste composition: the output method and the material flow approach (Debra et al., 1996). Both of these methods offer advantages and disadvantages. For this study, the output method is used since the material flows approach is more applicable to large geographical areas such as the entire country rather than local studies (Debra et al., 1996). According to Tchabanoglous et al. (1993), the output method takes place at the disposal site and involved sampling, sorting and weighing of the individual components.

The field study was carried out using the output method, for a period of May-June-July-August 2006 in representative four (04) neighborhoods in Yaounde, namely, Carrière, Mokolo-Briqueterie, Nsimeyong and Mvog-mbi. These areas were selected on the base of opportunity that inhabitants have to discard household waste within the municipal waste system.

The municipal waste system in Yaounde comprises fixed dumping-collecting sites where the populations dump household wastes, which will then be collected and transported to the municipal repository site to bury or landfill. This system of collection is efficient in quarters with transport facility networks that ease the weekly collection of waste by the municipality waste trucks. In contrast to such zones, the city of Yaounde comprises mostly slum neighborhoods with poor facilities to ease the collection of household waste by the municipality, leading to the common practice of uncontrolled dumping and burning. This practice also results from the non-respect of timetable of collection at the dumpsites by the municipality.

Exhausted portable batteries were collected and the labelling (ANSI C18.1M, Part 1-2001, IEC 60086-1 and IEC 60086-2) on each unit allowed the determination of different trademarks, model numbers, battery designation, nominal voltage, countries of origin, chemical systems and the cautionary notes. This leads to inventory potential recovery materials and hazardous substances from these exhausted portable batteries.

3- Labeling of exhausted portable batteries from uncontrolled dumping in Yaounde

These exhausted portable batteries are labeled as follows: battery type, trademark, nominal voltage, model number, country of origin, chemistry and cautionary notes and reported in annexes (Annexe 1, Annexe 2, Annexe 3 and Annexe 4). Annexes also show the number of units of exhausted batteries collected in each neighborhood.

3.1: Different battery types

These exhausted portable batteries are classified according to their common designation by:

- Type D
- Type C
- Type AA
- Type AAA
- Type 123
- Type 9-volt

This classification based on the shape, dimensions and chemistry, are commonly used to distinguish different types of batteries (ANSI C18.1M, Part 1-2001).

Type D battery with a weight of c. 138 g each, has a cylinder shape of c. 61 mm in length and 34 mm in diameter, and shows a recessed negative terminal. Type C with c. 50 mm in length and 26.2 mm in diameter weighs c. 100g also shows recessed negative terminal.

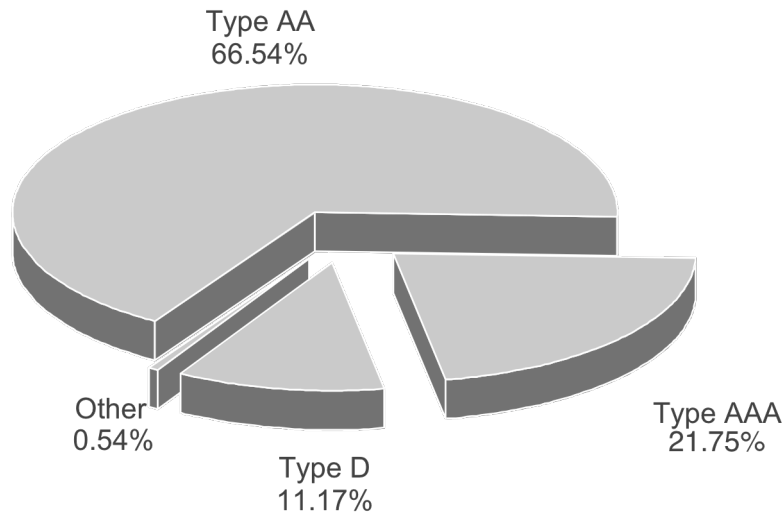
Type AA battery shows a recessed negative terminal with a weight of c. 24 g each and a cylinder shape of c. 47 mm in length and 13 mm in diameter.

Type AAA is smaller showing cylinder shape with c. 42 mm in length and 10 mm in diameter, and weighs c. 11 g each. Type AAA batteries are composed of exhausted non-rechargeable and rechargeable batteries.

Type 123 is the Lithium battery with a cylinder shape showing a diameter of 14 mm with 24 mm or 25 mm in length.

Type 9-volt battery weighs 46 g each with a square shape of c. 48.5 mm in height, 26.5 mm in length and 17.5 mm in width.

Type AA batteries are abundant and represent 66.54 % of all batteries collected in this study. They are followed by type D and type AAA with 21.75 % and 11.17 % of all batteries collected, respectively. Exhausted batteries of type 123, type C and type 9-volt constitute less than 0.54 % of all batteries collected for this study (Fig. 1)



Other : Type 9-volt, Type 123 and Type C

Fig. 1: Battery types of exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

In this study, corroded exhausted batteries do not show any information about the trademark, nominal voltage, model number and country of origin. They have been weathered with the labeling rub off and sometimes with torn battery cans. They are abundant in type D and type AAA batteries.

3.2: Trademarks

A total of 83 trademarks (Tab. 1) are labeled on these exhausted batteries from uncontrolled dumping in Yaounde. Type D batteries are labeled with 07 different trademarks. Type AA, type AAA, type 123 and type 9-volt labelled by 67, 31, 01 and 01 trademarks, respectively. Hellekens, Golston and Hitachi are labelled-trademarks dominating batteries of type D. Type AA batteries are dominated by the following labelled-trademarks: Golston, Hellekens, Royal, Vinnic, Duracell, Getready and Gao Feng Li. The trademark Panasonic dominates rechargeable batteries and type 123 batteries. Golston and Royal are trademarks dominantly labeled on type AAA batteries. These trademarks with at least 10 battery units collected are dominantly labeled on these exhausted portable batteries. These batteries represent 91.46 % of all exhausted batteries collected in this study.

Table 1 : Trademark, country of origin and number of units of exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

N°	Trademark	Country of origin	Battery types						Total
			D	C	AA	AAA	9-volt	123	
1	Golston	China	75		754	316			1145
2	Hellesens	Cameroon	79		509				588
3	Royal	China			206	53			259
4	Duracell	EC			22	8			30
5	Vinnic	unknown			26	2			28
6	Getready	China			17				17
7	Gao Feng Li	China			13				13
8	Panasonic	Japan/ USA				3		3 5	6 5
9	Eveready	Indonesia/ Singapore			3 6				3 6
10	Digital	China				9			9
11	Sonarl	China			5	4			9
12	Xionjian	China				9			9
13	Evergold	China			8				8
14	Hitachi	Japan	8						8
15	Tudor	unknown			7				7
16	Kodak	Germany/ USA			4 3				4 3
17	Durasonic	unknown			1	6			7
18	HW	China			2		4		6
19	Alcatel	unknown				6			6
20	Energy	wiped out			5				5
21	Tigerhead	China			5				5
22	Golden P.	China				4			4
23	Philips A.	China			4				4
24	Toshiba	Japan			1	3			4
25	Qunxing t.	China			3				3
26	Henghan	unknown			3				3
27	Yarico	China			3				3
28	Xionjian	China			3				3
29	Durabatt	unknown			3				3
30	Tectron	unknown			1	2			3
31	Energizer	Singapore			1	2			3
38	Tiger	China	1		1	1			3
32	East Power	unknown			1	1			2
33	Aerocell	EU			2				2
34	Everyday	unknown			2				2
35	Panasuper	Russia		2					2
36	Tetron	unknown			2				2
37	Maxwell	Japan			2				2
38	Saline	UE			2				2
40	East Power	China			1	1			2
41	Super Electric	Indonesia	2						2
42	Sony	Japan	1			1			2
43	Paiyi	China				2			2

Table 1 (continued)

N°	Trademarks	Country of origin	Battery types						Total
			D	C	AA	AAA	9-volt	123	
44	MC Zen G.	China				2			2
45	TD force	China				2			2
46	Philips P.	China			1				1
47	Brothers	unknown			1				1
48	Evepower	unknown			1				1
49	Huatai	China			1				1
50	Cegasa I.	UE			1				1
51	Dongba	China			1				1
52	Zengyi	China			1				1
53	Tinko	unknown			1				1
54	Livstar	unknown			1				1
55	Universal A.	Germany			1				1
56	Arico	China			1				1
57	Superpower	unknown			1				1
58	GP Ultra	China			1				1
59	Super E.	Indonesia			1				1
60	CNB Chener	unknown			1				1
61	Sharp	Japan			1				1
62	Daimon	Belgium			1				1
63	Kingwell	unknown			1				1
64	Longlife	China			1				1
65	Photo	Germany			1				1
66	Spadelove	unknown			1				1
67	Megation	China			1				1
68	Bigpower	unknown			1				1
69	Alcava	Korea			1				1
70	Super A.	UE			1				1
71	Philips L.	Poland			1				1
72	Sonnie	UE			1				1
73	Radiant	wiped out			1				1
74	Samsung	unknown			1				1
75	DQ Power	China			1				1
76	Durata	China	1						1
77	Best ultra	wiped out				1			1
78	Hongba	China				1			1
79	Nova	China				1			1
80	Huafeng	China				1			1
81	Amsua	unknown				1			1
82	Whitehawk	unknown				1			1
83	Motorola	Japan				1			1

Out of these trademarks, 9 to 4 battery units were collected for 16 trademarks, which represent 4.6 % of all these exhausted batteries. The remaining 63 trademarks represent 3.84 % of all batteries collected and show less than 4 battery units collected for the entire study.

3.3: Nominal voltage and model number

The labeling shows that the nominal voltage of these exhausted portable batteries is 1.5 V for type D, type AA and some non-rechargeable type AAA batteries. Rechargeable type AAA batteries show 1.2 V with some labeled 1.5 V. The label of type 123 and type 9-volt batteries shows 3 V and 9 V, respectively.

3.4: Model number

Each model number on these batteries comprises the battery type and an IEC Designation. These batteries show the following IEC designations:

- R20, R20C, R20P or LR20 for type D batteries,
- R6, R6C, R6P, R6M or LR6 for type AA batteries,
- R03, R03C, R03P or LR03 for type AAA batteries,
- CR123, CR123A or CR2 for Lithium batteries,
- R14C and 6F22 for type C and type 9-volt batteries, respectively.

Thus, to an IEC designation above is added a prefix or a suffix to get the model number for each type of batteries. For example, trademarks Hellesens and Golston label their type D batteries as IEC R20 and UM1 R20C, respectively (Annexe 1). The model numbers on trademarks Golston, Hellesens, Royal and Vinnic for type AA batteries are labeled as R6C UM3, IEC R6, R6P UM3 and R6 SUM3, respectively (Annexe 2). For type AAA batteries (Annexe 3), the model numbers are labeled as R03C UM4, R03P UM4, R03 UM-4, R03 UM4 and MN 2400 LR03 for trademarks Golston, Royal, Digital, Xiongjian and Duracell, respectively.

3.5: Countries of origin

Twelve (12) countries of origin are labeled on spent portable batteries collected from the uncontrolled dumping in Yaounde. Out of 2287 exhausted battery units collected, 1515, 588, 89, 36, 23, 8, 7, 6 and 6 are from China, Cameroon, unknown origin, EU, Japan, USA, Singapore, Germany and Indonesia, respectively. The remaining 5 battery units are from Russia, Poland, Belgium and Korea (Tab. 2).

Chinese trademarks dominate exhausted type AAA batteries. Trademarks from China and Cameroon lead type D and type AA exhausted batteries in this study. Trademarks from

USA and Japan are labeled on lithium batteries. The major part of trademarks of all rechargeable type AAA batteries are from Japan.

3.6: Labelled chemical compositions

Type D, type AA and non-rechargeable type AAA spent portable batteries collected in this study are labeled as “Heavy Duty” or “Alkaline” to which can be coupled the percentage of added Mercury and/or Cadmium. Rechargeable type AAA batteries are labeled as containing NiMH (Nickel Metal Hydride). Type 123 is labeled as containing lithium and type 9-volt as Mercury and Cadmium free.

The percentages of added mercury added on these exhausted portable batteries of type D, type AA and type AAA batteries are 0.01 %, < 0.025 % or 0.025 %, with some just showing the mark “Low mercury” (Annexe 1, Annexe 2 and Annexe 3). These units with added mercury represent 51.38 % of all batteries with a label. None of these batteries is labeled as containing cadmium (Tab. 3), but only 3.28% of these batteries show the mark of “cadmium/mercury free”(Fig. 4).

An example chemical labelling is for the trademark Golston with the mark “Extra Heavy Duty, 0.025 % Mercury” for type D, type AA and type AAA batteries (Annexe 1, Annexe 2 and Annexe 3). This mark is “Heavy Duty, 0 % Mercury-Cadmium” for the trademark Durata (Annexe 1). For the type 9-volt batteries the chemical labelling is only “0 % Mercury and 0 % Cadmium”.

A major part of batteries with heavy duty has labelling indicating the rate of mercury and/or cadmium. Out of 2286 exhausted portable batteries units showing labeling in this study, 648 units do not have a mark on chemical composition. This lack of a mark on the chemistry is observed on all batteries belonging to the domestic trademark (Hellesens). Other batteries with an unknown origin do not have a mark on the chemistry and some from China, UE, Indonesia, Singapore and Poland, as well.

Table 2 : Number of units per country for exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

Country of origin	Battery types						Total
	D	C	AA	AAA	9-volt	123	
Cameroon	79		509				588
China	77		1034	404			1515
Unknown			63	22	4		89
EU			28	8			36
Japan	9		3	8		3	23
USA			3			5	8
Singapore			7				7
Germany			6				6
Indonesia	2		4				6
Russia		2					2
Poland			1				1
Belgium			1				1
Korea			1				1
Total	167	2	1660	442	4	8	2283
Chemical systems							
Carbon Zinc	166	2	1618	420	4		2210
Alkaline manganese	1		42	10			53
NiMH			16				16
Lithium					8		8

Table 3 : Number of units with Mercury and Cadmium labeled on exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

Labeling on Mercury and Cadmium	Battery types						Total
	D	C	AA	AAA	9-volt	123	
Units with Mercury	75		771	331	0		1177
Units with Cadmium	0		0	0	0		0
Mercury free units	1		42	30	2		75
Cadmium free units	1		34	21	2		58
Mercury non-labeled	91		850	81	2		1024
Cadmium non-labeled	91		1629	421	2		2143
No chemical label	80		555	1	2		638
Labeled Units	167	2	1663	442	4	8	2286
Corroded Units	122	0	59	143	0	0	324
TOTAL	289	2	1721	585	4	8	2610

3.6: Cautionary notes

The cautionary notes for type D, type AA, non-rechargeable type AAA and type 9-volt batteries warn to not recharge these batteries, not to discard them in fire and not to insert improperly. Some cautionary messages warn not to mix used batteries with new one and to respect polarity, not to put them in backwards, not to open batteries, not to short-circuit, disassemble or heat up.

The cautionary note for the trademark Golston is “Do not recharge or dispose of in fire”, and that for Sony is “May explode or leak if recharged or dispose of in fire”. Some trademarks as Durata, Duracell and Eveready translated their cautionary message into two or more languages (Annexe 1 and Annexe 2).

The domestic trademark Hellesens does not label any cautionary notes on their batteries. Exhausted portable batteries belonging to trademarks Gao Feng Li, Xionjian, Panasuper and Maxwell (Annexe 2) show cautionary notes only in foreign languages unreadable by local people.

The cautionary notes for Lithium batteries refer to risk of fire, explosion and burns and warn not to recharge, disassemble, not to heat above 212 °C (100 °C) or incinerate. This message also warns not to mix with used or other battery types and ask to keep these batteries away from children (Annexe 4).

There are also no cautionary notes for rechargeable batteries belonging to trademarks Alcatel and Panasonic (Annexe 4). The trademark Toshiba warns to use the battery-pack only, not to use these batteries for other purposes, not to disassemble or mutilate, incinerate or heat and short circuit, since it may cause burns, burst or release toxic materials (Annexe 1). There is also warning about not to put them in backwards, mix with used or other battery types or dispose of in fire. The trademaker Sony even warns to use Sony battery chargers.

4: Data Interpretation and discussions

Exhausted portable batteries collected from the uncontrolled dumping in Yaounde are mostly composed of type AA, type AAA and type D batteries, due to their common use to energize remote controls, house watches, torches, toys, radios and cassette players in this city. Rechargeable batteries of type AAA are also present indicating their use in portable telephone battery-packs and digital cameras. Lithium batteries of type 123 were also collected suggesting their use in common cameras. However, no button cell battery was

collected whereas this type of battery is present on the market in Yaounde. It is commonly sold to energize portable watches and calculators.

China is labeled as the country of origin on 66.33% of these exhausted batteries. 25.74% of these batteries bear the domestic trademark. Other labelled countries/communities such as EC and Japan show 1.54% and 1.01%, respectively. Germany, USA, Indonesia, Singapore, Russia, Poland, Belgium and Korea are labeled on less than 1.70 % of all exhausted batteries collected (Fig. 2). Japanese trademarks are dominant labelled-trademarks on type AAA batteries with NiMH chemical system. However, trademarks not showing any label about the country of origin represent 3.72 % of all spent batteries collected in this study.

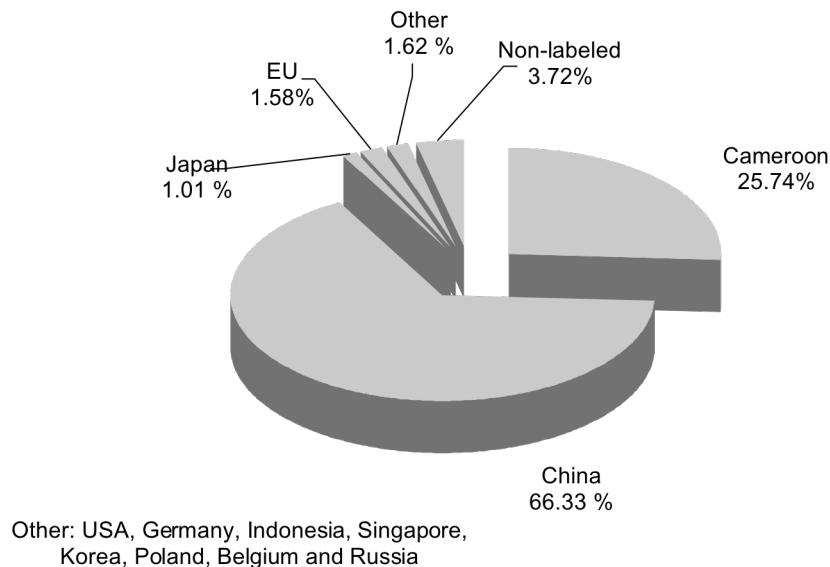


Fig. 2 : Countries of origin of exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

Less than four (04) exhausted battery units were collected for some trademarks with no labelling about the country of origin. This may suggest that batteries without the country of origin labelled-on were primary manufactured for a local market not subject to exportation. Then, these batteries were imported in Cameroon, already inserted in electronic products or appliances, such as toys, radios, cassette players, and dumped after the end of their lifetime.

The chemical systems are carbon zinc, Alkaline manganese, NiMH and Lithium batteries. These batteries belong mostly to the carbon zinc chemical system with 98.12%.

Alkaline manganese system represents 1.00 % of these exhausted batteries. NiMH and Lithium batteries represent 0.53 % and 0.35 % of these batteries, respectively (Fig. 3).

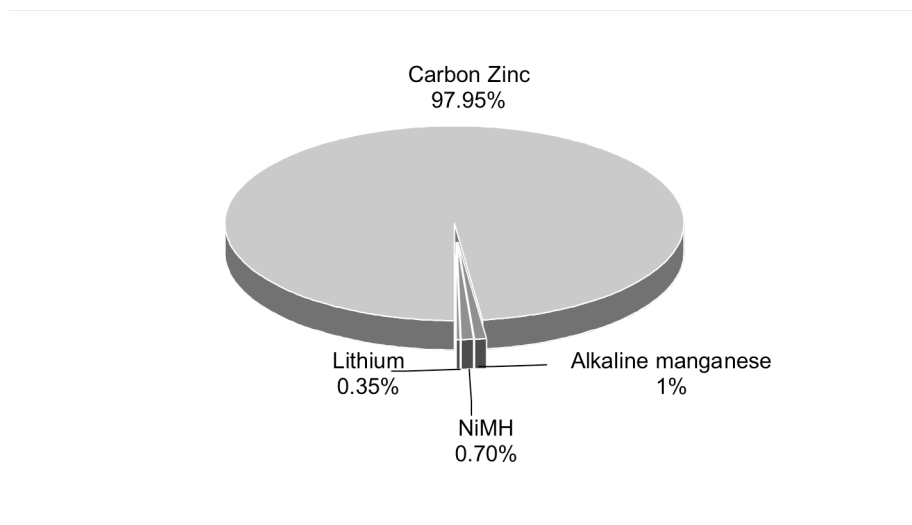


Fig. 3 : Chemical systems of exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

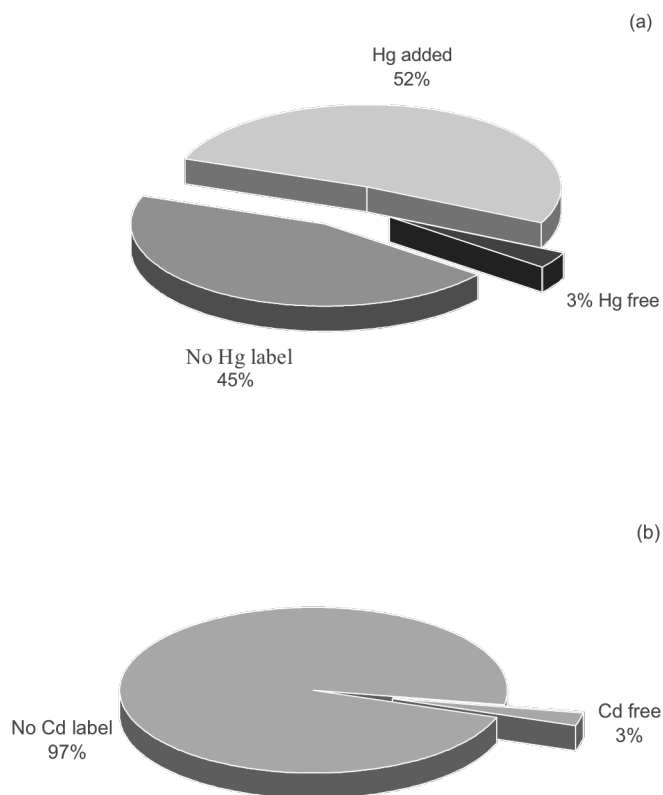


Fig. 4 : Percentage of added (a) Mercury and (b) Cadmium in exhausted portable batteries collected from the uncontrolled dumping in Yaounde, Cameroon

The hazardous metals frequent in non-rechargeable portable batteries are mercury and cadmium. 52 % of these batteries are labelled as containing added mercury; and 45 % without any label on the mercury content. 3 % show that these batteries are mercury-free (Fig. 4a). For cadmium, 3 % are cadmium-free with 97 % not showing any mark about the percentage of added cadmium (Fig. 4b). Acidic compounds are present in these exhausted batteries, since carbon zinc chemical system batteries contain ammonium chloride and/or zinc chloride as electrolyte (ANSI C18.1M, Part 1-2001).

Of all these exhausted batteries, about 13 % are corroded with torn or ruptured cans indicating the direct discharge of hazardous chemicals contained in these products into the local environment by rains and gravity forces. The major part of these exhausted batteries will end up in uncontrolled burning practiced by the local population to reduce the quantity of waste. This is in contrast with the cautionary notes warning by different trademarks not to dispose of batteries in fire. However, no trademark shows any label about the sound disposal of these batteries.

Then, toxic chemicals such as mercury and acids will be released into the local environment, as well as the potential toxic chemicals such as alkaline, zinc, manganese.

No button cell batteries were collected in this study. Nevertheless, they are commonly used and not separately collected in Yaounde. Their very low weight and smaller sizes may have led them to be easily hidden in the waste or taken away by rains. Since they content 1-2 % mercury, their adverse effect in the environment will exacerbate that of carbon zinc batteries with air, soils and ground water pollution.

The chemical system of these batteries also indicates the recovery potential of zinc enclosed in the cans. However, mercury content usually hampers the recovery of zinc in the exhausted portable batteries.

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Annexe 1: Labelling and number of units of exhausted portable batteries of type D collected from the uncontrolled dumping in Yaoundé, Cameroon

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Cautionary notes	Ca	Mb	Ns	Mm	Total
HELLESENS Type 733	1.5	IEC R20	none	none	40	15	10	14	79
GOLSTON		UM1 R20 C	100 % Extra Heavy Duty 0.025 % Mercury	Do not recharge or dispose of in fire	33	39	02	01	75
HITACHI		R20P (G)	In Japanese	In Japanese		08			08
SUPER ELECTRIC		corroded	corroded	None	02				02
SONY		LR20 (SG)	Alkaline	May explode or leak if recharged or dispose of in fire		01			01
DURATA		R20 SG Size SUM1	Heavy Duty 0 % Mercury- Cadmium	May explode in fire! Not rechargeable! Ne pas jeter au feu! Non rechargeable		01			01
TIGER		R20 UM1 "D" size	None	None	01				01
PANASUPER		Type C R14C	In Russian	In Russian	02	-	-	-	02

Abbreviation: V: Nominal voltage; Ca: Carrière; Mb: Mokolo-Briqueterie; Ns: Nsimeyong; Mm: Mvog-mbi

Annexe 2: Labelling and number of units of exhausted portable batteries of type AA collected from the uncontrolled dumping in Yaounde, Cameroon

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Cautionary notes	Ca	Mb	Ns	Mm	Total
GOLSTON	1.5	Size AA R6C UM3	100 % Extra Heavy Duty 0.025 % Mercury	Do not recharge or dispose of in fire	267	375	55	57	754
HELLESENS		IEC R.6	none	none	183	177	44	105	509
ROYAL		Size AA R6P UM3	100 % Extra Heavy Duty	Do not connect improperly, charge or dispose of in fire	56	123	04	23	206
VINNIC		Size AA R6 SUM3	Extra heavy Duty 0 % Hg/Cd added	May explode or leak if charged or disposed of in fire. Do not use used battery with new one. Make sure of the polarity	13	11	02	-	26
DURACELL		Size AA LR6 MN1500	Alkaline	May explode or leak if charged or disposed of in fire. Do not mix used battery with new one. Make sure of the polarity	13	07	-	02	22
				Respecter les polarités + et -. Ne pas recharger (Translated into many languages)					
				Connect properly. Do not recharge Do not connect improperly, charge or dispose of in fire. Battery may explode or leak					
GETREADY		Size AA R6 C	None	May explode or leak if recharged or disposed of in fire. Do not use used battery with new one. Make sure of the polarity	10	07	-	-	17
GAO FENG LI	Size AA R6 UM3	100 % Extra Heavy Duty < 0.025 % Mercury	In Chinese	04	08	-	01	13	

Annexe 2 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution	Ca	Mb	Ns	Mm	Total
EVEREADY		AA LR6	Alkaline	Insert correctly (+/-). Do not recharge (In many languages)	03	-	-	-	09
		Size AA R6	Heavy Duty Zero mercury added	corroded		06			
EVERGOLD		Size AA R6 SUM	Super Heavy Duty	May explode or leak if charged or disposed of in fire. Do not mix used battery with new one. Make sure of the polarity	08	-	-	-	08
TUDOR		R6 R6-9	None	None	01	06	-	-	07
Trademark	V	Model number	Composition	Caution	Ca	Mb	Ns	Mm	Total
KODAK	1.5	AA LR6	Alkaline	Do not recharge or dispose of in fire (in many European and Asian languages)	-	04	-	-	07
				Do not recharge or dispose of in fire. Ne pas recharger ou jeter dans le feu	01	-			
ENERGY		AA size R6 UM	rusted	Do not recharge or dispose of in fire (also in French)	03	02	-	-	05
SONARL		Size AA R6C UM3	In Chinese	Do not connect improperly, charge or dispose of in fire. Battery may explode or leak	01	04	-	-	05
TIGERHEAD		AA Size R6 UM-3	Super quality battery	none	01	04	-	-	05
PHILIPS ACCESSORIES		SBC EB1280	NiMH	Do not dispose of in fire. Do not short circuit	-	04	-	-	04

Annexe 2 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution	Ca	Mb	Ns	Mm	Total
QUNXING Toys	1.5	Size AA R6 SUM-3	none	Do not connect improperly, charge or dispose of in fire. Battery may explode or leak	01	02	-	-	03
YARICO		Size AA R6 UM3	none	none	02	01	-	-	03
XIONJIAN		Size AA R6 UM3	100 % Extra Heavy duty	In Chinese	03	-	-	-	03
HENGHAN		Size AA UM3	Super heavy Duty	none	03	-	-	-	03
DURABATT		Size AA R6 UM3	Extra heavy Duty	Do not connect improperly. Do not recharge or dispose of in fire, may leak or explode	02	01	-	-	03
POWER		Size AA R6 UM3	none	Do not dispose of in fire, recharge, put in backwards, mix with used or other battery types. May explode or leak	02	-	-	-	02
AEROCELL		Size AA LR6, mignon	0 % Hg/Cd Superalkaline	Ne pas recharger, Do not recharge. Utiliser correctement. Do not misuse. Respecter les polarités. Connect correctly	01	01	-	-	02
			Alkaline 0 % Cd/Hg						
EVERYDAY		Size AA R6	None	May explode in fire! Not rechargeable	02	-	-	-	02
TETRON		Size AA UM3	Extra Heavy Duty 0.025 % Mercury	Do not recharge or dispose of in fire	-	02	-	-	02
HW		Size AA HR6 MX	Heavy Duty 0 % Hg/Cd	Do not recharge or dispose of in fire or use used battery with new and make sure of the polarity	-	02	-	-	02
MAXWELL	LR6 (K) c- 8511-582034	Alkaline ACE	In Japanese	-	-	02	-	02	

Annexe 2 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution	Ca	Mb	Ns	Mm	Total
SALINE	1.5	AA R6	none	none	-	-	02	-	02
PHILIPS Power Life		AA LR6	Ultra Alkaline	Utiliser correctement. Non rechargeable. Do not misuse, not rechargeable	-	01	-	-	01
TINKO		AA R6	Heavy Duty, Mercury free	May explode or leak if recharged, inserted improperly or disposed of in fire. Do not open battery	01	-	-	-	01
LIVSTAR		AA R6 UM-3	0 % Mercury		01	-	-	-	01
BROTHERS		Size AA	None		01	-	-	-	01
TECTRON		Size AA R6 UM3	Extra Heavy Duty 0.025 % Hg	Do not recharge or dispose of in fire	01	-	-	-	01
EVEPOWER		AA Size R6	None	May explode if recharged or improperly installed	01	-	-	-	01
CEGASA International		Size AA			01	-	-	-	01
TIGER		AA size UM-3			01	-	-	-	01
HUATAI		Type R6C	In Chinese	In Chinese	01	-	-	-	01
DONGBA		0 % Hg			01	-	-	-	01
Universal Alkaline		None	0 % Mercury/Cadmium	May explode in fire. Not rechargeable (also in French)	01	-	-	-	01
ARICO		Size AA R6 UM3	none	none	01	-	-	-	01
SHARP		R6P SUM-3C	In Japanese	In Japanese	-	01	-	-	01
GP ULTRA		Size AA LR6	Alkaline, 0 % Mercury/Cadmium	May explode or leak if recharged, disposed of in fire or dissected	01	-	-	-	01

Annexe 2 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution	Ca	Mb	Ns	Mm	Total
TOSHIBA		AA	Alkaline	May explode or leak and cause personal injury, if recharged, disposed of in fire, put in backwards, short-circuited, disassembled, heated up, mixed with used or other battery types, immediately remove used batteries	01	-	-	-	01
EAST POWER		Size AA R6P	Extra Heavy Duty 0 % Mercury/Cadmium	Battery may explode or leak if recharged or dispose of in fire	01	-	-	-	01
SUPER ELECTRIC		Size AA R6P IEC/SUM-3	none	May explode or leak if recharged, connected improperly or dispose of in fire	-	01	-	-	01
CNB CHENER		Size AA R6M SUM3	Extra Heavy Duty	May explode if charged or set reversely	-	01	-	-	01
KINGWELL		ER SUM-3 Size		Do not dispose of in fire, recharge. May explode or leak	-	01	-	-	01
SPADELOVE		Size AA R6 UM3	Low mercury	Do not connect improperly or dispose of in fire. Battery may explode or leak	-	01	-	-	01
SUPERPOWER		Size AA R6 UP	none	Do not recharge, short or dispose of in fire	01	-	-	-	01
DAIMON		LR6	Alkaline	Do not misuse. Connect properly. Do not recharge. Utiliser correctement, respecter les polarites. Ne pas recharger	-	01	-	-	01
PHOTO		AA LR6		Do not open, recharge, dispose of in fire	-	01	-	-	01

Annexe 2 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution	Ca	Mb	Ns	Mm	Total
ENERGIZER		AA Size LR6 AM3	none	Do not install backwards, charge or put in fire. May explode or leak	-	01	-	-	01
MEGATON	1.5	Size AA R6R UM3	none	Do not recharge or dispose of in fire	-	01	-	-	01
BIGPOWER		AA R6 UM	Extra Heavy Duty 0 % Mercury and Cadmium	Do not throw in fire. Do not recharge. Do not mix used batteries	-	01	-	-	01
ALCAVA		AA Size RA6	In Korean	In Korean	-	01	-	-	01
SUPER ALKALINE		LR6	Alkaline	Non rechargeable/Ne pas jeter au feu/ Respecter les polarites	-	-	01	-	01
DQ. POWER		AA Size R6	none	Do not connect improperly, charge or dispose of in fire. Battery may explode or leak	-	-	-	01	01
ZENGYI		Size AA R6C			01	-	-	-	01
LONGLIFE		AA Size R6 UM-3	High quality battery		-	01	-	-	01
DURASONIC		Size AA	Extra Heavy Duty		-	01	-	-	01
PHILIPS LONGLIFE		AA R6		Do not misuse, not rechargeable	-	01	-	-	01
SONNIE		Size AA R6 UM3			-	-	01	-	01
RADIANT		AA R6 UM3	100 % Extra Heavy Duty	none	-	-	-	01	01
SAMSUNG		AA Size R6P UM3	none					01	01

Annexe 3: Labelling and number of units of exhausted portable batteries of type AAA collected from the uncontrolled dumping in Yaounde, Cameroon

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Cautionary notes	Cr	Mb	Ns	Mm	Total
GOLSTON	1.5	Size AAA R03C UM4	100 % Extra Heavy Duty 0.025 % Mercury	Do not recharge or dispose of in fire	101	156	31	28	316
ROYAL		Size AAA R03P UM4	100 % Extra Heavy Duty	Do not connect improperly, charge or dispose of in fire	19	01	04	29	53
DIGITAL		Size AAA R03 UM-4	Extra Heavy Duty 0 % Hg/Cd	Do not connect improperly, charge or dispose of in fire. Battery may explode or leak	04	03	02		09
XIONGJIAN			100 % Extra Heavy Duty Hg < 0,025 %	none	-	09		-	09
DURACELL		Size AAA LR03 MN 2400	alkaline	Connect properly. Do not recharge (in many languages)	01	03	-	04	08
DURASONIC		Size AAA R03 Art. N.014	100 % Extra heavy Duty 0 % Mercury	Do not connect improperly, charge or dispose of in fire. Battery may explode	03	01	02	-	06
ALCATEL		1.2	AAA	NiMH	none			06	
SONARL		Size AAA R03 UM4	In Chinese	Do not connect improperly, charge or dispose of in fire. Battery may explode or leak	04	-	-	-	04
GOLDEN POWER			0.00 % Hg/Cd	Battery may explode or leak if recharged or disposed of in fire	-	04	-	-	04
PAIYI			Extra heavy Duty 0.025 % Hg	Do not connect improperly, charge or dispose of in fire	01	01			02
MC ZEN GUANGZOU			100 % Extra Heavy Duty Hg < 0.025 %	Connect properly. Do not recharge	-	02	-	-	02

V: nominal voltage; Cr: carrière; Mb: Mokolo-briqueterie; Ns: Nsimeyong; Mm: Mvog-mbi

Annexe 3 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution/warning	Cr	Mb	Ns	Mm	Total
TD FORCE		Size AAA R03P	Extra heavy Duty Mercury/Cadmium free	May explode or leak if recharged, inserted improperly or dispose of in fire. Do not open battery	-	02	-	-	02
VINNIC	1.5	Size AAA SUM4 R03	Extra heavy Duty 0 % Hg/Cd added	May explode or leak if charged or disposed of in fire. Do not use used battery with new one. Make sure of the polarity	-	02	-	-	02
TECTRON		Size AAA R03 UM4	Extra Heavy Duty 0.01 % Hg	Do not recharge or dispose of in fire	02	-	-	-	02
ENERGIZER		AAA LR03 AAA E92 AM4	Alkaline 0 % Hg	Insert properly. Do not recharge. Respecter les polarites (+/-). Ne pas recharger	-	02	-	-	02
PANASONIC		AAA	NiMH	none	02				02
TOSHIBA		Size AAA		Battery-pack use only. Do not use for any other purposes. Do not disassemble or mutilate. May cause burns; burst or release toxic materials. Do not short circuit, may cause burns		02			
	1.2	Size AAA R03 UG	Super Heavy Duty Hg/Cd free	Do not recharge, short or dispose of in fire				01	01
MOTOROLA		none	NiMH	Do not put in backwards, disassemble, mix with used or other battery types	01				01
SONY		Size AAA mignon		Use Sony battery chargers for NH-AAA. Do not disassemble or dispose of in fire or short-circuit		01			01

Annexe 3 (continued)

Labelling					Number of units per neighborhood				
Trademark	V	Model number	Composition	Caution/warning	Cr	Mb	Ns	Mm	Total
BEST ULTRA	1.5	AAA R03 UM-4	none	Correct improperly. Do not recharge (In many languages)	01	-	-	-	01
PANASONIC		Size AAA R03 UG	Super Heavy Duty Hg/Cd free	Do not recharge, short or dispose of in fire	-	-	-	01	01
HONGBA		Size AAA R03C UM	Extra Heavy Duty	none	01	-	-	-	01
HUAFENG		Size AAA R03 UM4			-	01	-	-	01
NOVA		Size AAA R03 P	0.00 % Hg/Cd	In Chinese	01	-	-	-	01
EASTPOWER		Size AAA R03P UM4			-	01	-	-	01
AMSUA		Size AAA R03 P	Super Heavy Duty	Do not dispose of in fire, recharge, put in backwards, mix with used or other battery types. May explode or leak and cause personal injury	-	01	-	-	01
WHITEHAWK		none	0.00 % Mercury	Do not recharge; open battery; dispose of in fire; insert incorrectly (+, -); mix with used or other battery types	-	01	-	-	01

Annexe 4: Labelling and number of units of exhausted portable Lithium and type 9-volt batteries collected from the uncontrolled dumping in Yaounde, Cameroon

Labeling					Number of units per neighborhood				
Trade name	V	Model number	Chemistry	Cautionary notes	Cr	Mb	Ns	Mm	Total
PANASONIC	3	CR123A	Power Lithium	Risk of fire; explosion and burns, do not recharge, disassemble, heat above 212 °F (100°C) or incinerate. Do not mix with used or other battery types. Keep away from children	-	03	-	-	03
		CR123			-	02	-	-	02
		CR2	Lithium		-	02	-	-	02
			Power Lithium		-	01	-	-	01
HW (Hi Watt)	9	6F22	0 % Mercury & 0% Cadmium	Do not recharge or dispose of in fire or use used battery with new one	-	-	02	-	02
			none	Do not recharge or discard in fire or used battery with new one. Make sure of the polarity	-	02	-	-	02

V: nominal voltage; Cr: Carrière; Mb: Mokolo-briqueterie; Ns: Nsimeyong; Mm: Mvog-mbi