

**CHEMICAL FOOTPRINT PROJECT:
LINKING SCIENCE TO EFFECTIVE ACTION**

**HANDBOOK ON REDUCING CHEMICAL
FOOTPRINTS**

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HANDBOOK ON REDUCING CHEMICAL FOOTPRINTS
TABLE OF CONTENTS

Chapter 1. Introduction

Background and Acknowledgements
Glossary
Acronyms and Units
Overview

Chapter 2. Chemical Footprints

Introducing the World of Chemicals
Rising Concerns Related to Chemical Exposures: Lessons from History
Government Oversight of Chemicals
 Oversight of Chemical Ingredients in Cosmetics and Personal Care Products
 Oversight of Chemical Ingredients in Household Products
 Oversight of Chemical Pesticides Used at Home
The Chemical Footprint Concept
 Chemical Footprint Evaluation and Response
Summary

Chapter 3. Chemicals of Concern

Defining Chemicals of Concern
History of Chemical of Emerging Concern Research
Chemicals of Concern in Common Consumer Products
Personal Care Products
 Antibacterials
 Fragrance
 Insect Repellent
 Plasticizers
 Preservatives
 Sun Protection
 Pharmaceuticals
Household Products
 Antibacterials in Household Products
 Fragrance in Household Products
 Plasticizers
 Surfactants and Dispersants
 Flame Retardants
Home Gardening Products
 Pesticides
 Gardening Accessories
Summary

Chapter 4. Human Health and Environmental Impacts from Chemical Exposures

Increased Risk of Cancers
Allergic and Contact Irritation Responses

- Antibacterial Resistance
- Environmental Effects
 - Bioaccumulation and Biomagnification through the Food Chain
 - Toxicity
 - Endocrine Disruption
- Summary

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

- The Water Cycle
- Toxins in Personal Care Products: From Home to the Water System
- Contaminant Movement from Household Products and Down the Drain
- Home Gardening Products: Stormwater Runoff
- Differing Effects of Contaminants Released into the Environment
- Summary

Chapter 6. Water Treatment: Chemicals of Concern are not Treated or Removed

- Federal Laws Requiring Water Treatment
- Water Treatment Overview
- Drinking Water Treatment
- Municipal Wastewater Treatment
 - Pollutants in Municipal Wastewater
- Exemptions from Wastewater Treatment Requirements: Nonpoint Source Pollution
 - Wastewater from Septic Systems
 - Household Runoff
- Advanced Treatment Technologies for Contaminants of Emerging Concern
 - Removal Technologies
 - Transformation Methods
- Summary

Chapter 7. Regulation

- What is Regulation?
- The Regulatory Challenge: Balancing Between Precautionary and Economic Interests
 - Risk Assessment
 - The Precautionary Principle
- Other Obstacles to Adopting New Regulations for Controlling Chemicals of Concern
- Prospects for Overcoming Regulatory Obstacles
 - US National-Level Regulatory Action
 - State-Level Regulatory Action
 - Regulatory Restrictions on Chemicals of Concern in Other Countries
- Summary

Chapter 8. Prevention and Mitigation

- Controlling Chemicals of Concern through Prevention and Mitigation
- Participants in Prevention and Mitigation
- Fostering Commitment to Prevention and Mitigation
 - Commitment

Norms
Prompts
Summary

Chapter 9. Reducing Our Chemical Footprints: Practical Steps

Ten Easy Ways to Reduce Your Chemical Footprint

More Tips for Reducing the Personal Care Chemical Footprint

1. Antibacterials in Body Care Products
2. Fragrance for Your Body
3. Insect Repellent
4. Phthalates: Hidden Ingredients in Cosmetics and Other Personal Care Products
5. Preservatives in Personal Care and Food Products (Parabens and BHA)
6. Chemical Sunscreen Ingredients

More Tips for Reducing the Household Chemical Footprint

1. Triclosan, All Around the House
2. Fragrance in Household Products
3. Plastics (Phthalates and BPA)
4. Surfactants and Dispersants

Tips for Reducing the Home Gardening Chemical Footprint

1. Pesticides
2. Gardening Tools

Summary

Chapter 10. Conclusion

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Chapter 1. Introduction

Background and Acknowledgements

The Institute for Environmental Solutions

The Institute for Environmental Solutions (IES) is an independent nonprofit organization founded in 2004 in Denver, CO. IES uses science-based research to engage stakeholders and deliver technically sound and cost-effective solutions to complex environmental and health problems. IES undertakes projects that are focused on environmental issues such as water and air pollution; these issues are tackled with the help of institute associates, volunteers, graduate interns, the Board of Directors, and informed stakeholders.

IES Chemical Footprint Project

IES's Chemical Footprint (CFP) Project evaluates and addresses the harm caused by contaminants of emerging concern (CECs) to human and environmental health. CECs are found in trace amounts in everyday household and personal care products. The CFP Project believes that prevention is cost-effective and more efficient than treatment, as many CECs are not adequately regulated nor removed at wastewater treatment plants. By working at a grassroots level in communities in the Denver Metro area, the CFP Project evaluates a community directly through surveys and focus groups to ascertain the knowledge, awareness, and barriers the community associates with the issue of CECs. Using this information, a workshop is designed to specifically address the identified barriers. The workshops provide simple and cost-effective alternatives to avoid toxic chemicals in household and personal care products.

Contaminants of Emerging Concern

Contaminants of emerging concern (CECs) are chemicals commonly found on farms, industries, and in our homes. Household and personal care products containing CECs include, but not limited to, lotions, bug repellent, sunscreens, and laundry detergents. There is growing scientific evidence that many CECs function as endocrine-disrupting compounds (EDCs). EDCs can alter normal hormonal functions of the endocrine system in the body, causing changes in cellular development that may lead to reproductive abnormalities or cancer. CECs have also been shown to persist in the environment. Recent developments in chemical analysis have allowed scientists to detect the increasing presence of CECs in our water resources. Scientists do not yet have adequate scientific data to determine exactly what level of exposure may be harmful to humans, but there is significant evidence to suggest high potential for adverse events.

IES encourages feedback and open communication. Additional resources and contact information can be found at the IES website (www.i4es.org). Contact IES: Solutions@i4es.org

Acknowledgments

The Contaminant Guidebook was researched and written by IES graduate interns and institute associates. Contributors include Shannon Oliver, Patrick King, Jodie Jones, Elodie Boucher, Andrea Stucky, Du Nguyen, Tim Smith, Kelsey Householder, Samantha Grant, and Helen McGrath. The document was edited by Nancy Billica and assembled by Jordan Truitt.

1. GLOSSARY

Abiotic - A non-living factor that shapes the environment like water, air, soil, or sunlight

Acceptable daily intake – Commonly referred to as ADI, acceptable daily intake refers to the amount of a substance (food additive, veterinary drug residue, or pesticide) that can be ingested daily over a lifetime without substantial risk.

Aerobic/Anaerobic processes - Aerobic process describes a process that can only occur in environmental conditions in which oxygen is present, such as atmospheric conditions or highly oxygenated surface waters. Anaerobic describes a process under conditions with little available oxygen, such as sediment layers, where natural degradation may be extremely difficult.

Alkyl group – An alkyl group is a functional group or sidechain that, like an alkane, consists solely of single-bonded carbon and hydrogen atoms.

Alkylphenol - nonionic surfactants that reduce the surface tension present in liquid, between two liquids, or in a liquid-solid interface.

Ames test - A bioassay that uses a set of histidine auxotrophic mutants of *Salmonella typhimurium* for detecting mutagenic and carcinogenic compounds.

Amphiphilic - Having a polar water-soluble group attached to a water-insoluble hydrocarbon chain, has both hydrophilic and hydrophobic parts.

Amphoteric - A molecule or ion that can react as an acid as well as a base.

Androgenic - A term referring to any of the male hormones, including testosterone and androsterone

Anionic - Chemical substances that possess a negatively charged ion and do not ionize in aqueous solutions

Antiandrogen - Antiandrogens are a class of chemical that block androgen receptors, decreasing the production of male hormones, in turn affecting the regulation of masculine secondary sex characteristics.

Antibacterial - A characteristic of a compound capable of killing or slowing the growth of bacteria.

Antibiotic resistance - When germs like bacteria and fungi develop the ability to defeat the drugs designed to kill them

Antimicrobial – A characteristic of a compound capable of killing or slowing the growth of microbes, a group of microorganisms including bacteria, fungi, and protozoans.

Antioxidant - A molecule capable of inhibiting the oxidation (loss of electrons) of another.

Anxiogenic - A substance that causes anxiety

Autoimmunity - The failure of an immune system to recognize natural components of its surrounding organism, allowing for an immune response against its own cells and tissues.

Bioaccumulation - A measure of the persistence of a chemical. Highly persistent chemicals will tend to stay stored in biological systems and can accumulate over time either in an organism or in the environment.

Bioconcentration - A process leading to a higher concentration of a substance in an organism than in environmental media to which it is exposed.

Biodegradation - The biologically catalyzed reduction of chemical compounds where organic substances are broken down into smaller compounds by living microbial organisms

Bioluminescence - The production and emission of light by a living organism

Biomagnification - The amplification of any concentration of a toxin.

Biomonitoring – A population-based (segmented by age, race, ethnicity, or sex) assessment of human exposure to environmental chemicals. Samples analyzed for environmental chemicals and their metabolites include blood, urine, and breast milk.

Bioremediation - The use of either naturally occurring or deliberately introduced microorganisms to clean up a polluted site by breaking down or consuming pollutants.

Biosynthesis - The production of complex molecules in living organisms or cells

Biota - The animal and plant life of a particular habitat, region, or geological period.

Biotic - A factor relating from living things like animals, fungi, bacteria, or protists

Biotransformation - The series of chemical reactions that occur in a compound, especially a drug, as a result of enzymatic or metabolic activities by a living organism.

Bioturbation - The disturbance of sedimentary deposits by living organisms

Bisphenol A (BPA) - A chemical used in the manufacturing of plastics and resins.

Butylated hydroxyanisole (BHA) - A phenolic compound used as a food additive and a preservative

Carcinogen - Any substance, radionuclide, or radiation that is an agent directly involved in causing cancer.

Carcinogenesis - The phase where cancer formation is initiating

Carcinoma - A type of cancer that begins in cells in the skin or tissue lining organs, like the liver or kidneys

Chemical Abstracts Services number – commonly referred to as CAS number in literature, this is a number assigned to a specific chemical compound by the American Chemical Society.

Comet assay – Also known as Single Cell Gel Electrophoresis assay, this is a technique for the detection of DNA damage at the level of the individual eukaryotic cell.

Cytotoxicity - Pertaining to an agent, such as a drug or virus, that exerts a toxic effect on cells.

Diethylmetatoluamide (DEET) - One of the active ingredients in insect repellent sprays, wipes, and lotions.

Degradation - Conversion of an organic compound to one containing a smaller number of carbon atoms, or the process of breaking down a chemical. This occurs in many ways, such as via biodegradation and photochemical degradation.

Dermal absorption - Absorption, or uptake, of a substance through the skin.

Detergent - A synthetic cleansing agent resembling soap in the ability to emulsify oil and hold dirt and containing surfactants which do not precipitate in hard water; may also contain protease enzymes and whitening agents.

Dose-response relationship - A relationship that describes the changing effect of varying levels of exposure/dosage to a chemical over time.

Electro-flocculation - the process where flocculation metal ions are electrolytically added to polluted water

Endocrine disruptor - Any chemical with the ability to cause adverse structural or functional changes to the endocrine system, which can result in harm to human or animal reproduction and development. For parabens too.

Environmental fate - The environmental fate of a particular chemical is where, ultimately, the chemical can be found and detected (or what happens to it after it is released into the environment). For example, the environmental fate of a harmless chemical may be complete degradation in wastewater treatment, while more persistent chemicals may end up stored in sediment layers or organisms. Environmental fate is a factor of what environmental medium the

chemical is in (air, water, or soil), how easily it can be transported through that media, and the rate of degradation.

Erythema - Localized redness of skin in areas of variable size.

Estrogenic - A chemical that acts in a similar manner to estrogen (the primary female sex hormone) in an organism. Estrogen is found in all vertebrates and even some insects, making estrogenic foreign contaminants extremely dangerous.

Flocculation - the process by which colloidal particles from sediment come out due to suspension by the addition of a clarifying agent

GC/MS - Gas chromatography/Mass Spectroscopy, a method of separating and identifying different substances in a test sample.

Genotoxicity - Pertaining to an agent that induces toxic, lethal, or heritable effects to nuclear and extranuclear genetic material in cells.

Hematopoietic system - The macrophage system, including all phagocytotic cells such as histiocytes, macrophages, reticular cells, monocytes, and microglia, except the granular white blood cells. Also known as the reticuloendothelial system.

Hepatotoxicity - Pertaining to an agent capable of damaging the liver.

Hydrolysis - a chemical reaction during which molecules of water are split into hydrogen cations) and hydroxide in the process of a chemical mechanism, typically catalyzed by an acid or base.

Hydrophilic - Having an affinity for, attracting, adsorbing, or absorbing water. 'Hydrophobic' describes the opposite, and is also often interchanged with 'lipophilic', which describes a molecule's affinity for lipids (which resemble a non-aqueous environment).

Hydrophobic - having little or no affinity for water.

Hyperplasia - Increase in cell number causing an increase in the size of a tissue or organ.

Immunologic – Relating to the structure or function of the immune system.

In vitro - Refers to studies or tests performed on components of an organism that have been isolated from their standard biological context.

In vivo – Refers to studies or tests performed on living organisms in their normal and intact state.

Inorganic - Refers to not consisting of or deriving from living matter

Intravenous – In or administered into a vein.

LC50 - Median Lethal Concentration. A statistically derived concentration of a substance that can be expected to cause death in 50% of test animals. It is usually expressed as the weight of substance per weight or volume of water, air or feed, e.g., mg/l, mg/kg or ppm.

Lipids - Class of organic compounds that are fatty acids or their derivatives and insoluble in water but soluble in organic solvents.

Lipophilicity - Refers to the ability of a chemical compound to dissolve in fats, oils, lipids, and non-polar solvents. It is conceptually similar to hydrophobicity.

Mechanism – In the biological sciences, a mechanism refers to the chemical procedure by which a reaction takes place.

Melanoma - A benign or malignant tumor composed of melanocytes.

Metabolite - A product of intermediary metabolism, or the chemical product of a metabolic degradation process, or biodegradation. For example, nonylphenol is a product of the degradation of nonylphenol ethoxylate in wastewater treatment processes.

Metaplasia - Transformation of one form of tissue to another.

Morphological – Relating to the structure or form of an organism without regard to function.

Mutagenicity - Pertaining to an agent that raises the frequency of mutation above the spontaneous or background rate.

Nanoparticles - A particle sized between 1 and 100 nanometers in diameter. Also known as 'ultrafine' particles.

NHANES – the National Health and Nutrition Examination Survey is conducted by the United States Centers for Disease Control and Prevention and is a program of studies designed to assess the health and nutritional status of adults and children in the United States.

Nitrification - The microbial process to reduce nitrogen compounds into oxidized nitrite and nitrate

Nonionic - dissociates into ions in an aqueous solution

Nonylphenol - toxic compound that disrupts endocrine function in the hormonal system in numerous organisms

Octanol: water partition coefficient - the ratio of concentrations of a compound in the two phases of a mixture of two immiscible solvents at equilibrium (here, octanol and water). The partition coefficient can be used to measure how hydrophilic or -phobic a substance is. In medical practice, partition coefficients are useful for example in estimating distribution of drugs in the body. Hydrophobic drugs with high partition coefficients are preferentially distributed to hydrophobic compartments such as lipid bilayers of cells while hydrophilic drugs (low partition coefficients) preferentially are found in hydrophilic compartments such as blood serum.

Ovariectomy - The excision of an ovary.

Oxybenzone - A group of organic chemicals that are used to protect the skin from ultraviolet solar radiation exposure

Parabens - a group of chemical compounds commonly used in the commercial manufacturing industry as preservatives in products such as food, drugs and cosmetics; esters of p-hydroxybenzoic acid, and come in multiple forms including methylparaben, propylparaben and butylparaben.

Percutaneous absorption - The process of absorption through the skin from topical application.

pH – A measure of the acidity or basicity of a solution, using a scale from 1 to 14. Low pH values (below 7) represent acidic conditions, while high pH values (above 7) represent basic conditions. Neutral water has a pH of 7.

Photoaging - Damage that is done to the skin from prolonged exposure, over a person's lifetime, to UV radiation.

Photocarcinogenesis - Sum of a complex of simultaneous and sequential biochemical events that ultimately lead to the occurrence of skin cancer.

Photodermatitis - Reaction of the skin caused or elicited by exposure to sunlight; may be phototoxic or photoallergic, and can also result from topical application, ingestion, inhalation, or injection of mediating phototoxic or photoallergic material.

Photogenerate - Generated by exposure to sunlight.

Photolysis - The decomposition or separation of molecule by the action of light

Photoprotection - The use of a physical (hat) or chemical (PABA) barrier to reduce UV light exposure.

Photostability - The incorporation of stabilizers in polymers, such as ultraviolet absorbers, to prevent photodegradation.

Photosynthesis - Process by which plants and some other organisms use sunlight to synthesize foods from carbon dioxide and water

Phthalates - A group of chemicals used to make plastics more flexible and harder to break.

P-Hydroxybenzoic acid – A chemical compound vital to the formation of parabens.

Picaridin - safe insect repellent that can be used directly on skin or clothing

Preservative – in the chemical processing and commercial production industries, the term preservative typically refers to a substance with the ability to prevent microbiological growth

Reactive oxygen species - Extremely reactive (due to an unpaired electron) molecules and ions of oxygen (superoxide, hydrogen peroxide, and hydroxyl radical) that may be toxic to cells; causing damage to such cellular macromolecules as DNA, lipids, and protein. ROS contributes to cancer, heart disease, and cerebrovascular disease.

Sexual dimorphism - the existence of two different forms in the same population; female and male species

Solubility – The ability or tendency for a substance to be dissolved into water or water-like substances such as blood or urine.

Sonochemistry - The use of ultrasound to enhance or alter chemical reactions

Sorption - A chemical and physical process by which one substance becomes attached to another

Spermatogenesis - The meiotic replication of male primary germ cells.

Surfactant - A type of chemical used to reduce the surface tension of a liquid, effectively increasing the ability of that solution to mix with particles that would otherwise be highly resistant.

Transactivation - Increased rate of gene expression directed by either viral or cellular proteins. These regulatory factors (diffusible gene products) act in trans -- that is, act on homologous or heterologous molecules of DNA.

Transcription - The process by which ribonucleic acid (RNA) is made from deoxyribonucleic acid (DNA).

Transgenic assay - A transgenic assay is a method of measuring the effects of a substance on a living organism by using genetic material from an organism that has been transplanted into another so that the host acquires the genetic traits of the transferred genes in its chromosomal composition.

Triclosan - An antibacterial or antifungal additive in household products like hand soaps and cosmetics.

Unoccluded - Not obstructed.

Uterotrophic assay - An assay that measures an estrogenic chemical's effect on the uterus; typically evaluated by uterine weight changes due to imbibition (absorption) of water and subsequent cell growth.

Vitellogenin induction (assay) - An assay used to measure vitellogenin, a yolk protein precursor, production in fish following exposure to endocrine disrupting compounds.

Volatility - The tendency of a substance to vaporize.

Wastewater Treatment - The removal of contaminants from wastewater (both runoff and domestic) and household sewage by physical, chemical, and biological processes.

2. ACRONYMS and UNITS

A. Acronyms

ADI – Acceptable daily intake
AE - Alcohol Ethoxylate
AhR - Aryl hydrocarbon receptor
AP - Alkylphenol
APE - Alkylphenol ethoxylate
BP - Benzophenone (12 derivatives)
CAS number – Chemical Abstracts Service number
CDC – Centers for Disease Control and Prevention
CEF - Food contact materials, enzymes, flavorings and processing aids
DNA – Deoxyribonucleic acid
E2 - Estradiol
EAC - Endocrine active chemical
EDC - Endocrine disrupting compound
EFSA – European Food Safety Authority
EPA (US EPA) – The United States Environmental Protection Agency
ER - Estrogen receptors
ePOP – Emerging persistent organic pollutant
EU – European Union
FAO – Food and Agriculture Organization
FDA (US FDA) – The United States Food and Drug administration
FIFRA – Federal Insecticide, Fungicide and Rodenticide Act
GC/MS - Gas chromatography/mass spectrometry
HC - Health Canada
JECFA – Joint Expert Committee on Food Additives
LOAEL - lowest observed adverse effect levels
LC50 - Median lethal concentration
NHANES – National Health and Nutrition Examination Study
NOAEL - No observed adverse effect levels
NP(E) - Nonylphenol (ethoxylate)
NTP - National Toxicology Program
OP(E) - Octylphenol (ethoxylate)
PABA - Para-aminobenzoic acid
POP - Persistent organic pollutant
ROS - Reactive oxygen species
SCCP - Scientific Committee on Consumer Products of the European Commission
SPF - Sun protection factor
SPM – Solid particulate matter
STP – Sewage treatment plant
TGA - Therapeutic Goods Administration, Australia
TiO₂ - Titanium dioxide
TSCA – Toxic Substance Control Act
USAN - US Adopted Name
WHO – World Health Organization

WWTPs - Wastewater treatment plants

ZnO - Zinc oxide

B. Units

g/kg/day – gram per kilogram per day

g/ml – gram per milligram

mg/cm² – milligram per centimeter squared

mg/kg-bw/day – milligram per kilogram of body weight per day

mg/kg/d – milligram per kilogram per day

mg/L – milligram per liter

ng/g – nanogram per gram

ng/kg BW/day – nanogram per kilogram of bodyweight per day

ng/L – nanogram per liter

nm – nanometer

µg/cm² - microgram per centimeter squared

µg kg-1 – microgram per kilogram

µg/kg/day – microgram per kilogram per day

µg/g – microgram per gram; 1 millionth (1×10^{-6}) of a gram

µg/L – microgram per liter; 10^{-6} grams per liter

µM – micrometer or micron

°F – degrees Fahrenheit

% - percentage

Overview

There is no place on Earth today that is free of hazardous chemicals. Chemically complex substances are in daily use in countless personal care and household products, and those substances accumulate in the air we breathe, the food we eat, the water we drink. While we might not be able to avoid exposure to all harmful chemicals, we share a collective responsibility to identify the substances that pose the greatest threats to human and ecological health and to reduce or eliminate the presence of those chemicals in our homes, communities, and ecosystems.

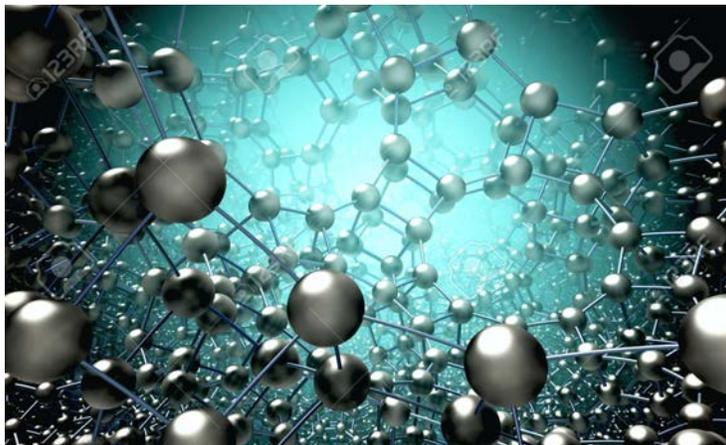


The Institute for Environmental Solutions (IES) was founded in 2004 with a mission to identify and implement scientifically proven strategies to solve Colorado's most pressing environmental problems. The accumulation of hazardous chemicals in the environment is one such problem. The mission of the IES Chemical Footprint Project is to prevent water pollution and protect human and environmental health by reducing household and commercial chemical footprints through research, outreach and education. The CFP Project is focused on delivering scientific knowledge so that consumers can make better choices and work collaboratively to implement those alternatives. The goal is to reduce water pollution from CECs found in personal care and household products. What are the chemicals of concern? What are the less hazardous and non-toxic options? How can we work together to reduce our exposure to chemicals of concern?

Answering these questions can build a basic understanding that will allow individuals and communities to make sound, sustainable decisions in the face of socio-ecological threats and uncertainty and thus contribute to protecting environmental and human health. The information in this handbook should be valuable to all citizens. For example, the explanations and examples provided in this document will allow educators to deepen their knowledge and prepare to share that knowledge with students of all ages. Decision makers will find the step-by-step information on the nature of the problem and alternatives very useful for setting agendas and advancing proposals. Community and business leaders will want to know what they can do to act responsibly.

This handbook is designed to provide a clear and succinct overview of the harmful chemical exposure challenge, detailing both the nature of the problem and the options for responding. In

particular, the handbook focuses on unregulated harmful chemicals in common consumer products. Chapter 2 introduces the chemical footprint concept, considering the growing volume of chemicals in personal and commercial use and the desirability of reducing such use. While chemicals are everywhere, Chapter 3 focuses on specific chemicals of concern, including where they are found. Chapter 4 explains some of the chief human health and environmental threats from exposure to chemicals of concern common in modern society. Chapter 5 traces the widespread movement of chemicals, showing the difficulty of containment and the many avenues of exposure. Chapter 6 examines existing water treatment methods and the shortcomings with respect to chemicals of concern that generally slip through untreated.



Chapter 7 addresses the limits of the US regulatory system and the difficulties in adopting new laws to restrict or ban chemicals with known and suspected risks. Chapter 8 highlights the importance of prevention in addressing chemicals of concern, including finding nontoxic alternatives and developing community-based responses. Chapter 9 identifies specific steps and options for reducing chemical footprints. Chapter 10 concludes with a summary of key information and practical guidelines to reduce our individual and collective chemical footprints.

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REDUCE YOUR

CHEMICAL FOOTPRINT