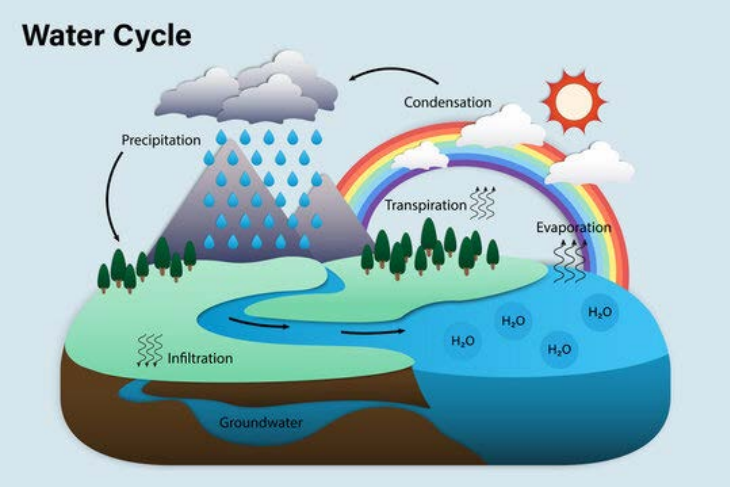
# HANDBOOK ON REDUCING CHEMICAL FOOTPRINTS

## Chapter 5. Transport of Chemicals from the Individual to the Environment and Back Again

This chapter examines the movement of contaminants in the environment. How do chemicals of concern (CECs) found in personal care, household, and home gardening products move from their initial use into the environment at large? While some contaminants disperse through the air or on the soles of shoes or other surfaces, water is the method of contaminant transport that is of major concern. The discussion that follows begins with the water cycle because humans obtain drinking water from and add waste to the same water systems. The chapter then traces chemicals of concern originating in common consumer products to the water system, starting with chemicals found in personal care products. Chemicals found in household items, including cleaning products and plastic containers, as well as those found in outdoor gardening products, are also traced through their various paths to our water systems and the environment at large.

### The Water Cycle




Humans live in the middle of a complex water cycle. Like all living beings, we depend on water, drawing it from rivers and wells, rainfall and snowmelt. We use water as a waste disposal channel. Thus, we initially use water that we hope is clean and then return the water, now used and dirtied, back to the same water system. The water cycle connects precipitation in the form of rain, hail, sleet or snow on the mountain tops to the streams, lakes and rivers where the water collects then moves downstream towards the oceans. Along the way, human communities take and return water, again and again, applying it to diverse uses such as drinking, washing, recreation, irrigation, manufacturing, power generation, waste removal, and other applications. Eventually, water evaporates and is drawn into the atmosphere where it forms new clouds and precipitation, repeating the cycle. The water cycle explains how water-borne contaminants can travel great distances and end up in unexpected places.

Water flows through a network of wastewater and drinking water treatment facilities designed to clean it before entering the community water distribution system, and then flows back to the water system once again after it is treated and discharged from the community wastewater system. Water is treated hundreds of times as it moves down river and through more communities.[1] Although these treatment processes are generally considered effective in terms of

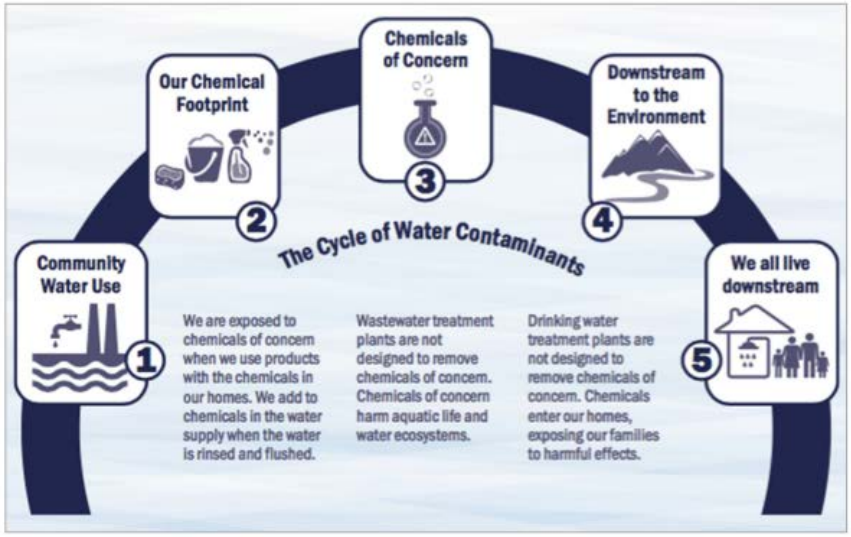
[1] There are two primary laws overseeing water quality in the US. The Clean Water Act (CWA) provides the foundation for surface water quality protection, focused on reducing direct pollutant discharges into waterways. The Safe Drinking Water Act (SDWA) sets pollutant standards to ensure the quality of Americans' drinking water. For

meeting specified human consumption standards, not every contaminant can be, nor is legally required to be, removed. With few exceptions, chemicals of concern are not being monitored, measured or removed as they cycle through local wastewater and drinking water systems (see Chapter 6 for more discussion of how contaminants of concern pass through water treatment processes.). This is primarily due to the lack or high cost of technology.

There is concern that more harmful chemicals may be produced as a result of degradation of the treated chemicals. Which chemicals of concern should be prioritized for treatment is a challenge.

**Toxins in Personal Care Products: From Home to the Water System**

Chemicals common in personal care products used for bathing, grooming, skin protection, and cosmetic enhancement are found in diverse ecosystems such as wetlands.[2] How do they get from our bodies to wetlands? Three principal channels typically carry chemicals from personal care products to the environment: the sink, the shower and the toilet.




Many personal care products go down the sink drain, such as toothpaste, mouthwash, face scrubs and the residues of lotions and other products that we wash from our hands and faces following application.

In the shower we apply and then rinse off shampoos, conditioners, and body washes which are then washed down the drain. This pathway introduces antibacterial agents, phthalates, synthetic fragrances, and preservatives (including BHA and BHT) into the water system. Other substances such as common skin protection products (e.g., moisturizers, sunscreens, insect repellents and deodorants) are also introduced via the shower. While some of

an overview of these and other US national water laws and regulations, see the EPA's "Water: Laws & Regulations" page at http://water.epa.gov/lawsregs/.

[2] USGS, Environmental Health: Toxic Substances, Research Projects: Emerging Contaminants, "Ecological Effects," modified May 6, 2014 (http://toxics.usgs.gov/regional/emc/ecological_effects.html).

them are absorbed into the skin and are not easily washed off, most leave a residue that mingles with sweat and leaves the skin while bathing.

The toilet is another important avenue for the transport of chemicals of concern from humans to the environment. Chemicals found in personal care products absorbed through the skin might be deposited in body tissues or excreted through feces or urine. For example, the common insect repellent ingredient DEET is known to partially absorb through the skin, and some of it is excreted in urine.[3] Similarly, active ingredients in chemical sunscreens (such as the UV-blocker benzophenone-3) are broadly found in urine samples.[4]


Many pharmaceuticals are also transported to the water system through the toilet. Most prescription and over-the-counter drugs are designed to address internal body issues and are thus typically ingested in the form of pills, liquids, inhalers, or injections. They are then excreted from the body either unchanged or as metabolites, which form as the drug degrades and changes in the body. The kidneys' primary function is excretion, delivering any unused drug or metabolite into urine that passes from the body. It is not uncommon (but not recommended) to flush unconsumed medications down the toilet, causing them to enter the sewage system.[5]

Water collection systems route sink, shower and toilet water to municipal sewage or septic treatment systems. Neither approach is typically designed to remove chemicals of concern from wastewater. For those households connected to a municipal wastewater system, all drainpipes lead to the municipal wastewater treatment plant, and then back to surface water following routine treatment.

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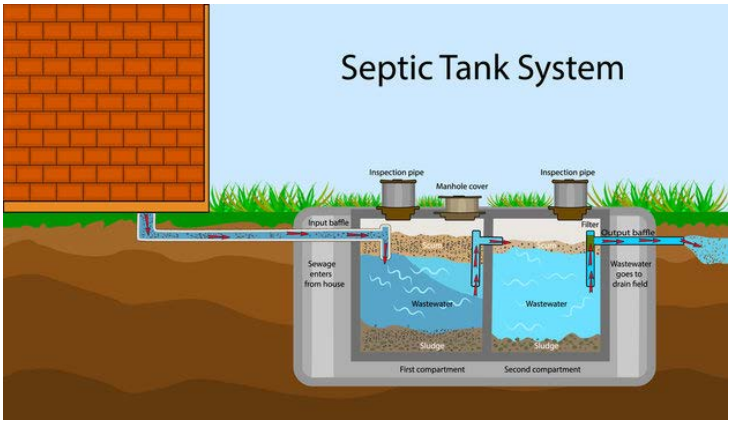
[3] US Agency for Toxic Substances & Disease Registry (ATSDR), Centers for Disease Control, Division of Toxicology and Human Health Sciences, "Pharmacokinetics/Toxicokinetics: DEET (N,N-Diethyl-meta-toluamide) Chemical Technical Summary for Public Health and Public Safety Professionals," December 6, 2004 (http://www.atsdr.cdc.gov/consultations/deet/pharmacokinetics.html).

[4] M. Krause, et al., "Sunscreens: Are they Beneficial for Health? An Overview of Endocrine Disrupting Properties of UV-filters," *International Journal of Andrology* 35, 3 (June 2012): 424-436 (http://www.ncbi.nlm.nih.gov/pubmed/22612478). The authors report that "one of the UV-filters, BP-3 [or oxybenzone], has been found in 96% of urine samples in the US."

[5] Kevin T. Bain, "Understanding the Public Health Implications of Household Pharmaceutical Waste in the US – Part Two," *Medical Waste Management,* Oct.-Dec. 2010 (http://www.wastexchange.org/upload_publications/ArticleonPharmaceuticalWaste.pdf).

Approximately one quarter of US households are served by individual onsite septic systems to treat their wastewater.[6] Septic systems rely on naturally occurring bacteria for decomposing ordinary household waste. Leachate is the liquid that remains after wastewater drains through septic solids. A well-functioning septic system provides an underground leach field that filters out pathogens and other pollutants before discharging to a drinking water aquifer or surface water supply. Chemical contaminants from personal care products are generally not removed from leachate and may, in fact, interfere with the natural microbial activity that makes a septic system work.




Unregulated chemicals of concern pass through municipal wastewater treatment systems because most are unregulated and not subject to direct treatment efforts. The result, according to recent findings by joint US-Canadian researchers, is that "only about half of the prescription drugs and other newly emerging contaminants in sewage are removed by treatment plants."[7] As lead researcher Antonette Arvai explains, "The compounds show up in low levels – parts per billion or parts per trillion – but aquatic life and humans aren't exposed to just one at a time, but a whole mix."[8]

Chemicals of concern from personal care products and pharmaceuticals have been found in the water in streams and lakes, in streambeds, groundwater, fish and other aquatic organisms, and coastal estuaries.[9] They have been found in drinking water supplies, indicating that they persist in the environment and are not removed by wastewater or drinking water treatment. A 2008 Associated Press investigation found trace concentrations of pharmaceuticals in the drinking water supplies of about 41 million Americans in 24 major metropolitan areas.[10]

**Contaminant Movement from Household Products Going Down the Drain**

Sinks, washing machines, and dishwashers are principal avenues for moving chemicals found in household products into the water system. Laundry detergents, dishwashing soaps, and drain cleaners, among other products, are directly added to water and then washed down the drain.

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[6] US Environmental Protection Agency, Office of Water, "Septic (Onsite/Decentralized) Systems," Water Infrastructure, last updated December 12, 2014 (http://water.epa.gov/infrastructure/septic/).

[7] Brian Bienkowski, "Only Half of Drugs Removed by Sewage Treatment," *Scientific American,* November 22, 2013, (http://www.scientificamerican.com/article/only-half-of-drugs-removed-by-sewage-treatment/).

[8] Ibid.

[9] USGS, Research Projects: Emerging Contaminants, "Ecological Effects," *op. cit.*

[10] Jeff Donn, Martha Mendoza and Justin Pritchard, Associated Press Investigation, "Pharmaceuticals Found in Drinking Water," March 2008 (http://hosted.ap.org/specials/interactives/pharmawater_site/day1_01.html).

Household cleaning products are often applied directly to surfaces that need to be cleaned – counters, ovens, stovetops, furniture and floors – and then wiped off using cleaning rags and sponges. Chemicals are washed down the drain when the rags and sponges are rinsed and washed.

Some contaminants, such as BPA, leach from containers (such as water bottles) and resins used to coat surfaces (such as food and beverage cans, water pipes and the paper used in sales receipts). Leaching occurs with regular use, reaction of detergents and high temperatures in the dishwasher, and acids found in foods stored in containers treated with the substances. Researchers have found that BPA can even be transferred from sales receipts to fingers,[11] and from fingers to the water that washes down the drain.

Contaminants released into the air through spray application of household products or fragrance particles also find their way into the water system. Fragrance compounds (including formaldehyde, musk-ketone, and phthalates) found in solid and spray air fresheners and toilet deodorizers are released into the air and some of these contaminants adhere to house dust.[12] These particles may transfer to water systems when dust is washed from dust rags, bodies and clothing.

Toxic flame retardants – which are deeply embedded in products such as upholstered furniture, mattresses, other foam materials and some clothing and fabrics – release dust particles. Recent research traced the chemicals found in flame-retardants from household dust entering washing machines to the sewage system, and then to surface waters.[13]

[11] Sandra Bidermann, Patrik Tshudin and Koni Grob, "Transfer of Bisphenol A from Thermal Printer Paper to the Skin," *Analytical and Bioanalytical Chemistry* 398, 1 (September 2010): 571-576 (available at http://www.ncbi.nlm.nih.gov/pubmed/20623271).

[12] See, for example, Wan-Li Ma, Bikram Subedi and Kurunthanchalam Kannan, "The Occurrence of Bisphenol A, Phthalates, Parabens and Other Environmental Phenolic Compounds in House Dust: A Review," *Current Organic Chemistry* 18, 17 (October 2014): 2182-2199 (available at http://benthamscience.com/journal/abstracts.php?journalID=coc&articleID=123695).

[13] Erika D. Schreder and Mark J. La Guardia, "Flame Retardant Transfers from U.S. Households (Dust and Laundry Wastewater) to the Aquatic Environment," *Environmental Science & Technology* 48, 19 (October 7, 2014): 11575–11583 (http://pubs.acs.org/doi/abs/10.1021/es502227h).

## Home Gardening Products: Stormwater Runoff

Not all household contaminants move directly through sewage pipes. Contaminants from home gardening typically enter water systems through stormwater runoff. Products such as weed killers, insecticides and fertilizers applied directly to plants and soils can move through the environment in several ways. Airborne particles can drift during application and settle on surface water, or can be washed from the air with rain. Pesticide residues that are applied in the garden are washed away with runoff from irrigation and precipitation into storm drains. Spilled pesticides and rinse water from product containers also enter storm drains. Runoff collected in stormwater systems eventually empties untreated into creeks and rivers that support wildlife and serve as our drinking water supply.[14]

Plastic and lead-containing backyard hoses release trace amounts of contaminants in runoff. Water discharged from lawns and gardens carries with it contaminants that flow into gutters and storm water channels which are not subject to treatment before draining directly into rivers, lakes and other surface water bodies. Runoff from home gardens joins other untreated stormwater runoff sources, including driveways, parking lots, streets, golf courses and farm fields.

Some contaminants found in outdoor gardening products end up in groundwater. For example, chemicals applied to plants, soils and pests can move with water that seeps into the ground, and can threaten contamination of underground aquifers that are used for drinking water supplies.

Chemicals of concern found in garden products are easily tracked on shoes, hands and clothing inside the house where they join other dust particles or where they are washed down the household drain.

## Differing Effects of Contaminants Released into the Environment

How far and long a contaminant's effects will last depend on the chemical's persistence, remaining unchanged, in composition, chemical state and physical status over time[15] and in different environmental conditions. Chemicals that rapidly degrade into non-toxic forms often are less harmful than those that persist and remain unchanged. Two chemicals may move equal

[14] Integrated Pest Management Program, Agriculture and Natural Resources, University of California, Davis, "How Pesticides Move to Other Locations," revised July 10, 2014 (http://www.ipm.ucdavis.edu/WATER/U/resident.html).

[15] USGS, Environmental Health: Toxic Substances, Research Projects: Emerging Contaminants, "Biodegradation of Emerging Contaminants," modified May 6, 2014 (http://toxics.usgs.gov/regional/emc/ec_biodegradation2.html).

distances from initial application to downstream deposit but have different effects. Persistent contaminants may build up over time, bioaccumulating in organisms and biomagnifying as the substances move through the food chain. Some of these chemicals are deposited and accumulate in streambed sediments and are later released or dispersed back into the water cycle.

**Many Different Fates for Chemical Contaminants in a River**

**Contaminants of concern in rivers can (1) deposit and accumulate in sediment; (2) diffuse from sediments back into the water; (3) biologically transform to intermediate compounds, or biodegrade for complete removal; (4) volatilize to the atmosphere; (5) bioconcentrate and magnify in the food chain; (6) undergo photolysis, or the breakdown of contaminants under the influence of sunlight; or (7) undergo hydrolysis, or the decomposition of contaminants by taking up the elements of water. These processes interact in the natural environment. River systems are dynamic, with distribution of contaminants continually changing depending on chemical, hydrological and climatic conditions.**
**Source: USGS**
**http://pubs.usgs.gov/circ/circ1133/**

Persistent contaminants can interact with other chemicals, with unknown synergistic or interactive effects. The effects of two or more interacting chemicals might pose a larger human health and ecological safety concern than the sum of the individual chemical components.[16] The list of possible synergistic combinations when chemicals of concern are transported into the environment is seemingly endless, further complicating the ability to understand the full impacts of chemicals of concern in the environment.

[16] The EPA acknowledges, "Although some potential environmental hazards involve significant exposure to only a single compound, most instances of environmental contamination involve concurrent or sequential exposures to a mixture of compounds that may induce similar or dissimilar effects over exposure periods ranging from short-term to lifetime." Still, chemical risk assessment studies generally consider the effects of only single chemical exposures. See US EPA, Office of Research and Development, Risk Assessment Forum Technical Panel, "Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures, EPA/630/R-00/002, August 2000 (http://www.epa.gov/raf/publications/pdfs/CHEM_MIX_08_2001.PDF).

**Summary**

Chemicals found in personal care products, including soaps, hair and skin care products, typically enter the municipal sewer system via the sink, shower and toilet. Household cleaners, detergents, and contaminant-laden dust particles from flame-retardants and air fresheners leave the home through the sink drain, washing machine, and dishwasher. Though water moving through the wastewater system is subject to treatment, chemicals of concern are typically neither fully monitored nor effectively removed in municipal wastewater treatment plants. Contaminants in septic systems, used by approximately one quarter of US households, are also not monitored or treated. Some contaminants, such as pesticides used in the garden, are discharged directly into rivers as runoff. The effects of contaminants as they move downriver depend on the varied characteristics of the chemicals themselves, their persistence, and their interactions with other chemicals.