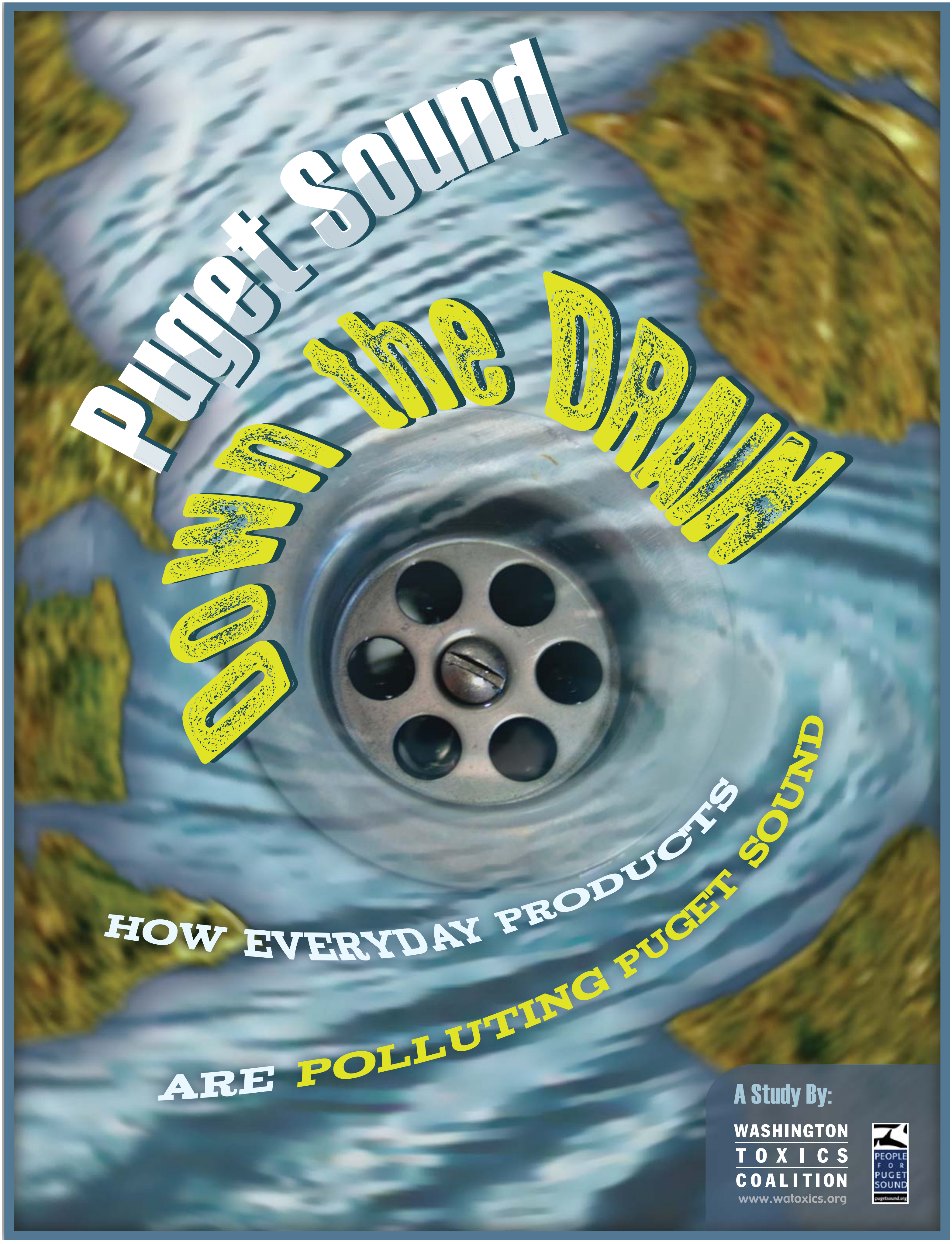

Puget Sound Down the Drain

How Everyday Products Are Polluting Puget Sound

A Study By:

WASHINGTON TOXICS COALITION
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PEOPLE FOR PUGET SOUND
pugetsound.org

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Protecting Health & the Environment

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Executive Summary

It is well known that toxic chemicals pose a major threat to the health of Puget Sound. For many chemicals, however, how they are getting from the products in our homes to the waters, sediments, and wildlife of the Sound remains mysterious. This study examines whether toxic chemicals are escaping consumer products in our homes, contaminating house dust, and then hitchhiking on our clothing. The chemicals could then enter the wastewater treatment system, and eventually Puget Sound, when we wash our clothes in the washing machine.

The study explores this possible pathway using phthalates, a family of chemicals widely present in consumer products. In our homes, phthalates are in plastics, personal care products, and many home and building materials such as vinyl flooring, wallpaper, and shower curtains. In the environment, they turn up in sediments and wildlife in Puget Sound and the discharges from wastewater treatment plants.

To investigate the route from home to environment, we tested washing machine rinse water and house dust from six homes around Puget Sound. Participating homes were located in Tumwater, Renton, Bainbridge Island, Seattle, Whidbey Island, and Bellingham.

Key Findings:

1 Phthalates from everyday products are making their way to Puget Sound by way of the clothes we wash in our washing machines.

Our testing uncovered the fact that the phthalates in the products in our homes aren't staying put: instead, they are migrating into dust, attaching to our clothing, and coming off when we do the laundry. We found phthalates in every sample we took of house dust and washing machine rinse water.

2 Dust from our homes hitchhiking on our clothes may constitute a significant source of water pollution.

Our calculations indicate that in the Puget Sound region, phthalates from our clothing contribute approximately 2110 pounds or 959 kilograms yearly of the phthalate DEHP to the flows entering wastewater treatment plants. This makes up approximately 17.5% of the total phthalate load entering treatment plants.

3 Washing machine detergent also contributes phthalates to Puget Sound.

We tested two popular detergents, and found the phthalate DEP in one of them, liquid Tide. If all households used a detergent that contained phthalates at this level, it would contribute approximately 40 kilograms or 87 pounds yearly of DEP to the flows entering wastewater treatment plants from Puget Sound residences.

Recommendations:

1 Washington should enact legislation to ensure that only the safest chemicals are used in products.

The Washington State Legislature should take action to eliminate the use of the most hazardous chemicals and replace them with safer alternatives. The Legislature can begin by granting the Washington State Department of Ecology authority to require that safer alternatives be used in place of harmful chemicals in consumer products.

2 Washington should take action to phase out the chemicals posing the greatest threat to Puget Sound's health.

The Puget Sound Partnership and other state agencies have yet to take action to phase out the highest priority toxic chemicals. State agencies must develop plans for addressing ongoing chemical pollution and take action to eliminate it.

3 Washington should help industry switch to safer alternatives and away from chemicals known to be harmful to Puget Sound.

Washington needs to help businesses adopt greener, healthier, and Puget Sound-friendly solutions by identifying safer solutions and providing technical support.

4 Companies should disclose what chemicals they are using to manufacture products.

Agencies must be able to access information on chemicals used in manufacturing in order to determine the opportunities for reducing pollution.

5 The Puget Sound Partnership should prioritize Action Agenda items that prevent toxic chemical pollution.

The Partnership should support the above recommendations in the legislature and other arenas and fully fund policies that keep toxic chemicals out of products and Puget Sound.

Introduction

Photo By: Berd Whitlock

A healthy Puget Sound has been a goal of this region's residents and leaders for many decades, since evidence first emerged that human activity was damaging the Sound's ecosystem. In recent years, restoring Puget Sound has become a major state priority, as Governor Gregoire and the Washington State Legislature established an aggressive goal of cleaning up and restoring the Sound to health by 2020. The Puget Sound Partnership, a new state agency, was established to develop and implement a plan to make the Sound a healthy place for all of us.

Both longtime residents of the area and newcomers have faced the devastating discovery that beneath the Sound's sparkling waters, there lurks severe toxic chemical pollution. The Puget Sound Partnership is charged with reversing the current trend of increased pollution and restoring the health of the Puget Sound basin.

To that end, among the Partnership's 2020 goals is to ensure:

> *Fresh and marine waters and sediments of a sufficient quality so that the waters in the region are safe for drinking, swimming, shellfish harvest and consumption, and other human uses and enjoyment, and are not harmful to the native marine mammals, fish, birds, and shellfish of the region. (WA State RCW 90.71.300)*

Specifically, the Partnership has envisioned a Puget Sound in which "pollution does not reach harmful levels in marine waters, sediments or fresh waters."

Sadly, that is not the case for today's Puget Sound. This stunningly beautiful water body hosts some of the most contaminated marine mammals in the world. For instance, our harbor seals have seven times the PCB (polychlorinated biphenyl) levels of their counterparts in neighboring Georgia Strait.[1] And the southern resident killer whales, suffering a steady decline in numbers, are contaminated with PCBs at levels that are likely to be impairing their health by compromising their immune systems.[2]

PCBs have been banned for more than 30 years, but orcas, salmon, and other Puget Sound resident species also encounter modern chemicals like the flame retardants PBDEs (polybrominated diphenyl ethers), the stain-protecting perfluorinated compounds (PFCs), and the widely used plasticizers known as phthalates. Manufacturers of consumer products from furniture to toys and clothing incorporate these chemicals into the items we bring into our homes and offices. Like PCBs, these consumer-oriented chemicals have also made their way to Puget Sound: research shows PBDE levels are increasing in orcas at an alarming rate,[3] and nearly three of four Duwamish Chinook have tested positive for the common phthalate DEHP (di-(2-ethylhexyl) phthalate).[4]

While scientists have clearly established the dire pollution problem in Puget Sound and the urgency of turning the tide, the question of exactly how these chemicals are popping out of our couches and contaminating killer whales remains something of a mystery. In some cases, the chemicals have industrial and outdoor uses as well and turn up in factory discharges and the runoff from streets and industrial sites. But for a number of these chemicals, it seems clear that the primary source is indeed the products within our homes.

Chemical Hitchhikers

This study set out to disentangle some of the complex threads that lead from products in our homes to contamination of our fresh and marine waters. It takes a closer look at the water leaving our homes as a potential source. Specifically, it examines whether it is plausible that toxic chemicals are escaping consumer products, contaminating house dust, and then hitchhiking on our clothing. The chemicals could then enter the wastewater treatment system, and eventually Puget Sound, when we wash our clothes in the washing machine.

Toxic chemicals may be escaping consumer products, contaminating house dust, and then hitchhiking on our clothing. The chemicals could then enter the wastewater treatment system, and eventually Puget Sound, when we wash our clothes in the washing machine.

The study explores this possible pathway using phthalates, a family of chemicals almost ubiquitous in consumer products. Phthalates make their way to our homes through their presence in plastics, personal care products, and many home and building materials such as vinyl flooring, wallpaper, and shower curtains (see Appendix 1 for a list of phthalates and their uses).[5] They are oily substances commonly used as plasticizers, and in some products make up as much as 40% or more of the actual product content. Because they are so common in products, they are also present at relatively high levels in house dust and make a good test case for investigating this possible pathway.[6]

Phthalates are chemicals of concern for both human and ecosystem health, with effects primarily on reproductive development and success. Since they are not chemically bound in products such as plastics, phthalates are believed to migrate to dust via off-gassing, or volatilization, and abrasion.[7,8] They also accumulate in films on windows and other surfaces.[9] And while limited, some research indicates that clothing can become a repository for dust: one study found that dirty clothing held three to ten times more particulate matter than clean clothing.[10]

Suds in the Sound

The Puget Sound ecosystem has been in decline since factors including habitat loss, overfishing, and pollution have taken their toll. According to the Puget Sound Partnership, "the current condition of Puget Sound shows signs that the web of life is fraying and that the many benefits we derive from our ecosystem may be in jeopardy."

Pollution became a serious threat to the Sound's health in the post-World War II chemical boom, when industries discharged large quantities of metals and other toxic chemicals into waterways with little to no oversight. While passage of the major environmental laws in the 1970s helped stop unfettered chemical discharges, chemicals such as PBDEs and phthalates continue to flow into the Sound.

Agency testing has discovered phthalates in sediments in Puget Sound and in the Duwamish River, typically in the greatest concentrations near outfalls for wastewater treatment plants and stormwater. [11] The phthalate DEHP (see Appendix 1 for phthalate name abbreviations and uses), used extensively in building materials and medical devices, has generally been found at the highest levels. Duwamish salmon have also tested positive for DEHP, with 14 of 19 Chinook tested harboring the chemical[4]. Phthalates are also present in English sole, crabs, shiner surfperch, and bottom-feeding invertebrates. [12]

Agencies have worked to quantify the amounts of phthalates entering the Sound via various pathways, and have identified stormwater, direct deposition from air pollution, industrial discharges, and sewage treatment plants.[13, 14] In many cases, these sources can be traced to the use of phthalates in consumer products. An inter-agency workgroup on phthalates and sediments has also hypothesized that out-of-doors, phthalates off-gas from PVC/vinyl products, attach to particles in the air, deposit on roads and other impervious surfaces, and wash into waterways. [15]

Phthalates from products may enter the wastewater treatment system from inside our homes via two routes: through the use of phthalate-containing cleaning products such as laundry detergent and tub and shower cleaners; and through the more diffuse pathway of off-gassing from plastic products, contaminating indoor dust, and then entering the wastewater treatment system through sink or laundry water.

However it arrives, a significant quantity of phthalates does make its way through the sewage treatment process, which is unable to completely remove the chemicals from effluent. The phthalate DEHP has been measured in flows from sewage treatment plants that discharge into the Puget Sound Basin, at levels high enough to exceed standards at 15 plants. The total load from sewage treatment plants is estimated at 9,363 pounds of the phthalate DEHP per year. [11]

Although phthalates are not considered persistent because they break down in oxygen-rich environments, they do accumulate in freshwater and marine sediments. In Puget Sound, phthalates are associated with 13 of the 18 Superfund sediment cleanup sites.[4] Perhaps most disturbing is evidence that ongoing sources of phthalates are re-contaminating areas in the Sound that have already been cleaned up. In the Duwamish River and in Tacoma's Commencement Bay at the top of the Thea Foss waterway, phthalates contaminated sediments within five years of cleanup.[15]

Research going back decades has identified toxic effects from phthalates on wildlife. Laboratory tests have found that some phthalates reduce fish survival and the ability of the water flea Daphnia to reproduce.[16, 17] Researchers have also seen changes in the levels of key enzymes in the brains, muscles, and livers of fish exposed to the phthalate DEP.[18] These changes in enzyme activity may have long-term effects on nerve function and metabolism in exposed fish.

Field studies confirm that phthalates threaten the Puget Sound food web: in Commencement Bay's Thea Foss Waterway, phthalates in the sediments caused problems with reproduction and survival for the mussel larvae, sand fleas, and other animals that live there.[19] With these animals forming the base of the food web, any decrease in their abundance and diversity means less food available for larger animals, creating a ripple effect throughout the ecosystem.

Widespread use of phthalates also creates serious concern for human health. Several phthalates have been found in laboratory studies to reduce testosterone production by the fetus, which can result in off-target reproductive development and abnormal genitals.[20, 21] In a human study looking at the reproductive health of baby boys with varying levels of phthalate exposure, Shanna Swan of the University of Rochester found a link between greater exposure to several phthalates and altered genital development.[22] Adult exposure has also been linked to problems with sperm quality, and children in homes with higher phthalate levels are more likely to have asthma and allergic symptoms.[5, 23]

Our Investigation

To test whether toxic chemicals could be hitchhiking from household products to Puget Sound via our clothing and laundry, we initiated a study of dust and laundry rinse water from six homes around Puget Sound (see Appendix 2 for detailed methods). We recruited six families, from north, central, and south Puget Sound, to participate in the study and conducted sampling between November 2008 and May 2009. Washing machine and dust samples were submitted to a certified laboratory for analysis.

Each family agreed to use Seventh Generation liquid laundry detergent, which had tested free of phthalates, for at least two weeks before sample collection. We also requested that families prepare a load of clothing for washing, including as much as possible clothing that had been worn around the home, and not vacuum floors for at least a week before sampling.

Researchers collected information on the presence and amount of vinyl flooring in the primary living areas of the home as well as other factors such as the age of the home and number of residents. To sample washing machine rinse water, researchers first ran the washing machine free of clothing and detergent and took a one liter water sample to serve as a field blank. They then added clothing and soap, set the machine to run a standard cycle with warm water, and removed a second one liter water sample at the end of the first agitation cycle.

Researchers collected dust from each home's primary living areas using a standardized protocol.[24] Dust was collected by vacuuming the home's primary living areas, which generally included kitchen, living room, dining room, bathroom, and children's bedrooms.

Analytical Sciences of Petaluma, California analyzed the rinse water and dust samples for sixteen phthalates.

Study Participants

Tracey Scalici
Student
Location: Tumwater

Tracy Collier
Research Scientist
at federal agency
Location: Bainbridge Is.

Erin Rehm
Dental Hygienist
Location: Bellingham

Jacqueline Moore
Community Leader
Location: Renton

James Rasmussen
Duwamish Tribe/
Longhouse Director
Location: Seattle

Joanna Snow Cruse
Community Leader
Location: Whidbey Island

Phthalates Sneaking from Our Homes to the Sound

Our results indicate that indeed, phthalates are likely to be moving from products to house dust to our clothing to washing machine water to Puget Sound. Our sampling found that phthalates are a ubiquitous presence in house dust and washing machine rinse water, suggesting that dust on our clothing could be a significant pathway for toxic chemicals to travel to waterways.

Collecting dust from the floor for testing.

Dust collecting under the furniture at one of the sampled residences.

Phthalates are Present in House Dust and Washing Machine Water

Phthalates in Dust

House dust from every home we sampled contained phthalates. Dust contained a wide variety of compounds, ranging from five to nine different phthalates. Concentrations ranged from less than 1 part per million (ppm) to 550 ppm. In all but one home, the phthalate DEHP, commonly used in building materials such as vinyl flooring and in home furnishings such as shower curtains, was present at higher concentrations than other phthalates. In those homes, DEHP made up from 51% to 80% of the total phthalates detected. One home had high concentrations of BBP, which can also be used as a plasticizer in PVC/vinyl flooring; in this home BBP made up 92% of the total phthalates.

Phthalate Abbreviations and Names

See Appendix I for uses of phthalates

DMP: Dimethyl phthalate
DEP: Diethyl phthalate
DIBP: Diisobutyl phthalate
DBP: Di-n-Butyl phthalate (also DnBP)
DMEP: Bis(2-Methoxyethyl) Phthalate
bMPP: Bis(4-Methyl-2-Pentyl) Phthalate
BEEP: Bis(2-Ethoxyethyl) Phthalate
DAP: Diamyl phthalate
DHP: Dihexyl phthalate
BBP: Butyl benzyl phthalate
BBEP: Bis(2-N-Butoxyethyl) Phthalate
DEHP: Di-(2-Ethylhexyl) Phthalate
DCP: Dicyclohexyl phthalate
DOP: Di-n-octyl phthalate (also DNOP)
DNP: Dinonyl phthalate
DINP: Diisononyl phthalate

Table 1: Phthalate Concentrations in House Dust (ppm)

Compound	Residence: Scalici	Collier	Moore	Rehm	Cruse	Rasmussen	MEAN	MEDIAN
DMP	<0.1	<0.1	<1	<0.1	<0.1	<0.1	0.05	0.11
DEP	0.35	0.66	2.0	2.1	1.1	1.7	1.10	1.14
DIBP	2.35	3.8	4.0	6.1	4.3	4.4	4.00	4.05
DBP	3.05	40	<1	8.5	6.6	70	6.60	18.86
DMEP	<0.5	<0.5	<5	<0.5	<0.5	<0.5	0.25	0.57
bMPP	<0.1	<0.1	<1	<0.1	<0.1	<0.1	0.05	0.11
BEEP	<0.5	<0.5	<5	<0.5	<0.5	<0.5	0.25	0.57
DAP	<0.1	<0.1	<1	<0.1	<0.1	<0.1	0.05	0.11
DHP	<0.1	3.6	<1	<0.1	0.67	<0.1	0.05	0.71
BBP	4.5	6.1	550	4.4	4.9	6.6	4.90	82.84
BBEP	<0.5	11	<5	<0.55	5.0	6.1	2.50	3.63
DEHP	210	93	38	85	41	100	93.00	109.57
DCP	<0.1	<0.1	<1	<0.1	<0.1	<0.1	0.05	0.11
DOP	<0.1	3.4	<1	<0.5	2.1	4.0	0.50	1.48
DNP	<0.1	5.6	5.0	<0.5	2.7	3.0	2.70	2.38
DINP	65.03	<0.1	<1	<0.5	<0.5	<0.5	0.25	9.48

Table 1 presents the results of testing for sixteen phthalates in samples of house dust from six homes. Results are presented in parts per million (ppm). For chemicals not detected, the level is reported as < limit of detection, which varied with the chemical and sample.

Taking a sample of the washing machine rinse water.

You can see how much dust ends up in the rinse water when it's poured into the white sink.

Phthalates in Washing Machine Water

Phthalates were found in the washing machine rinse water from every home, with total concentrations ranging from 19.7 parts per billion (ppb) to 92.8 ppb and a mean concentration of 49.43 ppb. DEHP was detected in all but one home, making up from 19% to 73% of the total phthalate load in homes where it was found. DEP, used primarily in fragranced items such as cosmetics, was present in rinse water from every home at a mean concentration of 10.42 ppb.

Table 2: Phthalate Concentrations in Washing Machine Rinse Water (ppb)

	Residence							
Compound	Scalici	Collier	Moore	Rehm	Cruse	Rasmussen	MEAN	MEDIAN
DMP	<1	<1	<1	<1	<1	<1	0.50	0.5
DEP	3.4	17	18	8.8	5.4	9.9	10.42	9.35
DIBP	<1	1.5	<1	<1	<1	<1	0.67	0.5
DBP	1.4	3.8	<1	<1	<1	<1	1.20	0.5
DMEP	<5	<5	<5	<5	<5	<5	2.50	2.5
bMPP	<1	<1	<1	<1	<1	<1	0.50	0.5
BEEP	<5	<5	<5	<5	<5	<5	2.50	2.5
DAP	<1	<1	<1	<1	<1	<1	0.50	0.5
DHP	<1	<1	<1	<1	<1	<1	0.50	0.5
BBP	3.5	<1	<1	<1	<1	<1	1.00	0.5
BBEP	5.6	<5	<5	<5	<5	<5	3.02	2.5
DEHP	56	19	<5	14	1.3	6.4	16.53	10.2
DCP	<1	<1	<1	<1	<1	<1	0.50	0.5
DOP	1.6	<1	<1	<1	<1	<1	0.68	0.5
DNP	5.5	<1	<1	<1	<1	<1	1.33	0.5
DINP	40	<1	<1	<1	<1	<1	7.08	0.5

Table 2 presents the results of testing for sixteen phthalates in six samples of laundry rinse water. Results are presented in parts per billion (ppb). For chemicals not detected, the level is reported as < limit of detection, which varied with the chemical and sample.

Analysis of Findings

Our results for phthalates in house dust are consistent with those of other U.S. studies, which have found primarily DEHP, BBP (butyl benzyl phthalate), and DBP (di-n-butyl phthalate).[6, 25] Studies in Europe have found slightly higher levels of these chemicals in dust (see Appendix 3).

To explore whether the house dust was the source of the phthalates in the laundry water, we examined the correlation between levels in dust and in rinse water for both DEHP and DEP. Interestingly, the correlation was very strong for DEHP (Spearman R = 0.77, p = 0.07): the levels of DEHP in the dust and the rinse water were closely related. This may indicate that the primary source for DEHP in dust on clothing was in fact dust from the home. Such a finding would be plausible because DEHP is found extensively in building materials and other home products such as flooring and shower curtains.

Previous studies have indeed found that homes with higher proportions of plastic building materials and carpeting have higher levels of phthalates in dust.[5, 26, 27] In particular, DEHP is known to off-gas from vinyl flooring.[7] Other PVC/vinyl products, including faux leather, wallpaper, and electric cables, emit phthalates as well.[28, 29]

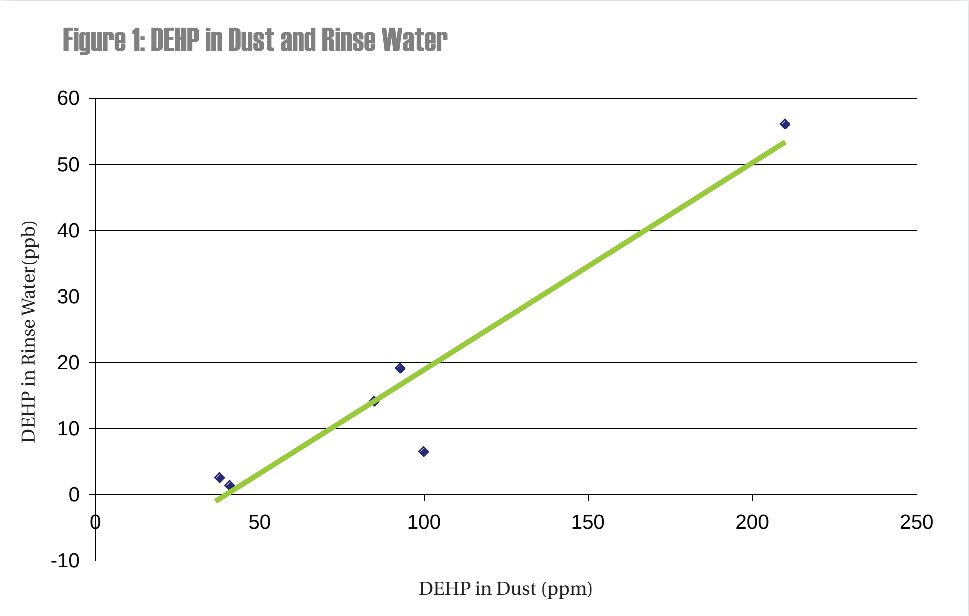

Figure 1: Concentrations of the phthalate DEHP in dust and rinse water samples. Each point (dark blue diamonds) represents the results from one home for house dust and rinse water. Levels in dust and rinse water were highly correlated (Spearman R=0.77, p=0.07), meaning a strong relationship was detected between findings in dust and in rinse water.

On the other hand, the correlation was weak for DEP (Spearman R = 0.43, p = 0.4), with no detectable relationship between the levels in dust and those in rinse water. This suggests that the DEP found on clothing may come from a different

Scalici Home

Tracey Scalici and her husband and son live in a rambler on a quiet street in Tumwater, Washington. With Tracey enrolled in an environmental science program at The Evergreen State College, the family has made an effort to reduce toxic chemicals in their home.

But the lab results turned up with the Scalici home having the study's highest levels of DEHP in both house dust and washing machine rinse water. The home has a very large kitchen, all floored in vinyl, which typically incorporates a high percentage of DEHP. This home also had the highest number of phthalate compounds and the second highest total phthalate concentration in the washing machine rinse water.

source. Since this chemical is used primarily in fragrances in products such as deodorant, perfumes and colognes, lotions, hair products, and cleaners, it seems likely that the DEP in the rinse water is the result of the chemical adhering directly to clothing.[30, 31]

We used Seventh Generation Liquid Laundry Detergent during our study because it tested phthalate-free.

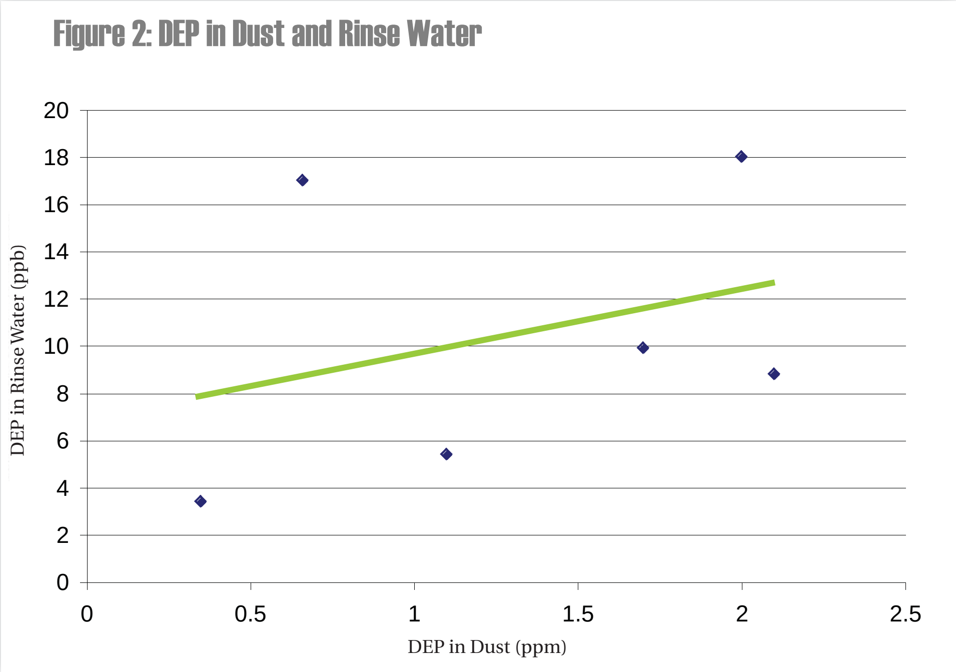

Figure 2: Concentrations of the phthalate DEP in dust and rinse water samples. Each point (dark blue diamonds) represents the results from one home for house dust and rinse water. Levels in dust and rinse water were poorly correlated, (Spearman R=0.43, p=0.4), meaning no relationship was detected between findings in dust and in rinse water.

Phthalate-Contaminated Dust in Washing Machine Water Contributes Significantly to Phthalates in Puget Sound

To estimate the contribution of dust from our clothing to the load of phthalates entering Puget Sound, we used the mean level of DEHP in our study (16.53 ppb) as an approximation of the average washing machine water in households in the region. With a per person average of 56.8 liters (15 gallons) used each day for the washing machine[i, 32] and a population of 4.1 million people,[33] the approximate total water flow from laundry in the Puget Sound region is 61.5 million gallons per day.

To estimate the total phthalate load to the wastewater treatment system, we calculated the amount of laundry water coming from homes that discharge to this system. Approximately 1.3 million Puget Sound residents discharge to septic systems, for a total of 19.5 million gallons per day of laundry water (the Washington State Department of Health estimates 500,000 septic systems in the region,[34] translating to 1.3 million people with an assumption of 2.6 people per house-

i The per person amount of 56.8 liters or 15 gallons per day is based on a survey of 1,188 homes in 12 U.S. suburban areas.

hold).[35] Therefore, we calculated the total flow from laundry water to wastewater treatment systems to be approximately 42 million gallons per day. A mean level of 16.53 ppb DEHP in this water would equate to a total of 2,110 pounds or 959 kilograms per year going to the wastewater treatment system. Individual septic systems receive approximately 979 pounds or 445 kilograms each year.

To estimate the contribution dust in laundry water makes to the Sound's total phthalate load, we used pretreatment reports filed by three Puget Sound wastewater treatment plants to determine an approximate DEHP concentration in all water entering the plants (called influent). With an estimated average concentration of 10.27 ppb and total Puget Sound Basin wastewater flows of approximately 386.71 million gallons per day,[ii] the total phthalate load entering wastewater treatment plants is approximately 12,067 pounds or 5,485 kilograms per year. Our estimate from laundry water is 2,110 pounds, or 17.5% of this total. Therefore, we estimate that phthalates in laundry water, reflecting the dust carried on clothing, are responsible for 17.5% of the total load of phthalates to Puget Sound.

While the contribution from laundry water is impressive for phthalates, it is likely to be proportionally even greater for other chemicals in products. For example, the toxic flame retardants PBDEs are also found in house dust, but are not found in cleaning or other products likely to be washed directly down the drain in households. Thus, the contribution chemicals hitchhiking on our clothing make to the Sound's total load may well be higher than 17% for other toxic ingredients in household products.

Washing Machine Detergent Also Contributes to Phthalates in Puget Sound

In order to ensure that the detergent used for the study was free of phthalates, we tested two brands of washing machine detergent, Tide and Seventh Generation. We chose liquid Tide as the best-selling product nationally, and Seventh Generation as one of the top brands that lists its ingredients on the label and is ostensibly free of phthalates.

The Seventh Generation sample tested free of phthalates, and the Tide sample tested at 2.3 ppm DEP. With 46 ml used per load and 0.37 loads per person per day,[32] this translates into 105.8 micrograms per load, or 38.8 micrograms per day, per person. If Tide or another detergent with an equivalent level of DEP were used in each Puget Sound household discharging to wastewater treatment plants, this would equate to 40 kilograms or 87 pounds each year from just this source.

Directions for Future Research

While valuable, this study is clearly limited by its small sample size and its restriction to one class of chemicals. Future research should broaden the analysis to other chemicals to further elucidate the transport of toxic chemicals from household products to Puget Sound and other water bodies. In addition, our study raises an interesting question related to chemical transport pathways as well as to human exposure, with our finding that the mixture of chemicals on our clothing may not always be highly reflective of the mixture of chemicals found in house dust.

Water treatment facility in Tacoma, WA.

Side-trip in Sludge

In the sewage treatment process, solids settle out into material called sludge or biosolids. A portion of the phthalates in the waste stream settles out with the solids, with the remainder discharged into waterways.[36] Phthalates have been detected in sludge in Washington at levels ranging from 0.3 to 160.0 ppm. Most of the estimated 93,000 dry tons of sludge produced annually in Washington is then applied to the land, with a smaller amount incinerated or landfilled.[11] With phthalates present in the sludge, some amount may make its way to waterways after land application.

ii This average concentration is an average of DEHP concentration in influents reported for three Puget Sound facilities: 1. South Treatment Plant in Renton:[52] 13.51 ug/L (Arithmetic mean of 58 samples from Jan 1996 to July 2004). 2. LOTT treatment plant in Thurston County:[53] 13 ug/L (2008). 3. Chambers Creek facility in Pierce County:[54] 4.3 ug/L (2004). We based our estimate of total influent flows on annual average discharges from the 103 Puget Sound wastewater treatment plants, calculated in Trim et al. 2008.[11]

Implications and Recommendations

This study demonstrates for the first time that at least for one widely used family of chemicals, their presence in everyday household products—and therefore their presence in the dust on our clothing—is likely to be translated directly into their presence in Puget Sound. The load of phthalates entering Puget Sound today threatens wildlife, and we show that laundry rinse water contributes significantly to that load. Our study focused on only one class of chemicals, but other toxic chemicals such as flame retardants and metals are also present in house dust and are likely making their way to Puget Sound in just this manner. Unless we can get toxics out of the products we bring into our homes, they will continue to take a stealthy trip to Puget Sound by way of our house dust, clothing, and washing machine water.

"...in the Puget Sound region, phthalates from our clothing contribute approximately 2110 pounds or 959 kilograms yearly of the phthalate DEHP to the flows entering wastewater treatment plants. This makes up approximately 17.5% of the total phthalate load entering treatment plants.

While this is certainly not the only way toxics are entering the Sound, it appears to be an important pathway and one that must be addressed. Failure to take action means salmon, orcas, and other wildlife will continue to be contaminated, cleanup efforts will be hampered, and our children will lose the opportunity to enjoy the riches of Puget Sound that have been our inheritance. For all of the state's efforts, without action to prevent further contamination we will keep running on the toxic treadmill of spending millions of taxpayer dollars on cleanup, while at the same time repolluting the Sound with chemicals found in everyday products.

The following actions are needed in Washington State to keep toxics from continuing to pollute Puget Sound:

1. Washington should enact legislation to ensure that only the safest chemicals are used in products and manufacturing.

The Washington State Legislature has taken action on specific chemicals that pollute Puget Sound, including mercury and the toxic flame retardants PBDEs. While action on individual chemicals is crucial, broader action is needed to more quickly and effectively eliminate the use of the most hazardous chemicals and replace them with safer alternatives. Washington can move down this path by granting the Washington State Department of Ecology authority to require that safer alternatives be used in place of harmful chemicals.

2. Washington should take action to phase out the chemicals posing the greatest threat to Puget Sound's health.

While the Puget Sound Partnership has named toxic pollution as one of the major threats to the Sound's health, and has quantified how much of key toxic chemicals, including phthalates, are making their way into the Sound, it and other state agencies have yet to take action to phase out these toxic chemicals. State agencies must develop plans for addressing ongoing chemical pollution and take action to eliminate it.

3. Washington should help industry switch to safer alternatives and away from chemicals known to be harmful to Puget Sound.

The Department of Ecology provides some assistance to businesses, but a new well-funded program is needed to identify less-toxic solutions for companies and help them transition. By identifying safer chemicals and materials, providing technical support to help businesses reduce their use of unsafe chemicals, and requiring better industry reporting of the chemicals they use, Washington can help businesses adopt greener, healthier, and Puget Sound-friendly business solutions.

4. Companies must disclose what chemicals they are using to manufacture products.

Currently, state agencies lack basic information needed to transition companies to safer chemicals and processes. Agencies must be able to access this information to determine the opportunities for reducing pollution. The Department of Ecology should use its existing authority in the Pollution Disclosure Act and its regulation on pollution prevention planning to collect this information, critical for cleaning up Puget Sound.

5. The Puget Sound Partnership should prioritize Action Agenda items that prevent toxic chemical pollution.

Once toxic pollution is created, it is very expensive to clean up. Only focusing on costly treatment at the end of the pipe is not a cost-effective solution. The Partnership should support the above recommendations in the legislature and other arenas and fully fund policies that keep toxic chemicals out of products and Puget Sound.

Conclusion

This study is a first step in exploring one possible source of toxic chemicals in Puget Sound: the ingredients in everyday products getting into our house dust and from there hitchhiking on our clothes to enter the wastewater stream that winds up in Puget Sound. While our study focused on only one class of chemicals, phthalates, other important chemicals such as toxic flame retardants and metals have also been found in house dust and are very likely making their way to Puget Sound in the same manner.

The route to water pollution may be circuitous, but the solution is simple: replace toxic chemicals in consumer products with safer alternatives. The benefits from this accomplishment will stretch back from Puget Sound into our homes as orcas, salmon, and people experience a safer, less-toxic environment.

Appendix 1: Phthalate Uses

PHTHALATE ABBREVIATION AND NAME	WHERE FOUND/USES
DMP: Dimethyl phthalate	Fragrance ingredient in cosmetics (hair products, bath soaps and detergents, deodorants and aftershave lotions) and in household cleansers, insect repellents, insecticides, solvents, explosives, solid rocket propellant, automotive parts, adhesives, putty hardeners, paints and coatings, plastic articles, printing inks, paper coatings and adhesives and as a fabric treatment
DEP: Diethyl phthalate	Fragrance base/solvent in personal care products (perfume, cologne, aftershaves, deodorants, shampoo, and hand lotion) and household cleansers, plasticizer in tools, automotive parts, toothbrushes, shoes, food packaging, and used in insecticides and epoxy resins
DIBP: Diisobutyl phthalate	Specialized plasticizer used a gelling aid and in paints, printing inks adhesives, rubber, nail polish, explosive material, lacquer
DBP: Di-n-Butyl phthalate (also DnBP)	Solvent or additive used in personal care products (nail polish, perfumes), pharmaceuticals, adhesives, floor finish, pipe joint compound, printing inks, lacquers, explosives, resin solvents, paper coatings, adhesives, solid rocket propellant, carpet backing, insecticides and insect repellent.
DMEP: Bis(2-Methoxyethyl) phthalate (also Di(Methoxyethyl)Phthalate)	Specialty plasticizer (used in cellulose ester plastics), cosmetics, solvent
bMPP: Bis(4-Methyl-2-Pentyl) phthalate (also di(4-methyl-2-pentyl) phthalate (DMPP)	PVC/vinyl products such as shower curtains, auto transmission lubricants
BEEP: Bis(2-Ethoxyethyl) phthalate (also Diethoxyethyl phthalate (DeoEP))	Ink, coatings, lacquers, varnishes, films, foils, adhesives, and plastics
DAP: Diamyl phthalate (also Di-n-Pentyl phthalate (DnPP))	Plasticizer/solvent in personal care products, inks, dyes, and in PVC/vinyl products including membrane electrodes
DHP: Dihexyl phthalate	Plasticizer (low temperature applications) used in PVC/vinyl floorings and wall coverings, expanded leather, PVC/vinyl foams, films, adhesives, and paint binders
BBP: Butyl benzyl phthalate (also Benzylbutyl Phthalate (BzBP))	Solvent and additive used in spray paint, caulk, adhesives, PVC/vinyl-flooring products, sealants, traffic cones, food conveyor belts, artificial leather, car-care products, adhesives, sealants, coating electric wire and, to a lesser extent, some personal-care products
BBEP: Bis(2-N-Butoxyethyl) phthalate (also Dibutoxyethyl phthalate (DBEP))	Nail polish, hair products, floor wax, solvent, binding material, plasticizer for surface coatings, PVC and vinyl chloride copolymers, coatings and polyurethane, wire insulation, automobile interiors, rubber
DEHP: Di-(2-Ethylhexyl) phthalate (also Bis(2-ethylhexyl) phthalate (BEHP))	One of the most extensively used phthalates. Primarily used as plasticizer in PVC/vinyl products such as toys, automotive components (including rubber components in automotive brake assemblies), flooring, waterproofing materials, cable sheathing/insulation, epoxy and polyurethane products, furniture, shoes, clothing, diaper covers, shower curtains, outdoor wear, building materials, and medical products. Also used as a fragrance base in cosmetics
DCP: Dicyclohexyl phthalate	Primary plasticizer or a secondary plasticizer for many polymers including nitrocellulose, ethyl cellulose, chlorinated rubber, polyvinyl acetate, and PVC/vinyl, and in inks, coatings, and contact adhesives. Used as primary ingredient (>60%) of hot melt adhesives
DOP: Di-n-octyl phthalate (also DNOP)	Primarily used as plasticizer in medical tubing and blood storage bags, wire and cables, carpetback coating, floor tile, and adhesives, as well as in cosmetics and pesticides
DNP: Dinonyl phthalate	Wire and cable insulation, furniture and automobile upholstery, flooring, wall coverings, coil coatings, pool liners, roofing membranes, and coated fabrics, thermoplastics, rubbers and selected paints and adhesives
DINP: Diisononyl phthalate	Most common phthalate used as plasticizer in children's PVC/vinyl toys. Also used as plasticizer in items needing heat resistance and in rubbers, as well as in inks and pigments, adhesives, sealants, paints, lacquers, and lubricants

Primary table sources: Australian Existing Chemical Hazard Assessment Reports,[37] NTP-CERHR Monographs [38]

Appendix 2: Detailed Methods

1. Study Design

Dust and washing machine rinse water were collected between November 2008 and May 2009. Six participating homes were selected from throughout the Puget Sound basin, in the following locations: Bellingham, Whidbey Island, Seattle, Renton, Bainbridge Island, and Tumwater.

Participants were provided with Seventh Generation liquid laundry detergent, which tested free of any phthalates. Participating families were asked to use the detergent for at least two weeks prior to sampling.

2. Dust Collection

Researchers visited each home once for dust collection. Participating families were asked not to vacuum their homes for at least one week prior to the visit. We used a standardized dust collection protocol employing a Eureka Mighty-Mite vacuum.[6, 24] Dust was collected into a cellulose filter thimble (Whatman International) fixed between the crevice tool and the vacuum tube extender using a stainless steel ring. Researchers sampled the entire floor surface of primary living areas of each home, including living room, dining room, kitchen, bathrooms, and children's bedrooms by drawing the crevice tool over the floor. Dust was not collected from furniture. After dust collection, the filters were placed in glass jars and stored at room temperature. A field blank was taken by vacuuming sodium sulfate from an unfinished wood surface using the same vacuum and filter set up as for dust collection. Dust and blank samples were analyzed by Analytical Sciences of Petaluma, California. Between samples, equipment was cleaned using Seventh Generation liquid laundry detergent and water.

3. Rinse Water Collection

Participants were asked to prepare a load of colored clothes, if possible worn primarily around the home. The washing machine was run using a regular warm water cycle. A field blank of washing machine water was taken by filling the machine and collecting a 1 liter sample before clothing and detergent were added. Clothing and Seventh Generation liquid detergent were then added, and the rinse water sample was obtained by collecting a 1 liter sample below the suds line at the end of the first agitation cycle. The water samples were maintained at room temperature and analyzed within a week by Analytical Sciences of Petaluma, California.

4. Laboratory Analysis

Following is the description of the method used by Analytical Sciences of Petaluma, California, to analyze dust samples for phthalates. Using a stainless steel spatula, the contents of a cellulose vacuum thimble were discharged onto a fresh sheet of white paper. One to two grams of a representative sample are weighed to the nearest milligram into a new tared 40 milliliter glass vial. Exactly 10 milliliters of hexane were added to the vial; the vial was then sealed and extracted with constant sonication for 45 minutes. The extract was allowed to cool and settle overnight. Internal standards were added to a 300 microliter portion of the cooled extract and 1 microliter was injected into a Hewlett Packard gas chromatograph outfitted with a mass spectrometer detector (GC/MS). The GC/MS was optimized and calibrated for 16 phthalate target compounds using phthalate specific mass ions. Results for all target phthalates were calculated on a mg/kg or parts per million (ppm) basis. Detection limits were estimated based upon the instrument sensitivity and the dilution utilized.

The method used to analyze rinse water samples for phthalates was as follows. One liter of sample water was placed into a clean and solvent-rinsed Teflon separatory funnel. A 10 microliter volume of mixed surrogates was added to monitor the extraction process. Approximately 30 milliliters of methylene chloride solvent were added to the funnel and the funnel was vigorously shaken for about two minutes. The immisible methylene chloride was allowed to settle to the bottom of the separatory funnel and collected into a 250 milliliter round bottom flask through a filter funnel containing sodium sulfate as a drying agent. The extraction with fresh methylene chloride was repeated twice and added to the same round bottom flask. The approximately 90 milliliters of methylene choride extract were mounted onto a rotoevaporater. The volume of methylene chloride was reduced to five milliliters and then to exactly two milliliters with the aid of a N-Evap concentrator. The extraction produces a 500X (one liter to two milliliter) concentration step for phthalates. Internal standards were added to a 300 microliter amount of the extract and then one microliter was injected into a gas chromatograph with a mass spectrometer detector (GC/MS). The GC/MS was operated, optimized and calibrated to detect 16 phthalate target compounds. Method Blanks (MB) and Laboratory Control Sample (LCS /LCSD) spikes provided laboratory extraction and analysis quality control.

5. Data Analysis

Water samples were not blank-corrected, as no phthalates were detected in the washing machine blanks. A small amount (0.24 ppm) DIBP was detected in the field blank for dust collection. Dust results were not blank-corrected, as the level of DIBP detected in samples was much higher (ranging from 1.3 to 6.1 ppm) and it appeared unlikely that the detection was the result of systematic contamination.

For statistical analysis, we applied a value of 1/2 the detection limit where the level was below the level of detection. To assess whether levels in house dust were related to those in washing machine water, we performed simple linear regression using the results for the two chemicals most frequently found in washing machine water, DEHP and DEP. We report the Spearman correlation coefficient because it is a non-parametric method.

Appendix 3: DEHP, BBP, and DBP in dust – other studies.

Dust results from previous studies (ppm, or ug/g). Table adapted from Abb et. al., 2009,[26] Hwang et al., 2008, [39] Kolarik et al., 2008,[40] Bornehag et al., 2005,[27] and Costner et al., 2004. [41]

Location and type	DEHP			BBP			DBP			Reference
	Median	Mean	95th percentile	Median	Mean	95th percentile	Median	Mean	95th percentile	
United States Studies										
Puget Sound: 6 homes	109.57	93.0	207	4.9	82.84	387	6.6	18.86	61	This study
US: 70 homes (pooled)		329.45	425*		69.37	137*		20.15	49.5*	Costner et al., 2005 (*25*)
Davis: 10 apmts and 1 comm. hall	386	645	1370							Hwang et al., 2008 (*39*)
Cape Cod: 120 homes	340	506	854	40		280**	20		40**	Rudel et al., 2003 (*6*)
International Studies										
Germany: 30 houses	604			15.2			87.4			Abb et. al., 2009 (*26*)
Belgium: 69 homes and offices (pooled)	245	339	841*	98	196	968*	32	32	113*	Al Bitar et al., 2004 (*42*)
Germany: 199 homes	420		1190	10		210	40		160	Becker et al., 2002 (*43*)
Germany: 252 homes	510		1840							Becker et al. 2004 (*44*)
Sweden: 346 children's bedrooms	770	1310	4069	130		600	150		570	Bornehag et al., 2004 (*5*)
Germany: 286 homes	740		2600	50		320	50		240	Butte et al. 2001 (*45*)
Denmark: 15 schools	858	3214	7063							Clausen et al., 2003 (*46*)
Denmark: 23 homes		858	2595							Clausen et al., 2003 (*46*)
Brazil: homes and offices		241.5			3.2			52.2		Costner et al., 2004 (*41*)
Germany: 30 apartments	703	776	1540	30		220	60		130	Fromme et al., 2004 (*47*)
Germany: 65	600		1600	20		230	50		180	Kersten and Reich 2003 (*48*)
Bulgaria: 177 children's bedrooms	990		7980	330		1560	9850		30800	Kolarik et al., 2008 (*40*)
Norway: 38 homes		640			110			100		Øie et al., 1997 (*49*)
Germany: 272 homes	450		2							Poehner et al., 1997 (*50*)
UK: 29 homes	195	192			56.5			50.2		Santillo et al., 2003 (*51*)

* maximum

* 90th percentile

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