



Toxic chemicals in a child's world: an investigation into PVC plastic products

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Summary

In this study, a variety of common vinyl chloride (PVC or vinyl) consumer products, with uses from childcare to home furnishing, were tested for phthalate plasticisers and heavy metal stabilisers including organotins. Earlier investigations detected the presence of significant levels of phthalates and heavy metals (cadmium and lead) in toys and other PVC products manufactured for children. Toys, however, represent only a small part of the PVC market. On the other hand, construction materials including home furnishing, comprising both rigid products (e.g. window frames, pipes) and softened products (e.g. floor and wall coverings, accessories), account for almost 60% of PVC use (Stringer & Johnston 2001). Although the most direct exposure of children to hazardous additives may be expected from toys and childcare items, the wide variety of other vinyl products in the home may also act as sources of exposure. The scope of samples investigated was therefore expanded to include materials in the home made of vinyl, such as wallpaper and floor coverings, with which children come into contact on a daily basis. The analyses revealed that:

- All except one of the PVC products tested contained detectable levels of phthalates, with a maximum of 38% by weight in a bath mat from Thailand. By far the most common phthalates detected were di(2-ethylhexyl) phthalate (DEHP) and di-isononyl phthalate (DINP).
- Two products from Japan contained bisphenol A, a chemical that affects the hormone system. One of which was a product intended to be put in a child's mouth - a teether.
- Cadmium was present in 19 samples, of which 18 were PVC. Among the PVC samples, the maximum level of cadmium detected was 230mg/kg found in a drawer liner from the USA, while plastic pants from New Zealand contained 132 mg/kg. Both products contained cadmium in excess of the 100mg/kg maximum level set for PVC products in Europe.
- Lead was detected in 26 samples, of which 21 were PVC. However, the most interesting result was discovered in a non-PVC product from the USA which contained 5220mg/kg of lead. Among the PVC samples the maximum level of lead detected was from Chilean wallpaper which contained 441mg/kg of lead.
- Nearly all of the fourteen products tested contained significant amounts of organotins. Floor tiles from Canada, on which children may spend a lot of time crawling and playing, contained the highest level of organotin.

Researchers have established clear evidence of severe toxic effects for many of the additives used in PVC. In particular, research has found that phthalates can impact the reproductive system, lead can affect IQ and cadmium is carcinogenic. Moreover, bisphenol A can disrupt the hormone system and organotins may affect the immune systems of mammals.

Concern over the hazards of additives in PVC has led to regulatory action, or product recalls in Europe and North America. Some of these actions have been a direct response to concerns over the exposure to these additives that children experience. The European Parliament has called for tighter legislation on PVC products and PVC additives. Elimination of these additives from products in the home environment would prevent unnecessary exposure of children.

Introduction- PVC additives

PVC (polyvinyl chloride) is a plastic widely used in many domestic and industrial applications: these include products for the construction industry, packaging products and medical devices together with a wide variety of domestic and other consumer products. PVC in its “raw” state is a highly unstable plastic requiring the use of various additives to prevent it breaking down either spontaneously, or under the influence of heat and sunlight. Other additives are required to counter the somewhat brittle nature of “raw” PVC and also to produce soft PVC when this property is required. Further additives are employed to suppress the flammability of PVC plastic and to colour it. Finally, a range of other additives may be used to modify mechanical properties, to “bulk out” the plastic (fillers), to prevent the build up of static electricity or to assist with the mechanical processing of PVC.

A key consideration in relation to these various additives is that they are not chemically bound to the PVC polymer. Rather, they exist as a simple mixture with the plastic. This creates the possibility that when PVC articles are subjected to certain conditions, these additives can be removed or released from the plastic. Such conditions might include mechanical abrasion (wear) or light-induced degradation, either of which may produce contaminated dust, as well as exposure to damp or wet conditions. Given that many of the additives have known hazardous properties, the possibility of human exposure and consequent impacts upon health is of considerable significance.

Of the chemicals added to PVC to stabilise and modify its physical and mechanical properties, some are known to be toxic. Nonetheless, they are often retained in widespread use for economic reasons. For others, their use continues because, although their hazardous properties are recognised, there is no legislative mechanism or incentive to control their use. Lead compounds, for example, are still routinely used in many PVC products, particularly those used in the construction industry. These additives are cheap and effective in slowing the degradation of PVC through exposure to sunlight, yet the hazardous nature of lead compounds has been recognised for a considerable time.

Other stabilisers in routine use include compounds that contain cadmium, barium and tin. These metals are potentially toxic, in the case of cadmium and tin compounds, highly so. Barium/cadmium stabilisers and organotin compounds are often used in the manufacture of transparent PVC products.

The construction industry uses large quantities of rigid PVC products such as pipes and window frames. For example, in cable coverings or in common consumer products such as squeeze toys or clothing, it must be softened by the addition of large quantities of softeners (also known as plasticisers). The most common chemicals used for this purpose are the phthalate esters, which are more commonly known as phthalates. Phthalates account for 69% of the plasticisers used in the USA, 81% of those used in Japan and 92% of those used in Western Europe (Bizarri *et al.* 1996). Taken together, the total consumption of phthalates in these three regional marketplaces is estimated to exceed two million tonnes per year.

Pigments or dyes are routinely used to colour PVC and these can be made both from organic and inorganic chemical compounds. Colourants containing metals are very commonly used and can incorporate cadmium, lead, chromium, iron, antimony, nickel, cobalt, copper, titanium, manganese and zinc. Almost all of these metal compounds are potentially toxic.

PVC, like other plastics, is flammable. Accordingly, flame-retardants are often added to suppress fire. Antimony trioxide is frequently used for this purpose, as are chlorinated paraffins. Antimony trioxide is a suspected carcinogen. Chlorinated paraffins are persistent organochlorine chemicals, i.e. chemicals that do not readily break down in the environment. Other additives include fillers, impact modifiers, antistatic agents and processing aids, such as lubricants to prevent PVC sticking to the processing machinery. This latter class can include lead and cadmium compounds (Matthews 1996).

With time, the range of additives used in PVC products has grown substantially. Currently, there are thousands of different PVC formulations on the market. The composition of a particular product may be dictated by local legislation. More commonly, a product manufacturer may simply specify the performance characteristics they require from the PVC formulation and leave decisions about the precise composition of the formulation to their supplier.

Toxicity of PVC additives

As noted above, because additives are not chemically bound to PVC, they can leach out of, or otherwise be released from, the product during use, a phenomenon which is now well established (see eg Steiner *et al.* 1998, Sadiki & Williams 1999, Sadiki *et al.* 1996, CPSC 1996, Yamamoto & Yasuhara 1999). Accordingly, concern over the toxicological and environmental properties of chemical additives to PVC has been growing over the last few years.

Phthalate plasticisers have been subjected to close scrutiny and as a result the toxicity of these chemicals is becoming better understood. In recent years, the endocrine (hormone) disrupting properties of some of the group have been revealed. For example, BBP (butyl benzyl phthalate) has been found to be oestrogenic (i.e. it mimics the action of the hormone oestrogen) in laboratory tests (Soto *et al.* 1995, Jobling *et al.* 1995). BBP has also been found to reduce sperm count in experimental animals, even though their exposure to the chemical took place before birth (Sharpe *et al.* 1995). Various phthalates are known to adversely affect reproduction and normal development in laboratory animals. In addition, other effects have been noted in the liver and kidneys of exposed experimental animals (Chan & Meek 1994, ATSDR 1997, Ema *et al.* 1993, 1994 & 1995, Gray *et al.* 1999). The significance of these findings for human health remains unclear, but they are certainly of concern. Recently, attention has been drawn to the high concentrations of potentially leachable phthalates present in children's toys (Stringer *et al.* 2000).

The phthalates, and, in particular, DEHP (di(2-ethylhexyl) phthalate), have been implicated in the increase in childhood asthma recorded in recent decades. Phthalates are found in significant quantities in house dust, as a result of their release from PVC

products in the home. A metabolite of DEHP is known to negatively affect the lung function of rats. A study of children in Norway found that the risk of bronchial obstruction appeared to be directly related to the amount of plasticiser-emitting material present in the home. Plasticised PVC flooring materials were quantitatively one of the most important contributors to this (Jaakola *et al.* 1999, Oie *et al.* 1997). There have also been recent calls for medical doctors to avoid using DEHP-containing medical devices in the treatment of premature infants because of the potential hazards associated with this additive (Rossi & Muehlberger 2000).

Other chemicals added to PVC have also been found to exhibit endocrine disrupting properties. Bisphenol A is added to PVC as an antioxidant or stabiliser (Yamamoto & Yasuhara 1999, Matthews 1996) although much larger quantities are used in other applications such as polycarbonate plastic manufacture and epoxy resin production (Furhacker *et al.* 2000). Bisphenol A is known to have oestrogenic properties (Soto *et al.* 1995).

For some additives used in PVC manufacture, evidence of their toxicity and other negative environmental impacts has arisen as a result of their use in other industrial applications. For example, most of the data regarding the toxicity of the organic tin compounds pertains to marine species, predominantly gastropod molluscs. These have been impacted (in some cases severely) by the use of organotins in anti-fouling paints applied to the bottom of ships and to other marine structures. As a result of the extreme hazards they present to the marine environment, use of these chemicals in marine applications is being progressively curtailed, together with their use as pesticides in agricultural production (see eg Evans 2000). PVC manufacture, therefore, now accounts for two thirds of their use (Sadiki & Williams 1999) despite evidence for potential impacts upon immune systems of mammals and the developing foetus (Kergosien & Rice 1998). There is also evidence that organotin chemicals can adversely affect the central nervous system of mammals (Eskes *et al.* 1999).

Recently, attention has been drawn to the potential hazards associated with metals present in additives to PVC (Di Gangi *et al.* 1997). The toxicological properties of lead have been known for many years. Exposure to this toxic heavy metal can cause anaemia and harm to the nervous system, the reproductive system and the kidneys. The impacts of lead upon the developing nervous system of children is of extreme concern since a permanent lowering of IQ can result (Nielsen *et al.* 2001, Pirkle *et al.* 1998, ATSDR 1997, Bernard *et al.* 1995, Goyer 1993, Nriagu 1988).

As a result of these concerns, in 1975 the Centre for Disease Control (CDC) in Atlanta in the United States recommended that the maximum permissible level of blood-lead be 30 ug/dl (for both adults and children). As the health effects of lead became better understood, and concerns grew, this level was revised downward in 1985 to 25 ug/dl, and again in 1991, when the blood-lead concentration of 10 ug/l was specified as an action or intervention level (ATSDR 1997). Perhaps even more important is the growing body of evidence that suggests that there may be no level of lead in blood that does not induce a toxic effect. The developing central nervous system is considered particularly vulnerable (ATSDR 1997, Goyer 1993).

The International Agency for Research on Cancer (IARC) and the US Department of Health and Human Services both categorise cadmium and cadmium compounds as

carcinogenic to humans (USDHHS 2000). Other targets of cadmium toxicity are the kidneys and the bones (ATSDR 1997).

Thus, the additives used in PVC formulations and which, therefore, ultimately are found in the final manufactured PVC product are associated with a number of recognised potential impacts upon human health. In the case of many of these negative effects, children can be considered to be particularly vulnerable (Nielsen *et al.* 2001). This vulnerability is due both to developmental processes being affected by hazardous chemicals, and to child behaviour patterns that can result in chemical exposure quite different to that in adults.

A significant exposure pathway for children to chemical additives in PVC is likely to be through chewing and mouthing toys or other PVC products such as toys. In addition children may spend considerable amounts of time chewing articles not intended for such activity, or may spend time in contact with them. For example, phthalates are released from PVC flooring both via evaporation as well as during washing (Cadogan 1993). Sources such as these may be of particular concern with respect to children since they spend a lot of time indoors with a breathing range close to the floors.

This study, accordingly, was designed to build on the earlier studies of the presence of additives in PVC toys and household articles with which children could come into contact on a regular basis (Di Gangi *et al.* 1997, Stringer *et al.* 2000, Allsopp *et al.* 2001).

Details of this study

In addition to the phthalate plasticisers and toxic metals analysed in previous studies (Di Gangi 1997, Stringer *et al.* 2000), the current study was extended to include organotin compounds in a subset of samples. These compounds are known to be commonly used as stabilisers in PVC and have the potential for negative impacts upon human health as well as their well-characterised hazard profile in natural ecosystems. Bisphenol A was also determined in all samples.

Samples of various products were obtained for analysis from 20 countries: Austria, Brazil, Canada, Chile, China, the Czech Republic, Denmark, France, Hungary, Italy, Japan, Mexico, the Netherlands, New Zealand, the Philippines, Russia, Spain, Thailand, the UK and the USA. These items were either designed specifically for children, or were common household items with which children would be likely to come into regular and possibly prolonged contact.

In total, 54 products were analysed. Two samples were subdivided, different components of each undergoing analysis. Sample CW0006 was a bottle of maize syrup from Mexico; bottle and syrup were analysed separately. Sample CW0140, a spoon from Italy, was of a shiny rigid plastic with a soft handle. A portion of each was analysed.

All samples were sent to STAT Analysis in Chicago, USA, where they were analysed for: chlorine, five phthalate esters: di(2-ethylhexyl) phthalate (DEHP); butyl benzyl phthalate (BBP); di-n-butyl phthalate (DBP); diethyl phthalate (DEP) and di-isononyl

phthalate (DINP); Bisphenol A, cadmium, lead and tin. Analytical methods are described elsewhere (Di Gangi 1997, Harmon 2001). Subsequently, a subset of 14 samples were sent to GALAB in Geesthacht, Germany, where they were analysed for eight organotin compounds: monobutyltin; dibutyltin; tributyltin; tetrabutyltin; mono-octyltin; dioctyltin; tricyclohexyltin and triphenyltin. Analysis was according to DIN EN 17025.

Results and discussion

11 of the samples and subsamples tested negative for chlorine. The remaining 45 were positive and therefore assumed to be manufactured of PVC. The maize syrup bottle was found to contain chlorine, but the syrup itself did not. The main body of the Italian baby spoon did not contain chlorine, but the soft handle did.

None of the non-PVC products contained any of the five phthalates, but all except one of the PVC ones did. The exception was a teether from Japan (CW0141). In other PVC samples, total phthalate concentrations ranged from a minimum of 103 mg/kg in the Mexican maize syrup bottle (CW0006a) to 378 590 mg/kg (almost 38%) in a bath mat from Thailand (CW0040), with the majority of items containing over 10% phthalates by weight.

By far the most common phthalates were di(2-ethylhexyl) phthalate (DEHP) and diisononyl phthalate (DINP). One or the other were present in all phthalate-containing samples and in most cases, both were present. DEHP was the predominant phthalate in 24 samples and DINP in 18. Butyl benzyl phthalate (BBP) was predominant in only two samples. Di-n-butyl phthalate (DBP) and diethyl phthalate (DEP) were not detected in any samples.

Bisphenol A was found in only two products, a teether (CW0141) and a rain hat (CW0142). Both products came from Japan.

Cadmium was present in 19 samples, of which 18 were PVC. The 19th was a bib from Russia (CW0008), which was 100% cotton yet contained just detectable quantities of cadmium (0.5 mg/kg). The source is not known, although it could have been present in pigments in the decoration on the bib.

Among the PVC samples, concentrations of cadmium ranged from 0.57 mg/kg in a bath mat from Thailand (CW0040) to 230 mg/kg in a drawer liner from the USA (CW0150). In addition, plastic pants from New Zealand (CW0055), contained 132 mg/kg of cadmium. Both the drawer liner and the pants contain cadmium in excess of the 100 mg/kg maximum set for PVC products in Europe (EEC 1991). Cadmium compounds are used in PVC as a stabiliser, as a pigment, and as a lubricant in the processing of plasticised PVC (Matthews 1996).

Lead was detectable in 26 samples, of which five were negative for chlorine. These non-chlorinated samples included the product with the highest concentration of lead, a bib from the USA (CW0115) which contained 5 220 mg/kg (0.5%) of lead. This may have come from the orange pigment in what was a brightly coloured product.

Among the chlorinated samples, lead concentrations ranged between 0.51 mg/kg in a pencil case from Denmark (CW0051) and 441mg/kg in Chilean wallpaper (CW0129). Like cadmium, lead can be a component of stabilisers, pigments and processing lubricants (Matthews 1996).

Tin was detectable in 17 PVC samples and two non-PVC samples. The lowest concentration detected was 3.45 mg/kg in waterproof pants purchased in the USA (CW0128) and the highest, 113 mg/kg, in wallpaper from Chile (CW0129).

Organotins were found in all except one of the 14 samples analysed, with concentrations ranging from 8.2 ug/kg (ppb) in a stroller cover from the USA (CW0107) to 51 338 ug/kg in a floor tile from Canada (CW0050). One of the samples analysed, a bib from the USA (CW0115) was not PVC, but nevertheless contained over 12 500 ug/kg total organotins.

Most samples contained more than one organotin, but two organotin compounds, tricyclohexyltin and triphenyltin, were not detected in any of the samples. Dibutyltin tended to be the predominant compound (six samples), followed by dioctyltin (five samples) and tributyltin (two samples). However, estimations of the amount of tin in the organotins identified do not account for the total tin found in any of the samples. This implies that there may be organotin compounds, or possibly inorganic tin compounds, present other than those that were analysed for.

Table 1 shows the results from a range of children's products, including the toys and teethers.

The only sample in this group that was not PVC (CW0007, a teether from Russia) did not contain any phthalates or metals. The concentrations of phthalates in the toys and teethers were generally in keeping with those found previously for toys from a variety of other countries (Stringer *et al.* 2000). Interestingly, both US teethers contained over 20% DINP. In the US, the Consumer Product Safety Commission requested in 1998 that companies remove phthalates from soft rattles and teethers (CPSC 1998). However this does not constitute a ban. Sale of this product would be prohibited under stricter European legislation (EC 1999) which specifies that products which are intended to be placed in the mouth by children under three years of age should not contain more than 0.1% DINP.

The only other additive of note in the teethers was slightly over 400 mg/kg of the antioxidant bisphenol A in the Japanese sample.

The four toys analysed were all PVC and all contained phthalates. However, one sample, a squeeze ball from Japan (CW0143), contained only 114 mg/kg of DINP, which would not have been sufficient to achieve any softening of this highly flexible product. It must therefore be plasticised by another material, and the DINP may be present as a contaminant from another manufacturing batch. In the three other samples, from Thailand (CW0027 & CW0033) and Austria (CW0060), DINP was the primary plasticiser, present at between 19% and 25%. Lead was also present in two of the samples, but bisphenol A, cadmium and tin were not detectable. Organotins were not determined.

Other children's products were a pencil case from Denmark (CW0051), a car sunshade from Brazil (CW0065) and a stroller rain cover from the USA (CW0107). Although low concentrations of metals were detected in these samples, the most notable chemical constituents in these samples were from the phthalates. DEHP was the predominant plasticiser in each case and DEHP concentrations ranged from over 18% to almost 24%.

Results for the items of children's clothing analysed are presented in Table 2. The most common items were the waterproof pants (diapers) and bibs. The four pairs of waterproof pants analysed all contained over 20% by weight phthalates and one, from Mexico (CW0005) contained over 30%.

Of the five bibs analysed, three did not contain chlorine. Indeed, one (CW0008, from Russia) did not contain any plastic at all. The two PVC-containing bibs, in addition to low to moderate concentrations of metals, were plasticised with phthalates at concentrations around 8% in the sample from China (CW0095) and 21% in the sample from Canada (CW0048). Although the Canadian bib contained the commonly found DINP, the Chinese bib was one of only two samples that incorporated significant quantities of BBP.

The chemical content of the non-chlorinated bibs merits comment. One, from the Czech Republic (CW0012) was negative for all parameters tested. However, the 100% cotton bib from Russia contained a small amount of cadmium and some 91mg/kg lead. As mentioned above, these might be from dyes or other colorants. Moreover, a plastic laminated cotton bib from the USA (CW0015) contained more lead than any other product tested during this survey, 5 220 mg/kg or 0.5%. Again, this may be from the colorants. In addition, this bib contained 12 671 ug/kg total organotins, the third highest result encountered. Approaching 90% of the organotin content was dibutyltin.

The remaining four clothing products all contained percentage levels of phthalates. The lowest was just under 15% DINP in a pair of sandals from the USA (CW0124). The section analysed was clear, so it was not surprising that these contained high concentrations of octyltin stabilisers since these are popular in this type of application. The other garments (a raincoat and two hats) contained 20-28% phthalates and one of the hats (CW0142 from Japan) contained not only lead (179 mg/kg) but also bisphenol A (176 mg/kg).

Twelve general household items were included in the survey; results are given in Table 3. Only one, a shower curtain from France (CW0134) tested negative for chlorine. This was clearly labelled as PVC on the packaging, but inspection, chlorine test and an almost complete absence of the typical additives all indicate that it was incorrectly labelled. In contrast, a US shower curtain (CW0112) consisted of over 22% DEHP. The other bathroom product, a bath mat from Thailand (CW0040), contained more DEHP- almost 38% - than any other product in this survey. Moreover, it contained 12.6 mg/kg tin, which could represent an appreciable loading of organotins, although these were not tested for.

Two floor tiles (CW0050 from Canada and CW0160 from the USA) had similar composition; 3-4% of phthalates, around half of which was BBP. Both also contained organotin stabilisers, though the loading in the Canadian tile, at 51 388 ug/kg, was not only over 10 times that of the US tile, but also the highest recorded in this survey. The third flooring sample, a carpet protector from the USA (CW0148) contained an order of magnitude more phthalates, but comparatively low concentrations of organotins.

Two wallpapers were analysed; both were heavily plasticised with phthalates and one, from Chile (CW0129) also contained notable concentrations of lead (441 mg/kg) and organotins (37 335 ug/kg). A plastic-coated paper drawer liner from the USA (CW0150) had almost 12% phthalates and some 230 mg/kg of cadmium. This last is over twice the concentration that would be acceptable in Europe (EEC 1991). The other samples in this category again were also plasticised with phthalates (21-29%) and one, a handbag from the USA (CW0113) was also stabilised with organotins.

Table 4 presents the results for products concerned with hygiene for a child: changing mats, waterproof mattress covers and so on. The plastic portions of all the five changing mats tested were PVC and all were softened with phthalates, at concentrations of between 7% (CW0105, Spain) and 20% (CW0056, New Zealand). One of the mats (CW0035, Thailand) contained lead and cadmium and two (CW0100, Netherlands and CW0110, USA) contained tin. This last US sample was also analysed for organotins and was found to contain over 4 000 ug/kg of tributyltin.

The three mattress covers analysed all contained phthalates; two (CW0106, USA and CW0145, UK), at around 6-7% and one (CW0037, Thailand) at over 17%. In addition the US mattress pad contained 83.3 mg/kg of cadmium.

Sample CW0138, a nasal aspirator bought in Italy, contained over 18% DEHP. The remaining two products in this category, a toothbrush and a medicine dispenser, (CW0078 & CW0079), both from the Philippines, tested negative for chlorine. Nevertheless, the medicine dispenser contained almost 248 mg/kg of lead.

Nine samples pertaining to food and mealtimes were analysed; results are presented in Table 5. Maize syrup from Mexico (CW0006a) was sold in a PVC bottle (CW0006b). The bottle contained traces of DEHP and significant quantities of organotins, mostly octyltin, but none of the parameters tested were present at detectable concentrations in the syrup itself.

One spoon (CW0092, from China) was non-PVC, as was the main body of one from Italy (CW0140a). However, the handle of this Italian spoon (CW0140b) was PVC and contained some 23% DINP as well as 6.88 mg/kg tin. The presence of tin makes it likely that there was a significant organotin content, but this was not analysed for. Coolers (CW0057 from Hungary and CW0062 from Brazil) were each softened with around 20% of DEHP, and both lead and cadmium, whereas only the Hungarian cooler contained tin. A high chair cushion from the UK (CW0144) was plasticised

with almost 10% phthalates, and lastly, a non-PVC place mat from Chile (CW0130) contained traces of lead and tin.

Number		CW0007	CW0027	CW0033	CW0051	CW0060	CW0065	CW0107	CW0109	CW0127	CW0141	CW0143
Country		Russia	Thailand	Thailand	Denmark	Austria	Brazil	USA	USA	USA	Japan	Japan
Description		teether	rubber duck	squeeze toy	school kit (pencil case analysed)	inflatable swim ring	car sunshade	stroller cover	crib rail teether	teether	teether	squeeze ball
Chloride screen		-	+	+	+	+	+	+	+	+	+	+
Di(2-ethylhexyl) phthalate	mg/kg	<100	100	<100	204000	1310	239000	187000	260	212	<100	<100
Butyl benzyl phthalate	mg/kg	<100	448	<100	<100	220	<100	<100	<100	<100	<100	<100
Di-n-butyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Diethyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Di-isononyl phthalate	mg/kg	<100	227000	197000	1550	249000	7560	9000	208000	287000	<100	114
Total phthalates	mg/kg	<500	227548	197000	205550	250530	246560	196000	208260	287212	<500	114
Bisphenol A	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	407.00	<100
Cadmium	mg/kg	<0.500	<0.500	<0.500	6.09	<0.500	3.47	1.09	<0.500	<0.500	<0.500	<0.500
Lead	mg/kg	<0.500	<0.500	35.40	0.51	1.37	3.27	1.03	<0.500	<0.500	<0.500	<0.500
Tin	mg/kg	<2.50	<2.50	<2.50	<2.50	<2.50	5.55	<2.50	<2.50	<2.50	<2.50	<2.50
Monobutyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	2.10	<0.3	n/a	n/a	n/a
Dibutyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	2.20	<0.3	n/a	n/a	n/a
Tributyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	0.40	<0.3	n/a	n/a	n/a
Tetrabutyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	<0.3	<0.3	n/a	n/a	n/a
Monooctyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	1.90	<0.4	n/a	n/a	n/a
Diocetyl tin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	1.60	<0.4	n/a	n/a	n/a
Tricyclohexyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	<0.3	<0.3	n/a	n/a	n/a
Triphenyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	<0.3	<0.3	n/a	n/a	n/a
Total organotins	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	8.20	<0.26	n/a	n/a	n/a

Table 1. Additives in a range of children's products. n/a= not analysed.

Number		CW0005	CW0010	CW0055	CW0128	CW0008	CW0012	CW0048	CW0095	CW0115	CW0124	CW0125	CW0135	CW0142
Country		Mexico	Czech Republic	New Zealand	USA	Russia	Czech Republic	Canada	China	USA	USA	USA	France	Japan
Category		clothing	clothing	clothing	clothing	clothing	clothing	clothing	clothing	clothing	clothing	clothing	clothing	clothing
Description		pants	pants	pants	pants	bib	bib	bib	bib	bib	shoes	hat	rain coat	rain hat
Chloride screen		+	+	+	+	-	-	+	+	-	+	+	+	+
Di(2-ethylhexyl) phthalate	mg/kg	319000	265000	268000	3100	<100	<100	1890	3250	<100	<100	203000	18600	267000
Butyl benzyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	144	55600	<100	<100	<100	<100	<100
Di-n-butyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Diethyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Di-isononyl phthalates	mg/kg	795	19700	<100	217000	<100	<100	213000	22400	<100	149000	<100	269000	14800
Total phthalates	mg/kg	319795	284700	268000	220100	<500	<500	215034	81250	<500	149000	203000	287600	281800
Bisphenol A	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	176
Cadmium	mg/kg	1.15	<0.500	132	<0.500	0.503	<0.500	<0.500	43.3	<0.500	<0.500	<0.500	<0.500	1.18
Lead	mg/kg	<0.500	<0.500	15.7	<0.500	91.7	<0.500	0.761	<0.500	5220	0.726	0.835	<0.500	179
Tin	mg/kg	5.34	<2.50	<2.50	3.45	<2.50	<2.50	<2.50	<2.50	83.7	9.83	3.62	<2.50	<2.50
Monobutyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1600	13.1	6.4	n/a	n/a
Dibutyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	11000	64.4	55.4	n/a	n/a
Tributyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	52.2	0.6	2.6	n/a	n/a
Tetrabutyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.1	0.8	<0.3	n/a	n/a
Monooctyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3.1	2860	5.1	n/a	n/a
Diocetyl tin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	14.8	5840	16.6	n/a	n/a
Tricyclohexyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<0.3	<0.3	<0.3	n/a	n/a
Triphenyltin	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<0.3	<0.3	<0.3	n/a	n/a
Total organotins	µg /kg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	12671.2	8778.9	86.1	n/a	n/a

Table 2. Additives in clothing, including waterproof underwear and bibs.

Number		CW0134	CW0112	CW0040	CW0050	CW0160	CW0148	CW0104	CW0129	CW0150	CW0053	CW0113	CW0098
Country		France	USA	Thailand	Canada	USA	USA	Spain	Chile	USA	Denmark	USA	Netherlands
Category		household	household	household	household	household	household	household	household	household	household	household	household
Description		shower curtain	shower curtain	bath mat	floor tile	floor tile	carpet protector	wallpaper	wallpaper	drawer liner	inflatable sofa	lady's handbag	suckers
Chloride screen		-	+	+	+	+	+	+	+	+	+	+	+
Di(2-ethylhexyl) phthalate	mg/kg	<100	221000	378000	115	<100	247000	26500	119000	22400	291000	217000	293000
Butyl benzyl phthalate	mg/kg	<100	<100	590	19700	16600	<100	<100	<100	394	<100	<100	<100
Di-n-butyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Diethyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Di-isononyl phthalates	mg/kg	<100	<100	<100	21100	12300	<100	15300	<100	97200	2350	<100	839
Total phthalates	mg/kg	<500	221000	378590	40915	28900	247000	41800	119000	119994	293350	217000	293839
Bisphenol A	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cadmium	mg/kg	<0.500	3.69	0.57	<0.500	<0.500	<0.500	<0.500	6.33	230	<0.500	0.59	0.869
Lead	mg/kg	3.14	17.4	<0.500	<0.500	0.774	<0.500	1.69	441	15.1	<0.500	32.9	2.22
Tin	mg/kg	<2.50	<2.50	12.6	76.5	<2.50	<2.50	<2.50	113	<2.50	<2.50	5.57	<2.50
Monobutyltin	µg /kg	n/a	n/a	n/a	2830	440	3.2	n/a	3530	n/a	n/a	102	n/a
Dibutyltin	µg /kg	n/a	n/a	n/a	13600	3160	0.8	n/a	15500	n/a	n/a	2250	n/a
Tributyltin	µg /kg	n/a	n/a	n/a	258	27.4	1.1	n/a	805	n/a	n/a	5.6	n/a
Tetrabutyltin	µg /kg	n/a	n/a	n/a	<0.3	7.3	<0.3	n/a	<0.3	n/a	n/a	<0.3	n/a
Monooctyltin	µg /kg	n/a	n/a	n/a	16000	8.1	2.8	n/a	3500	n/a	n/a	278	n/a
Dioctyltin	µg /kg	n/a	n/a	n/a	18700	34.8	9.2	n/a	14000	n/a	n/a	410	n/a
Tricyclohexyltin	µg /kg	n/a	n/a	n/a	<0.3	<0.3	<0.3	n/a	<0.3	n/a	n/a	<0.3	n/a
Triphenyltin	µg /kg	n/a	n/a	n/a	<0.3	<0.3	<0.3	n/a	<0.3	n/a	n/a	<0.3	n/a
Total organotins	µg /kg	n/a	n/a	n/a	51388	3677.6	17.1	n/a	37335	n/a	n/a	3045.6	n/a

Table 3: Additives in household items. n/a- not analysed.

Number		CW0035	CW0056	CW0100	CW0105	CW0110	CW0037	CW0106	CW0145	CW0138	CW0078	CW0079
Country		Thailand	New Zealand	Netherlands	Spain	USA	Thailand	USA	UK	Italy	Philippines	Philippines
Category		hygiene	hygiene	hygiene	hygiene	hygiene	hygiene	hygiene	hygiene	hygiene	hygiene	hygiene
Description		changing mat	changing mat	bag and changing mat	changing mat	changing mat	mattress cover	mattress pad	mattress cover	nasal aspirator	toothbrush	medicine dispenser
Chloride screen		+	+	+	+	+	+	+	+	+	-	-
Di(2-ethylhexyl) phthalate	mg/kg	168000	198000	154000	17300	6610	170000	184	<100	182000	<100	<100
Butyl benzyl phthalate	mg/kg	<100	240	703	<100	311	<100	<100	<100	<100	<100	<100
Di-n-butyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Diethyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Di-isononyl phthalates	mg/kg	4530	4810	1820	22500	67200	3650	68800	60900	956	<100	<100
Total phthalates	mg/kg	172530	203050	156523	39800	74121	173650	68984	60900	182956	<500	<500
Bisphenol A	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cadmium	mg/kg	35.7	<0.500	<0.500	<0.500	<0.500	16.2	83.3	<0.500	<0.500	<0.500	<0.500
Lead	mg/kg	74.5	<0.500	<0.500	<0.500	<0.500	35.8	<0.500	<0.500	<0.500	<0.500	248
Tin	mg/kg	25.4	30.5	3.51	<2.50	6.05	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50
Monobutyltin	µg /kg	1.1	n/a	n/a	n/a	173	n/a	n/a	13.7	n/a	n/a	n/a
Dibutyltin	µg /kg	2.7	n/a	n/a	n/a	73.3	n/a	n/a	43.7	n/a	n/a	n/a
Tributyltin	µg /kg	2.5	n/a	n/a	n/a	4120	n/a	n/a	192	n/a	n/a	n/a
Tetrabutyltin	µg /kg	<0.3	n/a	n/a	n/a	6.4	n/a	n/a	<0.3	n/a	n/a	n/a
Monooctyltin	µg /kg	6.7	n/a	n/a	n/a	<0.4	n/a	n/a	4.3	n/a	n/a	n/a
Diocetyl tin	µg /kg	11.4	n/a	n/a	n/a	<0.4	n/a	n/a	12.3	n/a	n/a	n/a
Tricyclohexyltin	µg /kg	<0.3	n/a	n/a	n/a	<0.3	n/a	n/a	<0.3	n/a	n/a	n/a
Triphenyltin	µg /kg	<0.3	n/a	n/a	n/a	<0.3	n/a	n/a	<0.3	n/a	n/a	n/a
Total organotins	µg /kg	24.4	n/a	n/a	n/a	4372.7	n/a	n/a	266	n/a	n/a	n/a

Table 4. Hygiene-related products. n/a= not analysed.

Number		CW0006b	CW0006a	CW0092	CW0140a	CW0140b	CW0057	CW0062	CW0144	CW0130
Country		Mexico	Mexico	China	Italy	Italy	Hungary	Brazil	UK	Chile
Category		mealtimes	mealtimes	mealtimes	mealtimes	mealtimes	mealtimes	mealtimes	mealtimes	mealtimes
Description		maize syrup bottle	maize syrup	spoon	spoon	spoon (handle)	cooler	cooler	high chair cushion	place mat
Chloride screen		+	-	-	-	+	+	+	+	-
Di(2-ethylhexyl) phthalate	mg/kg	103	<100	<100	<100	811	184000	205000	67200	<100
Butyl benzyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100
Di-n-butyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100
Diethyl phthalate	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100
Di-isononyl phthalates	mg/kg	<100	<100	<100	<100	231000	1560	<100	32600	<100
Total phthalates	mg/kg	103	<500	<500	<500	231811	185560	205000	99800	<500
Bisphenol A	mg/kg	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cadmium	mg/kg	<0.500	<0.500	<0.500	<0.500	<0.500	69.9	18.5	<0.500	<0.500
Lead	mg/kg	<0.500	<0.500	<0.500	<0.500	<0.500	22.7	179	<0.500	0.845
Tin	mg/kg	28.5	<2.50	<2.50	<2.50	6.88	13.3	<2.50	111	3.71
Monobutyltin	µg /kg	19.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dibutyltin	µg /kg	68.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tributyltin	µg /kg	1.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tetrabutyltin	µg /kg	<0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Monooctyltin	µg /kg	819	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Diocetyl tin	µg /kg	3940	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tricyclohexyltin	µg /kg	<0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Triphenyltin	µg /kg	<0.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total organotins	µg /kg	4848.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 5. Additives in food and related products. n/a = not analysed.

International initiatives to regulate hazardous chemicals found in PVC products

In 1999, the European Commission effectively banned the use of six phthalates in children's toys which were intended to be put in the mouths of children under three years of age. This was due to concerns over exposure of children to these chemicals at a sensitive stage in their development and followed prior action taken by several European governments. Six phthalates (di-iso-nonyl phthalate (DINP), di(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), di-iso-decyl phthalate (DIDP), di-n-octyl phthalate (DNOP) and butylbenzyl phthalate (BBP)) should not be present at more than 0.1% in products intended to be placed in the mouths of children under three years of age (EC 1999 & 2001).

Phthalate plasticisers were found to leach into foods (see e.g. MAFF 1987 & 1990) from PVC food wrapping, including that for domestic use, over a decade ago. Subsequently, its use in this application declined considerably. According to some researchers, the most common plasticisers in PVC food wraps today are adipates (Kawamura *et al.* 1999) although high concentrations of phthalates can remain (van Lierop 1997) and it is probable that the situation varies widely from country to country.

European legislation, based both on general environmental and health concerns, prevents cadmium compounds being used as either a stabiliser or a dye in PVC (EEC 1991), although it can still be used as a stabiliser in PVC profiles (EC 2000). A maximum concentration of 0.01% (100 parts per million) cadmium is set (EEC 1991). On the other hand, though lead (carbonates and sulphates) are banned in paints, they are not banned in PVC (EEC 1989). Several EC countries have imposed, or want, tighter legislation (EC 2000). The use of cadmium in all stabilisers is banned in Sweden, Austria and the Netherlands (EC 2000). Denmark has a national ban on lead stabilisers in plastic (Greenpeace International 2000).

In the USA in 1996 lead-containing PVC blinds were taken off the market when it was discovered that lead-containing dust was released from them and could be ingested by children (Di Gangi 1997). The US Consumer Product Safety Commission (CPSC) confirmed that children under 6 years of age could be at risk and recommended that parents take the blinds down from their windows (CPSC 1996). In June 2000, approximately 87 000 vinyl mini-blinds were recalled in the US as they were found to have elevated concentrations of lead. The blinds had been on the market for around 10 months before the recall occurred (CPSC 2000).

Disposal problems with PVC have also prompted the EC to evaluate the generic hazards of PVC and its additives (EC 2000). As part of this ongoing process, the European Parliament has called on the European Commission to bring in a substitution policy for soft PVC and phase out lead and cadmium stabilisers. Legislation to ban imports of PVC containing lead and cadmium into the EU may also be developed and implemented in the future. The hazards of organotin are also recognised and regulations on their use are also possible (EP 2000).

Conclusions

Despite the various regulatory initiatives which have been, or are currently being developed in relation to PVC additives, these chemicals are still being widely used in products either specifically marketed for children, or for use in applications which could entail children experiencing significant exposure through regular or prolonged contact. In some cases, chemicals with known significant hazards, such as organotins, are being used. Despite being subject to widespread and progressive regulation leading to phase-outs in other applications, they are not currently regulated in relation to their use as PVC additives.

Childhood is a developmentally, and hence toxicologically, sensitive time. Exposure to toxic chemicals can do permanent damage, with the immune, reproductive and nervous systems thought most likely to be affected by exposure to toxic chemicals (Nielsen *et al.* 2001).

Many of the regulations being proposed to deal with the hazards of the additives in PVC are based on trying to calculate the degree of exposure that is “safe” for children (CPSC 1997, CSTEE 1998). To date, attempts to formulate regulations on this basis have proven to be methodologically flawed, and the techniques devised impossible to replicate reliably. Given the relative sensitivity of children to the impacts of toxic chemicals this is clearly a high-risk regulatory strategy. Exposure of children and indeed other sectors of the population to PVC chemical additives are entirely unnecessary and avoidable. Logically, therefore, the only way to protect children from these harmful chemicals is to eliminate them from the products and hence from the home environment.

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