Hazardous properties of mineral and organo-mineral plastic additives and management of hazardous plastics

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Supplementary material

Tables

Table SI 1: Elements of additives of this study and their functions (by decreasing occurrences of elements and functions)

Elements	Pigments agents	Heat stabilisers	Flame retardants	Other functions	Other stabilisers	Antistatic	Plasticisers	Antioxidants	Nucleating agents	Total
Al	8		4	3	1					16
Zn	6	3	1	2		1	1	1	1	16
Cr	12									12
Cu	11				1					12
Pb	2	5		1						8
Sn	1	6								7
Ti	6									6
Co	5			1						6
Mn	5									5
Sb	3		1							4
Ba	3									3
B			2			1				3
Ni	3									3
Cd	3									3
F	2									2
I					2					2
Li				1						1
V	1									1
Bi	1									1
Pr	1									1
Total	**73**	**14**	**8**	**8**	**4**	**2**	**1**	**1**	**1**	**112**

Table SI 2: The 57 substances that are not hazardous or that are used at concentrations lower than the concentration making the plastics hazardous

Elt	Function	CAS no	Substance	Formula	CLP notifications	Harmonised Classification	FC	Min FC	Max FC	H by min FC	H by max FC	OBL
Al	PA	1344-28-1	Aluminium oxide	Al2O3	NC, (H335), (H370), (H372), (H332)		0.25	0.25	0.25	NH	NH	Yes
Al	PA	12769-96-9	Ultramarine Violet	(S)1,2Al6Na8O24S2Si6	NC		0.5	0.5	0.5	NH	NH	
Al	PA	11097-59-9	[carbonato(2-)]hexadecahydroxybis(aluminium)hexamagnesium	CH16Al2Mg6O19	NC		0.5	0.5	0.5	NH	NH	Yes
Al	PA	101357-30-6	Silicic acid, aluminum sodium salt, sulfurized	Al2Na4O6S3Si	NC		5	5	5	NH	NH	
Al	PA	70131-50-9	Bentonite, acid-leached		NC		5	5	5	NH	NH	
Al	FR	1318-23-6	Boehmite (Al(OH)O)	Al(OH)O	NC		5	5	5	NH	NH	
Al	F	92704-41-1	Kaolin	Al2O7Si2	NC, (H372), (H373)		15 - 20	15	20	NH	NH	Yes
Al	L	EC 939-582-4	Fatty acids, C16-18 (even numbered), aluminum salts	(CH2)14,16(CH2)14,16(CH2)14,16(CH2)14,16(CH2)14,16(CH2)14,16C12H21Al3O15	NC		n.a.	n.a.	n.a.	NH	NH	
Al P	PA	13530-50-2	Aluminium tris(dihydrogen phosphate)	AlH6O12P3	H318, NC		n.c.	*0.1%*	*3.4% (50%)**	NH	NH	
Al P	PA	13939-25-8	Aluminium dihydrogen triphosphate	AlH2O10P3	H319, NC, (H411)		n.c.	*0.1%*	*3.4% (50%)**	NH	NH	
Ba	PA	7585-41-3	Barium 4-[(5-chloro-4-methyl-2-sulphonatophenyl)azo]-3-hydroxy-2-naphthoate		NC, (H302), (H332)		2	2	2	NH	NH	
Ba	PA	5160-02-1	Barium bis[2-chloro-5-[(2-hydroxy-1-naphthyl)azo]toluene-4-sulphonate]	C34H24BaCl2N4O8S2	NC, H302, H332		2	2	2	NH	NH	Yes
Ba	PA	7727-43-7	Barium sulfate	BaO4S (not Ba.H2O4S)	NC, (H302), (H332), (H373), (H319)		50	50	50	NH	NH	Yes
Bi V	PA	14059-33-7	Bismuth vanadium tetraoxide	BiO4V	H373, (NC), (H372)		0.5	0.5	0.5	NH	NH	
Co	PA	1308-06-1	Tricobalt tetraoxide	Co3O4	NC (Not notified)		1	1	1	NH	NH	
Co Al	PA	1345-16-0	Cobalt aluminate blue spinel		H319, H315, H335, NC, (H400)		5	5	5	NH	NH	Yes
Co Zn Al	PA	68186-87-8	Cobalt zinc aluminate blue spinel		NC		5	5	5	NH	NH	
Cr (III)	PA	1308-38-9	Chromium (III) oxide	Cr2O3	NC, H317, H319, H302, H360 (15% of notifications), (H334), (H413)		1	1	1	NH, HP 10 if H360	NH, HP 10 if H360	Yes
Cr (III)	PA	68909-79-5	Hematite, chromium green black	Cr (III)	NC		5	5	5	NH	NH	

Elt	Function	CAS no	Substance	Formula	CLP notifications	Harmonised Classification	FC	Min FC	Max FC	H by min FC	H by max FC	OBL
Cr (III)	PA	12737-27-8	Chromium iron oxide	CrFeO3 (Cr (III))	NC		5	5	5	NH	NH	
Cr (III)	PA	68187-11-1	Cobalt chromite blue green spinel	Al2CoCr2O7 (Cr (III))	NC, (H373)		5	5	5	NH	NH	
Cr (III) Co	PA	68186-97-0	Iron cobalt chromite black spinel	CoCr2Fe3O8 (Cr (III))	NC, H317, H334		5	5	5	NH	NH	
Cr (III) Cu	PA	68186-91-4	Copper chromite black spinel		NC		0.5	0.5	0.5	NH	NH	
Cr (III) Ni	PA	71631-15-7	Nickel iron chromite black spinel		NC		5	5	5	NH	NH	Yes
Cr (III) Sb Ti	PA	68186-90-3	Chrome antimony titanium buff rutile.	CrMnNiO18Sb5Ti3 (Cr (III))	NC, H302, H411, H332		1	1	1	NH	NH	
Cr (III) W Ti	PA	68186-92-5	Chrome tungsten titanium buff rutile.	Cr2O8TiW (Cr (III))	NC		5	5	5	NH	NH	
Cu	PA	27614-71-7	Copper (tetrachloro-29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32	C32H12Cl4CuN8	NC		0.05	0.05	0.05	NH	NH	
Cu	PA	147-14-8	29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32 copper	C32CuN8	NC, (H413), (H317)		0.5 - 2	0.5	5	NH	NH	Yes
Cu	PA	1328-53-6	Polychloro copper phthalocyanine		NC, (H319), (H312)		1	1	1	NH	NH	
Cu	PA	28654-73-1	[N,N,N',N',N'',N''-hexaethyl-29H,31H-phthalocyaninetrimethylaminato(2-)-N29,N30,N31,N32]copper	C32H15CuN8	H317, NC		2	2	2	NH	NH	
Cu	PA	81457-65-0	Copper, [29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32]-, [[3-(1-methylethoxy)propyl]amino]sulfonyl derivs.	C32H14CuN8	NC		2	2	2	NH	NH	
Cu	PA	68987-63-3	Copper, [29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32]-, chlorinated	C32H15ClCuN8	NC		2	2	2	NH	NH	
Cu	PA	68512-13-0	Copper, [29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32]-, brominated chlorinated	C32H8Br4Cl4CuN8	NC		2	2	2	NH	NH	
Cu	PA	14302-13-7	[1,3,8,16,18,24-hexabromo-2,4,9,10,11,15,17,22,23,25-decachloro-29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32]copper		NC		2	2	2	NH	NH	
Cu	PA	12239-87-1	Copper chlorophthalocyanine	C32H15ClCuN8	NC, (H302)		2	2	2	NH	NH	
F	PA	79953-85-8	3,3'-[(2-chloro-5-methyl-p-phenylene)bis[imino(1-acetyl-2-oxoethylene)azo]]bis[4-chloro-N-[2-(4-chlorophenoxy)-5-(trifluoromethyl)phenyl]benzamide]		NC		2	2	2	NH	NH	
F	PA	68134-22-5	N-(2,3-dihydro-2-oxo-1H-benzimidazol-5-yl)-3-oxo-2-[[2-(trifluoromethyl)phenyl]azo]butyramide		NC, H319		2	2	2	NH	NH	
I	PA	7681-11-0	Potassium iodide	IK	H319, H315, H372, H317, H302, NC, H411, H334, H335, (H360), (H373), (H312)		n.a.	*0.2%*	*0.7% (1%)**	NH	NH	Yes

Elt	Function	CAS no	Substance	Formula	CLP notifications	Harmonised Classification	FC	Min FC	Max FC	H by min FC	H by max FC	OBL
Mn	PA	12062-81-6	Iron manganese trioxide	FeMnO3	NC		0.5	0.5	0.5	NH	NH	
Mn	PA	68186-94-7	Manganese ferrite black spinel	Fe3Mn3O8	NC		5	5	5	NH	NH	
Mn	PA	10101-66-3	Ammonium manganese(3+) diphosphate		NC		5	5	5	NH	NH	Yes
Ni	PA	EC 939-379-0	Reaction mass of melamine and Nickel, 5,5'-azobis-2,4,6(1H,3H,5H)-pyrimidinetrione complexes	C11H10N12NiO6	NC		2	2	2	NH	NH	
Sb Ni Ti	PA	8007-18-9	Antimony nickel titantium oxide yellow		H302, H332, H411, (H317), (H334), (H3501A), (H372)		1	1	1	NH	NH	Yes
Sn	HS	57583-34-3	2-ethylhexyl 10-ethyl-4-[[2-[(2-ethylhexyl)oxy]-2-oxoethyl]thio]-4-methyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate		H361d, H302, H311, H412, H341, H373, H317, H335, (H312), (H413)	H361d	2	2	2	NH	NH	Yes
Sn	PA	18282-10-5	Tin dioxide	O2Sn	H335, NC, H413, (H319), (H315)		5	5	5	NH	NH	
Ti	PA	13463-67-7	Titanium dioxide	O2Ti	NC, H351	(H351: powder 1% < 10µm, inhalation)	5 - 20	5	20	NH	NH	Yes
Ti	PA	1317-80-2	Titanium dioxide (rutile)	O2Ti	NC, (H351)		5	5	5	NH	NH	Yes
Zn	NU	91051-00-2	Fatty acids, C8-10, zinc salts	C36H68O8Zn2	H400, H411, NC		n.a.	*0.2%*	*0.2% (0.2%)**	NH	NH	
Zn	HS	35674-68-1	Zinc bis[12-hydroxyoctadecanoate]		NC		2	2	2	NH	NH	
Zn	PA	1314-98-3	Zinc sulphide	SZn	NC, (H410), (H317), (H334), (H400), (H319), (H335), (H332), (H331)		2 - 10	2	10	NH	NH	Yes
Zn	HS	91051-01-3	Fatty acids, C16-18, zinc salts	(CH2)14,16(CH2)14,16C4H6O4Zn	NC, (H412)		2	2	2	NH	NH	
Zn	HS	2452-01-9	Zinc dilaurate	C12H24O2.1/2Zn	NC, (H412)		2	2	2	NH	NH	
Zn	PA	68187-51-9	Zinc ferrite brown spinel		NC, (H318), (H315), (H335), (H336)		5	5	5	NH	NH	
Zn Al	L	169314-88-9	Aluminium-magnesium-zinc-carbonate-hydroxide	CH11AlMgO5	H413. H412	H413	n.a.	*0.1%*	*2.3% (20%)**	NH	NH	Yes
Zn Cr (III)	PA	1373399-58-6	Reaction mass of willemite, white and zinc iron chromite brown spinel	Chromium iron silicon zinc oxide, spinel-willemite-type	NC (Not notified)		5	5	5	NH	NH	
Zn Cr (III) Al	PA	68186-88-9	Zinc iron chromite brown spinel		H413, NC		5	5	5	NH	NH	
Zr Pr	PA	68187-15-5	Zirconium praseodymium yellow zircon	O9Pr3SiZr	NC		5	5	5	NH	NH	

Table SI 3: The 34 substances that are hazardous or that are used at concentrations higher than the concentration making the plastics hazardous

Elt	Function	CAS no	Substance	Formula	CLP notifications	Harmonised Classification	FC	Min FC	Max FC	H by min FC	H by max FC	OBL
Al	FR	21645-51-2	Aluminium hydroxide	AlH3O3	NC, H319, H335, H315		0.25 - 50	0.25	50	NH	HP 4	Yes
Li	OF	1310-65-2	Lithium hydroxide	HLiO	H314 1B, H302, H318, H314 1A, H301, H311, (H411), (NC), (H412)		n.a.	*0.1*	*2.3*	NH	HP 4, HP6	Yes
Al	FR	12251-53-5	Aluminium sodium tetrahydroxide	AlH4NaO4	H314, H318, H290 (metal corrosive 1)		n.a.	*0.3*	*13.7*	NH	HP 4, HP8	
Mn	PA	1317-35-7	Trimanganese tetraoxide	Mn3O4	H361, H319, H315, H335, NC, (H373)		n.a.	*0.1*	*3.4*	NH	HP 10	
Co	OF	136-52-7	Cobalt bis(2-ethylhexanoate)	C8H16O2.1/2Co	H317, H302, H319, H400, H411, H315, H317, H412, H361, H360Fd, H226, H410, (H334), (H373), (H351)		n.a.	*0.1*	*2.3*	NH	HP 10, HP 14	
V	PA	1314-62-1	Divanadium pentaoxide	O5V2	H341, H361d, H411, H335, H372, H332, H302, H318, (H300)	H341, H361d, H411, H335, H372, H332, H302	n.a.	*0.1*	*3.4*	NH	HP 10, HP 14	Yes
Cu	PA	7758-98-7;7758-99-8	Copper sulphate	CuO4S	H410, H400, H302, H315, H319, H318, (H373), (H350), (H360), (H301)		n.a.	*0.1*	*3.4*	NH	HP 14	Yes
Zn	AO	61617-00-3	1,3-dihydro-4(or 5)-methyl-2H-benzimidazole-2-thione, zinc salt	C16H14N4S2Zn	H361f, H302, H332, H373, H410, H317, H317, H411, (H360), (H312		n.a.	*0.01*	*0.7*	NH	HP 14	
Al	FR	1302-42-7	Aluminium sodium dioxide	AlNaO2	H318, H314 1B, H290 (Met. Corr. 1), H314 1A, H271 (Ox. Liq. 1)		n.a.	*0.3*	*13.7*	HP 2	HP 2, HP 4	
Sn	HS	77-58-7	Dibutyltin dilaurate	C32H64O4Sn	H341, H400, H360FD, H410, H372, H315, H302, H370, H317, H319, H314, H318, H312, H373, H360	H341, H360FD, H372	3	3	3	HP 4, HP 5, HP 10, HP 11, HP 14	HP 4, HP 5, HP 10, HP 11, HP 14	Yes
Sn	HS	68109-88-6	Ethyl 9,9-dioctyl-4,7,11-trioxo-3,8,10-trioxa-9-stannatetradeca-5,12-dien-14-oate	C28H48O8Sn	H372, H361, H315, H413, H319		2	2	2	HP 5, HP 10	HP 5, HP 10	Yes
Sn	HS	15571-58-1	2-ethylhexyl 10-ethyl-4,4-dioctyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate	C36H72O4S2Sn	H302, H372, H360D, H410, H400, H317, H373, H413, H361, H315, (H412)	H372, H360D, H410, H400	2	2	2	HP 5, HP 10, HP 14	HP 5, HP 10, HP 14	Yes
Sn	HS	27107-89-7	2-ethylhexyl 10-ethyl-4-[[2-[(2-ethylhexyl)oxy]-2-oxoethyl]thio]-4-octyl-7-oxo-8-oxa-3,5-dithia-4-stannatetradecanoate		H400, H410, H373, H315, H361, H360, H412, H372, H411		2	2	2	HP 5, HP 10, HP 14	HP 5, HP 10, HP 14	Yes
Sb	FR	1309-64-4	Diantimony trioxide	O3Sb2	H351, (H373), 'H411), (H332), (H412), (H372), (H360)	H351	8	8	8	HP 7	HP 7	Yes
Pb Cr (VI)	PA	1344-37-2	Lead sulfochromate yellow, CI 77603	-	H360Df, H400, H410, H350, H373	H360Df, H400, H410, H350, H373	1	1	1	HP 7, HP 10, HP 14	HP 7, HP 10, HP 14	Yes
Pb Cr (VI) Mo	PA	12656-85-8	Lead chromate molybdate sulfate red	CrMoO12Pb3S	H360Df, H400, H410, H350, H373	H360Df, H400, H410, H350, H373	5	5	5	HP 7, HP 10, HP 14	HP 7, HP 10, HP 14	Yes

Elt	Function	CAS no	Substance	Formula	CLP notifications	Harmonised Classification	FC	Min FC	Max FC	H by min FC	H by max FC	OBL
B	FR	13308-51-5	Boron orthophosphate	BO4P	H319, H315, H335, H360, H302, (NC)		n.a.	*0.3*	*13.7*	HP 10	HP 10	
B	AS	1330-43-4;1303-96-4;12179-04-3	Disodium tetraborate, anhydrous	B4Na2O7	H360FD, H319, (H360)	H360FD	5	5	5	HP 10	HP 10	Yes
Pb	OF	1314-41-6	Orange lead	O4Pb3	H360Df, H302, H332, H400, H410, H373 + H372, H351, H362, H272, H341	Lead and its compounds: H360Df, H302, H332, H400, H410, H373	n.a.	*0.1*	*2.3*	HP 10	HP 5, HP 10, HP 14	Yes
Pb	HS	62229-08-7	Sulfurous acid, lead salt, dibasic	H2O5Pb2S	H360Df, H302, H332	Lead and its compounds: H360Df, H302, H332, H400, H410, H373	2	2	2	HP 10, HP 14	HP 10, HP 14	Yes
Pb	HS	12578-12-0	Dioxobis(stearato)trilead	(CH2)14,16(CH2)14,16C4H6O6Pb3	H360Df, H302, H332, H400, H410, H373 + H372, H351, H362	Lead and its compounds: H360Df, H302, H332, H400, H410, H373	2	2	2	HP 10, HP 14	HP 10, HP 14	Yes
Pb	HS	12202-17-4	Tetralead trioxide sulphate	O7Pb4S	H360Df, H302, H332, H400, H410, H373 + H372, H351, H362	Lead and its compounds: H360Df, H302, H332, H400, H410, H373	2	2	2	HP 10, HP 14	HP 10, HP 14	Yes
Pb	HS	12065-90-6	Pentalead tetraoxide sulphate	O8Pb5S	H360Df, H302, H332, H400, H410, H373 + H372, H351, H362	Lead and its compounds: H360Df, H302, H332, H400, H410, H373	2	2	2	HP 10, HP 14	HP 10, HP 14	Yes
Pb	HS	91031-62-8	Fatty acids, C16-18, lead salts	UVCB	H360Df, H302, H332, H400, H410, H373 + H372, H362	Lead and its compounds: H360Df, H302, H332, H400, H410, H373	2	2	2	HP 10, HP 14	HP 10, HP 14	Yes
Sn	HS	15546-11-9	Methyl (Z,Z)-8,8-dibutyl-3,6,10-trioxo-2,7,9-trioxa-8-stannatrideca-4,11-dien-13-oate	C18H28O8Sn	H314, H360, H370, H373, H410, H302, H318, H341, H317		2	2	2	HP 10, HP 14	HP 10, HP 14	
Cd Se	PA	58339-34-7	Cadmium sulfoselenide red	-	H302, H312, H332, H315, H335	Cd and its compounds: H332, H312, H302, H400, H410	5	5	5	HP 14	HP 14	Yes
Cd Zn	PA	8048-07-05	Cadmium zinc sulfide yellow	CdS2Zn	-	Cd and its compounds: H332, H312, H302, H400, H410	5	5	5	HP 14	HP 14	Yes

Elt	Function	CAS no	Substance	Formula	CLP notifications	Harmonised Classification	FC	Min FC	Max FC	H by min FC	H by max FC	OBL
Cd Zr	PA	102184-95-2	Silicic acid, zirconium salt, cadmium pigment-encapsulated	CdO3SiZr	-	Cd and its compounds: H332, H312, H302, H400, H410	5	5	5	HP 14	HP 14	Yes
Cu I	PA	7681-65-4	Copper iodide	CuI	H400, H332, H315, H335, H319, H410, H318, H372, H411, H317		0.5	0.5	0.5	HP 14	HP 14	
Sb Mn Ti	PA	68412-38-4	Manganese antimony titanium buff rutile		H411, H302, H332, NC		5	5	5	HP 14	HP 14	
Zn	PL	13598-37-3	Zinc bis(dihydrogen phosphate)	Zn(H2PO4)2	H400, H332, H411, H410, (NC)		n.a.	*0.5*	*20.4*	HP 14	HP 14	
Zn	AS	1314-13-2	Zinc oxide	OZn	H400, H410, (H360), (H302), (H332), (H373)	H400, H410	5	5	5	HP 14	HP 14	Yes
Zn B	FR	12767-90-7	Hexaboron dizinc undecaoxide	B6O11Zn2	H400, H319, H361d, H411, H410, (H335), (H341)		0.3 - 0.4	0.3	0.4	HP 14	HP 14	
Zn	L	557-05-1	Zinc distearate	C18H36O2.1/2Zn	NC, H400, H335, H413, (H319), (H302)		0.5 - 1	0.5	1	NH, HP14 product	NH, HP14 product	Yes

Note: Sb_2O_3 is presented here to be exhaustive but is also presented in the paper on flame retardants (Hennebert 2021b). It has not been counted twice in the synthesis Table 4.

Table SI 4: The number of mineral and organo-mineral additives that makes plastics hazardous (according to the waste classification)

Number of additives	**Minimal Functional Concentration**	**Maximal Functional Concentration**
The additivated plastic is hazardous	26 (= 29% of 91)	34 (= 37% of 91)
The additivated plastic is non-hazardous	65	57
Total	91	91

Table SI 5: The number and frequency of hazardous properties of the 34 hazardous plastics (by decreasing frequencies)

HP	**Number of occurrences at minimum functional concentration (n)**	**Number of occurrences at maximum functional concentration (n)**	**Number of occurrences at maximum functional concentration (%)**
HP 14 'Ecotoxic'	20	24	41%
HP 10 'Toxic for reproduction'	15	18	31%
HP 5 'Specific target organ Toxicity'	4	5	9%
HP 4 'Irritant'	0	4	7%
HP 7 'Carcinogenic'	3	3	5%
HP 2 'Oxidising'	1	1	2%
HP 11 'Mutagenic'	1	1	2%
HP 6 'Acute Toxicity'	0	1	2%
HP 8 'Corrosive'	0	1	2%
Total	44	58	100%
Substances	26	34	
n HP/additive	1.7	1.7	