Environmental Science Advances

PAPER

View Article Online
View Journal

Cite this: DOI: 10.1039/d5va00484e

An innovative method to identify chemical content of building materials and implications for global plastic pollution reduction

Cassidy Clarity,*[a] Ryan Johnson, *[a] Rebecca Stamm, [a] Veena Singla, [b] Bethanie Carney Almroth[c] and Teresa McGrath[a]

Received 19th December 2025
Accepted 30th March 2026

DOI: 10.1039/d5va00484e

rsc.li/esadvances

Plastic pollution is transgressing planetary boundaries that maintain the safe operating space for humanity. The building and construction sector is the second largest user of plastics after packaging but has been largely excluded from plastic reduction efforts. One barrier to addressing plastics in building materials is a lack of data on the chemical content of products. We outline a method for estimating the chemical content, including plastic polymers and additives, of building materials using publicly available data. The results identify plastic polymers across many material types, including commonly used materials that may not be thought of as plastic or disclose plastic polymers. This assessment of polymer types reveals that polyvinyl chloride (PVC) and polystyrene are used extensively in the built environment even though alternative building materials using little to no plastic are available for many applications. The analysis reveals that chemicals of concern (PlastChem priority chemicals) are common in over a third of the building materials studied. Finally, an insulation materials case study highlights the utility of considering attributes beyond weight percentage that contribute to the mass of plastic polymers present in products as installed. This information supports proposed solutions to reduce plastics in the built environment. The method and dataset are offered to further this emerging research on the environmental health impacts of building materials.

Environmental significance

Plastic pollution is a threat to planetary health, but information is lacking on a major driver of plastic pollution: building materials. Through the development and application of a novel methodology, plastic polymers and chemicals of concern are analyzed in a set of building materials. Building materials commonly contain polymers of concern including polyvinyl chloride (PVC) and polystyrene and chemicals such as orthophthalates and organometallics that present health and environmental risks. This data and approach can support research and inform policies and other initiatives to reduce harmful plastic pollution.

Introduction

Plastic pollution is often thought of as a waste management issue but actually occurs over the full life cycle of plastics with emissions of chemicals and pollutants occurring from production to use and end of life. Plastic materials include polymers, additives, and other chemicals, which are almost exclusively derived from coal, oil, and natural gas, the extraction and refinement of which has many adverse human health and environmental impacts.[1–5] Over 16 000 plastic chemicals have been identified, and more than 4200 of these are classified as chemicals of concern due to persistence, bioaccumulation, mobility, and/or toxicity.[6] The health and environmental impacts of plastics and related chemicals across the life cycle are well documented.[7–11]

There is considerable evidence that plastic pollution is causing transgression of planetary boundaries critical to Earth system processes which are necessary for humanity and ecosystems to thrive.[12,13] This is due to both the specific boundary containing plastics and synthetic chemicals (novel entities) being breached, as well as the impact of plastic pollution on all the other boundaries, especially climate change and biodiversity.[12,13]

If current trends continue, plastic use is projected to almost triple by 2060.[14] The building and construction sector is the second largest user of plastics behind packaging.[15–17] Widely used building products such as polyvinyl chloride (PVC) pipes, carpet, luxury vinyl tile, paint, and foam insulation are made with plastic.

[a]Habitable, 4911 7th Street NW, Washington, DC 20011, USA. E-mail: cclarity@habitablefuture.org; rjohnson@habitablefuture.org; rstamm@habitablefuture.org; tmcgrath@habitablefuture.org; Tel: +(202) 741-5717

[b]Program on Reproductive Health and the Environment, University of California San Francisco, San Francisco, CA, USA. E-mail: Veena.Singla@ucsf.edu

[c]Department of Biological and Environmental Science, University of Gothenburg, 405 30 Goteborg, Sweden. E-mail: bethanie.carney@bioenv.gu.se

Building materials contribute significantly to releases of microplastics, an emerging health and environmental concern. For instance, an estimated 18% of known microplastic leakage into oceans and waterways comes from paint used for buildings, which can be released during application, wear, removal, and disposal of painted materials.[18,19]

Building materials comprise a large portion of the market for polymers of highest concern, including polyvinyl chloride (PVC) and polystyrene, both of which present human and environmental hazards throughout their life cycles, from production to use to end of life.[20,21] The building and construction sector is by far the largest user of PVC, accounting for 70% of global production.[22] PVC production includes the use of feedstocks such as carcinogenic ethylene dichloride and vinyl chloride monomer[23–25] and formation of hazardous by-products, *e.g.*, chlorinated dioxins and furans,[26] and use of hazardous additives, such as organotin stabilizers and orthophthalates.[27–32] PVC disposal practices contribute to hazards through leaching and toxic emissions of chemicals.[33]

Building and construction accounted for 30% of global polystyrene use in 2019, mostly for insulation.[22] Both benzene, required in the production of styrene monomers, and styrene are carcinogenic.[21,34] Polystyrene insulation typically contains flame retardant additives, which can also introduce hazards throughout their production and use.[35,36] Polystyrene from building and construction is a significant source of macro- and microplastic pollution released to the environment.[37,38] Landfilled polystyrene can release microplastics and leach additives.[35,39]

Unfortunately, a lack of data on building material content often hampers research and reduction efforts, as there are no manufacturer requirements to provide complete chemical content information. For instance, United States (U.S.) and European laws do not require disclosure of chemicals that: (1) do not have a known hazard classification (which includes most plastic polymers and chemicals used in plastics);[6] (2) do not have data; or (3) are hazardous but present below a reporting threshold, typically 0.1% or 1.0%.[40,41] A recent global analysis of plastics and health highlights the lack of transparency regarding plastic chemicals' uses and their presence in plastics and the resultant gaps in our understanding of their harms to human and planetary health.[42]

To fill this critical data gap, a novel method is presented here for synthesizing publicly available data to generate generic formulations of the chemical content of building materials, including both plastic materials and alternatives. Presented, for the first time, is a dataset reporting the approximate amount of plastic polymer, polymer types, and particular plastic chemicals of concern typically found in many common building materials. Plastic reduction solutions are offered that aim to alleviate pressure on planetary boundaries. This method and dataset can also be used to explore the relationship between the built environment and human health, inform effective policies, and further research into safer alternatives.

Methods

Building product composition research

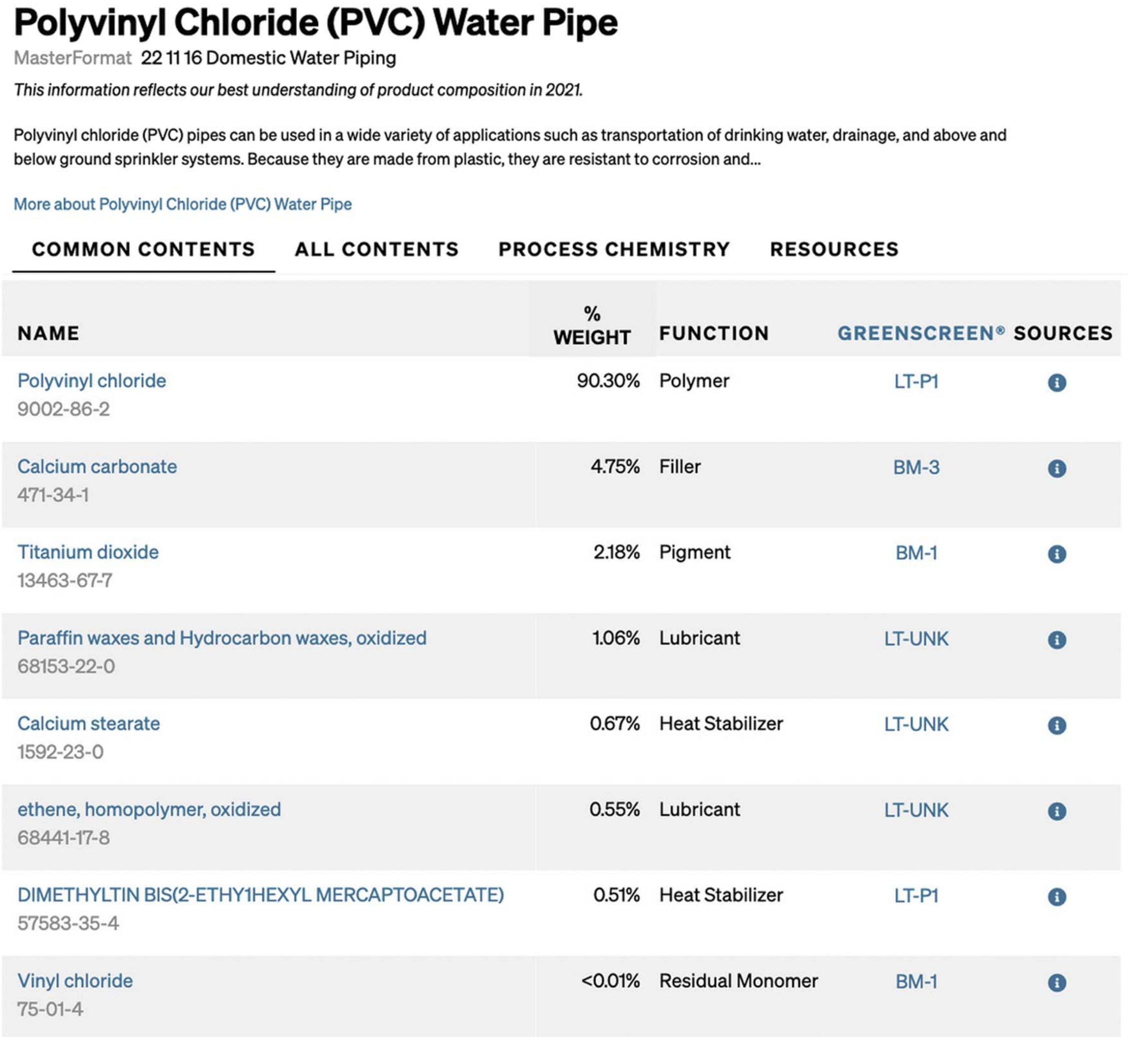
A unique methodology, not previously described, was used to generate Common Product profiles for 246 building material types.[43] Common Products are created by first identifying the manufacturers of a specific product type (such as carpet tile, PVC water pipes, or fiber cement siding) and then creating a generic product formulation not specific to any manufacturer. They are created by incorporating data on a single material type from various publicly available sources to generate a complete chemical makeup of a generic material. Sources include, but are not limited to, trade association documents, Environmental Product Declarations (EPDs),[44] Health Product Declarations (HPDs),[45] Declare labels,[46] patents, safety data sheets (SDSs), technical product documents, and documents authored by government and academia. This analysis considers both direct content disclosure as well as marketing language that can reveal additional content that is not otherwise disclosed, such as a data sheet that notes that a product "contains antimicrobial agents", and technical publications detailing the state of the art of material science.

Source data are compiled to gather all functions required to create the material, the most common chemical reported for each function, and reported weight percentage values. The compiled data are reviewed to determine whether any chemical content is likely missing. For example, if antioxidants or stabilizers would likely be required for a plastic product but none have been identified, these are flagged as potential omissions from the reporting sources. An additional search is then performed to determine whether or not these additives are common in the material or product type, and supplier websites are searched to determine if specific additives are marketed for use in the product type. This step is necessary because publicly available information on specific products can be incomplete when chemicals lack hazard data, chemical identifiers are withheld as trade secrets, chemicals are present below reporting thresholds, or regulations do not require reporting the data.

Once all likely functions have been accounted for, the reported weight percentage values are used to derive a single median percent weight for each chemical common in the material. Then the common content percentages are summed and normalized to total 100%, keeping each chemical percentage within the range reported. The chemical, function, and median percent weight of the substances are hosted publicly in each Common Product's profile in the Pharos database where chemical content is also linked to hazard data from numerous authoritative and screening hazard lists (see the example of a Common Product profile in Fig. 1).[43] Common Product profiles are based largely on North American product data and represent material form and composition as delivered to a jobsite. See the SI for a full description of the method including content inclusion criteria and sourcing requirements.[47] For the full list of Common Products see Table S1. The SI does not include the full chemical content for each Common Product, only the content highlighted in this paper's analysis. The complete common content information is available in the Pharos database.

Percent plastic polymer calculations

Plastics are materials made wholly or partly of synthetic or semi-synthetic polymers.[48] Plastic chemicals are chemicals potentially used or present in plastic materials and products; this



Polyvinyl Chloride (PVC) Water Pipe

MasterFormat 22 11 16 Domestic Water Piping

This information reflects our best understanding of product composition in 2021.

Polyvinyl chloride (PVC) pipes can be used in a wide variety of applications such as transportation of drinking water, drainage, and above and below ground sprinkler systems. Because they are made from plastic, they are resistant to corrosion and...

More about Polyvinyl Chloride (PVC) Water Pipe

COMMON CONTENTS ALL CONTENTS PROCESS CHEMISTRY RESOURCES

NAME	% WEIGHT	FUNCTION	GREENSCREEN®	SOURCES
Polyvinyl chloride 9002-86-2	90.30%	Polymer	LT-P1	i
Calcium carbonate 471-34-1	4.75%	Filler	BM-3	i
Titanium dioxide 13463-67-7	2.18%	Pigment	BM-1	i
Paraffin waxes and Hydrocarbon waxes, oxidized 68153-22-0	1.06%	Lubricant	LT-UNK	i
Calcium stearate 1592-23-0	0.67%	Heat Stabilizer	LT-UNK	i
ethene, homopolymer, oxidized 68441-17-8	0.55%	Lubricant	LT-UNK	i
DIMETHYLTIN BIS(2-ETHY1HEXYL MERCAPTOACETATE) 57583-35-4	0.51%	Heat Stabilizer	LT-P1	i
Vinyl chloride 75-01-4	<0.01%	Residual Monomer	BM-1	i

Fig. 1 Simplified view of an example Common Product profile.

includes plastic polymers, additives, processing aids, and non-intentionally added substances.[49] For this analysis, we define plastic polymers as organic or partially-organic polymeric materials (exclusive of additives), excluding unmodified natural polymers.[50] This definition includes all thermoplastics, thermosets, and elastomers (including rubber and silicones). It includes polymers if they are synthetic (polymerized from either petrochemical or biobased monomers), or semisynthetic (natural polymers such as cellulose and natural rubber that are chemically modified, such as rayon), but does not include naturally occurring polymers (*e.g.*, cellulose, cotton, natural rubber).[51]

A query was conducted on all Common Products in the Pharos database, omitting seven Common Products that capture content that may be present in post-consumer recycled materials, not finished products. For the remaining Common Products ($N = 239$) a decision tree was used (Fig. S1) to screen for substances meeting the definition of plastic polymer using R version 4.5.0.[52] First, CASRNs from Common Products that appeared on the Canadian Environmental Protection Act 1999 (CEPA) Domestic Substances List (DSL) were identified. The CEPA DSL is an authoritative list that contains a detailed categorization of over 22 000 substances, which was completed in 2006. Using these categorizations, content was classified as a plastic polymer if its substance category was "polymer" or unknown or variable composition, complex reaction products or biological materials (UVCBs) classified as "UVCBs-polymer".[53,54] The detailed CEPA DSL categorizations were chosen because they have been curated by a government agency. Screening substances on the CEPA DSL by these classifications is advantageous because substances appearing on the list can be identified as plastic polymers without relying on substance names, which can vary greatly from source to source. Newer versions of the CEPA DSL were not used for this analysis because they do not contain these detailed categorizations. Substances on the CEPA DSL that were not in either of these two categories were not identified as a plastic polymer, unless the substance names indicated that they were silicone polymers (Table S3a). The CEPA DSL classifies silicone polymers as UVCBs-organic. Since silicone polymers meet the definition of plastic polymer described above, any silicones identified in the CEPA DSL were identified as plastic polymers.

All remaining substances identified in Common Products that were not listed or had no classification in the CEPA DSL were screened for keywords suggesting polymer chemistry using the process and search terms shown in Table S3b. This screening also accounted for reactants that are precursors to polymers commonly formed in products that react when applied at the build site (Table S3c), such as polyurethane sealants. The total percent weight of plastic polymers in each Common Product was calculated by summing the percent weight of all substances assigned as plastic polymers or plastic polymer precursors. Substance names were also screened to identify the type of plastic polymers in each product. The resulting data set includes the total percent weight plastic polymer content and total percent weight of each polymer type for each Common Product. A full description of the plastic polymer screening methodology is available in the SI.

Screening for plastic chemicals of concern

In addition to screening for plastic polymers, the potential to utilize the Common Product dataset to screen products for the presence of additional chemicals of concern is demonstrated. Most Common Products contain some chemicals with known or suspected health hazards based on the hazard screening data from the hazard lists available in Pharos.[55] To illustrate how a targeted analysis of chemical content could be used to identify specific priority chemicals of concern, we used a previously identified priority list, PlastChem priority chemicals. To identify chemicals of concern, each CASRN identified in a Common Product was cross-referenced with the PlastChem database. This database classifies over 16 000 plastic chemicals and defines 15 priority groups as "consisting of at least 40% of known chemicals of concern or having strong evidence for the entire group to be hazardous" based on persistence, bioaccumulation, mobility, and toxicity.[6] This illustrative analysis identifies content belonging to one of these 15 priority groups (PlastChem priority chemicals).[49] The total percent weight of these priority chemicals identified in each Common Product is reported by priority group.

Mass plastic polymers calculations: insulation case study

As a case study, insulation materials were compared to estimate the mass of plastic polymers contained in products designed to meet a given thermal resistance value. Insulation materials are used throughout buildings including in walls and roofs to prevent heat loss or gain and keep occupied spaces at a comfortable temperature. The *R*-value indicates how well a material resists heat flow, with a higher *R*-value indicating better thermal resistance. Both the inherent properties of a material and the thickness of the material used determine the overall *R*-value of insulation installed.[56] Using the median density and median *R*-value/inch the thickness of insulation required to achieve a value of *R*-13 (RSI = 2.3) was calculated. Then, the mass of plastic polymers present in products at the calculated thickness and density was estimated based on the median percent weight plastic polymers for that Common Product.

To illustrate the uncertainty in these estimates, the ranges in density, *R*-value per inch, and percent weight of the primary plastic polymer from the underlying sources are reported. The decision to report uncertainty in the estimates in this way was made due to the small number of data points, and also due to the lack of transparency in chemical weight percentages. Weight percentages of substances in building product formulations are typically reported by manufacturers as ranges in order to protect proprietary product formulations. The U.S. Code of Federal Regulations, for instance, explicitly defines ranges that should be used on Safety Data Sheets when a substance's concentration is being claimed as a trade secret.[40] The median weight percent in Common Products is thus a point estimate based on reported minima and maxima, and could not be calculated from a sample distribution. For this reason reporting the range was a conservative approach that made no assumptions about the underlying data.

Results

Percent plastic polymer

716 unique substances were identified across the Common Product dataset (Table S2). 181 of these were found to be plastic polymers or plastic polymer precursors. Plastic polymers were identified in 194 of 239 Common Products (81%). See SI (Table S1) for the dataset summarizing the estimates of plastic polymer percentage by weight and polymer types for each Common Product. In some cases, plastic polymers accounted for a substantial percentage of products' weights even when plastic was not mentioned in the product name. For instance, fiberglass window frames contain an estimated 32% plastic polymers. Mineral silicate paint, which primarily uses a non-plastic binder, still contains about 5% acrylic polymer binder. Base cabinetry, while mostly composed of wood, contains an estimated 13% plastic polymers due to binders and contact adhesive. Cultured marble countertops contain an estimated 21% plastic polymers due to their use of crosslinked polyester binder.

The assessment of polymer types found that many high-use products contain PVC and polystyrene. Tables 1 and 2, a subset of the overall dataset, summarize the Common Products containing PVC or polystyrene. PVC or CPVC (chlorinated polyvinyl chloride) was identified in 21 Common Products. In most of these products, PVC constitutes the majority of the plastic polymer content. Polystyrene, while identified in only five products, is present in large amounts in both expanded polystyrene (EPS) (96%) and extruded polystyrene (XPS) (88%) insulation.

Chemicals of concern screening

15 of the 21 Common Products containing PVC also contained at least one PlastChem priority chemical. Most of the priority chemicals identified were orthophthalates and organometallics. Eight Common Products contained orthophthalates, which are identified as plasticizers used in flexible PVC products and sealants.[49] Orthophthalates were also found at the highest

Table 1 Percent weight plastic polymers, PVC, and PlastChem priority chemicals in Common Products containing PVC. N/A means that priority chemicals were not identified in the Common Product

Product category	Common product	% Weight plastic polymers	% Weight PVC	% Weight PlastChem priority chemicals
Pipes	Solvent weld soil and waste pipe	91%	90%	0.6%
	Polyvinyl chloride (PVC) water pipe	91%	90%	0.5%
	Chlorinated polyvinyl chloride (CPVC) water pipe	89%	83%	N/A
Flooring	Multilayer resilient flooring (wood plastic composite or WPC)	36%	34%	N/A
	Heterogeneous vinyl resilient sheet flooring	35%	28%	N/A
	Luxury vinyl tile (LVT)	23%	22%	N/A
	Vinyl composition tile	11%	11%	N/A
Adhesives & sealants	CPVC solvent cement	18%	18%	0.2%
	Single-component polyurethane sealant	54%	16%	20%
Insulation	Closed cell elastomeric foam pipe insulation	40%	11%	13%
Acoustical panels	Vinyl-faced gypsum acoustical ceiling panels	2%	0.6%	0.01%
Cement board	Cementitious backerboard	0.7%	0.3%	0.2%
	Magnesium oxide board	0.2%	0.2%	0.1%
Windows and siding	Rigid PVC window profile	87%	82%	0.9%
	Composite window frame	52%	46%	N/A
	Vinyl siding	89%	77%	0.9%
Roofing	Reinforced PVC roofing membrane	53%	48%	27%
Other	Horizontal louver blinds (PVC) slats	86%	83%	0.9%
	Vinyl wall base	14%	14%	35%
	Vinyl-coated wire shelving	4%	4%	1%
	Exterior door w/Insulated glass unit (IGU)	2%	0.01%	0.01%

weight percentage among the 15 priority groups screened, with four products containing them at concentrations equal to or greater than 13% weight of the product. This analysis only captures where the priority chemicals are commonly found in each material type, not all cases in which the priority chemicals may be used. For example, none of the four vinyl flooring Common Products list orthophthalates, which have historically been used as plasticizers in vinyl flooring.[57] These Common Products do not report the use of orthophthalates because the most commonly cited plasticizers at the time of the research were non-orthophthalate plasticizers, such as bis(2-ethylhexyl) terephthalate. Some manufacturers still report small percentages of orthophthalates in vinyl flooring products, which may be present from incorporating recycled content or other additives.[57–60] Several PVC-containing products contained organometallic heat stabilizers. Additional priority chemicals identified in PVC-containing products included chlorinated paraffins, benzotriazoles, and benzothiazoles.

The screening flagged PlastChem priority chemicals in three of the five polystyrene-containing products. These chemicals include orthophthalates, chlorinated paraffins, organometallics, and PFAS. PFAS was identified at 6% weight in extruded polystyrene insulation because it includes the blowing agent HFC-134a, which has one fully fluorinated carbon atom and is

Table 2 Percent weight plastic polymers, polystyrene and PlastChem priority chemicals in Common Products containing polystyrene. N/A means that priority chemicals were not identified in the Common Product

	Common product	% Weight plastic polymers	% Weight polystyrene	% Weight PlastChem priority chemicals
Insulation	EPS insulation (expanded polystyrene)	97%	96%	N/A
	XPS insulation (extruded polystyrene)	90%	88%	6%
Windows	Fiberglass window frame	32%	0.9%	N/A
Doors	Exterior door w/IGU	2%	1%	0.01%
Backerboard	Cementitious backerboard	0.7%	0.4%	0.2%

Table 3 Common Products and product types containing chemicals from selected PlastChem priority groups

PlastChem priority group	Number of common products containing chemicals from the group	Examples of product types commonly containing chemicals from the group
Organometallics	34	Sealants; adhesives; PVC products including pipes, flooring, window frames
Alkylphenols	22	Paints; coatings; plastic pipes
Orthophthalates	20	PVC products including wall base and waterproofing/roofing membranes; sealants
Benzotriazoles	17	Plastic decking; roofing membranes; water pipes; cladding; flooring; sealants
PFAS	10	Carpet; foam insulation; coated metal; pipe thread sealant

classified as PFAS in the PlastChem database. This classification is consistent with the widely accepted definition of PFAS used by the Organisation for Economic Cooperation and Development.[61] Orthophthalates and chlorinated paraffins were not identified in any products as polystyrene additives. Rather, they were identified in two products that also contained PVC and were additives associated with the latter. Orthophthalates were identified in a PVC-coated alkali-resistant fiberglass scrim included in the cementitious backerboard Common Product, which also contains expanded polystyrene beads as a lightweight aggregate. Both orthophthalates and chlorinated paraffins were identified in a closed-cell PVC foam glazing tape included in an exterior door Common Product that also contained expanded polystyrene insulation.

Considering the full Common Product dataset, chemicals in the PlastChem priority groups were identified in 83 of the 194 Common Products that contain plastic polymers or plastic polymer precursors (43%). Table 3 shows the most common priority groups found and examples of the types of products that contained the chemicals of concern. See the SI (Table S1) to view the total weight percentage of each group of PlastChem priority chemicals identified in each Common Product.

Mass plastic polymer calculations: insulation case study

Thermal insulation was selected as a case study to illustrate how use considerations for materials impact the final amount of plastic placed in a building. Mass plastic polymers per unit area at a constant thermal resistance (*R*-13) was calculated for different types of insulation that contain various percent weight plastic polymers (Table 4). This is a common use-case for insulation; often builders wish to achieve a desired thermal resistance for a particular area of a building.

Due to the wide range of reported weight percentages for individual chemicals, as well as in density and *R*-value, there is a high degree of uncertainty in the estimates of mass plastic polymers in insulation products. Table 5 summarizes the variability of reported values for different parameters used to estimate this mass. Note that only the weight percentage of primary

Table 4 Estimated mass of plastic polymers in insulation at *R*-13 (13 ft^2 hr F/Btu) or RSI = 2.3 m^2 K W^{-1}

	Calculated thickness for *R*-13 (RSI = 2.3 m^2 K W^{-1})		Estimated Mass of plastic polymers		
Common product	Inches	mm	lbs plastic $ft^{-}2$	kg plastic m^{-2}	Estimated % Weight plastic polymers
EPS insulation (expanded polystyrene)	3.3	83	0.36	1.7	97%
XPS insulation (extruded polystyrene)	2.6	66	0.31	1.5	90%
Closed cell spray foam insulation	1.9	48	0.26	1.3	84%
Polyisocyanurate wall insulation board	2.0	51	0.25	1.2	81%
ASJ-faced fiberglass board insulation	3.0	77	0.25	1.2	16%
Wood fiber insulation boards	3.6	92	0.083	0.41	4%
Unfaced cellulose/Cotton batt insulation	3.5	89	0.079	0.38	11%
Mineral wool board insulation	3.2	81	0.033	0.16	2%
Mineral fiber batt insulation	3.1	79	0.026	0.13	5%
Wet-blown cellulose insulation	3.4	87	0.025	0.12	3%
Unfaced fiberglass batt insulation	3.5	89	0.011	0.056	9%
Kraft-faced fiberglass batt insulation	3.5	89	0.011	0.052	8%
Spray-applied fiberglass insulation	3.1	79	0.0080	0.039	1%
Dense pack cellulose insulation	3.5	89	0.00	0.00	0%
Dense pack fiberglass	3.0	77	0.00	0.00	0%
Expanded cork board insulation	3.4	87	0.00	0.00	0%
Loose fill cellulose insulation	4.3	110	0.00	0.00	0%
Loose fill fiberglass insulation	5.0	127	0.00	0.00	0%

Table 5 Variability in reported data for insulation (U.S. units) See SI Table S6 for additional methodological description and metric units

	Density (lbs ft^{-3})		R-value/Inch		% Weight primary plastic polymer	
Common product	Median (min, max)	N	Median (min, max)	N	Median (min, max)	N
ASJ-faced fiberglass board insulation	5.99 (1.1, 6.99)	4	4.3 (4, 4.6)	4	15 (5, 30)	3
Closed cell spray foam insulation	2 (1.5, 2.4)	9	6.9 (6.2, 7)	9	87	9
Dense pack cellulose insulation	3.45 (3.4, 3.5)	2	3.7 (3.5, 3.8)	2	N/A	N/A
Dense pack fiberglass	1.8 (1.5, 2)	5	4.3 (4.2, 4.6)	5	N/A	N/A
EPS insulation (expanded polystyrene)	1.35 (0.7, 3)	ASTM standard	4 (3.1, 4.3)	ASTM standard	97 (92, 100)	9
Expanded cork board insulation	7.25 (7, 7.5)	2	3.8 (3.6, 4.2)	2	N/A	N/A
Kraft-faced fiberglass batt insulation	0.45 (0.44, 0.46)	2	3.4 (2.9, 4.3)	4	6.6 (3.4, 8.2)	4
Loose fill cellulose insulation	0.29 (0.27, 0.34)	3	3 (2.8, 3.4)	3	N/A	N/A
Loose fill fiberglass insulation	0.45 (0.32, 0.5)	5	2.6 (2.1, 2.7)	5	N/A	N/A
Mineral fiber batt insulation	2 (0.56, 2.18)	2	4.2 (4, 4.3)	2	5 (1, 20)	3
Mineral wool board insulation	6 (4, 10)	4	4.1 (3.4, 4.2)	4	2 (0.8, 6)	5
Polyisocyanurate wall insulation board	1.87 (1.5, 2.5)	2	6.5 (5.4, 6.9)	5	80 (55, 99)	5
Spray-applied fiberglass insulation	2.13 (1, 3)	5	4.2 (4, 4.3)	3	0.9	1
Unfaced cellulose/Cotton batt insulation	2.5 (1.2, 3.5)	3	3.7 (3.5, 4)	4	10 (5, 20)	4
Unfaced fiberglass batt insulation	0.45 (0.44, 0.46)	2	3.4 (2.9, 4.3)	4	7 (3.7, 8.8)	3
Wet-blown cellulose insulation	3.43 (2.7, 4.3)	3	3.8 (3.6, 3.8)	4	2.5 (2.3, 2.7)	3
Wood fiber insulation boards	6.9 (3.1, 16.9)	7	3.6 (2.9, 3.9)	6	4 (0.3, 4)	4
XPS insulation (extruded polystyrene)	1.6 (1.2, 3)	ASTM standard	5 (3.9, 5)	ASTM standard	90 (60, 100)	5

plastic polymer is shown in this table as an illustrative example of the type of ranges reported in Common Product sources. Some mineral- and biological-based insulation products contain plastic polymers as binders, which are added to hold the materials together.

Mineral fiber batt insulation has the widest range of reported binder (primary polymer) weight percentages, with a median value (5%) that is four times larger than the minimum reported value (1%) and is one quarter of the maximum reported value (20%). The narrowest range of reported weight percentage of primary polymer was observed in EPS insulation, which had a reported maximum (100%) about 3% larger than the calculated median (97%) and a reported minimum (92%) about 5% smaller than the calculated median.

Discussion

Scientists are calling for interventions on plastic production, use, and releases to reduce threats to planetary boundaries and maintain biosphere integrity.[12,13] As of 2022, a global effort is underway to address plastic pollution through adoption of a legally-binding plastics treaty.[62] With the global building sector's floor area set to double between 2017 and 2060, plastic production for use in construction will further increase, likely surpassing 2019 plastic packaging levels by 2050 without intervention.[63,64] PVC and polystyrene are priorities for action based on several life cycle hazard analyses, and the building sector is a large user of both.[65,66] Therefore, any comprehensive plastic pollution reduction strategy must include interventions on plastic building materials.

This analysis reveals large quantities of plastic polymers in building products, including some that would not be expected to contain plastic based on the product name, such as fiberglass window frames, and it enables further research into the health and environmental impacts of building materials that can support comprehensive plastic reduction solutions. This paper introduces a publicly available dataset that summarizes chemicals commonly identified in building materials. The analysis of this paper supplements existing hazard screening data by estimating the plastic polymer types and percentages in each product type. The plastic polymer percentage and identity is a valuable addition to the existing hazard screening data because polymers themselves contribute to plastic pollution. They do this through hazardous chemical emissions during fossil fuel extraction, polymer production, use, and end of life (building fires, wildfires, and incineration, in particular, contribute to end of life emissions).[42] Plastic polymers also contribute to microplastic pollution, an emerging health concern, and common hazard screening methodologies do not assess details about plastic polymers, including their presence and quantity in products.[6,12,42,51,67–69]

Very few previous studies have explored the chemical composition of building materials and those that do acknowledge that data are lacking.[70,71] The dearth of data results in prior analyses that include few product types and a limited ability to accurately and transparently assign plastic polymer weight percentages.[70] Those that link manufacturer data (*e.g.* SDSs) to specific manufacturer products may not have complete formulations and do not offer a simple way to conduct analyses comparing product types, such as those presented here.[71] The analysis conducted here adds to this work by expanding the number of products assessed and synthesizing disparate public documents to create complete generic product profiles for a wide array of building materials, including those containing plastic. This dataset allows for analyses such as those presented here, more accurate materials flow analyses, and identification of potential chemicals of concern in products for circularity considerations. In addition, the Common Product dataset continues to be expanded and updated, allowing for more expansive analyses over time. For example, the exposure modeling conducted by Huang, *et al.* was based on an earlier version of the Common Product dataset containing 142 building materials.[72,73] Since then, 102 new Common Products have been added to Pharos, 45 have been updated, and five have been retired, resulting in profiles for 239 materials being included in the present analysis.

Future analyses could be greatly strengthened by government and industry policies requiring public disclosure of the full chemical composition of products, as well as production-related chemicals and transformation products. Other commercial sectors have overcome issues of proprietary information in the interest of increased transparency including the cosmetics industry on a global scale[74] and cleaning products at the regional level.[75] Transparency efforts are underway in the automotive industry, though there is still limited public disclosure.[76,77]

Public disclosure of building product composition is already happening to some degree. Manufacturer participation in voluntary content disclosure programs in the building and construction sector has increased in recent years, likely due to the addition of incentives to use these programs through credits incorporated into green building standards.[78–82] At least one of these voluntary disclosure programs has been adapted to screen chemicals against hazard lists that are regionally relevant in the European Union, expanding applicability from the national to international level.[83] The existence and increasing participation in these voluntary programs along with regulations at national and sub-national levels for other industries illustrates that public disclosure requirements for building materials are feasible.

Voluntary disclosures or certifications do, however, typically allow for some or all of the product content to be held proprietary.[84,85] These programs may also introduce bias toward products containing less hazardous content based on which companies choose to participate, and based on which products they select to include in such programs; products with the worst chemicals of concern may be excluded from these voluntary efforts. Several product-specific building product databases exist, though these often provide an incomplete picture of the chemical composition of building products.[86] To our knowledge the Common Product database is the only publicly available database cataloging the type and concentrations of chemicals in generic building product types and lending itself to the modeling analysis presented here that attempts to account for these potential biases. Content transparency supports continued development of datasets like the one presented here and enables hazardous chemical reduction more broadly; such chemicals are also contributing to the pressure on planetary boundaries.[13,87,88]

PVC was identified in 21 Common Products across a variety of categories, with a particularly high percentage use in pipes. Polystyrene was found in five Common Products including EPS and XPS, both widely used as building insulation materials.[89] Alternatives are available for many PVC and polystyrene applications that contain little to no plastic.[33,65] The scale of PVC and polystyrene consumption, the availability of alternatives that reduce the use of plastic and other hazardous chemicals, and the known environmental and human health impacts make these polymers a high priority for phaseout.

In addition to the inherent hazards in the life cycle of plastic polymers, additives and other chemicals found in plastic products are often hazardous. PlastChem priority chemicals are common in PVC and polystyrene building materials as well as other building products. This analysis is meant to be illustrative of potential screening and is not inclusive of all plastic chemicals of concern. Further analyses are possible with the full publicly available data set in Pharos.

The insulation case study demonstrates that performance (in this case *R*-value) and density are important to consider when calculating the volume of plastics used in a building. EPS and XPS had the highest mass plastic polymers per area of all insulation materials assessed. Polyisocyanurate insulation and ASJ-faced fiberglass board insulation were estimated to contain roughly the same mass of plastic polymers per area (Table 4), despite ASJ-faced fiberglass having a significantly lower weight percent plastic polymers. The mass of plastic polymers in ASJ-faced fiberglass board insulation is both a factor of its median density (6.0 lbs ft^{-3} or 96 kg m^{-3}) and its required thickness (3.0 in. or 77 mm) to achieve the same thermal resistance compared to that of polyisocyanurate wall insulation (1.9 lbs ft^{-3} or 30 kg m^{-3}, 2.0 in. or 51 mm). This type of information, however, is not always reported for building materials. When it is, it may be spread across various documents covering multiple products with a range of content and densities, making it difficult to tie a particular formulation to a particular density. This sort of disparate and sparse information further complicates efforts to understand the mass of plastic polymers in a particular product. Researchers and practitioners hoping to assess the mass of plastic polymers in materials need to consider attributes outside of percent weight plastic to approximate the real-world application of these materials.

Other factors that influence the volume of plastics used by the building industry include cutoff waste during installation, actual service life, maintenance practices, and reuse potential. Plastic waste from building and construction is increasing at a similar rate as production, and this rate will likely increase in the coming years as more structures containing plastic materials reach the end of their life spans.[11,17] The interventions that most significantly decrease plastic pollution across the life cycle focus on using fewer materials by implementing complementary material efficiency strategies during building design (designing to use less material), extending material and building lifespans, and reuse at end of life.[90,91]

Limitations

The Common Product dataset is not representative of the entire building materials market. It is a convenience sample, and while it captures many widely used materials, it does not capture all categories or all materials. Some categories only include a subset of possible products, with excluded types that may contain plastic or specific plastic polymers. For instance, carpet tile may commonly use a PVC backing, but the Common Product included in the dataset details carpet tiles with polyolefin backings, so did not capture that particular use of PVC. The dataset is based on publicly available data and was not validated using product testing. Under-reporting of toxic chemicals has been found in other contexts.[92]

Likewise, within any product type, specific additives included in Common Products should not be assumed to be representative of all products on the market. While the research aims to identify all manufacturers of similar products, some manufacturer's products may not be represented in an analysis due to factors such as lack of publicly available data or variability in available product formulations. The representativeness of the chemicals listed in a Common Product will vary widely between different chemicals listed in a given Common Product and also across Common Products. For example, eight manufacturers of spray polyurethane foam roofing were identified. All were researched and any available content information was included in the analysis. Most manufacturers have a version of the product made with a hydrofluorocarbon (HFC) blowing agent and a version with a hydrofluoroolefin (HFO) blowing agent. Because only a few U.S. states had implemented regulations requiring the phase out of HFCs, and HFO blowing agents were more expensive, the Common Product was scoped to describe the HFC-type of product. Five of the eight manufacturers disclosed a blowing agent. In all cases, this was HFC-245fa. The industry average EPD also listed HFC-245fa as the specific blowing agent. It is possible that the three manufacturers that did not disclose a blowing agent use a different chemical for this function, but HFC-245fa was the most commonly cited by manufacturers for this function in this type of product.

Another limitation is that market share data are not typically publicly available. Consequently, even if one manufacturer's formulation dominates the market, its formulation is weighted equally with that of a manufacturer who represents a smaller market share. While lack of market share data may mean that the specific substances included in Common Products are not representative of the market, the types of additives (*i.e.* what function they perform) included in formulations are likely impacted to a lesser degree. This is because the decision to include additives is driven by the chemistry of the type of product itself. For instance, products containing PVC typically require heat stabilizers to prevent the polymer from degrading during processing.[93,94]

In some cases, however, authoritative government sources lent a high degree of confidence to the selection of content. For instance, the inclusion of the polymeric brominated flame retardant in the XPS insulation Common Product was deemed appropriate because a U.S. EPA alternatives assessment and a feasibility study available through the European Chemicals Agency's website, indicated that the market was shifting from hexabromocyclododecane (HBCD) to this polymeric brominated flame retardant.[95–97] Finally, manufacturer documentation commonly contains general information on products' underlying chemistries, such as polyurethane, acrylic, or styrene butadiene rubber. Thus, while specific details like the average molecular weight of a polymer are often not available, there is a high degree of confidence in the accuracy of polymer types included in Common Product formulations.

Since the underlying data used to generate these estimates are based on reported ranges (as opposed to precise estimates or sample data), there is a degree of uncertainty in the estimates of percent weight plastic polymers. This is demonstrated by the wide range of insulation product primary plastic polymer weight percentages reported across different data sources.

For this reason, the analysis did not statistically compare the median of the plastic polymer content of products. This is a limitation of publicly available data on the chemical makeup of building materials. This limitation does not prevent broad conclusions on the approximate amount of plastic polymers in materials and the types of polymers used from being drawn. For instance, the weight percentage of primary plastic polymers reported for EPS (92 to 100%), XPS (60 to 100%), and polyisocyanurate insulation (55 to 99%) are well above those reported for wood fiber insulation boards (0.3 to 4%). In this example, these estimates can be seen as useful approximations, especially given the lack of data on building material chemical content. However, it is difficult to determine with any accuracy whether EPS or XPS has a higher weight percent of plastic polymers from these data alone since the reported ranges overlap. In addition, because the underlying data are reported as simple ranges, it is difficult to discern the directionality of any error (whether plastic polymer content in any of the products is overestimated or underestimated).

This analysis does not capture all the potential instances of the 15 priority chemical groups for a number of reasons. Common Products capture the most common chemicals for each function, so they do not include all possible content. Therefore, this analysis does not identify when priority chemicals are used but not common. In addition, while the research for each material is extensive, it is based on publicly available literature, which can be incomplete for a number of reasons. Regulations and voluntary disclosure frameworks typically require reporting based on known health hazards and based on the amount of chemical present in a product.[40,84,85] Chemicals may not be reported when toxicology data are lacking and where present below these reporting thresholds. Manufacturers may choose not to disclose chemicals, holding them as trade secrets, or they may be unable to disclose them, barring any regulatory requirements, due to lack of transparency from complex supply chains.

Data and methodology use

The authors encourage future research into the impacts of building materials using this methodology and data. The data offer opportunities for new research including: sources of chemical and microplastic exposures and releases; identifying content common in products considered for reuse or recycling; and modeling approximate health and environmental impacts of material choices.

The Common Product methodology could be used or adapted for estimating chemical formulations of products, including weight percentage of plastic polymers, using publicly available data in other industries without adequate chemical content transparency. This method for estimating weight percentage of plastic polymers from an existing database of chemicals may also be useful to other researchers in the field.

Conclusions

This novel data set of common chemical contents of building products brings together data from thousands of disparate sources on a range of plastic and non-plastic building products. Our analysis of percent weight plastic polymer and polymer types provides, for the first time, an estimated amount and type of plastic polymers in common building materials.

In light of the growing concern around plastic pollution and pressure on planetary boundaries, it is critical both to improve the data on building material content through market and policy initiatives and independent research such as those described in this paper, and to take timely action to change the growth trajectory of this materials sector. While uncertainty remains, it does not preclude action—the available data are sufficient to make better informed policy and market decisions to reduce plastic building material and related hazardous chemical use.

Author contributions

Conceptualization: T. McGrath; data curation: R. Stamm, R. Johnson, C. Clarity; formal analysis: R. Johnson; funding acquisition: T. McGrath; methodology: T. McGrath, R. Stamm, R. Johnson; project administration: C. Clarity; software: R. Johnson; visualization: C. Clarity, R. Johnson, R. Stamm; writing – original draft: C. Clarity, R. Johnson; investigation and writing – review & editing: C. Clarity, R. Johnson, R. Stamm, T. McGrath, B. C. Almroth, V. Singla.

Conflicts of interest

There are no conflicts to declare.

Data availability

The full Common Product dataset, which contains all Common Product chemical content, percent weight, function in the product, and sources is freely available on Habitable's chemical hazard and Common Product database, Pharos: https://pharos.habitablefuture.org/.[43]

Supplementary information (SI): dataset of 239 Common Products' percent weight plastic polymers, associated polymer types, and percent weight priority plastic chemicals by chemical class. The SI also includes additional methodological details and supplementary tables. See DOI: https://doi.org/10.1039/d5va00484e.

Acknowledgements

Habitable provided funding support for V. S. and B. C. A. Funding for C. C., T. M., R. S., and R. J. was provided by Beyond Petrochemicals.

References

1 D. A. Garcia-Gonzales, S. B. C. Shonkoff, J. Hays and M. Jerrett, Hazardous Air Pollutants Associated with Upstream Oil and Natural Gas Development: A Critical Synthesis of Current Peer-Reviewed Literature, *Annu. Rev. Publ. Health*, 2019, **40**, 283–304, DOI: 10.1146/annurev-publhealth-040218-043715.
2 T. J. Woodruff, Health Effects of Fossil Fuel–Derived Endocrine Disruptors, *N. Engl. J. Med.*, 2024, **390**, 922–933, DOI: 10.1056/NEJMra2300476.
3 H. Boonhat, Y. L. Guo, C.-C. Chan and R.-T. Lin, Estimates of the global burden of cancer-related deaths attributable to residential exposure to petrochemical industrial complexes from 2020 to 2040, *Environ. Pollut.*, 2024, **350**, 123955, DOI: 10.1016/j.envpol.2024.123955.
4 J. Trowbridge, D. E. Goin, D. Abrahamsson, R. Sklar and T. J. Woodruff, Fossil fuel is the common denominator between climate change and petrochemical exposures, and effects on women and children's health, *Int. J. Gynecol. Obstet.*, 2023, **160**, 368–371, DOI: 10.1002/ijgo.14408.
5 J. E. Johnston, E. Lim and H. Roh, Impact of upstream oil extraction and environmental public health: A review of the evidence, *Sci. Total Environ.*, 2019, **657**, 187–199, DOI: 10.1016/j.scitotenv.2018.11.483.
6 L. Monclús, H. P. H. Arp, K. J. Groh, A. Faltynkova, M. E. Løseth, J. Muncke, Z. Wang, R. Wolf, L. Zimmermann and M. Wagner, Mapping the chemical complexity of plastics, *Nature*, 2025, **643**, 349–355, DOI: 10.1038/s41586-025-09184-8.
7 M. MacLeod, H. P. H. Arp, M. B. Tekman and A. Jahnke, The global threat from plastic pollution, *Science*, 2021, **373**, 61–65, DOI: 10.1126/science.abg5433.
8 H. P. H. Arp, D. Kühnel, C. Rummel, M. MacLeod, A. Potthoff, S. Reichelt, E. Rojo-Nieto, M. Schmitt-Jansen, J. Sonnenberg, E. Toorman and A. Jahnke, Weathering Plastics as a Planetary Boundary Threat: Exposure, Fate, and Hazards, *Environ. Sci. Technol.*, 2021, **55**, 7246–7255, DOI: 10.1021/acs.est.1c01512.
9 M. B. Tekman, B. A. Walther, C. Peter, L. Gutow and M. Bergmann, *Impacts of Plastic Pollution in the Oceans on Marine Species, Biodiversity and Ecosystems*, WWF Germany, Berlin, 2022, https://zenodo.org/records/5898684.
10 R. C. Thompson, C. J. Moore, F. S. vom Saal and S. H. Swan, Plastics, the environment and human health: current consensus and future trends, *Philos. Trans. R. Soc. Lond. B Biol. Sci.*, 2009, **364**, 2153–2166, DOI: 10.1098/rstb.2009.0053.
11 P. J. Landrigan, H. Raps, M. Cropper, C. Bald, M. Brunner, E. M. Canonizado, D. Charles, T. C. Chiles, M. J. Donohue, J. Enck, P. Fenichel, L. E. Fleming, C. Ferrier-Pages, R. Fordham, A. Gozt, C. Griffin, M. E. Hahn, B. Haryanto, R. Hixson, H. Ianelli, B. D. James, P. Kumar, A. Laborde, K. L. Law, K. Martin, J. Mu, Y. Mulders, A. Mustapha, J. Niu, S. Pahl, Y. Park, M.-L. Pedrotti, J. A. Pitt, M. Ruchirawat, B. J. Seewoo, M. Spring, J. J. Stegeman,

W. Suk, C. Symeonides, H. Takada, R. C. Thompson, A. Vicini, Z. Wang, E. Whitman, D. Wirth, M. Wolff, A. K. Yousuf and S. Dunlop, The Minderoo-Monaco Commission on Plastics and Human Health, *Ann. Glob. Health*, 2023, **89**, 23, DOI: 10.5334/aogh.4056.

12 P. Villarrubia-Gómez, B. Carney Almroth, M. Eriksen, M. Ryberg and S. E. Cornell, Plastics pollution exacerbates the impacts of all planetary boundaries, *One Earth*, 2024, **7**(12), 2119–2138, DOI: 10.1016/j.oneear.2024.10.017.

13 L. Persson, B. M. Carney Almroth, C. D. Collins, S. Cornell, C. A. de Wit, M. L. Diamond, P. Fantke, M. Hassellöv, M. MacLeod, M. W. Ryberg, P. Søgaard Jørgensen, P. Villarrubia-Gómez, Z. Wang and M. Z. Hauschild, Outside the Safe Operating Space of the Planetary Boundary for Novel Entities, *Environ. Sci. Technol.*, 2022, **56**(3), 1510–1521, DOI: 10.1021/acs.est.1c04158.

14 OECD, *Global Plastics Outlook: Policy Scenarios to 2060*, Organisation for Economic Co-operation and Development, Paris, 2022, https://www.oecd-ilibrary.org/environment/global-plastics-outlook_aa1edf33-en.

15 OECD, *Global Plastics Outlook: Plastics Use by Application*, 2024, doi: DOI: 10.1787/234a9f22-en, (accessed 5 December 2025).

16 B. C. Almroth and V. Singla, Plastics treaty: Address building materials, *Science*, 2024, **386**, 736–737, DOI: 10.1126/science.adu2039.

17 R. Geyer, J. R. Jambeck and K. L. Law, Production, use, and fate of all plastics ever made, *Sci. Adv.*, 2017, **3**(e1700782), DOI: 10.1126/sciadv.1700782.

18 P. Paruta, M. Pucino and J. Boucher, Plastic Paints the Environment, *Environ. Action*, 2022, pp. 14–35, https://www.e-a.earth/wp-content/uploads/2023/07/plastic-paint-the-environment.pdf.

19 T. McGrath, R. Stamm, V. Singla, and B. Carney Almroth, *Buildings' Hidden Plastic Problem: Policy Brief and Recommendations*, Habitable, 2024, https://habitablefuture.org/resources/constructions-hidden-plastic-problem-policy-brief-and-recommendations/.

20 J. Thornton, *Environmental Impacts of Polyvinyl Chloride Building Materials*, 2002, https://habitablefuture.org/wp-content/uploads/2024/03/94-environmental-impacts-of-polyvinyl-chloride-building-materials.pdf.

21 IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, *Benzene*, International Agency for Research on Cancer, Lyon (FR), 2018, vol. 120, https://publications.iarc.fr/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Benzene-2018.

22 OECD, Global Plastics Outlook: Plastics use in 2019, 2024, https://data-explorer.oecd.org/vis?pg=0&bp=true&snb=1&tm=plasticsusein2019&df[ds]=dsDisseminateFinalDMZ&df[id]=DSD_PU_2019DF_PU_2019&df[ag]=OECD.ENV.EEI&df[vs]=1.0&dq=&pd=C&to[TIME_PERIOD]=false, (accessed 12 September 2024).

23 NTP (National Toxicology Program), in Report on Carcinogens, U.S. Department of Health and Human Services, Public Health Service, Research Triangle Park, NC, 5th edn, 2021, vol. **1**,p. 2-Dichloroethane.

24 ECHA, Registration Dossier - 1,2-dichloroethane, https://echa.europa.eu/registration-dossier/-/registered-dossier/15430/2/3, (accessed 2 May 2025).

25 IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, in *Chemical Agents and Related Occupations*, International Agency for Research on Cancer, Lyon (FR), 2012, vol. 100F, Vinyl Chloride, https://publications.iarc.who.int/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Chemical-Agents-And-Related-Occupations-2012.

26 H. Pohl, F. Llados, L. Ingerman, P. Cunningham, J. H. Raymer, C. Wall and T. Gasiewicz, *Toxicological Profile for Chlorinated Dibenzo-P-Dioxins*, Agency for Toxic Substances and Disease Registry (US), Atlanta (GA), 1998, Potential for Human Exposure, https://www.ncbi.nlm.nih.gov/books/NBK602040.

27 W. A. Adams, Y. Xu, J. C. Little, A. F. Fristachi, G. E. Rice and C. A. Impellitteri, Predicting the Migration Rate of Dialkyl Organotins from PVC Pipe into Water, *Environ. Sci. Technol.*, 2011, **45**, 6902–6907, DOI: 10.1021/es201552x.

28 P. Tomboulian, L. Schweitzer, K. Mullin, J. Wilson and D. Khiari, Materials used in drinking water distribution systems: contribution to taste-and-odor, *Water Sci. Technol.*, 2004, **49**, 219–226, DOI: 10.2166/wst.2004.0575.

29 D. R. Faust, K. J. Wooten and P. N. Smith, Transfer of phthalates from c-polyvinyl chloride and cross-linked polyethylene pipe (PEX-b) into drinking water, *Water Supply*, 2016, **17**, 588–596, DOI: 10.2166/ws.2016.164.

30 C. Bi, J. P. Maestre, L. Hongwan, G. Zhang, R. Givehchi, A. Mahdavi, K. A. Kinney, J. Siegel, S. D. Horner and Y. Xu, Phthalates and organophosphates in settled dust and HVAC filter dust of U.S. low-income homes: Association with season, building characteristics, and childhood asthma, *Environ. Int.*, 2018, **121**, 916–930, DOI: 10.1016/j.envint.2018.09.013.

31 C.-G. Bornehag, B. Lundgren, C. J. Weschler, T. Sigsgaard, L. Hagerhed-Engman and J. Sundell, Phthalates in indoor dust and their association with building characteristics, *Environ. Health Perspect.*, 2005, **113**, 1399–1404, DOI: 10.1289/ehp.7809.

32 A. Afshari, L. Gunnarsen, P. A. Clausen and V. Hansen, Emission of phthalates from PVC and other materials, *Indoor Air*, 2004, **14**, 120–128, DOI: 10.1046/j.1600-0668.2003.00220.x.

33 European Commission: Directorate-General for Environment and Ramboll, *The use of PVC (poly vinyl chloride) in the context of a non-toxic environment - Final report*, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2779/375357.

34 IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, *Styrene, Styrene-7,8-oxide, and Quinoline*, International Agency for Research on Cancer, Lyon (FR), 2019, vol. 121, https://www.ncbi.nlm.nih.gov/books/NBK551039/.

35 B. J. Seewoo, E. V. S. Wong, Y. R. Mulders, L. M. Goodes, E. Eroglu, M. Brunner, A. Gozt, P. Toshniwal, C. Symeonides and S. A. Dunlop, Impacts associated with the plastic polymers polycarbonate, polystyrene, polyvinyl chloride, and polybutadiene across their life cycle: A review, *Heliyon*, 2024, **10**, e32912, DOI: 10.1016/j.heliyon.2024.e32912.

36 L. Minet, A. Blum, S. R. Fernández, K. M. Rodgers, V. Singla, A. Soehl and M. L. Diamond, High Production, Low Information: We Need To Know More About Polymeric Flame Retardants, *Environ. Sci. Technol.*, 2021, **55**(6), 3467–3469, DOI: 10.1021/acs.est.0c08126.

37 G. H. Y. Gao, P. Helm, S. Baker and C. M. Rochman, Bromine Content Differentiates between Construction and Packaging Foams as Sources of Plastic and Microplastic Pollution, *ACS ES&T Water*, 2023, **3**, 876–884, DOI: 10.1021/acsestwater.2c00628.

38 V. Zadjelovic, R. J. Wright, T. R. Walker, V. Avalos, P. E. Marín, J. A. Christie-Oleza and C. Riquelme, Assessing the impact of chronic and acute plastic pollution from construction activities and other anthropogenic sources: A case study from the coast of Antofagasta, Chile, *Mar. Pollut. Bull.*, 2023, **195**, 115510, DOI: 10.1016/j.marpolbul.2023.115510.

39 OECD, Case study on insulation: An example of chemical considerations for sustainable plastics design, Environment, Health and Safety, *Environment Directorate*, OECD, 2021, https://www.oecd.org/chemicalsafety/risk-management/sustainable-plastic-products 20insulation.pdf.

40 Occupational Safety and Health Administration, Department of Labor, Hazard communication., 2025, vol. 29 CFR 1910.1200, https://www.ecfr.gov/current/title-29/part-1910/section-1910.1200.

41 Regulation (EC) No 1907/2006, Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, 2006, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEXA02006R1907-20191030.

42 P. J. Landrigan, S. Dunlop, M. Treskova, H. Raps, C. Symeonides, J. Muncke, M. Spring, J. Stegeman, B. C. Almroth, T. C. Chiles, M. Cropper, M. Deeney, L. Fuller, R. Geyer, R. Karasik, T. Mafira, A. Mangwiro, D. M. Matias, Y. Mulders, Y. Park, C. A. Velis, R. Vermeulen, M. Wagner, Z. Wang, E. M. Whitman, T. J. Woodruff and J. Rocklöv, The Lancet Countdown on health and plastics, *Lancet*, 2025, **406**, 1044–1062, DOI: 10.1016/S0140-6736(25)01447-3.

43 Habitable, Pharos Common Products, 2026, https://pharos.habitablefuture.org/common-products.

44 EPD International, https://www.environdec.com/home, (accessed 12 March 2025).

45 HPDC, *HPD Public Repository*, https://hpdrepository.hpd-collaborative.org/Pages/Results.aspx, (accessed 27 January 2021).

46 ILFI, Declare, https://declare.living-future.org/, (accessed 25 January 2021).

47 Habitable, Common Product Methodology, February 23, 2021, https://pharos.habitablefuture.org/common-products/methodology, (accessed 7 March 2025).

48 C. Sparks, R. Thompson, A. Jahnke, M. Wagner, M. Filella, J. Frias, M. Wang, T. Farrelly, E. Kentin and C. Velis, Comments on Article 2: Definitions, Scientists' Coalition for an Effective Plastics Treaty, 2025, https://zenodo.org/records/16760982.

49 M. Wagner, L. Monclús, H. P. H. Arp, K. J. Groh, M. E. Løseth, J. Muncke, Z. Wang, R. Wolf and L. Zimmermann, *State of the Science on Plastic Chemicals - Identifying and Addressing Chemicals and Polymers of Concern*, 2024, DOI: 10.5281/zenodo.10701706.

50 European Parliament and Council, Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment, 2019, https://eur-lex.europa.eu/eli/dir/2019/904/oj.

51 L. Trasande, R. Krithivasan, K. Park, V. Obsekov and M. Belliveau, Chemicals Used in Plastic Materials: An Estimate of the Attributable Disease Burden and Costs in the United States, *J. Br. Endod. Soc.*, 2024, **8**(2), DOI: 10.1210/jendso/bvad163.

52 R Core Team, *R: A Language and Environment for Statistical Computing (version 4.3.1)*, R Foundation for Statistical Computing, Vienna, Austria, 2023, https://www.R-project.org.

53 Environment and Climate Change Canada, Detailed categorization results of the Domestic Substances List - Open Government Portal, https://open.canada.ca/data/en/dataset/1d946396-cf9a-4fa1-8942-4541063bfba4, (accessed 7 March 2025).

54 Health Canada, Chemical substances glossary, October 27, 2006, https://www.canada.ca/en/health-canada/services/chemical-substances/chemical-substances-glossary.html, (accessed 7 March 2025).

55 Habitable, *Pharos Hazard Lists*, 2026, https://pharos.habitablefuture.org/hazard-lists, (accessed 10 March 2026).

56 Federal Trade Commission, *Labeling and Advertising of Home Insulation: Trade Regulation Rule*, 2005, 16 CFR Part 460, vol. 70, FR, 31258–31276, https://www.federalregister.gov/documents/2005/05/31/05-10683/labeling-and-advertising-of-home-insulation-trade-regulation-rule.

57 H. Wiesinger, C. Bleuler, V. Christen, P. Favreau, S. Hellweg, M. Langer, R. Pasquettaz, A. Schönborn and Z. Wang, Legacy and Emerging Plasticizers and Stabilizers in PVC Floorings and Implications for Recycling, *Environ. Sci. Technol.*, 2024, **58**, 1894–1907, DOI: 10.1021/acs.est.3c04851.

58 KDF Co., *Ltd, Health Product Declaration v2.3. UnidecoTile, Looselay Tile, and Click Tile*, December 9, 2022, https://hpdrepository.hpd-collaborative.org/repository/HPDs/

575_UnidecoTile_Looselay_Tile_and_Click_Tile.pdf, (accessed 17 November 2025).

59 K. C. C. Glass, *Health Product Declaration v2.3. Sensitile Pro, Sensetile Trendy*, Senselay, June 12, 2024, https://hpdrepository.hpd-collaborative.org/repository/HPDs/1328_SENSITILE_PRO_SENSETILE_TRENDY_SENSELAY.pdf, (accessed 17 November 2025).

60 M. Mills, Health Product Declaration v2.3. Luxury Vinyl Tile & Plank (LVT/LVP) - 2.5 (40 mil) and 3.2mm, March 19, 2025, https://hpdrepository.hpd-collaborative.org/repository/HPDs/42_Luxury_Vinyl_Tile_Plank_LVT_LVP_2_5_40_mil_and_3_2mm.pdf, (accessed 17 November 2025).

61 Organisation for Economic Co-operation and Development, Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance, 2021, https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf.

62 United Nations Environment Assembly, End plastic pollution: Towards an international legally binding instrument [UNEP/EA.5/Res.14], United Nations Environment Programme, 2022, https://wedocs.unep.org/handle/20.500.11822/39764.

63 United Nations Environment Programme, *2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector*, Nairobi, 2021, https://globalabc.org/sites/default/files/2021-10/GABC_Buildings-GSR-2021_BOOK.pdf.

64 OECD Environment Statistics (database), *Global Plastics Outlook: Plastics Use by Application - Projections*, OECD, Paris, 2022, DOI: 10.1787/c768d873-en.

65 K. Senathirajah, A. Kemp, M. Saaristo, S. Ishizuka and T. Palanisami, Polymer prioritization framework: A novel multi-criteria framework for source mapping and characterizing the environmental risk of plastic polymers, *J. Hazard. Mater.*, 2022, **429**, 128330, DOI: 10.1016/j.jhazmat.2022.128330.

66 S. Suh, A.-M. Boulay, P. Fantke, D. Li, D. Menon, R. Meys and L. Milà i Canals, Conceptual framework for identifying polymers of concern, *Front. Sustain.*, 2024, **5**(1399431), DOI: 10.3389/frsus.2024.1399431.

67 R. B. Weingrill, M.-J. Lee, P. Benny, J. Riel, K. Saiki, J. Garcia, L. F. A. de M. Oliveira, E. J. da S. Fonseca, S. T. de Souza, F. de O. S. D'Amato, U. R. Silva, M. L. Dutra, A. L. X. Marques, A. U. Borbely and J. Urschitz, Temporal trends in microplastic accumulation in placentas from pregnancies in Hawai'i, *Environ. Int.*, 2023, **180**, 108220, DOI: 10.1016/j.envint.2023.108220.

68 N. Chartres, C. B. Cooper, G. Bland, K. E. Pelch, S. A. Gandhi, A. BakenRa and T. J. Woodruff, Effects of Microplastic Exposure on Human Digestive, Reproductive, and Respiratory Health: A Rapid Systematic Review, *Environ. Sci. Technol.*, 2024, **58**(52), 22843–22864, DOI: 10.1021/acs.est.3c09524.

69 V. Colliver, Microplastics in the Air May Be Leading to Lung and Colon Cancers, December 18, 2024, https://www.ucsf.edu/news/2024/12/429161/microplastics-air-may-be-leading-lung-and-colon-cancers, (accessed 20 December 2024).

70 M. P. Drewniok, Y. Gao, J. M. Cullen and A. Cabrera Serrenho, What to Do about Plastics? Lessons from a Study of United Kingdom Plastics Flows, *Environ. Sci. Technol.*, 2023, **57**, 4513–4521, DOI: 10.1021/acs.est.3c00263.

71 S. Handa, K. K. Isaacs, J. T. Wall, A. Larger, S. Burns, L. E. Koval, K. Baron-Furuyama, C. M. Elonen, D. Lyons, K. L. Dionisio, M. B. Horton and K. A. Phillips, The Chemical and Products Database v4.0, an updated resource supporting chemical exposure evaluations, *Sci. Data*, 2025, **12**, 950, DOI: 10.1038/s41597-025-05240-0.

72 L. Huang, P. Fantke, A. Ritscher and O. Jolliet, Chemicals of concern in building materials: A high-throughput screening, *J. Hazard. Mater.*, 2022, **424**, 127574, DOI: 10.1016/j.jhazmat.2021.127574.

73 L. Huang, N. Anastas, P. Egeghy, D. A. Vallero, O. Jolliet and J. Bare, Integrating exposure to chemicals in building materials during use stage, *Int. J. Life Cycle Assess.*, 2019, **24**, 1009–1026, DOI: 10.1007/s11367-018-1551-8.

74 M. Ferreira, A. Matos, A. Couras, J. Marto and H. Ribeiro, Overview of Cosmetic Regulatory Frameworks around the World, *Cosmetics*, 2022, **9**, 72, DOI: 10.3390/cosmetics9040072.

75 SB 258- Cleaning Product Right to Know Act of 2017, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB258, (accessed 27 March 2025).

76 Global Automotive Declarable Substance List (GADSL), April 2, 2014, https://www.gadsl.org/, (accessed 27 March 2025).

77 International Material Data System (IMDS), https://www.mdsystem.com/imdsnt/startpage/index.jsp, (accessed 27 March 2025).

78 Health Product Declaration Collaborative, HPD Open Standard, https://www.hpd-collaborative.org/hpd-open-standard-all-versions/, (accessed 13 February 2026).

79 International Living Future Institute, About Declare - Living Future, May 11, 2022, https://living-future.org/declare/basics/, (accessed 13 February 2026).

80 U.S. Green Building Council, Criteria Areas & Achievement Levels in LEED v5 - Additional Guidance for Materials & Resources Credit: Building Product Selection & Procurement, 2025, https://www.usgbc.org/sites/default/files/2025-11/BPSP 20Criteria 20Areas 20and 20Levels 20Resource_v1.2.pdf.

81 International WELL Building Institute, WELL v2 Q2 2025, 2025, https://v2.wellcertified.com/en/wellv2/materials/feature/7.

82 MATERIALS, https://www.greencommunitiesonline.org/materials, (accessed 13 February 2026).

83 J. Toffoli, HPD Collaborative Launches HPD Open Standard v3.0, October 31, 2025, https://www.hpd-collaborative.org/category/press-release/, (accessed 13 February 2026).

84 Health Product Declaration Collaborative, Health Product Declaration Open Standard Version 3.0, 2025, https://www.hpd-collaborative.org/wp-content/uploads/2025/10/HPD-Open-Standard-_v3.0_Final.pdf.

85 International Living Future Institute, LPC 2.0 Documentation Requirements, May 2022, https://living-future.org/wp-content/uploads/2022/05/LPC-2.0-Documentation-Requirements.pdf, (accessed 8 December 2025).
86 C. Olisah, L. Melymuk, R. Vestergren, K. Rumar, T. Wickman, N. Melander, P. Talasniemi, S. Brandsma, U. Boije af Gennäs and M. Scheringer, Toward Product Safety and Circularity: Understanding the Information Structure of Global Databases on Chemicals in Products and Articles, *Environ. Sci. Technol.*, 2025, **59**, 1897–1908, DOI: 10.1021/acs.est.4c07992.
87 J. L. Ohayon, C. Polsky and M. R. Schwarzman, How a Right-to-Know Law Shifts Industry away from Chemicals of Concern: The Case of California's Proposition 65, *Environ. Sci. Technol.*, 2025, **59**, 3344–3354, DOI: 10.1021/acs.est.4c07495.
88 Z. Wang and A. Praetorius, Integrating a Chemicals Perspective into the Global Plastic Treaty, *Environ. Sci. Technol. Lett.*, 2022, **9**, 1000–1006, DOI: 10.1021/acs.estlett.2c00763.
89 C. Lassen, M. Warming, J. Kjølholt, B. Novichkov, J. Strand, L. Feld and L. Bach, *Survey of Polystyrene Foam (EPS and XPS) in the Baltic Sea*, 2019, https://www.helcom.fi/wp-content/uploads/2019/10/Survey-of-polystyrene-foam-EPS-and-XPS-in-the-Baltic-Sea.pdf.
90 S. Pickard and S. Sharp, *Phasing out plastics: the construction sector, ODI*, 2020, https://www.odi.org/en/publications/phasing-out-plastics-the-construction-sector/.
91 United Nations Environment Programme, Building Materials And The Climate: Constructing A New Future, Nairobi, 2023, http://www.unep.org/resources/report/building-materials-and-climate-constructing-new-future.
92 S. de Marchi and J. T. Hamilton, Assessing the Accuracy of Self-Reported Data: an Evaluation of the Toxics Release Inventory, *J. Risk Uncertain.*, 2006, **32**, 57–76, DOI: 10.1007/s10797-006-6666-3.
93 I. Fischer, W. F. Schmitt, H.-C. Porth, M. W. Allsopp and G. Vianello, in *Ullmann's Encyclopedia of Industrial Chemistry*, John Wiley & Sons, Ltd, 2014, Poly(Vinyl Chloride), pp. 1–30.
94 B. Pelzl, R. Wolf and B. L. Kaul, in *Ullmann's Encyclopedia of Industrial Chemistry*, John Wiley & Sons, Ltd, 2018, Plastics, Additives, pp. 21–26.
95 Secretariat of the Stockholm Convention, Listing of POPs in the Stockholm Convention, https://www.chm.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx, (accessed 11 February 2026).
96 US EPA, Flame Retardant Alternatives for Hexabromocyclododecane (HBCD), 2014, https://www.epa.gov/sites/production/files/2014-06/documents/hbcd_report.pdf.
97 C. Corden, D. Tyrer, R. Whiting and I. Kirhensteine, *Chemtura Manufacturing UK Ltd Feasibility Study on Substituting HBCD with Polymeric Flame Retardant*, AMEC Environment & Infrastructure UK Limited, 2014, https://www.echa.europa.eu/documents/10162/18074545/a4a_comment_563_1_attachment_en.pdf.

