

1 **Lead in plastics – recycling of legacy material and**
2 **appropriateness of current regulations**

3
4 Andrew Turner

5 School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus,
6 Plymouth PL4 8AA, UK

7
8 Montserrat Filella*

9 Department F.-A. Forel, University of Geneva, Boulevard Carl-Vogt 66, CH-1205 Geneva,
10 Switzerland; email: montserrat.filella@unige.ch

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16 **Abstract**

17 X-ray fluorescence **spectrometry** has been employed to measure Pb in a wide range of
18 consumer and environmental plastics, including food-packaging material, household goods,
19 electronic casings, beach litter and agricultural waste. Results reveal high concentrations of Pb
20 ($> 1000 \text{ mg kg}^{-1}$) in historical items that are still in use or circulation (e.g. toys, construction
21 plastics, wiring insulation) and variable, but **generally lower concentrations** in more recently
22 manufactured articles. Analysis of Br, Cl and Cr, proxies for brominated flame retardants,
23 polyvinyl chloride (PVC) and chromate pigments, respectively, suggests that as historical
24 material is recycled, Pb from electronic plastics and pigments, but not PVC, is dispersed into a
25 variety of newer products. Although **most cases in the consumer sector comply with relevant**
26 **EU Directives, some products that are non-compliant highlight shortfalls in regulations where**
27 **recycling is involved and potential problems arising from the direct fashioning of industrial**
28 **plastics into new consumer goods through attempts to be environmentally positive.** The
29 uncontrolled loss of historical and recycled plastics has also resulted in Pb contamination of
30 the environment. Here, it is proposed that litter can be classified as hazardous depending on its
31 Pb content and according to existing regulations **that embrace** consumer plastics.

32

33 **Keywords:** XRF; historical plastic; consumer goods; recycling; contamination; environmental
34 litter; EU directives

35

36 **1. Introduction**

37 Current consensus in the scientific community is that there is no safe level of exposure to lead
38 (Pb), and in particular for young children (Lanphear, 2017; Spungen, 2019). Thus, cumulative
39 childhood exposure can result in damage to the brain and nervous system, slowed growth,
40 anaemia, hearing loss, **and behavioural and learning problems**, while in adults exposure can
41 increase blood pressure and incidence of hypertension, decrease kidney function and reduce
42 fertility (Agency for Toxic Substances and Disease Registry, 2007).

43 The widespread use of leaded gasoline caused the dispersion of large quantities of airborne Pb
44 throughout the environment in the 20th century, resulting in serious exposure for both humans
45 and ecosystems (Caprino and Togna, 1998; Kristensen, 2015). Despite the phasing out of Pb
46 as an antiknock agent, dusts and soils with high concentrations of legacy automotive Pb are
47 still present in cities and close to major roads (**Mielke et al., 2010**; Filella and Bonet, 2017).
48 Other legacy sources of Pb in the environment and/or in the household include old paints that
49 are deteriorating or disturbed, leaded plumbing and industrial and mining waste (Clark et al.,
50 2004; Howard et al., 2015; Shu et al., 2015; Ruckart et al., 2019).

51 **An additional source** of legacy Pb that has received less attention is historical plastic or plastic
52 that has been recycled from historical plastic. Lead was commonly used in a range of plastics
53 as a series of chromate pigments and in polyvinyl chloride as a heat and UV stabiliser (Hansen
54 et al., 2013). However, strict regulations on Pb concentrations in electrical plastics (Restriction
55 of Hazardous Substances – RoHS – Directive; Commission Delegated Directive, 2015), toys
56 (Toy Safety Directive 2009/48/EC; European Parliament and Council of the EU, 2009),
57 packaging (Packaging and Packaging Waste Directive 94/62/EC; European Parliament and
58 Council of the EU, 1994) **and food contact material (EC Directive 2002/72/EC; Commission**
59 **Directive, 2002)**, coupled with the voluntary phasing out of Pb by the PVC industry (VinylPlus,

60 2014), have effectively eliminated the intentional introduction of the metal into new products
61 on the European market. In the US, the Consumer Products Safety Improvement Act now limits
62 the amount of Pb in products intended for children under 12 years, including plastics
63 (Consumer Product Safety Commission, 2008), while the Institute of Electrical and Electronics
64 Engineers Standard 1680 regarding personal computer products adopts the RoHS and
65 packaging and Packaging Waste directives and refers to an optional limit of intentionally added
66 Pb in plastic computer components (IEEE, 2006). Despite these regulations, evidence for the
67 dispersion of Pb at lower levels in contemporary consumer plastics that result from the legal
68 and illegal recycling of historical plastics has recently emerged (Turner and Filella 2017;
69 Turner, 2018).

70 **In this study, we use a rapid, non-destructive X-ray fluorescence (XRF)** technique to determine
71 the concentrations of Pb and various other elements serving as proxies for the origin of Pb in
72 both contemporary and historical consumer plastics and in material lost to the environment.
73 The results provide a valuable insight into the extent of Pb contamination in plastics in
74 circulation and that pervade in the environment, and allow us to assess whether current
75 regulations are being met or, in many circumstances, are entirely appropriate, and in particular
76 where material is recycled.

77 **2. Materials and methods**

78 *2.1. Materials*

79 **About 1500 samples were considered** here that had been analysed as part of previous research
80 programmes (Turner and Solman, 2016; Turner and Filella, 2017; Filella and Turner, 2018) or
81 had been acquired specifically for the present study. Samples constitute hard plastics (i.e.
82 **excluding rubbers and foams**) and, while textiles have not been included, we consider
83 constructions of coarser and longer fibres like rope and twine. Table 1 categorises and

84 quantifies the plastics according to use or source and provides general examples for each
85 category. Thus, agriculture and beached refer to plastics lost in nature through agricultural and
86 aquatic-maritime activities and from littering and municipal (and industrial) waste and
87 embraces primary objects and secondary fragments (including microplastics of < 5 mm in
88 diameter). Agricultural samples were collected from the edges of fields in Luxembourg and
89 Spain during spring and summer of 2018 and beached samples were retrieved from the
90 strandlines of sandy shores of southwest England in mid-2015 and the gravel shores of Lake
91 Geneva in March 2016.

92 Single-use food defines plastics used for the packaging of food and the containment or
93 takeaway of fast food and drinks that had been acquired since 2016. Consumer goods refers to
94 products commonly encountered in the household, office or workplace and includes items
95 purchased in the UK within the last five years and in Switzerland in 2018 as well as older
96 articles (up to 45 years) that are in common circulation or use because of their durability or
97 their function (e.g. structural and plumbing). Electronic plastics are casings and housings of
98 electronic and electrical equipment and insulation for wiring (excluding rubbers). Note that in
99 Table 1, and based on signage or estimated age, consumer and electronic plastics are
100 subdivided (by number) according to whether articles had been purchased, manufactured or
101 installed before or since the original RoHS Directive (2002/95/EC; European Parliament and
102 Council, 2003) came into effect in July 2006.

103 Table 1: Quantities (*n*) and categories of plastic considered in the present study, along with
104 general examples and the number of PVC-based samples (*n*-PVC) in each category. Shown in
105 parentheses are the numbers of samples estimated or known to be manufactured pre-RoHS and
106 post-RoHS.

Category	<i>n</i>	<i>n</i> -PVC	Examples
Agriculture	55	2	film, gauze-mesh, packaging, potting, tree protection, twine, tarpaulin
Beached (lacustrine)	584	32	primary and secondary plastics
Beached (marine)	217	2	primary and secondary plastics and microplastics (< 5 mm)
Consumer goods	353 (193/160)	58 (31/27)	toys, storage, stationery, apparel, sports gear, plumbing, construction, tools, decor
Electronic	193 (115/78)	18 (16/2)	phones, chargers, wiring, laptops, white goods, appliances, sockets-switches, remotes
Single-use food	95	2	packaging, trays, cutlery, cups, bottles, lids, stirrers
Total	1497	114	

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108 2.2. XRF analysis

109 Samples were analysed by energy-dispersive FP-XRF using a Niton XL3t 950 He GOLDD+
110 operated in a standardless ‘plastics’ mode (Turner and Solman, 2016). The majority of samples
111 were analysed in the laboratory in an accessory stand and by remote activation of the
112 instrument, with a thickness correction algorithm applied between 50 µm and 12 mm.
113 Thickness was determined through the measurement surface using Allendale digital callipers
114 or, where inaccessible, was estimated from the thickness of samples of similar construction.
115 Samples were analysed for a suite of elements, of which the present focus was on Pb, Br (a
116 proxy for brominated flame retardants), Cl (a proxy for PVC above a concentration of 15%;
117 Turner and Filella, 2020) and Cr (whose association with Pb may indicate the presence of lead
118 chromate pigments). Counting was undertaken for periods ranging from 30 to 180 s, depending
119 on sample thickness, that were distributed equally or in a 1:2 ratio between a low energy range
120 (20 kV and 100 µA) and main energy range (50 kV and 40 µA). Spectra were quantified by
121 fundamental parameter coefficients to yield concentrations on a dry weight basis (in mg kg⁻¹)
122 and with a counting error of 2σ (95% confidence). For samples too large to be contained by
123 the accessory stand or that were permanent fixtures in the household setting the instrument was
124 used handheld and with a backscatter shield under the conditions described above.

125 As a performance check, polyethylene reference discs Niton PN 180-619 (Cr = 101 ± 10 mg
126 kg⁻¹; Pb = 150 ± 12 mg kg⁻¹) and Niton PN 180-554 (Br = 495 ± 20 mg kg⁻¹; Cr = 995 ± 40 mg
127 kg⁻¹; Pb = 1002 ± 40 mg kg⁻¹) were analysed throughout each measurement session, with the

128 instrument returning concentrations that were consistently within 15% of certified values.
129 Detection limits varied depending on counting time, sample size and thickness and whether the
130 instrument was deployed in a stand or activated handheld but indicative values based on the
131 lowest counting errors returned throughout the study were about 6 mg kg⁻¹ for Br and Pb and
132 12 mg kg⁻¹ for Cl and Cr. Precision, defined as the relative standard deviation arising from
133 quintuplicate measurements of selected samples, was better than 10% in most cases but
134 approached 20% for small or thin samples or where concentrations were close to detection
135 limits.

136 **3. Results**

137 The number of cases in which Pb was detected and summary statistics for concentrations of
138 the metal are shown for each plastic sample category in Table 2. Note that the data for the
139 beached samples differ slightly to those published previously because here we have focused on
140 hard plastics and have neglected foams, paints and rubbers (Turner and Solman, 2016; Filella
141 and Turner, 2018). Detection occurred across all categories and was most frequent (on a
142 percentage basis) among beached samples and electronic plastics and was lowest in the single-
143 use food category. Overall, Pb concentrations were variable, spanning four orders of magnitude
144 and ranging from < 10 mg kg⁻¹ to about 3.4% by weight, and >20% of Pb-positive samples in
145 each category with the exception of single-use food exceed the RoHS limit for Pb of 1000 mg
146 kg⁻¹.

147 Samples of PVC, defined as returning a Cl content greater than 15% by the XRF, were
148 encountered in all categories but were most abundant (on a percentage basis) among consumer
149 goods and least abundant in beached marine plastics (Table 1). Associations of Pb with PVC
150 were most frequent in consumer goods and electronic plastics while associations with Br and

151 Cr were most frequent in beached litter; in contrast, no associations of Pb with PVC or Cr and
152 just one association with Br were observed in the single-use food category (Table 2).

153 Table 3 shows the number of cases in which Pb was detected and summary statistics for
154 concentrations of the metal for electronic and consumer plastics categorised according to
155 whether they were estimated or known (from signage) to have been manufactured, sold or
156 installed pre-RoHS or post-RoHS. Thus, about a third of electronic articles manufactured
157 before the directive came into effect (in 2006) contained detectable Pb, with an exceedance of
158 the RoHS limit of 1000 mg kg^{-1} in 19 cases and an association with PVC in 14 samples. In
159 contrast, only four post-RoHS electronic samples contained detectable Pb with no exceedance
160 of the RoHS limit or association with PVC. Despite these differences, however, a Mann-
161 Whitney U test undertaken in Minitab v19 revealed no significant difference ($p = 0.119$) in
162 median concentrations between the two groups. With respect to consumer plastics, Pb detection
163 rate was similar among products manufactured pre-RoHS and post-RoHS, and although mean,
164 median and maximum concentrations were greater in pre-RoHS consumer articles than post-
165 RoHS items, a Mann-Whitney U test indicated no significant difference ($p = 0.131$) in median
166 concentrations.

167 Table 2: Number and percentage of samples in which Pb was detected (n (%)) and summary
168 statistics defining Pb concentrations (in mg kg^{-1}) in each category. Also shown are the number
169 of samples that exceed the RoHS limit of 1000 mg kg^{-1} ($n > \text{RoHS}$), and the number of cases
170 where Pb was detected in PVC ($n\text{-PVC}$) and with Br ($n\text{-Br}$) or Cr ($n\text{-Cr}$).

	Agriculture	Beached (lacustrine)	Beached (marine)	Consumer goods	Electronic	Single-use food
<i>n</i> (%)	6 (10.9)	134 (22.9)	47 (21.7)	42 (11.9)	41 (21.2)	4 (4.2)
mean	4500	2150	765	3300	5570	114
sd	8060	4010	2010	5560	8080	152
median	390	433	142	573	512	43.2
min	62.1	5.9	6.3	3.9	17.3	26.9
max	20400	23500	13200	21700	34100	342
Q1	302	41.0	30.8	137	104	32.8
Q3	4230	2210	704	3720	10000	124
<i>n</i> > RoHS	2	55	9	18	19	0
<i>n</i> -PVC	0	16	0	14	14	0
<i>n</i> -Br	0	43	20	11	19	1
<i>n</i> -Cr	5	88	32	12	4	0

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173 **Table 3: Number and percentage of pre-RoHS and post-RoHS electrical plastics and consumer**174 **goods in which Pb was detected (*n* (%)) and summary statistics defining Pb concentrations (in**175 **mg kg⁻¹) in each category. Also shown are the number of samples that exceed the RoHS limit**176 **of 1000 mg kg⁻¹ (*n* > RoHS), and the number of cases where Pb was detected in PVC (*n*-PVC)**177 **and with Br (*n*-Br) or Cr (*n*-Cr).**

	Pre-RoHS	Post-RoHS	Pre-RoHS	Post-RoHS
	Electronic		Consumer	
<i>n</i> (%)	37 (32.2)	4 (5.1)	23 (11.9)	19 (11.9)
mean	6160	149	5070	1160
sd	8300	91.0	6870	1970
median	1070	149	1190	302
min	17.3	48	3.87	9.64
max	34100	251	21700	7240
Q1	158	89.7	282	68.0
Q3	10500	209	9000	1040
<i>n</i> > RoHS	19	0	13	5
<i>n</i> -PVC	14	0	10	4
<i>n</i> -Br	16	3	5	6
<i>n</i> -Cr	4	0	6	6

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179

180 **4. Discussion**181 *4.1. Legacy Pb in plastics*

182 Evidently, Pb is widely and heterogeneously distributed in plastics that are in circulation and

183 production as well as lost in nature. **The presence of Pb in older plastics is expected because**

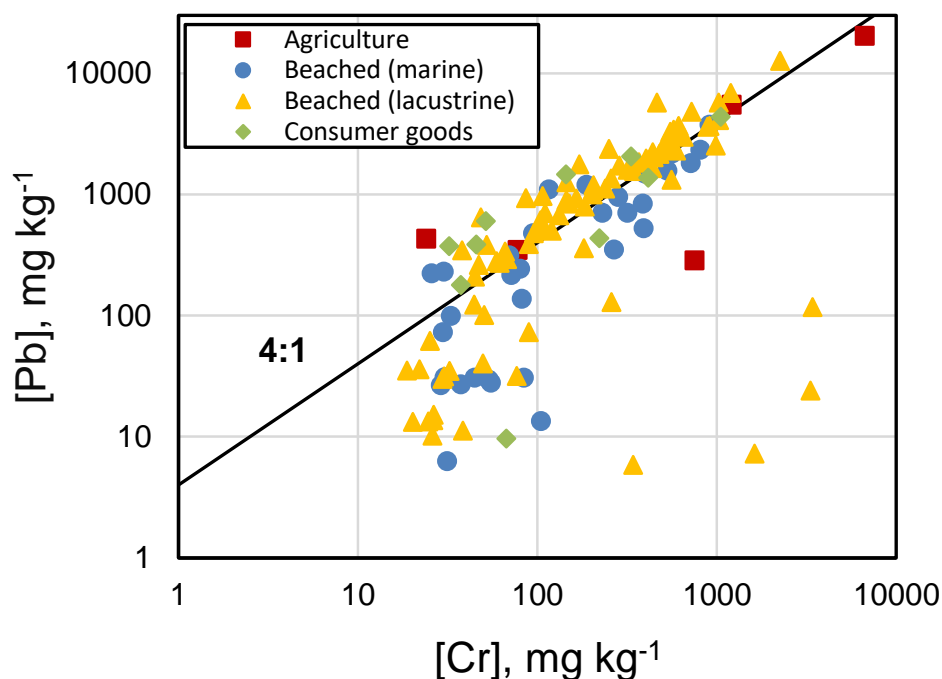
184 the metal chromate was used in a number of coloured pigments in a range of plastics and
185 various leaded compounds acted as heat and UV stabilisers in PVC until they were restricted
186 or phased out according to a series of international regulations and agreements (Hansen et al.,
187 2013). Thus, in many older consumer and electronic plastics, high concentrations of Pb were
188 encountered in unplasticised PVC (e.g. window and door frames) and plasticised PVC (e.g.
189 electrical wire insulation, garden hosing and inflatable toys) and in a range of brightly coloured
190 articles. These traits also characterise many (presumably older) articles and fragments retrieved
191 from the environment, and in particular from beaches, where decadal-old plastics derived from
192 the municipal waste stream, littering or loss (e.g. at sea) may be washed up or exposed (Watts
193 et al., 2017; Turner et al., 2020).

194 4.2. Legacy use and recycling of lead chromate

195 The presence and pervasiveness of lead chromate is evident from the association of Pb and Cr
196 in consumer goods and environmental plastics shown in Figure 1. Thus, the highest
197 concentrations ($[Pb] > 1000 \text{ mg kg}^{-1}$) generally arise from older samples coloured with chrome
198 yellow ($PbCrO_4$), chrome green ($PbCrO_4$ mixed with Fe-based Prussian blue) and chrome
199 orange-red ($PbCrO_4 \cdot PbO$) (Oldring, 2001), with the majority of data close to the line defining
200 the mass ratio of [Pb] to [Cr] in pure $PbCrO_4$ (~ 4). Samples lying close to the line but having
201 Pb and Cr concentrations too low to act as a colourant (e.g. $[Pb] \sim 100 \text{ to } 1000 \text{ mg kg}^{-1}$) were
202 encountered in each category shown and for both contemporary and historical articles. Here,
203 presumably, chromate-based pigments are widely encountered as contaminants of the
204 mechanical recycling of coloured plastics. For Pb concentrations below about 100 mg kg^{-1} ,
205 data points in Figure 1 are more heterogeneously dispersed and generally lie well below the
206 slope defining the composition of $PbCrO_4$. This may be attributed to the more general Pb

207 contamination of recycled plastic (including electronic-based waste; see below) and the use of
208 additional Cr pigments that are free of Pb.

209 The general observations above are consistent with the phasing out of Pb chromate pigments
210 in Europe and, effectively, since an EU court overruling authorisation for production and export
211 by a Canadian company in March 2019, an outright ban (EVISA, 2019). However, XRF results
212 returned for some samples analysed suggest that these pigments are still circulating as
213 colourants in a limited number contemporary products. Specifically, Pb above a concentration
214 of 1000 mg kg^{-1} was found in association with Cr above a concentration of a few hundred mg
215 kg^{-1} in a green clothes peg, red and yellow “environmentally sustainable” shoulder bags that
216 had been fashioned from PVC truck tarp, and pieces of yellow and green agricultural packaging
217 that appeared to have been discarded recently.



218
219 Figure 1: Concentration of Pb versus concentration of Cr in consumer goods and plastics lost
220 to the environment. Note that samples of PVC employing Pb-based stabilisers are not included.

221 The line of slope 4:1 defines the mass ratio of Pb to Cr in pure lead chromate.

222 4.3. Lead contamination from electrical and electronic plastic recycling

223 Although Br is a constituent of the halogenated copper phthalocyanine pigments (Ranta-Korpi
224 et al., 2014), the principal use of brominated compounds in plastics is as flame retardants in
225 electronic components, casings and insulation (Papazoglou, 2004). Thus, an association of Pb
226 with Br provides an upper estimate of the number of samples in each category where the metal
227 is derived from the poorly managed and often illegal use or recycling of contaminated
228 electronic and electrical waste (Turner, 2018). **The highest percentage of Br-Pb associations**
229 **among Pb-positive samples occurs in the electronic category (Table 2) and associations are**
230 **observed in both pre- and post-RoHS articles (Table 3), presumably reflecting the use of**
231 **recycled electronic and electrical plastic in what is intended to be a regulated, circular economy.**
232 **Significantly, there were no associations of Br-Pb-Cr in this category, suggesting that Pb in**
233 **electronic and electrical plastic is contaminated by additional sources other than lead chromate**
234 **pigments (e.g. PVC and soldering residues). Associations of Br-Pb were also observed in**
235 **several consumer products, a single-use food item (cocktail stirrer) and various plastic items**
236 **and fragments retrieved from coastal and lacustrine beaches. Moreover, in these categories Cr**
237 **was also detected in the presence of both Br and Pb in many cases. This suggests that the**
238 **recycling of electronic waste is not constrained to the electrical and electronic industries but**
239 **that some material has been (and continues to be) exported for use in a broader array of plastic**
240 **products that may or may not be contaminated by residues of lead chromate pigments.**

241 4.4. Lead in PVC

242 The frequency distributions of Pb concentrations amongst the samples of PVC in each category
243 are shown in Table 4. Overall and within each category Pb concentrations display a distinctly
244 bimodal distribution; that is, out of **114 PVC-based samples Pb concentrations are focussed**
245 **above 1000 mg kg⁻¹ (n = 39) and below the detection limit (n = 69).** PVC samples containing

246 [Pb] > 1000 mg kg⁻¹ were dominated by older consumer products, plastics associated with pre-
 247 RoHS electrical and electronic items (and occasionally containing traces of Br) and articles and
 248 fragments of beached lacustrine litter, while Pb-free PVC samples comprised newer consumer
 249 goods, post-WEEE electrical plastics, single-use food articles and various plastics lost to the
 250 environment (Tables 2 and 3). Presumably, this observation reflects the historical use of Pb-
 251 based heat and UV stabilisers in PVC in various sectors and the gradual and voluntary phasing
 252 out and replacement of Pb in the more recent manufacture of PVC (VinylPlus, 2014). Unlike
 253 the case for Pb chromate, however, there is no evidence for the widespread contamination of
 254 newer PVC products by Pb-based stabilisers. (The only notable exception is the pair of PVC
 255 shoulder bags described above, but here Pb appears to be related to the more general use of
 256 lead chromate in colour pigments rather than the presence of Pb-based stabilisers.) These
 257 observations suggest one or more of the following: the mechanical recycling of PVC has been
 258 more targeted at and successful in eliminating older Pb-based materials; Pb-based PVC is
 259 recycled for more specific, industrial or professional purposes; the recycling of PVC in general
 260 has been reduced in order to avoid product contamination.

261 Table 4: Frequency distribution of Pb concentrations (mg kg⁻¹) in samples of PVC from each
 262 category. < LOD = below the detection limit.

Category	< LOD	< 100	100-1000	1000-10,000	>10,000
Agriculture	2				
Beached (lacustrine)	15	1	1	10	4
Beached (marine)	2				
Consumer goods	44		4	6	4
Electronic	4			4	11
Single-use food	2				

264 4.5. Compliance with and appropriateness of current regulations

265 There are several cases in the present study that highlight regulations which target certain
266 products but neglect the life cycle of the material. For example, the current RoHS limit for Pb
267 in any component of electrical and electronic equipment is 1000 mg kg⁻¹ (Commission
268 Delegated Directive, 2015), and while this is only exceeded among electrical plastics which
269 pre-date the 2006 implementation of the original Directive (European Parliament and Council,
270 2003), it is exceeded in several newly purchased consumer plastics, some of which are likely
271 to have been manufactured from recycled (and pre-RoHS) electronic plastic. That is, a directive
272 that is specific to electrical plastic does not apply to products that are repurposed from regulated
273 material.

274 Adding to this complexity, and although not electrical in origin, PVC truck tarp that appears to
275 be free of leaded stabilisers but that is coloured by Pb chromate pigments would be non-
276 compliant according to the RoHS. However, this material has been fashioned directly (without
277 mechanical recycling) into shoulder bags produced in Switzerland that are currently on sale in
278 the EU. Subsequent acquisition and XRF analyses of a wider range of bags ($n = 9$) revealed the
279 more general presence of Pb chromate pigments in such products. This is an example of what
280 is designed to be an environmentally positive process that transfers a hazardous plastic from
281 the industrial (transportation) sector to consumer products and one that evades the various
282 regulations on Pb that are currently in place.

283 The dispersion of Pb into plastics more widely through recycling can also result in the non-
284 compliance or potential non-compliance of specific types of consumer plastic. For example, a
285 recent amendment to the latest iteration of the Toy Safety Directive stipulates a migration limit
286 (in dilute HCl) of Pb from material that can be scraped off, including plastic, of 23 mg kg⁻¹
287 (The Council of the European Union, 2017). This means that, in theory, any toy contaminated

288 with Pb above the concentration limit (and ascertained by XRF) could be subject to migration
289 testing. Article II of the Packaging and Packaging Waste Directive (European Parliament and
290 Council of the EU, 1994) states that the sum of concentrations of Pb, Cd, Hg and Cr(VI) present
291 in packaging or packaging components shall not exceed 100 mg kg⁻¹. Since the directive also
292 includes industrial packaging, it would appear that at least two fragments of agricultural
293 wrapping waste greatly exceed the limit value with respect to Pb alone or with respect to Pb
294 combined with Cr(VI). Directive 2002/72/EC relating to plastics intended to come into contact
295 with foodstuffs (Commission Directive, 2002) stipulates an upper limit of 2 mg kg⁻¹ of Pb in
296 the raw material prior to granulation. On this basis, therefore, four single-use food contact items
297 reported here (three drinks stirrers and a coffee cup lid; Pb = 27 to 342 mg kg⁻¹) are non-
298 compliant.

299 One of the key objectives of many of the directives above was to limit noxious metals in plastics
300 because of their environmental impacts, and in particular, to reduce their presence in emissions,
301 ash or leachate arising from controlled disposal. Specific regulations are, however, neither
302 feasible nor appropriate for metal-rich plastics that have accumulated in the environment from
303 a multitude of historical and, likely, transboundary sources. That said, existing regulations or
304 limit values could be used as a framework to define whether plastic litter, including
305 microplastics, is chemically hazardous or not and whether it poses a risk to wildlife or the
306 environment.

307 **5. Conclusions**

308 This study has revealed the wide distribution of Pb in plastics that are in circulation, in
309 production and lost in nature. Observations are attributed to the historical use of the metal as a
310 pigment and additive in plastics (including PVC) and the contamination of contemporary
311 products through mechanical material recycling. Consequently, some currently manufactured

312 products are non-compliant with respect to various directives aimed at protecting human health
313 and the environment. Although plastics lost in nature are not embraced by any specific
314 regulation, limit values could be used as an aid to assess potential impacts in the environment.

315

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