Playing Dirty

Analysis of hazardous chemicals and materials in games console components

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Contents

***Cover**: The three games controllers - Xbox 360, Playstation 3 and Nintendo Wii - are pictured here before the dismantling process begins.*
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***Left**: The Nintendo Wii outer box to the motherboard is dismantled.*
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Executive Summary

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The Xbox 360 controller is dismantled. © Greenpeace/Will Rose

The use of hazardous chemicals and materials in electronic products is widespread. Despite some recent improvements – a result of a combination of legal restrictions in some parts of the world, and voluntary action by companies – many devices still contain a variety of hazardous substances. These include chemicals which fall outside current legislative controls, as highlighted in recent studies on certain mobile phone and laptops[1]. Some manufacturers, recognising the health and environmental concerns arising from the presence of such substances throughout product lifecycles, are already starting to phase out certain hazardous substances and materials from their electronic products, including the use of all brominated flame retardants (BFRs) and the chlorinated plastic polyvinyl chloride (PVC).

Other companies have made commitments to eliminate or reduce their uses in the near future. Nevertheless, the presence of these and other hazardous substances is likely to be widespread in many electronic goods currently on the market.

Games consoles represent one of the fastest growing markets in consumer electronics. Microsoft, Sony and Nintendo are the major manufacturers in this sector. Of these, Microsoft has made a commitment to eliminate the use of PVC and BFRs in its hardware by 2010[2]. Sony committed to phase out PVC and certain uses of BFRs by 2010, though only for its mobile products and not including game consoles other than the PlayStation Portable (PSP)[3].

Nintendo very recently committed to eliminate PVC in its products, but failed to give a timeline for doing so[4].

1 Brigden, K., Webster, J., Labunska, I. & Santillo, D. (2007) Toxic chemicals in computers Reloaded. Greenpeace Research Laboratories Technical Note 06/2007: 52 pp. [http://www.greenpeace.to/publications /laptopreport2.pdf]. Brigden, K. & Santillo, D. (2006) Determining the presence of hazardous substances in five brands of laptop computers. Greenpeace Research Laboratories Technical Note 05/2006: 20 pp. [http://www.greenpeace.to/publications/toxic-chemicals-in-computers.pdf]. Santillo, D., Walters, A., Labunska, I. & Brigden, K. (2007) Missed Call iPhone's hazardous chemicals Greenpeace Research Laboratories Technical Note 08/2007: 12 pp. [http://www.greenpeace.to/publications /iPhones-hazardous-chemicals.pdf]

2 Microsoft Commitment to Environmental Sustainability, Fact Sheet February 2008. http://download.microsoft.com/download/f/8/f/f8f0fc33-3c5d-4fd8-a36e-348543f3539f/SustainabilityFactSheet.doc

3 http://www.sony.net/SonyInfo/Environment/activities/products/index.html

4 Nintendo 2007 CSR report, p. 22 http://www.nintendo.co.jp/corporate/en/csr/pdf/nintendo_csr2007e.pdf

To assess the progress of these manufacturers in eliminating these and other hazardous chemicals and materials from their products, and towards meeting their pledges, Greenpeace purchased and deconstructed one game console from each company in November 2007.

Manufacturer	Console	Country of purchase
Microsoft	Xbox 360 Elite	UK
Sony	Playstation PS3 40Gb	UK
Nintendo	Wii	Netherlands

The consoles were dismantled at the Greenpeace Research Laboratories, based at the University of Exeter (UK). A wide selection of internal and external materials and components were subsequently analysed at our laboratory and at two independent laboratories. The analyses predominantly focused on those substances regulated under the European Union's Restriction of Hazardous Substances (RoHS) Directive (2005/84/EC), which prevents the use of lead, cadmium, mercury, hexavalent chromium (VI) and certain BFRs in electrical and electronic equipment. Additional testing was carried out for certain other hazardous substances and materials, including PVC, the toxic phthalate plasticisers that it commonly contains, and beryllium-containing alloys.

Summaries of the results from the various analyses are presented below:

- For all three consoles, all components that were tested appeared to comply with the EU RoHS Directive, in that a) no cadmium or mercury was detected in any material, b) lead and chromium, found in a fraction of all samples tested, were present at relatively low concentrations, and c) hexavalent chromium, the most toxic and regulated form of chromium, was not detected in any of the metallic components tested.

- However, just over half of all the analysed components were found to contain bromine, at over 1% of the total composition of the material in almost all cases. Overall, bromine was identified in a similar fraction of the tested materials from each of the consoles, indicating continued widespread use of either additive or reactive forms of BFRs by all three manufacturers. The highest level (13.8%) was found in the fan housing from the PS3 console. All but two of the fifteen circuit boards tested contained high levels of bromine, with both 'bromine-free' materials coming from the PS3. One housing material from each of the Wii and PS3 consoles contained bromine at a high level, particularly the Wii (12.5%) and to a lesser extent the PS3 (0.3%), only trace levels were seen in equivalent materials from the XBox 360. However, the presence of the specific BFRs regulated under the RoHS Directive was not further investigated in the bromine-containing materials; therefore it cannot be confirmed whether all materials comply with the regulation for these chemicals. Nevertheless, all forms of BFRs (even those chemically-bound into polymers) can act as a significant source of toxic and persistent brominated pollutants during incineration or high temperature processing once these devices enter the waste stream.

- PVC was identified in a number of flexible materials (wire and cable coatings) from all consoles, with only small differences between the consoles. The use of PVC in these materials requires the use of plasticisers or softeners, and in many cases these included phthalate esters (phthalates). Very high levels of these were present in three materials (two from the XBox 360 and one from the PS3) making up 10.6 to 27.5% of the total weight of the materials. Although the use of PVC and phthalates is not currently regulated under RoHS, it is noteworthy that the XBox 360 and PS3 contained very high levels of two phthalates not permitted in components of toys or childcare articles sold in the EU (game consoles are not currently defined as toys under EU regulations). One of the phthalates, DEHP, is classified as toxic to reproduction: category 2[5], due to its ability to interfere with sexual development in mammals, especially males. The other phthalate identified in the XBox 360, DiNP, is also prohibited from use in toys and childcare articles if they can be placed in the mouth by children.

- The presence of beryllium-containing alloys in two components from each of the XBox 360 and PS3 consoles (though not in equivalent materials from the Wii console) raises additional concerns. Despite the recognised hazardous nature of these materials, (see page 16) beryllium is not currently regulated under RoHS.

- While a diverse range of materials was investigated, including many of the larger materials such as plastic casings and circuit boards, this study was able to analyse only a fraction of the numerous different components and materials that make up these complex electronic devices. Without extensive additional testing, it is not possible to verify whether all materials used in these devices comply with EU regulations.

5 Langezaal, I. (2002) The classification and labelling of Carcinogenic, Mutagenic, Reprotoxic and Sensitising substances. Publ. European Chemicals Bureau, Joint Research Centre, Ispra, Italy: 193 pp. [http://ecb.jrc.it/documents/Classification-Labelling/The_CL_process_in_general_and_substances_in_Annex_I_with_CMR_and_sensitising_properties.doc]

Nintendo Wii controller is dismantled. © Greenpeace/Will Rose

- These results not only show the presence of hazardous chemicals and materials in many components from all consoles, but also demonstrate the feasibility of substituting them in these devices. For almost all types of material found to contain either bromine, PVC, phthalates or beryllium, examples of equivalent materials, free of such chemicals and used for similar purposes were identified in one or more of the consoles tested.

In other words, while there were many similarities in the types and amounts of hazardous chemicals and materials used in the various components tested, there was evidence that each of the manufacturers had avoided or reduced uses of individual substances in certain materials within their console. In the Nintendo Wii, for example, beryllium alloys were not identified in electrical contacts, and the use of PVC and phthalates was found to be relatively limited. At the same time, the Sony Playstation PS3 included examples of 'bromine-free' circuit boards, and the Microsoft XBox 360 had lower usage of brominated materials within housing materials.

The types and amounts of hazardous chemicals and materials in the tested components of the game consoles were, in many cases, similar to those reported in 2007 for some equivalent materials from laptop computers, including the widespread presence of bromine, PVC and phthalates among the materials tested. Although not directly comparable for most of the types of materials tested in both studies, bromine and PVC were more frequently identified in tested materials from the consoles, including bromine in printed wiring boards (PWBs) and housing materials. For Sony, the only brand in this study that manufactures both game consoles and laptop computers, materials tested from the PS3 console included a greater proportion containing either PVC or bromine (including bromine in the PWBs), and a higher phthalate concentration in a single material, compared to equivalent materials tested from the Vaio TX laptop computers.

This study indicates that those materials tested from all three consoles appear to comply with the EU RoHS Directive in terms of regulated heavy metals. However, all consoles still contain a number of hazardous chemicals and materials, including PVC and BFRs which give rise to concerns for both environmental contamination and human exposure during manufacture, use and disposal of such products. The manufacturers of the products studied in this investigation will clearly have to make further significant improvements if they are to meet their current pledges on specific hazardous chemicals and materials (where these have been made) and to make the necessary changes that will ultimately see all hazardous substances 'designed-out' of their full product ranges.

Introduction

Greenpeace analysis of internal and external components from well-known brands of laptop computers and a mobile phone purchased in 2006-2007 has demonstrated that a range of hazardous substances and materials were common for many components, including brominated materials, PVC and phthalate esters[1]. This report extends the scope of these earlier studies through investigating another commonly-used type of electronic device, game consoles. The consoles tested were the Microsoft XBox 360 Elite, the Sony Playstation 3 and the Nintendo Wii. Although similar, there are differences between the three consoles, including their individual computing power.

Greenpeace has previously demonstrated workplace and environmental contamination resulting from the disposal and recycling of old electrical and electronic equipment containing hazardous chemicals and materials[6], as well as environmental pollution due to the use of hazardous chemicals in the manufacture of new equipment[7].

Under EU law, all electrical and electronic goods placed on the market in the EU from July 2006 onwards must comply with strict limits relating to a number of specific hazardous chemicals. Under the RoHS Directive[8] homogenous materials and components must not contain more than 0.1% by weight of the heavy metals lead, hexavalent chromium (VI) and mercury or of certain brominated flame retardants (BFRs), and no more than 0.01% by weight of cadmium. The RoHS regulations do not however address all hazardous chemicals and materials commonly used in electronics. Even for those substances that are regulated, numerous exemptions allow for their use in specific applications. Therefore, this and our previous studies focus not only on RoHS compliance, but also investigate the presence of other hazardous chemical additives and materials commonly incorporated into electronic devices, including other brominated chemicals, PVC, and phthalates. This study also includes beryllium.

***Left**: The Nintendo Wii console before dismantling.*
© Greenpeace/Will Rose

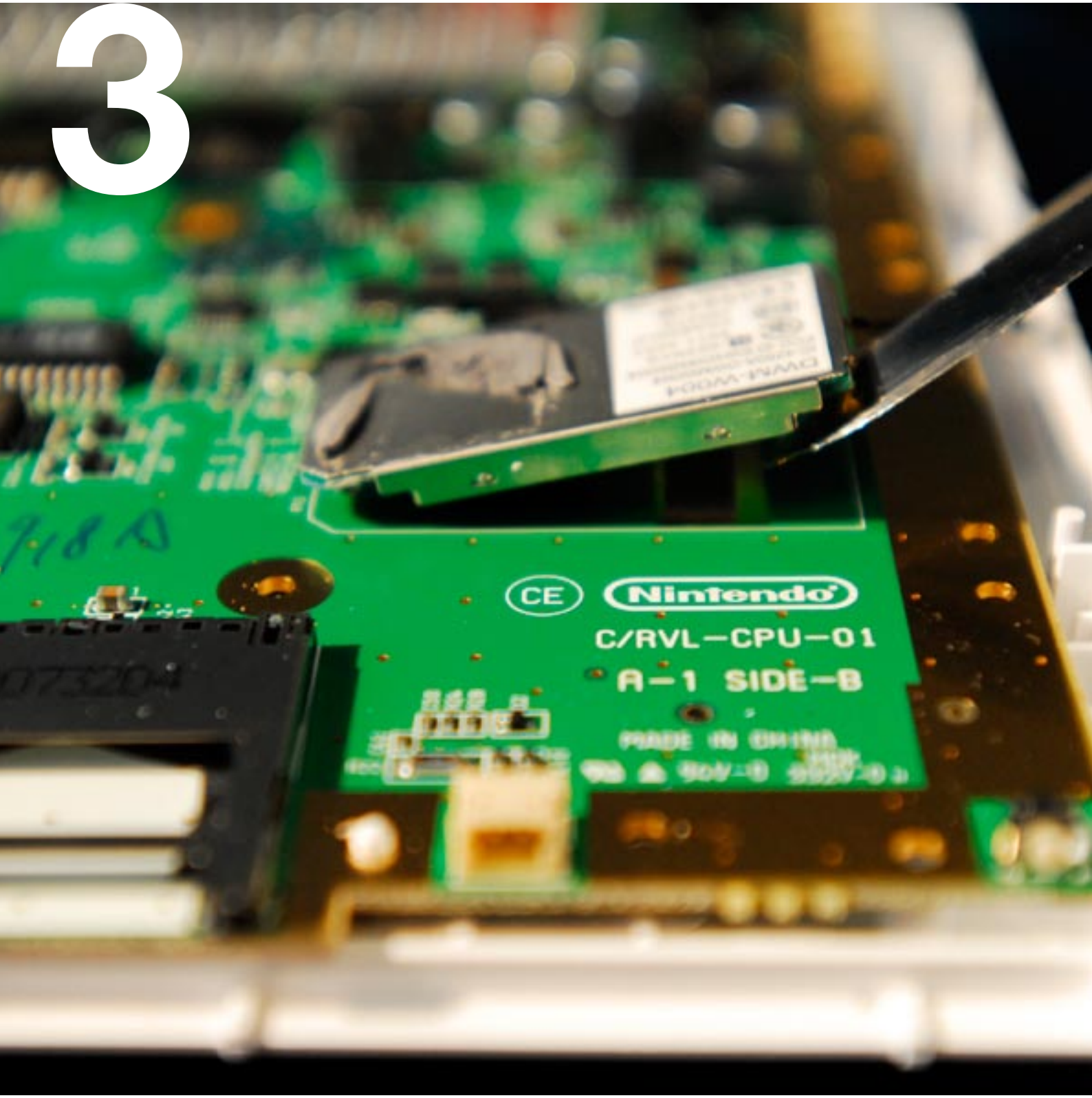
6 Brigden, K., Labunska, I., Santillo, D. & Allsopp, M. (2005) Recycling of electronic wastes in China and India: Workplace and environmental contamination. www.greenpeace.org/international/press/reports/ recycling-of-electronic-waste

7 Brigden, K., Labunska, I., Santillo, D., Walters, A. (2007) Cutting Edge Contamination - A Study of Environmental Pollution during the manufacture of Electronic Products. www.greenpeace.org/international/press/reports/cutting-edge-contamination-a

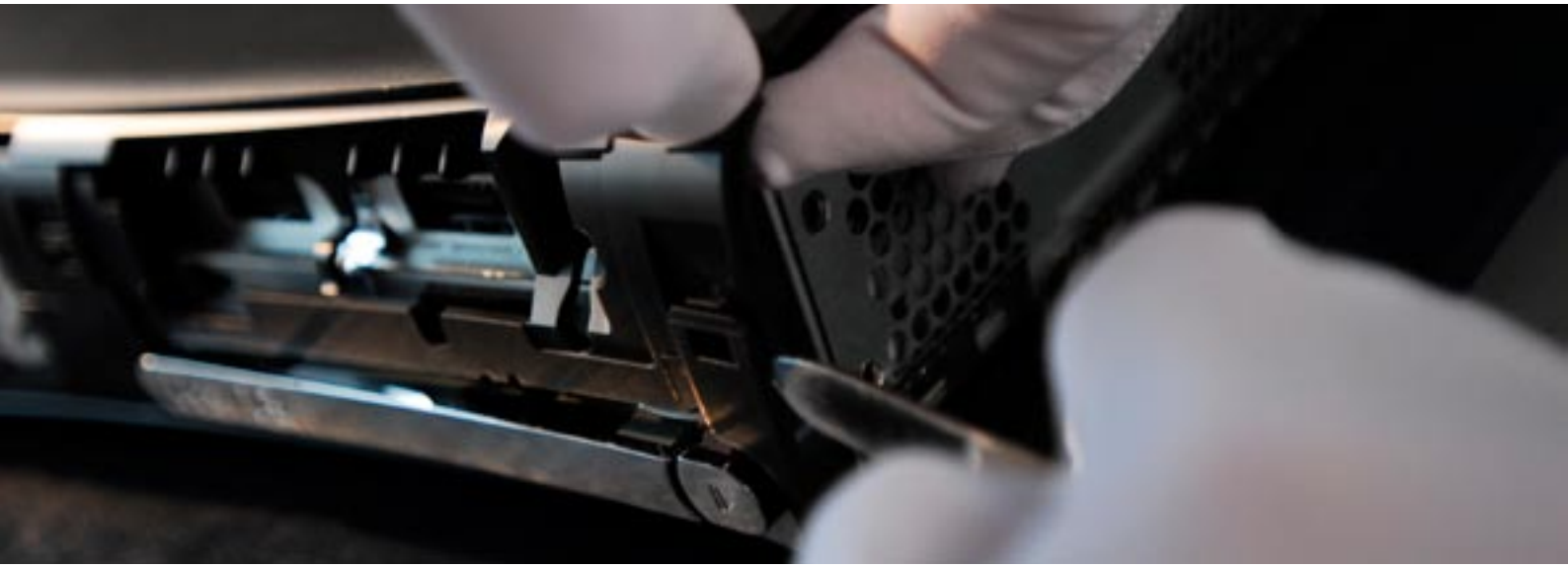
8 Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Official Journal L 037, 13/02/2003: pp. 0019-0023 [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0095: EN:HTML]

Materials and Methods

3



The Nintendo Wii motherboard is dismantled.
© Greenpeace/Will Rose



The Xbox 360 is dismantled to be tested for hazardous and toxic components. © Greenpeace/Will Rose

In November 2007, a Microsoft XBox 360 Elite, a Sony Playstation PS3 and a Nintendo Wii were purchased. The XBox and Playstation were bought in the UK, the Wii in the Netherlands (due to limited availability in the UK at the time). The three consoles were taken to the Greenpeace Research Laboratories at the University of Exeter (UK) for dismantling and analysis.

The consoles and their peripheral equipment were dismantled in our laboratory, taking care to avoid contamination with dust and grease and cross-contamination between different components. Individual components were placed in antistatic bags for storage prior to analysis. Measures were taken to verify that storage and processing (grinding) prior to analysis did not cause contamination of individual materials.

Many of the chemicals and materials included in this investigation are, or have been, principally used in certain types of component or materials within electronic devices. The analyses carried out in this study therefore focused on these areas;

- **bromine,** and other elements regulated under the RoHS Directive (*i.e.* **cadmium**, **chromium**, **mercury**, **lead**), in polymeric materials, analysed using XRF (X-Ray Fluorescence spectrometry). Identification of bromine indicates the presence of BFRs, i.e. brominated additives or polymeric materials used for fire retardancy purposes.
- **phthalate esters** and **PVC** in plastic coatings of wires and cables, and other flexible plastics. Phthalate esters were analysed using gas chromatography/mass spectrometry, PVC content was determined using Fourier transform infrared (FTIR) Spectroscopy.
- **lead** and **cadmium** in plastic coatings of wires and cables, determined by inductively coupled plasma-optical emission spectrometry (ICP-OES) following acidic dissolution[9].
- **lead** in electrical solders, as previously described for laptop computers[1].
- **hexavalent chromium (Cr VI)** in metallic surfaces, as previously described[1].
- **beryllium** in electrical contacts, using a method based upon that used for solders[1].

The XRF analysis and the PVC analysis were carried out at the laboratories of LPD Laboratory Services in the UK. The quantification of phthalate esters in flexible plastics was undertaken at the laboratories of LGC Ltd, UK. All other analyses were carried out at the Greenpeace Research Laboratories. Details of the individual samples tested from each console are given within the results section and in Annex 1. Further details of the methods employed can be provided on request.

9 Varian (2005) Monitoring heavy metals by ICP-OES for compliance with RoHS and WEEE directives. ICP-OES Application Note Number 40. http://www.varianinc.com/image/vimage/docs/applications/apps/ io-040.pdf

Results

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The XBox Motherboard.
© Greenpeace/Will Rose

Summaries of the results from the various analyses are presented below. Additional detailed results are provided in Annex 1.

XRF analysis

The XRF analysis provided data on the composition of bromine and certain other elements within the materials analysed, with detection limits of between 20-50 parts per million (ppm) or 0.002-0.005 % of the total composition.

Sample #	Description	Bromine concentration (ppm)		
		XBox 360	PS3	Wii
XRF01	housing; main external console case	<20	<20	<20
XRF02	housing; hand controller (*)	<20	<20	<20
XRF02B	housing; second hand controller (a) (*)	n.a.	n.a.	<20
XRF03	housing; power transformer block (b)	907	<20	<20
XRF04	housing; external hard disc drive (HDD) (c) (*Wii only)	<20	n.a.	<20
XRF05	coating of main external power cable (*)	<20	<20	<20
XRF06	housing; large internal housing (d) (*Wii only)	<20	3270	125000
XRF07	cooling fan (*PS3 & Wii only)	81000	67300	54574
XRF08	fan housing; immediately around fan (*)	84400	138000	65600
XRF09	DVD drive; main housing within DVD (*)	558	<20	<20
XRF10	PWB; motherboard (*)	32300	29400	22400
XRF11	PWB; hand controller (*)	57200	<20	24900
XRF12	PWB; power transformer (*)	62100	66400	99300
XRF13	PWB; hard disc drive (HDD) (e) (*)	15500	20900	n.a.
XRF14	PWB; DVD drive (*)	41100	<20	31100
XRF15	resin plate inside transformer case (appears same as transformer PWB)(f) (*)	n.a.	n.a.	56900

Table 1. Concentrations of bromine in materials analysed by XRF.

*n.a. no equivalent material. * sample ground prior to XRF analysis.*

(a) Wii has second 'Nunchuk' hand controller.

(b) PS3 has internal transformer.

(c) PS3 has metal casing; Wii has no HDD, sensor bar housing analysed instead.

(d) XBox 360 large white housing around fan and its immediate fan housing (#08); PS3 large internal housing immediately inside external case; Wii internal black plastic housing.

(e) XBox 360 Hitachi HDD; PS3 Seagate HDD; Wii no HDD. (f) XBox 360 and PS3 have no equivalent material

A scientist is pictured dismantling the Playstation 3 DVD drive. © Greenpeace/Will Rose

The concentrations of bromine in the various materials are presented in Table 1. Detailed results from the XRF analyses, including the composition of cadmium, chromium, mercury and lead, are provided in Annex 1. Although other elements were detected in some materials at trace levels, all far below RoHS limits, the most significant results from this set of analysis are the high levels of bromine present in many of the materials.

1. **bromine** was detected in just over half of the samples tested (23 out of 42), at levels ranging from 558 parts per million (ppm) to 138000 ppm (or 13.8% by weight of the material). In almost all samples where bromine was detected, levels were over 1% by weight.

2. for each console, a similar number of tested materials contained high levels of bromine (over 1000 ppm, or 0.1%).

3. all but two contained high levels of bromine, all at over 1% by weight. The PS3 was the only console in which some 'bromine-free' circuit boards were identified; bromine was not detected in two of the five PWBs tested.

4. for other materials, the highest levels of bromine were found in the fan and the fan housing, for all consoles, all with similar levels (5.5-8.4%) other than the PS3 fan housing which had the highest level of all samples (13.8%).

5. for the PS3 and Wii consoles, one internal housing material contained high levels of bromine, particularly the material from the Wii (12.5%, XRF06).

6. none of the external housing materials contained detectable levels of bromine, other than a relatively low level in the XBox 360 transformer case (0.09%).

The results indicate the widespread use of BFRs in these products, particularly in PWBs, though XRF analysis does not provide information on the chemical forms of the bromine in the various components. Based on experience with similar components in laptop computers and a mobile phone[1], it seems likely that the bromine in these components is predominantly present in reactive polymeric forms (such as cross-linked TBBPA-based formulations) or, at least, in poorly extractable oligomeric forms. In these forms, the exact chemical nature of the brominated compounds cannot be quantified using gas chromatographic techniques previously employed in similar investigations.[1] Other techniques, however, are able to provide additional information on the form of the brominated compounds.

The presence of such high proportions by weight of bromine, in any form, in many materials is of concern with respect to the disposal or recycling of game consoles at end-of-life. Even polymeric-bound bromine can contribute to the formation of toxic chemicals, including persistent and bioaccumulative brominated dioxins and related compounds during thermal destruction or processing[10].

In addition to bromine, low concentrations of **lead** (59-131 ppm) were present in a fraction of the materials, all far below maximum allowable RoHS limits. A small number also contained low concentrations of total **chromium** (60-157 ppm). Although it was not possible to confirm the absence of hexavalent chromium in these materials, there is no reason to believe that any significant quantities of the chromium present was in this toxic and regulated form. There was no evidence for the presence of **cadmium** or **mercury** in any of the materials analysed (above detection limits of 20 ppm).

10 **Gullett, B.K., Linak, W.P., Touati, A., Wasson, S.J., Gatica, S., King, C.J.** (2007) Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations. Journal of Material Cycles and Waste Management 9(1): 69–79

Phthalate esters

For each console, eight or nine flexible plastic materials (coatings of wires and cables, and other materials) were screened to identify whether any readily-extractable chemicals were present, including phthalate esters commonly used as plasticisers in flexible PVC. The screening gave a general indication of the amounts of these chemicals in the various materials, but not precise concentrations. Some of these materials were subsequently analysed to determine the precise levels of phthalates (see below). Details of the samples screened and the phthalates identified are given in Table 2. Some of these materials were also analysed for PVC, and the heavy metals lead and cadmium (see below).

Overall, phthalates esters (more commonly known as phthalates) were predominantly found in the power cable coatings, in both outer (ph01) and inner (ph02) sheaths, and the outer coating of the AV cable (ph04). The screening identified only one phthalate (DEHP) in each of these materials, except in the case of the AV cable from the XBox 360, which was also found to contain DiBP.

Very high levels of DEHP were found in cable coatings from the XBox 360 and PS3 consoles, though in different types of cables for each of the consoles. It is noteworthy that each of these consoles included an example of a cable coating that did not have a very high DEHP level. All equivalent materials from the Wii contained DEHP though only at trace levels. One other material, the coating of an internal wire from the XBox 360 (ph06), contained a very high level of another phthalate, DiNP. This was not found in equivalent materials from the PS3 and Wii consoles.

The predominant phthalate-containing materials identified by the screening (ph01, ph04 and XBox 360-ph06) were further analysed to determine the precise levels of a range of phthalates. For each console, the screening indicated that the inner (ph01) and outer (ph02) coatings of the power cables had almost identical phthalate ester compositions, and therefore only the outer coatings were analysed in more detail. The results of the detailed phthalate analyses are given in Table 3. In summary;

1. The detailed quantification of phthalates in these samples confirmed the results from the initial screening. The three materials that screening had indicated to have very high levels, all contained phthalates at over 10% by weight and, in two cases, over 20% by weight.

2. The XBox 360 yielded the material with the highest concentration of extractable phthalates, 27.5% by weight of DEHP in the outer coating of a power cable. A similar material from the PS3 contained a slightly lower level, 21.2% by weight, of DEHP (AV cable outer coating).

3. The levels of phthalates in all other equivalent materials from all three consoles were far lower; DEHP in the range 0.01-0.09%, and DiBP at 0.02%.

4. The one other material analysed from the XBox 360 (ph06) contained DiNP at 10.6% by weight.

In all cases, where a material in one console contained a very high level of phthalates, equivalent materials from the other consoles contained only trace levels or none at all (above detectable levels).

All three consoles contained materials plasticised with phthalates. For the XBox 360 and PS3 (though not the Wii), phthalate concentrations far exceeded those allowable in toys and childcare articles in the EU, though game consoles are not currently defined as toys under EU regulations[11]. Two of the phthalates identified in these samples, including the most abundant phthalate DEHP, are classified in the EU as 'toxic to reproduction: category 2" [5], as a result of their ability to interfere with sexual development in mammals, especially in males. These phthalates are prohibited from use in all toys or childcare articles put on the market in EU (with a limit of 0.1% by weight), according to Directive 2005/84/EC. The one other phthalate identified in sample XBox 360-ph06 (DiNP) is also prohibited under the same Directive from use in toys and childcare articles if they can be placed in the mouth by children.

11 **Directive 2005/84/EC** of the European Parliament and of the Council of 14 December 2005 amending for the 22nd time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (phthalates in toys and childcare articles): [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:344:0040:0043:EN:PDF]

Directive 88/378/EEC of 3 May 1988 on the approximation of the laws of the Member States concerning the safety of toys. Official Journal L 187, 16/07/1988: pp.0001-0013 [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31988L0378:EN:HTML]

Sample		XBox 360						PS3						Wii					
					Phthalate						Phthalate						Phthalate		
No.	Description	PVC	Pb (%)	Cd (%)	DEHP	DiBP	DiNP	PVC	Pb (%)	Cd (%)	DEHP	DiBP	DiNP	PVC	Pb (%)	Cd (%)	DEHP	DiBP	DiNP
ph01	main external power cable; outer	Y	<0.001	<0.001	++			Y	<0.001	<0.001	t			Y	<0.001	<0.001	t		
ph02	main external power cable; inner	-	-	-	++			-	-	-	t			-	-	-	t		
ph03	external component cable; outer(a)	Y	<0.001	<0.001				Y	<0.001	<0.001				Y	<0.001	<0.001	t		
ph04	AV cable; outer	Y	<0.001	<0.001	t	t		Y	<0.001	<0.001	++			Y	<0.001	<0.001	t		
ph05	internal wire to fan; coating	Y	-	-	t			N	-	-				N	-	-			
ph06	internal wire; coating (b)	Y	-	-			++	Y	-	-	t			N	-	-			
ph07	hand controller; soft plastic beneath buttons	-	-	-				-	-	-				-	-	-			
ph08	hand controller; cover of joystick	N	-	-				N	-	-				N	-	-			
ph09	hand controller; soft plastic case(c)	-	-	-	-----			-	-	-	-----			-	-	-			
ph10	AV cable; inner wire (yellow)(d)	N	<0.001	<0.001	-----			-	-	-	-----			N	<0.001	<0.001	-----		
ph11	transformer cable, inner wire (yellow)(e)	Y	<0.001	<0.001	-----			Y	<0.001	<0.001	-----			-	-	-	-----		
ph12	HDD to PWB cable, inner wire (yellow)(f)	Y	<0.01	<0.001	-----			-	-	-	-----			-	-	-	-----		
ph13	DVD drive; wire to motor (yellow)(g)	-	-	-	-----			-	-	-	-----			N	<0.01	<0.001	-----		
ph14	Nunchuk cable; inner wire (yellow)(g)	-	-	-	-----			-	-	-	-----			Y	<0.01	<0.001	-----		

Table 2. Analyses of flexible plastic materials for PVC, lead (Pb) & cadmium (Cd); screening for the presence of phthalates (samples ph01-ph09 only), indicating those samples quantified for a range of phthalates.

'-' indicates sample not present or not tested.

PVC: Y indicates presence of PVC; N indicates absence of PVC.

Phthalate screening: '++' very high concentration; 't' trace concentration.

(a) PS3 USB cable; XBox 360 HDMI cable; Wii nunchuk cable

(b) XBox 360 & Wii wire on motherboard; PS3 wire from power socket to internal transformer, parallel to ph11

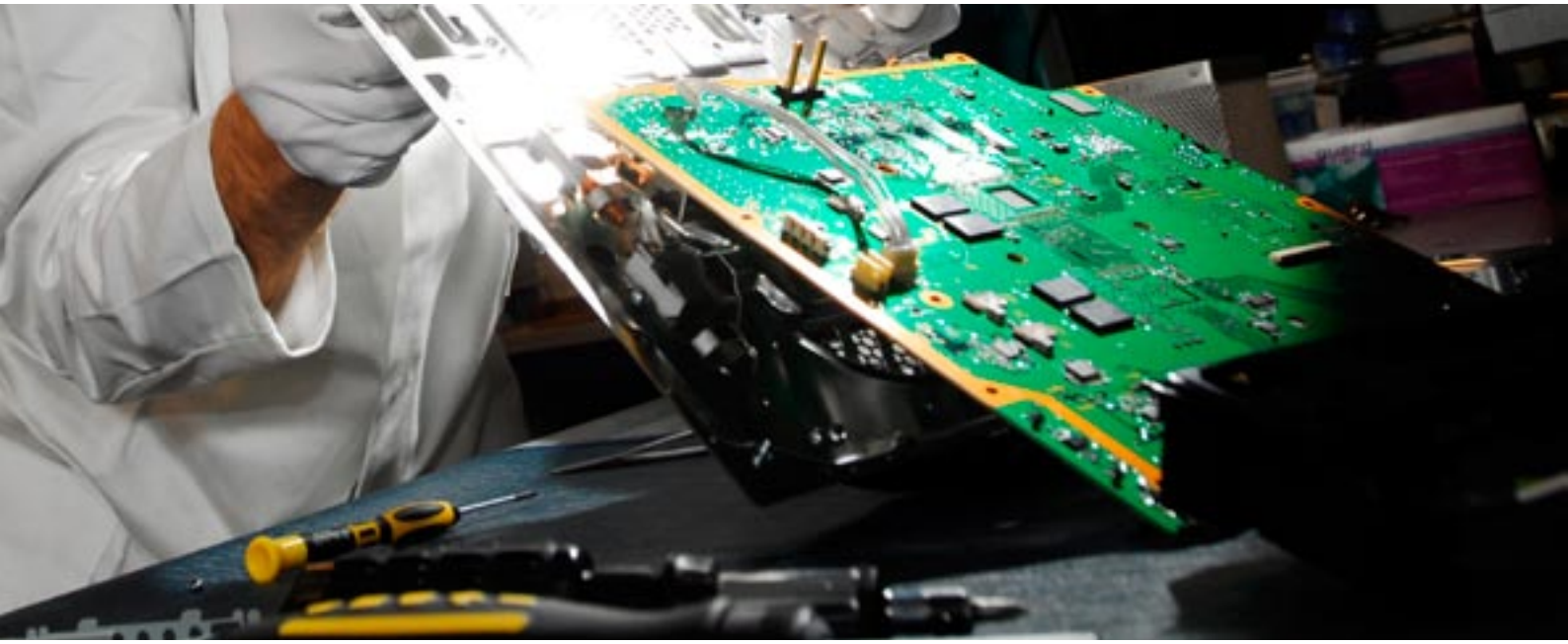
(c) only Wii has this material

(d) PS3 no yellow wire

(e) XBox 360 external cable, transformer to console; PS3 internal cable from external power socket to internal transformer

(f) PS3 no yellow inner wire; Wii no HDD

(g) XBox 360 & PS3 no equivalent wire



A scientist is pictured dismantling the motherboard of the Playstation 3. © Greenpeace/Will Rose

	Power cable outer; ph01			AV cable outer; ph04			Internal wire; ph06
phthalate	**XBox 360**	**PS3**	**Wii**	**XBox 360**	**PS3**	**Wii**	**XBox 360**
DEHP	**27.5**	**0.09**	**0.02**	**0.01**	**21.2**	**0.01**	<0.005
DiBP	<0.005	<0.005	<0.001	**0.02**	<0.005	<0.001	<0.005
DBP	<0.005	<0.005	<0.001	<0.001	<0.005	<0.001	<0.005
DiNP	<0.25	<0.25	<0.05	<0.05	<0.25	<0.05	**10.6**
DiDP	<0.3	<0.3	<0.06	<0.06	<0.3	<0.06	<0.3
BBP	<0.005	<0.005	<0.001	<0.001	<0.005	<0.001	<0.005
DnOP	<0.005	<0.005	<0.001	<0.001	<0.005	<0.001	<0.005

Table 3. Concentrations of seven phthalate esters in flexible coatings of wires and cables from the XBox 360, Playstation PS3 and Wii game consoles, in % by weight

It is unclear whether the consoles or their components could in the future be classified as components of toys. What is clear, however, is that the presence of high levels of phthalates in such materials could contribute to overall levels of exposure to these chemicals for users, including children.

The screening of the flexible plastic materials identified a number of other chemicals in various samples, including chemicals used as plasticisers in flexible plastics, as well as phosphorus-based compounds used as either plasticisers or flame retardants. The analysis indicated that some of the materials are silicon-based polymers that do not require the use of plasticisers to provide flexibility. Details of these additional chemicals identified in the screened materials are given in Annex 1.

PVC

PVC was identified in the majority of the six flexible plastic materials from each of the consoles that were screened for phthalates (ph01-ph08), including all cable coatings from all three consoles. The soft covering on the hand controller joystick (ph08) did not contain PVC for any of the consoles. PVC was most commonly identified in materials from the XBox 360, in all five coatings of wires and cables. For the other consoles, most (but not all) materials contained PVC; four out of five coatings from the PS3, and three out of five from the Wii. Details of all samples analysed for their PVC content are given in Table 2 on page 13.

All of the PVC-containing materials that were screened were also found to contain plasticiser chemicals, in many cases phthalates. Indeed, all samples that were found to contain phthalates, albeit at low levels in some, were composed of PVC.

The phthalate and PVC data for these consoles were very similar to those recently reported in equivalent materials (power cable coating) from laptop computers. The high levels of phthalates in some console materials were equivalent to the highest levels found in the laptop materials, though different phthalates were predominant[1]. Similarly, for wire and cable coatings from both laptops and consoles, PVC was commonly identified, and materials containing phthalates at high levels were generally those composed of PVC.

The PVC content was also determined for all yellow-coloured plastic coating of wires, due to the possibility that these materials contained high levels of lead or cadmium[12] (see below). Just over half of all these materials contained PVC, including at least one material from each console. Again, the Wii console fared best, with PVC detected in only one of three materials tested.

Lead (Pb) and cadmium (Cd) in plastic coatings of wires and cables

Compounds of lead and cadmium have historically been used as stabilisers in certain plastics, including those used as insulation coating for wires and cables. There have been recent cases[12] of lead in such materials at levels exceeding those allowed under the RoHS Directive, including the outer coating of power cables and yellow-coloured coatings of wires.

However, neither lead nor cadmium was detected in any of the wire and cable coatings analysed. This included the outer coatings of three cables from each console (power and data cables) that were also screened for phthalates, as well as all yellow-coloured wire coatings within each console. All samples were also analysed for their PVC content. Details of the samples analysed are given in Table 2 on page 13.

Lead in electrical solder

Lead was not detected (above 0.1%) in any of the eight or nine samples of electrical solder analysed from each of the consoles. Details of the samples analysed are given in Annex 1. The solders consisted principally of tin with varying low levels of other metals, consistent with the compositions commonly used for 'lead-free' solders[13].

Hexavalent chromium (Cr VI) in metallic surfaces

Hexavalent chromium was not detected in any of the individual metallic surfaces analysed from each of the consoles (between eight and twelve samples per console). Details of the materials analysed are given in Annex 1.

12 **ENDS (2007)** RoHS enforcement body refuses to name offender. Environmental Data Services ENDS Report 395: 26-27

13 Li, Y., Moon, K., Wong, C.P. (2005) Electronics without lead. Science 308(5727): 1419–1420

Beryllium in electrical contacts

Of the eight to ten individual electrical contacts analysed from each of the consoles, beryllium was present in two contacts from the XBox 360 Elite and two from the PS3 (for both consoles, in a connector linked to the power transformer, and a contact on the PWB within the hand controller), see Table 4. None of the equivalent contacts analysed from the Wii console contained detectable levels of beryllium.

For three samples, the beryllium concentrations (1.75-1.95%) were consistent with reported composition of beryllium alloys in this type of equipment, i.e. 2% beryllium[14]. The other sample, from the XBox 360 Elite, contained beryllium at a lower level (0.35%).

The processing of beryllium alloys, including through recycling processes, can produce dusts and fumes of beryllium and beryllium oxide. Exposure to these, even at very low levels and for short periods of time, can cause beryllium sensitisation that can lead to chronic beryllium disease (CBD), an incurable debilitating lung disease[15]. Furthermore, beryllium and beryllium compounds are recognised as known human carcinogens as a result of workplace exposures[16].

All contacts consisted principally of copper, with varying levels of other metals including gold (<0.02-2.4%), nickel (<0.01-4.2%) and tin (<0.1-9.4%) and, in some cases, beryllium. It is likely that the presence of tin in some samples is due to traces of electrical solder on the contacts.

		Beryllium concentration (%)		
Sample #	**Description**	**XBox 360**	**PS3**	**Wii**
Be01	connector of AV video cable(a)	<0.01	<0.01	<0.01
Be02	connector of data cable(b)	<0.01	<0.01	<0.01
Be03	connector of power cable transformer to console(c)	**0.35**	<0.01	<0.01
Be03B	transformer output connector to motherboard(d)	-	**1.75**	-
Be04	motherboard; socket of HDMI / AV cable	<0.01	<0.01	<0.01
Be05	motherboard; USB socket	<0.01	<0.01	<0.01
Be06	hand controller PWB; contact for battery(e)	**1.95**	<0.01	-
Be07	hand controller PWB; socket for data cable	<0.01	**1.82**	<0.01
Be08	hand controller contact for joystick(f)	<0.01	-	-
Be09	connector HDD to motherboard(g)	<0.01	<0.01	<0.01
Be10	wireless PWB contact(h)	<0.01	<0.01	<0.01

Table 4. Electrical contact samples analysed for their beryllium content.

(a) XBox 360 HDMI cable.

(b) XBox 360 network cable; PS3 USB cable; Wii Nunchuk cable

(c) PS3; socket of external cable to internal transformer

(d) PS3 only due to internal transformer

(e) Wii; different contact type due to use of AA batteries

(f) PS3 & Wii, equivalent part plastic

(g) XBox 360 HDD end of connecting cable; PS3 contacts on motherboard; Wii no HDD, connector on sensor bar tested

(h) XBox 360 RF module; PS3 bluetooth PWB; Wii WiFi antenna

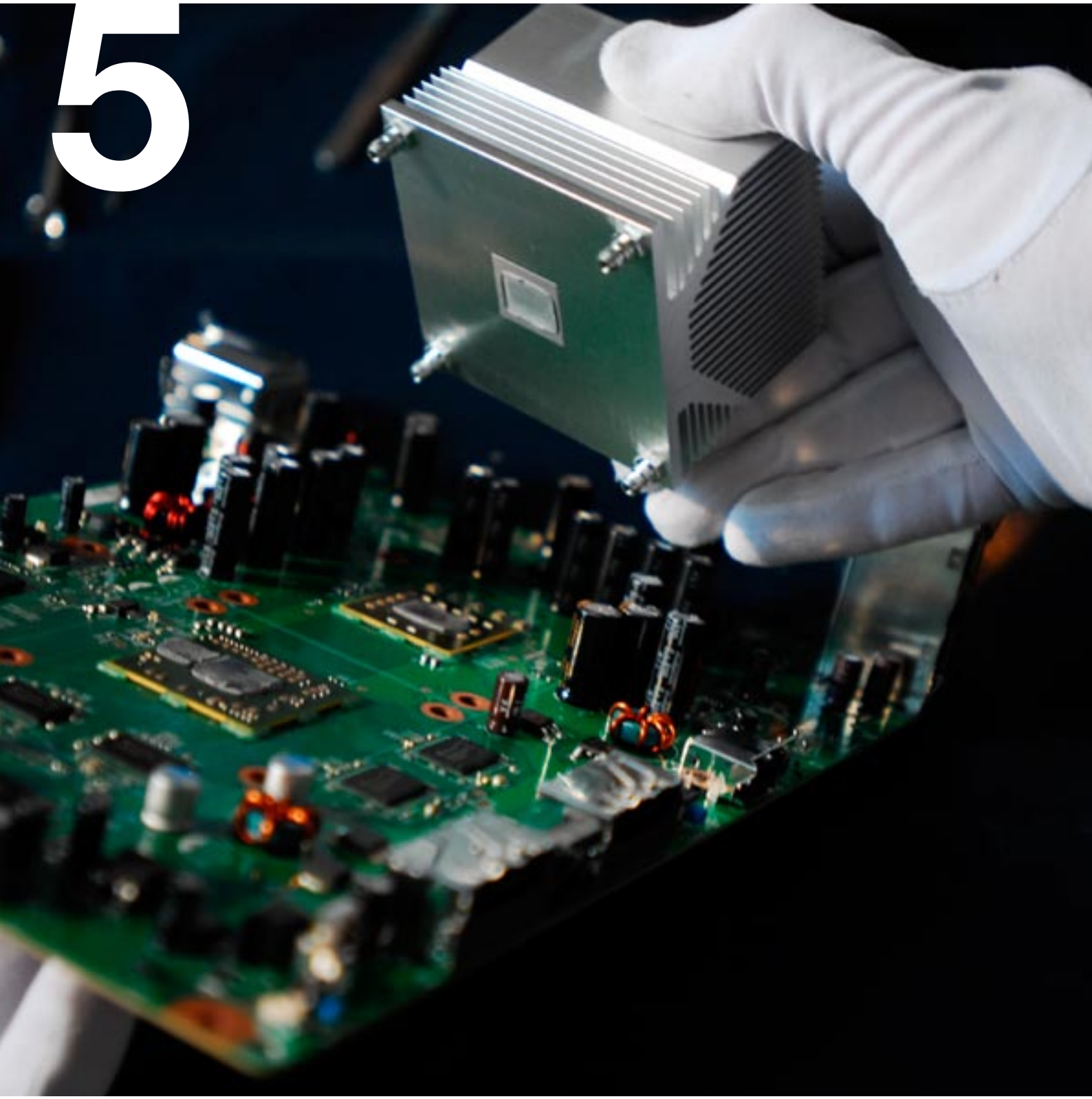
14 OECD (2003) Technical guidance for the environmentally sound management of specific waste streams: used and scrap personal computers. Organisation for Economic Co-operation and Development (OECD) Working Group on Waste Prevention and Recycling. ENV/EPOC/WGWPR(2001)3/FINAL

15 Schuler, C.R., Kent, M.S., Deubner, D.C., Berakis, M.T., McCawley, M., Henneberger, P.K., Rossman, M.D. & Kreiss, K. (2005) Process-related risk of beryllium sensitization and disease in a copper-beryllium alloy facility. American Journal of Industrial Medicine 47(3): 195-205. Infante, P.I. & Newman, L.S. (2004) Beryllium exposure and chronic beryllium disease. The Lancet 363: 415-416

16 International Agency for Research on Cancer, IARC (1997) Beryllium and Beryllium Compounds. In International Agency for Research on Cancer (IARC) monograph; Beryllium, Cadmium, Mercury, and Exposures in the Glass Manufacturing. IARC monograph, Vol. 58, 21pp.

Conclusions

5



The XBox Motherboard is dismantled.
© Greenpeace/Will Rose

For all three consoles, all internal and external components that were tested appear to be compliant with the EU RoHS Directive that regulates the use of certain hazardous substances in electronics and electrical goods, in that;

- no cadmium or mercury was detected in any sample.
- lead and chromium were detected in a small number of samples, though at relatively low concentrations and all significantly below RoHS limits.
- no lead or cadmium was detected in any coatings of wires and cables.
- hexavalent chromium, the toxic and regulated form of chromium, was not detected in a wide range of metallic components tested.

However, it should be noted that:-

1. Although this study included as wide a range of different components and materials as possible in the various analyses, the testing was inevitably limited in scope to the specific samples selected. It is not possible, therefore, to conclude from these results whether every individual component and material used in each of the three consoles is fully RoHS compliant, or whether other untested materials contain other hazardous chemicals or materials that are not currently regulated under the RoHS directive (e.g. PVC, phthalates or beryllium). This would need to be subject to more detailed investigation.

2. Just over half of all the components analysed tested positive for bromine (at over 1% of the total composition of the material in almost all cases), in a similar fraction of all the tested materials from each console despite certain differences between the consoles, including their individual computing power. These results indicate continued widespread use of either additive or reactive BFRs by all three manufacturers and other polymeric materials (fans and housing materials). Among the circuit boards and housing materials tested, there were examples of materials that did not contain detectable levels of bromine, indicating the potential for eliminating brominated materials in these components. Investigation of the precise chemical forms of the bromine in these materials was not part of this study, and therefore the presence of specific BFRs regulated under RoHS remains unknown. The presence of organic-bound bromine, in any form, can act as a significant source of toxic and persistent brominated pollutants during incineration or high-temperature processing once these devices enter the waste stream.

3. PVC was identified in the majority of the flexible materials (wire and cable coatings) tested from each of the consoles. While the differences between the three consoles were not large, the XBox 360 had the highest fraction of tested samples containing PVC, while the Wii had the least.

4. All PVC-containing materials analysed also contained plasticiser chemicals, in many cases phthalates. Three of these materials contained very high levels of phthalates; two from the XBox 360 (10.6-27.5% by weight) and one from the PS3 (21.2% by weight). Although equivalent materials from the Wii also included phthalates, these were at much lower levels - 0.01-0.02%. Even though the use of PVC and phthalate esters are not currently regulated under RoHS, it is noteworthy that the two predominant phthalates found in this study are not permitted for use in components of toys or childcare articles sold in the EU at levels above 0.1%, though game consoles are not currently defined as toys under EU regulations. One of the phthalates, DEHP, is known to be toxic to reproduction in mammals.

5. All three consoles included PVC-based materials containing other types of plasticiser chemicals, principally a mellitate and various adipates, at apparently high levels in some instances. The use of these substances provides flexibility to the materials without the use of phthalates, but raises similar concerns regarding the potential for resulting exposure to, and toxicity of, these leachable chemical additives. Rather than providing reassurance, therefore, their presence highlights the reliance on leachable additives that stems from the use of PVC as a material and the value in replacing PVC with polymers that do not require the use of such additives.

6. Beryllium alloys were identified in two of the electrical contact materials tested from each of the XBox 360 and PS3 consoles (though not the Wii). Again, while beryllium and its compounds and alloys are not currently regulated under RoHS, such alloys are known to pose a risk to the health of workers recycling electronic goods at the end of a product's life.

XBox console before dismantling. © Greenpeace/Will Rose

Overall there were many similarities in the types and amounts of hazardous chemicals and materials used in the three consoles. The results indicate that, in each case, the manufacturers have reduced or even avoided uses of individual hazardous substances in specific components;

– Nintendo Wii; beryllium alloys were not identified in electrical contacts and there was lower use of PVC and phthalates in those materials tested.

– Sony Playstation PS3; included examples of 'bromine-free' PWBs.

– Microsoft XBox 360; lower use of brominated materials in the housing materials tested.

In general, this study found many similarities between the types and amounts of hazardous chemicals and materials in the components tested from the game consoles and those recently reported in equivalent materials tested in a related study of laptop computers[1]. In both studies, the use of brominated materials was found to be widespread, particularly in PWBs. Similarly, many of the flexible materials tested (wire and cable coatings) contained PVC, in some cases incorporating phthalates at high levels. While it is not possible to draw direct comparisons between the two different sets of devices, a larger proportion of most materials tested from all consoles contained brominated materials or PVC-containing materials, compared to equivalent types of materials tested from laptops, including bromine in PWBs and housing materials. Where investigated, the use of phthalates in PVC-based materials was found to be similar in both studies, though different phthalates were predominant in the consoles.

Sony is the only brand included in this study that manufactures both game consoles and laptop computers. Again, while not directly comparable, it is noteworthy that among the tested materials from the Sony PS3 console, a greater proportion contained either PVC or bromine (including bromine in the PWBs) compared to similar materials tested from the Sony Vaio TX laptops. Similarly, the highest phthalate level found in a PVC material from the console (22.1%) was far higher that in similar materials tested from the Sony laptops (7.3%).

This study indicates that those materials tested from all three consoles appear to comply with the EU RoHS Directive in terms of the regulated heavy metals. However, all consoles still contain a number of hazardous chemicals and materials, including PVC and BFRs, which give rise to concerns for both environmental contamination and human exposure during manufacture, use and disposal of such products. The manufacturers of the products studied in this investigation will clearly have to make further significant improvements if they are to meet their current pledges on specific hazardous chemicals and materials (where these have been made) and to make the necessary changes that will ultimately see all hazardous substances 'designed-out' of their full product ranges.

Annex 1

Detailed results from certain analyses of materials from the Microsoft XBox 360 Elite, Sony Playstation PS3 and Nintendo Wii game consoles

XRF analysis of bromine (Br), cadmium (Cd), chromium (Cr), mercury (Hg) and lead (Pb) in materials from the XBox 360, PS3 and Wii consoles. All values are in parts per million, ppm

Sample #	Description	XBox 360					PS3					Wii				
		Br	Cd	Cr	Hg	Pb	Br	Cd	Cr	Hg	Pb	Br	Cd	Cr	Hg	Pb
XRF01	housing; main external console case	<20	<20	<50	<20	<50	<20	<20	<50	<20	<50	<20	<20	<50	<20	<50
XRF02	housing; hand controller (*)	<20	<20	**71**	<20	<50	<20	<20	<50	<20	<50	<20	<20	**157**	<20	<50
XRF02B	housing; second hand controller (a) (*)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<20	<20	<50	<20	<50
XRF03	housing; power transformer block (b)	**907**	<20	<50	<20	<50	<20	<20	<50	<20	<50	<20	<20	<50	<20	<50
XRF04	housing; external HDD (c) (*Wii only)	<20	<20	<50	<20	<50	n.a.	n.a.	n.a.	n.a.	n.a.	<20	<20	<50	<20	<50
XRF05	coating of main external power cable (*)	<20	<20	<50	<20	<50	<20	<20	<50	<20	<50	<20	<20	<50	<20	<50
XRF06	housing; large internal housing (d)(*Wii only)	<20	<20	<50	<20	<50	**3270**	<20	<50	<20	<50	**125000**	<20	<50	<20	**80**
XRF07	cooling fan (*PS3 & Wii only)	**81000**	<20	<50	<20	**70**	**67300**	<20	**76**	<20	**94**	**54574**	<20	<50	<20	**59**
XRF08	fan housing; immediately around fan (*)	**84400**	<20	<50	<20	**71**	**138000**	<20	<50	<20	**72**	**65600**	<20	**60**	<20	**60**
XRF09	DVD drive; main housing within DVD (*)	**558**	<20	<50	<20	<50	<20	<20	<50	<20	<50	<20	<20	**76**	<20	**131**
XRF10	PWB; motherboard (*)	**32300**	<20	<50	<20	<50	**29400**	<20	<50	<20	<50	**22400**	<20	<50	<20	**67**
XRF11	PWB; hand controller (*)	**57200**	<20	<50	<20	**72**	<20	<20	<50	<20	<50	**24900**	<20	<50	<20	<50
XRF12	PWB; power transformer (*)	**62100**	<20	<50	<20	<50	**66400**	<20	<50	<20	<50	**99300**	<20	<50	<20	<50
XRF13	PWB; HDD(e) (*)	**15500**	<20	<50	<20	<50	**20900**	<20	<50	<20	<50	n.a.	n.a.	n.a.	n.a.	n.a.
XRF14	PWB; DVD drive (*)	**41100**	<20	<50	<20	<50	<20	<20	<50	<20	<50	**31100**	<20	<50	<20	<50
XRF15	resin plate inside transformer case (appears same as transformer PWB) (f) (*)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	**56900**	<20	<50	<20	<50

Table A1. Concentrations of bromine (Br), cadmium (Cd), chromium (Cr), mercury (Hg) and lead (Pb) in materials analysed by XRF. n.a. no equivalent material. (*) sample ground prior to XRF analysis. (a) Wii has second 'Nunchuk' hand controller. (b) PS3 has internal transformer. (c) PS3 has metal casing; Wii has no HDD, sensor bar housing analysed instead. (d) XBox 360 large white housing around fan and its immediate fan housing (#08); PS3 large internal housing immediately inside external case; Wii internal black plastic housing. (e) XBox 360 Hitachi HDD; PS3 Seagate HDD; Wii no HDD. (f) XBox 360 and PS3 have no equivalent material

Analysis of PVC content and extractable plasticisers in flexible plastic materials from the XBox 360, PS3 and Wii consoles

Sample		XBox 360									PS3									Wii									
			plasticisers									plasticisers									plasticisers									
			phthalate			other						phthalate			other						phthalate			other					
No.	Description	PVC	DEHP	DiBP	DiNP	TEHTM	TPP+TCP	DiNA+DiDA	DEHA	siloxanes	PVC	DEHP	DiBP	DiNP	TEHTM	TPP+TCP	DiNA+DiDA	DEHA	siloxanes	PVC	DEHP	DiBP	DiNP	TEHTM	TPP+TCP	DiNA+DiDA	DEHA	siloxanes
ph01	main power cable to wall plug; outer	Y	++								Y	t			++					Y	t			++				
ph02	main power cable to wall plug; inner	-	++								-	t			++					-	t			++				
ph03	external component cable; outer(a)	Y				++	+				Y						++			Y	t			++			+	
ph04	AV cable; outer	Y	t	t		++	+				Y	++			+					Y	t			++			+	
ph05	internal wire to fan coating	Y	t			+					N									N								
ph06	internal wire coating (b)	Y			++						Y	t			++					N								
ph07	hand controller; soft plastic beneath buttons	-								+	-								+	-								+
ph08	hand controller; cover of joystick	N									N									N								
ph09	hand controller; soft plastic case(c)	-	--------			----------					-	-------			----------					-								+

Table A2. Analyses of flexible plastic materials for PVC, and screening for the presence of plasticisers. ' '- indicates sample not present or not tested. PVC: Y indicates presence of PVC, N indicates absence of PVC. For plasticiser screening: ' ++' very high concentration; '+' high concentration; 't' trace concentration.

(a) PS3 USB cable; XBOX 360 HDMI cable; Wii nunchuk cable (b) XBox 360 & Wii wire on motherboard; PS3 grey wire from power socket to internal transformer, parallel to PS3ph11 (c) only Wii has this material (d) PS3 no yellow wire (e) XBox 360 external cable from transformer to console; PS3 internal cable from external lead socket to internal transformer (f) PS3 no yellow inner wire; Wii no HDD (g) XBox 360 & PS3 no equivalent wire

DEHP- diethylhexyl phthalate; DiBP- diisobutyl phthalate; DiNP- diisononylphthalate

TEHTM- trisethylhexyl trimellitate; TPP- triphenyl phosphate; TCP- tricresyl phosphate (tentatively identified); DEHA- diethylhexyl adipate; DiNA- diisononyl adipate (tentatively identified); DiDA- diisodecyl adapate (tentatively identified); siloxanes- indicative of silicon-based polymer

Analysis of lead in electrical solders from the XBox 360, PS3 and Wii game consoles

Sample #	Description	Beryllium concentration (%)		
		XBox 360	PS3	Wii
S01	HDD; solder pads on PWB(a)	<0.1%	<0.1%	-
S02	DVD drive; PWB	<0.1%	<0.1%	<0.1%
S03	DVD drive; on small motor	<0.1%	<0.1%	<0.1%
S04	solder pads on communication PWB(b)	<0.1%	<0.1%	<0.1%
S05	hand controller PWB	<0.1%	<0.1%	<0.1%
S05B	2nd hand controller PWB(c)	-	-	<0.1%
S06	cooling fan PWB (within body of fan)	<0.1%	<0.1%	<0.1%
S07	transformer PWB	<0.1%	<0.1%	<0.1%
S08	main PWB	<0.1%	<0.1%	<0.1%
S09	sensor bar PWB(d)	-	-	<0.1%

Table A3. Electrical solder samples analysed for their lead content. (a) Wii has no HDD (b) XBox 360 RF module; PS3 bluetooth board; Wii WiFi antenna (c) second Wii hand controller – Nunchuck (d) Wii only

Analysis of hexavalent chromium in metallic surfaces from the XBox 360, PS3 and Wii game consoles

Sample #	Description	Presence of hexavalent chromium Cr(VI)		
		XBox 360	PS3	Wii
Cr01	transformer block internal plate	nd	nd	nd
Cr02	motherboard USB socket	nd	nd	nd
Cr03	main cooling grill	nd	nd	nd
Cr04	secondary cooling grill	nd	nd	nd
Cr05	main internal metal case of console	nd	-	nd
Cr06	large heat sink clamps	nd	nd	-
Cr07	large internal metal plate	nd	nd	nd
Cr08	metal plate inside HDD case(a)	nd	-	-
Cr09	screws (one of each type)	nd	nd	nd
Cr10	HDD case attached to PWB(a)	nd	nd	-
Cr11	HDD metal housing(a)	nd	nd	-
Cr12	DVD metal casing	nd	nd	nd
Cr13	metal plate attached to fan	-	nd	-

Table A4. metallic surface analysed for the presence of hexavalent chromium, Cr (VI). nd – not detected. (a) Wii has no HDD

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