Information Needs in Green Chemistry & Chemicals Policy




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GETA – NorCal SETAC
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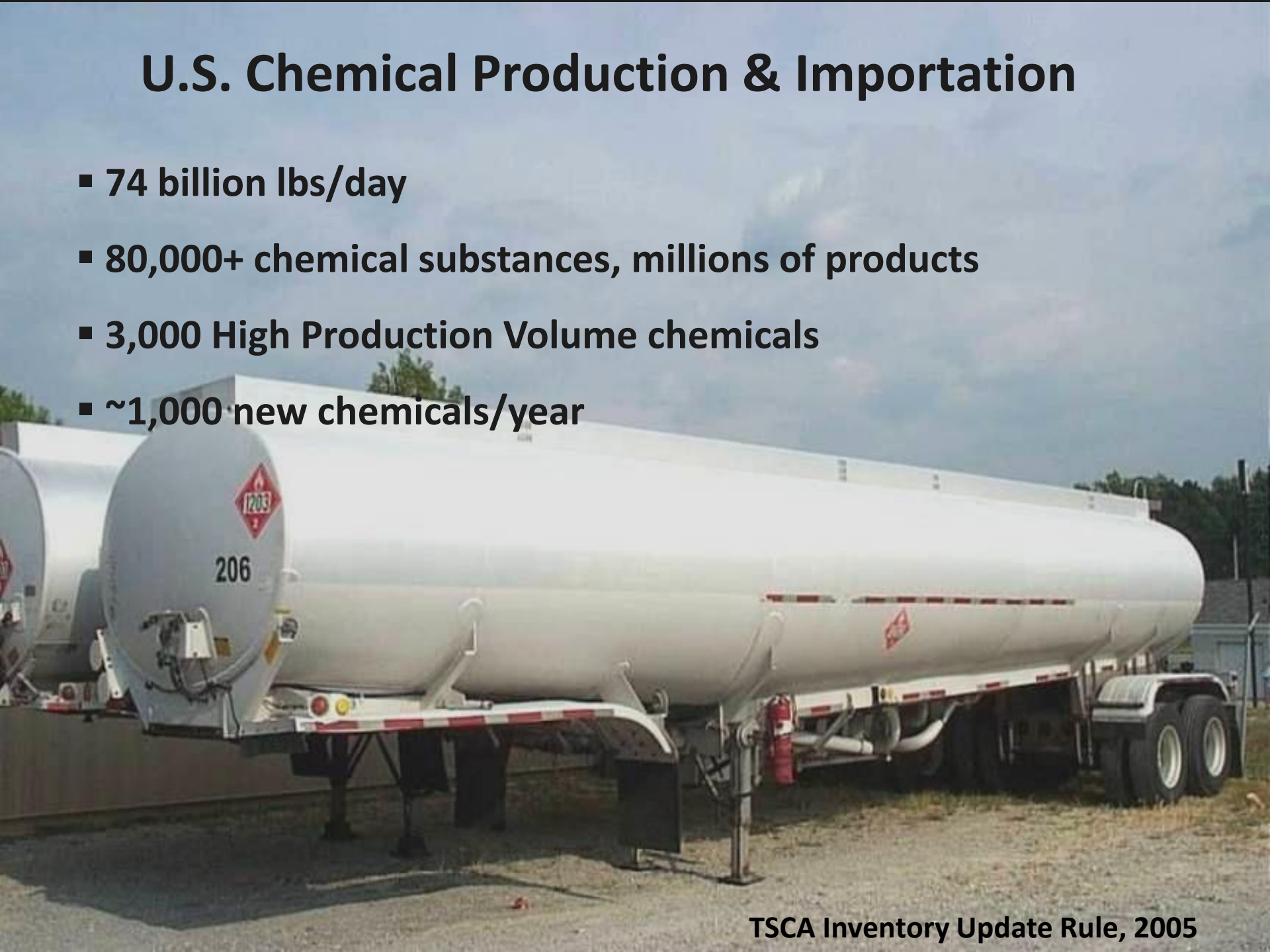
U.S. Chemical Production & Importation

- 74 billion lbs/day
- 80,000+ chemical substances, millions of products
- 3,000 High Production Volume chemicals
- ~1,000 new chemicals/year



TSCA Inventory Update Rule, 2005

Federal Policy Governing Chemicals & Pollutants

- Toxic Substances Control Act 83,000

- Clean Water Act (CWA) 148
- Resource Conservation and Recovery Act 502
- Clean Air Act (CAA) 189
- Occupational Safety and Health Act 453
- Emergency Planning and Community Right-to-Know (EPCRA): 600
  - Toxics Release Inventory (TRI)

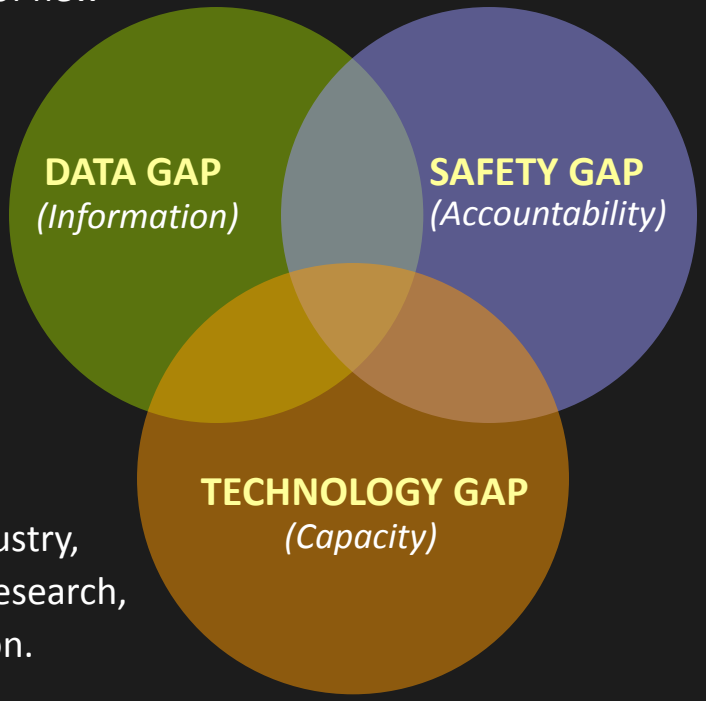
Total 1,134 (with overlap)

Durnbach. 1997. *Harvard Law Review* 21(1):1-57.

The Toxic Substances Control Act (TSCA)

A Legacy of Three Policy Gaps

62,000 chemicals grandfathered;
90 day review for new chemicals;
Health data absent in 85% of new chemical notices



EPA must provide "substantial evidence" of unreasonable risk to health/environment,
AND
benefits of regulation outweigh cost to industry or lost social value of a product,
AND
EPA has chosen the least burdensome solution.

5 chemicals/classes formally regulated under TSCA since 1976

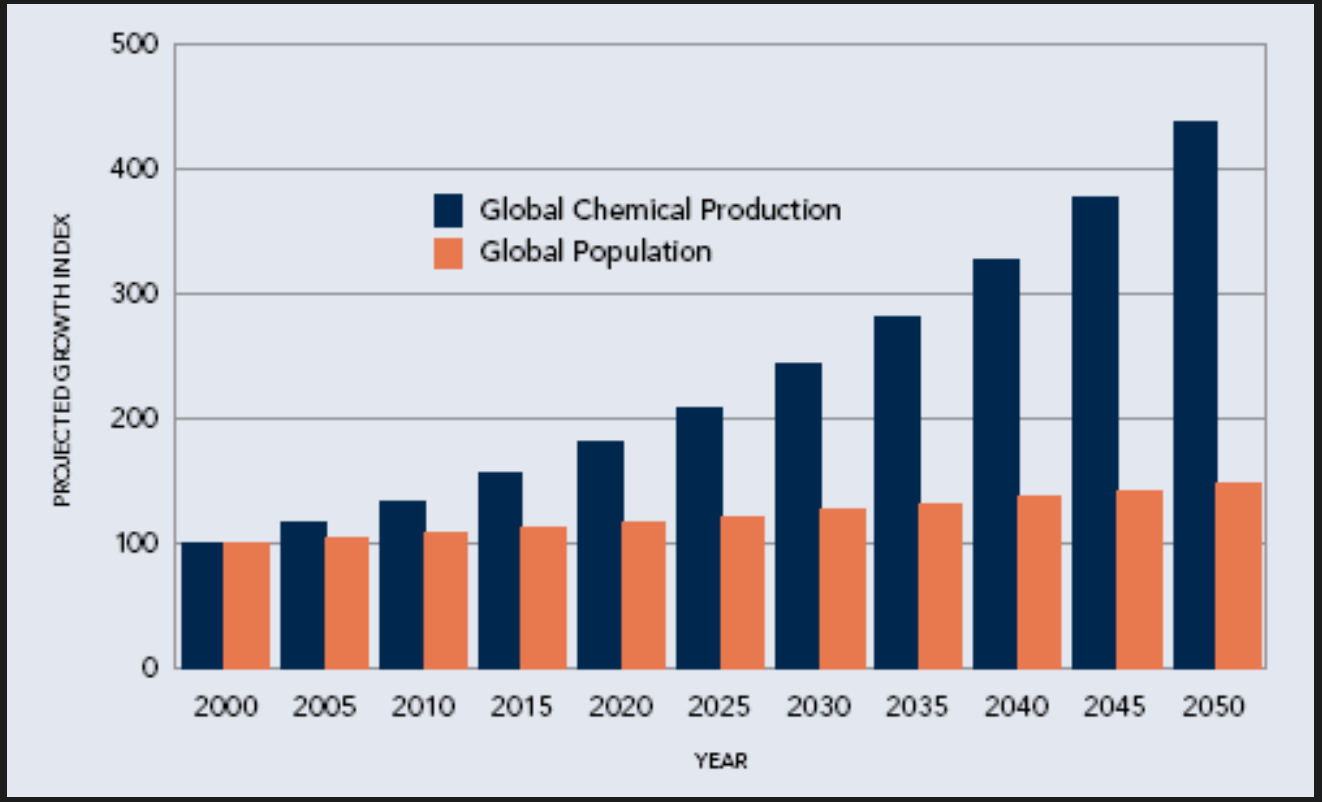
Minimal investment by industry, government, academia in research, development, and education.

Wilson and Schwarzman, *Environmental Health Perspectives*, 117:8, August, 2009.

Global Chemical Production

Growing 3% per year

Doubling every 25 years



Hazardous waste

50% of substances at hazardous waste sites are carcinogens and/or teratogens

61 of 85 of CA largest hazardous waste sites leaking into groundwater.

94% of those pose “a major threat to human health or the environment.”

Cleaning up existing sites in California: 400 years at current rate.

600 new sites will be needed in the U.S. each month (US EPA)

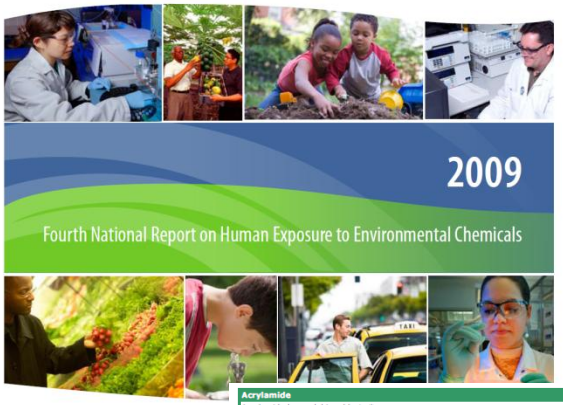
426,000 cell phones retired each day in the U.S.


Photo: Kate Davison, Greenpeace


Photo: DanWatch

E-waste Recycling and Disposal: Africa and China

Biomonitoring of Chemicals



CDC measured 212 substances in the 2003-04 NHANES cohort

Acrylamide
Acrylamide hemoglobin adducts *
Glycidamide hemoglobin adducts *

Cotinine

N,N-Diethyl-*meta*-toluamide (DEET)

Environmental Phenols
Benzophenone-3 (2-Hydroxy-4-methoxybenzophenone) *
Bisphenol A (2,2-*bis* [4-Hydroxyphenyl] propane) *
4-*tert*-Octylphenol (4-[1,1,3,3-Tetramethylbutyl] phenol) *
Triclosan (2,4,4'-Trichloro-2'-hydroxyphenyl ether) *

Perchlorate *

Pesticides
Fungicides
Pentachlorophenol
ortho -Phenylphenol
Herbicides
Acetochlor mercapturate
Alachlor mercapturate
Atrazine mercapturate
2,4-Dichlorophenoxyacetic acid
Metolachlor mercapturate
2,4,5-Trichlorophenoxyacetic acid
Carbamate Insecticides
Carbofuranphenol
2-Isopropoxyphenol
Organochlorine Pesticides
Aldrin
Dieldrin
Endrin
o,p'-Dichlorodiphenyltrichloroethane
p,p'-Dichlorodiphenyldichloroethene (DDE)
p,p'-Dichlorodiphenyltrichloroethane (DDT)
Heptachlor epoxide
Hexachlorobenzene
beta -Hexachlorocyclohexane
gamma -Hexachlorocyclohexane (Lindane)
Mirex
trans -Nonachlor
Oxychlordane
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
Organophosphorus Insecticides: Dialkyl Phosphate Metabolites
Diethyldithiophosphate (DEDTP)
Diethylphosphate (DEP)
Diethylthiophosphate (DETP)
Dimethyldithiophosphate (DMDTP)
Dimethylphosphate (DMP)
Dimethylthiophosphate (DMTP)
Organophosphorous Insecticides: Specific Metabolites
3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol
2-(Diethylamino)-6-methylpyrimidin-4-ol/one
2-Isopropyl-4-methyl-6-hydroxypyrimidine
Malathion dicarboxylic acid
para -Nitrophenol
3,5,6-Trichloro-2-pyridinol
Pyrethroid Pesticides
cis -3-(2,2-Dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid
cis -3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid
trans -3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid
4-Fluoro-3-phenoxybenzoic acid
3-Phenoxybenzoic acid

Metals
Antimony
Arsenic, Total *
Arsenic (V) acid *
Arsenobetaine *
Arsenocholine *
Arsenous (III) acid *
Dimethylarsinic acid *
Monomethylarsonic acid *
Trimethylarsine oxide *
Barium
Beryllium
Cadmium
Cesium
Cobalt
Lead
Mercury
Molybdenum
Platinum
Thallium
Tungsten
Uranium

Perfluorochemicals
Perfluorobutane sulfonic acid (PFBuS) *
Perfluorodecanoic acid (PFDeA) *
Perfluorododecanoic acid (PFDoA) *
Perfluoroheptanoic acid (PFHpA) *
Perfluorohexane sulfonic acid (PFHxS) *
Perfluorononanoic acid (PFNA) *
Perfluorooctane sulfonamide (PFOSA) *
Perfluorooctane sulfonic acid (PFOS) *
2-(N-Ethyl-perfluorooctane sulfonamido) acetic acid (Et-PFO
2-(N-Methyl-perfluorooctane sulfonamido) acetic acid (Me-P
Perfluorooctanoic acid (PFOA) *
Perfluoroundecanoic acid (PFUA) *

Phthalates
Mono-benzyl phthalate (MBzP)
Mono-n-butyl phthalate (MnBP)
Mono-(3-carboxypropyl) phthalate (MCPP)
Mono-cyclohexyl phthalate (MCHP)
Mono-ethyl phthalate (MEP)
Mono-(2-ethyl-5-carboxypentyl) phthalate (MECPP) *
Mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP)
Mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP)
Mono-2-ethylhexyl phthalate (MEHP)
Mono-isobutyl phthalate (MiBP)
Mono-isononyl phthalate (MiNP)
Mono-methyl phthalate (MMP)
Mono-n-octyl phthalate (MOP)

Phytoestrogens
Daidzein
Enterodiol
Enterolactone
Equol
Genistein
O-Desmethylangolensin

Brominated Fire Retardants
2,2',4-Tribromodiphenyl ether (BDE 17) *
2,4,4'-Tribromodiphenyl ether (BDE 28) *
2,2',4,4'-Tetrabromodiphenyl ether (BDE 47) *
2,3',4,4'-Tetrabromodiphenyl ether (BDE 66) *
2,2',3,4,4'-Pentabromodiphenyl ether (BDE 85) *
2,2',4,4',5-Pentabromodiphenyl ether (BDE 99) *
2,2',4,4',6-Pentabromodiphenyl ether (BDE 100) *
2,2',4,4',5,5'-Hexabromodiphenyl ether (BDE 153) *
2,2',4,4',5,6'-Hexabromodiphenyl ether (BDE 154) *
2,2',3,4,4',5',6-Heptabromodiphenyl ether (BDE 183) *
2,2',4,4',5,5'-Hexabromobiphenyl (BB 153) *

Non-Dioxin-Like Polychlorinated Biphenyls
2,4,4'-Trichlorobiphenyl (PCB 28)
2,2',3,5'-Tetrachlorobiphenyl (PCB 44) *
2,2',4,5'-Tetrachlorobiphenyl (PCB 49) *
2,2',5,5'-Tetrachlorobiphenyl (PCB 52)
2,3',4,4'-Tetrachlorobiphenyl (PCB 66)
2,4,4',5-Tetrachlorobiphenyl (PCB 74)
2,2',3,4,5'-Pentachlorobiphenyl (PCB 87)
2,2',4,4',5-Pentachlorobiphenyl (PCB 99)
2,2',4,5,5'-Pentachlorobiphenyl (PCB 101)
2,3,3',4',6-Pentachlorobiphenyl (PCB 110)
2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128)
2,2',3,4,4',5' and 2,3,3',4,4',6-Hexachlorobiphenyl (PCB 138 & 158)
2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146)
2,2',3,4',5',6-Hexachlorobiphenyl (PCB 149)
2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151)
2,2',4,4',5,5',-Hexachlorobiphenyl (PCB 153)
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170)
2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172)
2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177)
2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178)
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180)
2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183)
2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187)
2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194)
2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195)
2,2',3,3',4,4',5,6' and 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB 196 & 203)
2,2',3,3',4,5,5',6-Octachlorobiphenyl (PCB 199)
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (PCB 206)
2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl (PCB 209) *

Dioxin-Like Chemicals
Polychlorinated Dibenzo-p-dioxins
1,2,3,4,6,7,8-Heptachlorodibenzo-*p* -dioxin (HpCDD)
1,2,3,4,7,8-Hexachlorodibenzo-*p* -dioxin (HxCDD)
1,2,3,6,7,8-Hexachlorodibenzo-*p* -dioxin (HxCDD)
1,2,3,7,8,9-Hexachlorodibenzo-*p* -dioxin (HxCDD)
1,2,3,4,6,7,8,9-Octachlorodibenzo-*p* -dioxin (OCDD)
1,2,3,7,8-Pentachlorodibenzo-*p* -dioxin (PeCDD)
2,3,7,8,-Tetrachlorodibenzo-*p* -dioxin (TCDD)
Polychlorinated Dibenzofurans
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)
1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)
2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF)
1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)
2,3,7,8-Tetrachlorodibenzofuran (TCDF)
Coplanar Polychlorinated Biphenyls
3,4,4',5-Tetrachlorobiphenyl (PCB 81)
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)
Mono-ortho-substituted Polychlorinated Biphenyls
2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)
2,3',4,4',5-Pentachlorobiphenyl (PCB 118)
2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)

Polycyclic Aromatic Hydrocarbons (PAHs)
2-Hydroxyfluorene
3-Hydroxyfluorene
9-Hydroxyfluorene
1-Hydroxynaphthalene (1-Naphthol)
2-Hydroxynaphthalene (2-Naphthol)
1-Hydroxyphenanthrene
2-Hydroxyphenanthrene
3-Hydroxyphenanthrene
4-Hydroxyphenanthrene
1-Hydroxypyrene

Disinfection By-Products (Trihalomethanes)
Bromodichloromethane *
Dibromochloromethane (Chlorodibromomethane) *
Tribromomethane (Bromoform) *
Trichloromethane (Chloroform) *

Volatile Organic Compounds (VOCs)
Benzene *
Chlorobenzene (Monochlorobenzene) *
1,2-Dibromo-3-chloropropane (DBCP) *
Dibromomethane *
1,2-Dichlorobenzene (*ortho*-Dichlorobenzene) *
1,3-Dichlorobenzene (*meta* -Dichlorobenzene) *
1,4-Dichlorobenzene (*para* -Dichlorobenzene) *
1,1-Dichloroethane *
1,2-Dichloroethane (Ethylene dichloride) *
1,1-Dichloroethene (Vinylidene chloride) *
cis -1,2-Dichloroethene *
trans -1,2-Dichloroethene *
Dichloromethane (Methylene chloride) *
1,2-Dichloropropane *
2,5-Dimethylfuran (DMF) *
Ethylbenzene *
Hexachloroethane *
Methyl *tert* -butyl ether (MTBE) *
Nitrobenze *
Styrene *
1,1,2,2-Tetrachloroethane *
Tetrachloroethene (Perchloroethylene) *
Tetrachloromethane (Carbon tetrachloride) *
Toluene *
1,1,1-Trichloroethane (Methyl chloroform) *
1,1,2-Trichloroethane *
Trichloroethene (Trichloroethylene, TCE) *
meta - and *para* -Xylene *
ortho -Xylene *

CDC, *Fourth National Report on Human Exposure to Environmental Chemicals, 2009*

Biomonitoring of Chemicals & Pollutants:
Umbilical Cord Blood and Breast Milk

PBDE Levels in Breast Milk, Sweden

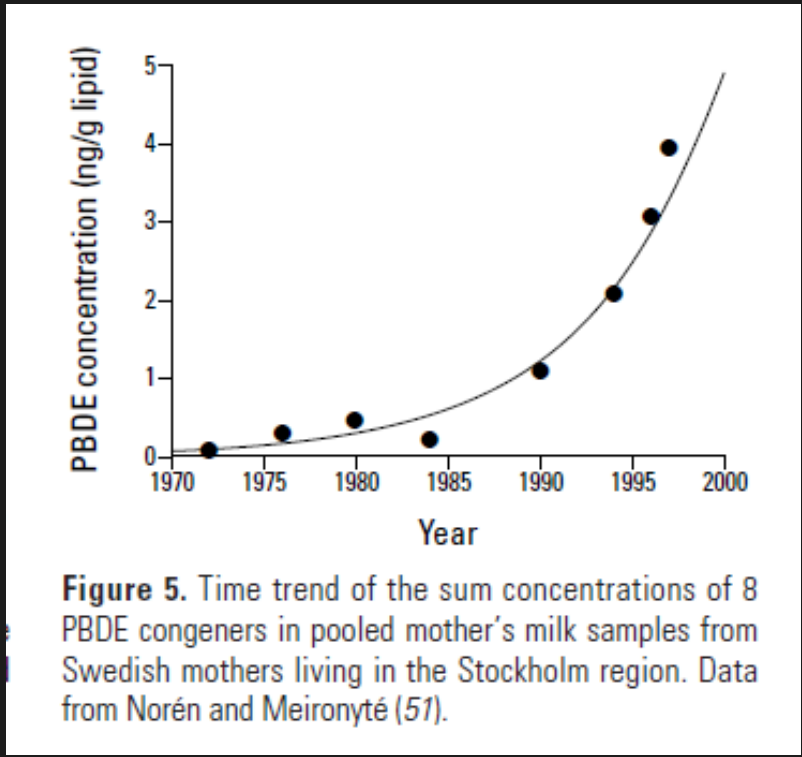


Figure 5. Time trend of the sum concentrations of 8 PBDE congeners in pooled mother's milk samples from Swedish mothers living in the Stockholm region. Data from Norén and Meironyté (*51*).

Darnerud et al. *Environ Health Persp,* 107 (supp1), March, 2001.

Prevention Through Green Chemistry?

GREEN CHEMISTRY

The design of chemical products and processes that are safer for health and ecosystems.

1. Make safer products
2. Use less-toxic feedstocks and processes
3. Design for cradle-to-cradle use
4. Account for energy efficiency

Anastas, P.T. and J. Warner. 1999. Green Chemistry Theory and Practice

European Union Affecting Global Change

REACH: Registration, Evaluation, Authorization, and Restriction of Chemicals (2007)

- Requires registration of all chemicals sold in EU > 1 ton/yr/producer
- Increasing data requirements based on volume in commerce
- Designates some chemicals as Substances of Very High Concern (SVHCs)
- Can require use-by use authorization for a subset of SVHCs
- Establishes “no data, no market” paradigm
- Shifts burden of proof of safety to manufacturers for chemicals of highest concern

35 Chemicals Bills in California, 2005-2006

AB 121 (Vargas)
AB 263 (Chan)
AB 289 (Chan)
AB 319 (Chan)
AB 342 (Baca)
AB 597 (Montanez)
AB 623 (Aanistad)
AB 639 (Aghazarian)
AB 752 (Karnette)
AB 815 (Lieber)
AB 816 (Lieber)
AB 848 (Berg)
AB 908 (Chu)
AB 912 (Ridley-Thomas)
AB 966 (Saldana)
AB 985 (Dunn)
AB 990 (Lieber)
AB 1125 (Pavley)
AB 1337 (Ruskin)
AB 1342 (Assem ESTM)
AB 1344 (Assem ESTM)
AB 1354 (Baca)
AB 1415 (Pavley)
AB 1681 (Pavley)
SB 419 (Simitian)
SB 432 (Simitian)
SB 484 (Migden)
SB 490 (Lowenthal)
SB 600 (Ortiz)
SB 838 (Escutia)
SB 849 (Escutia)
SB 982 (Sen EQ comm)
SB 989 (Sen EQ comm.)
SB 1067 (Kehoe)
SB 1070 (Kehoe)

New Chemicals Policy in the U.S.

Federal Toxic Substances Control Act reform

- House and Senate versions, 2010
- Will require chemical testing

California EPA Green Chemistry Initiative

- Ingredient Disclosure (SB 928 pending)
- Create an Online Toxics Clearinghouse (SB 509)
- Accelerate the Quest for Safer Products (AB 1879)

New Chemicals Policy in California

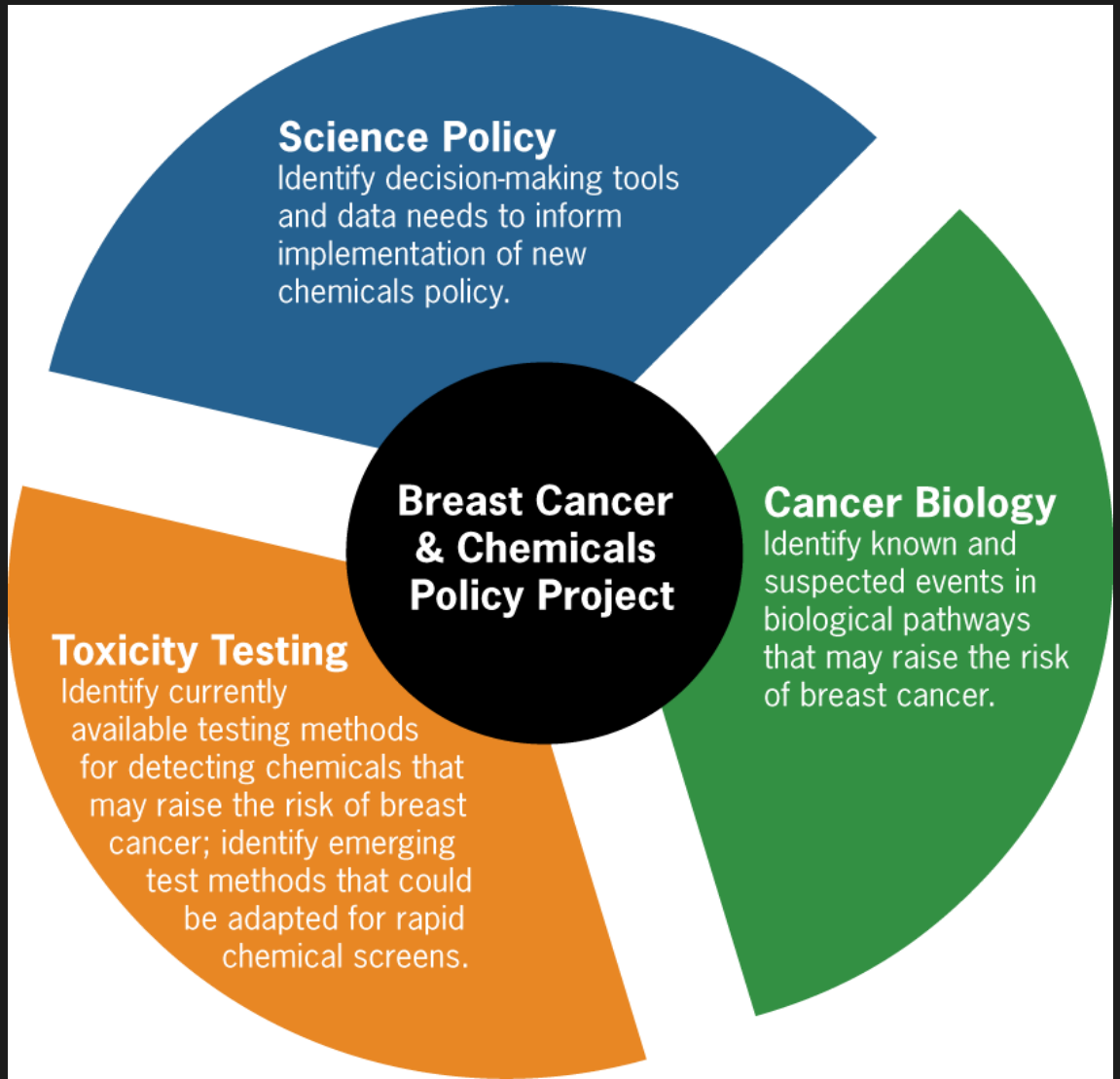
Accelerate the Quest for Safer alternatives

Systematic process for:

- Evaluating chemicals of concern in consumer products
- Identifying safer alternatives
- Stimulating investment in CA's product development sector

1. Generate list of Chemicals of Concern (CoC)
2. Identify products containing CoCs
3. Create a list of Priority Products based on exposure potential
4. Perform an alternatives analysis (AA) using a lifecycle approach
5. Complete requirements of a regulatory response

Breast Cancer & Chemicals Policy Project



Breast Cancer & Chemicals Policy Project

Core Question

As new chemicals policies develop toxicity testing requirements, what body of toxicity data– obtained using *existing methods*– could best identify chemicals that may increase the risk of breast cancer?

Breast Cancer & Chemicals Policy Project Goals

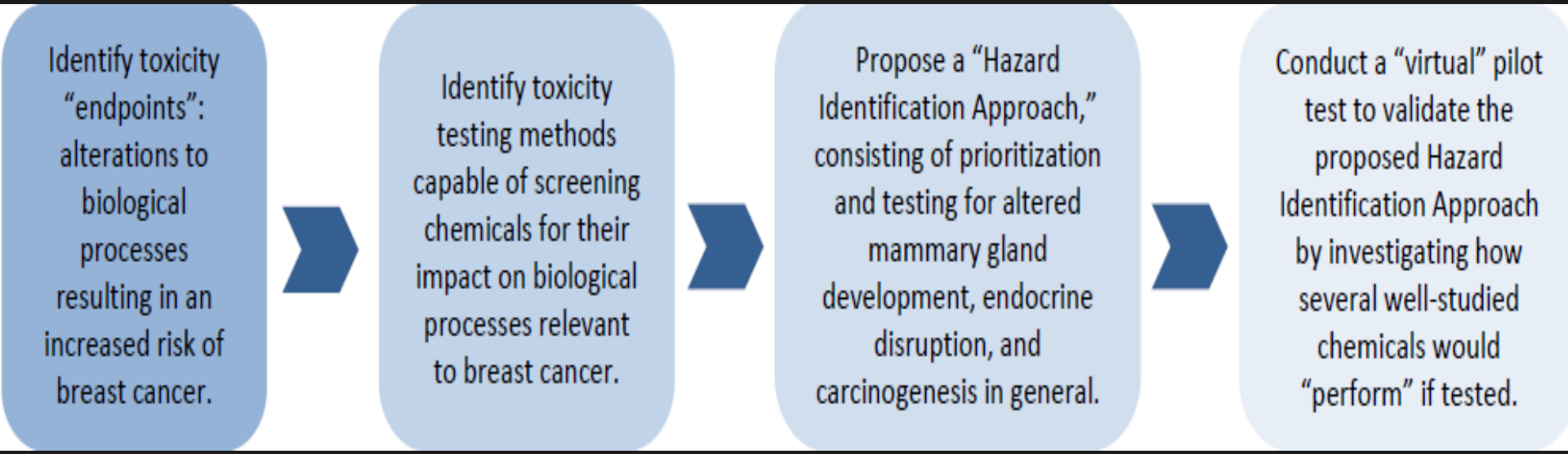
1. **Develop an approach for identifying chemicals** that may contribute to the development or progression of breast cancer;
2. **Identify research needs** and recommend improvements to existing test methods; and
3. **Pilot a model process** that can be applied to other disease endpoints, enabling the ultimate aim of producing a comprehensive approach for identifying hazardous chemicals.

Expert Panel

- **Susan Braun, MA** Commonweal
- **Vincent James Cogliano, PhD** WHO International Agency for Research on Cancer
- **Shanaz Dairkee *, PhD** California Pacific Medical Center Research Institute
- **Suzanne Fenton, PhD** National Institute of Environmental Health Sciences
- **William H. Goodson III, MD** California Pacific Medical Center Research Institute
- **Joe Guth *, PhD, JD** Science and Environmental Health Network
- **Dale Johnson, PharmD, PhD** University California Berkeley & Emiliem
- **Jean Latimer, PhD** School of Medicine University of Pittsburgh
- **Ron Melnick, PhD** National Institute of Environmental Health Sciences
- **Rachel Morello-Frosch, PhD, MPH** University of California Berkeley
- **Ruthann A. Rudel, MS** Silent Spring Institute
- **Gina Solomon*, MD, MPH** University of California San Francisco & Natural Resources Defense Council
- **Carlos Sonnenschein, MD** Tufts University School of Medicine
- **Lauren Zeise*, PhD** Cal/EPA Office of Environmental Health Hazard Assessment

Steps of the Breast Cancer and Chemicals Policy Project

An interdisciplinary panel with expertise in breast cancer biology, toxicology, epidemiology, risk assessment, chemicals policy, community advocacy met to:



Step 1. Events in Biological Processes Associated with Breast Cancer

Cellular & Molecular Events

- Alterations in hormone levels, metabolism or receptors
- Changes in gene transcription & translation
- Cell cycle changes
- Peptide hormones (growth hormones)
- Genotoxicity
- Oxidative stress
- Immune modulation
- Limitless replication potential
- Evasion of apoptosis
- Self-sufficiency in growth

Tissue Changes

- Breast density
- Tissue invasion
- Sustained angiogenesis
- TEB proliferation
- Altered mammary gland development
- Ductal hyperplasia
- Atypical hyperplasia

Susceptibility Factors

- Obesity
- Early onset of breast development
- Alterations in cyclicity
- Genetic polymorphisms in metabolizing enzymes
- Duration of lifetime estrogen exposure

Step 2: Identify test methods (Sample 1)

	Detectable Events Affecting Breast Cancer Risk					
	Molecular Mechanisms			**Phenotypic Indicators**		
Model System	Gene Expression	Genotoxicity	Steroid Hormones	Pathological Markers	TEB Proliferation	Carcinoma
In Silico						
In Vitro						
In Vivo						
Epidemiological						

http://coeh.berkeley.edu/greenchemistry/cbcrpdocs/matrix.pdf

Step 2: Identify Test Methods (Sample 2)

	Detectable Events Affecting Breast Cancer Risk					
	Susceptibility Factors			**Biological Programs**		
Model System	Altered Cyclicity	Metabolic Factors	Estrogen Exposure	Immune Modulation	Oxidative Stress	Apoptosis Evasion
In Silico						
In Vitro						
In Vivo						
Epidemiological						etc…

http://coeh.berkeley.edu/greenchemistry/cbcrpdocs/matrix.pdf

Step 3. Hazard Identification Approach:
Chemical Prioritization

Chemical Prioritization

Chemicals, their metabolites and degradation products, should be prioritized for testing based on the following parameters:

Hazard indicators

including structural similarities to other mammary gland carcinogens, or indicators that a chemical or its possible metabolite have endocrine activity, alter breast development or gene expression, or create genetic mutations.

Exposure potential

predicted by physical-chemical properties that indicate potential for bioaccumulation, persistence in the environment, or result in exposure to breast tissue. Also those identified by biomonitoring, environmental monitoring, or other proxy measures such as high production volume or dispersive use in consumer products or workplaces. Exposure potential should be assessed across the entire human life-cycle, and the product lifecycle from manufacturing through disposal.

Step 3. Hazard Identification Approach:

Rapid Screening Methods

Hazard Identification Approach

Rapid (in vitro) screening

Genotoxicity

Mutagenicity (e.g., Ames or equivalent)

Chromosome aberrations (e.g., OECD TG 473)

Micronuclei formation (e.g., OECD TG 487)

DNA strand breaks (e.g., COMET assay)

Cell cycle changes

Cell division (e.g., ^{3}H thymidine proliferation assay)

Altered apoptosis (e.g., TUNNEL assay)

Endocrine disruption

Activation or inhibition of:

Estrogen-mediated transcription (e.g., E-screen)

Androgen-mediated transcription (e.g., A-screen)

Enzymes specific to synthesis or metabolism of estrogen, androgen or progesterone (e.g., aromatase activity assay)

Step 3. Hazard Identification Approach:

in vivo studies

Hazard Identification Approach

Animal studies (in vivo): development and maturation

Genotoxicity in breast epithelial cells

Mutagenicity

Chromosome aberrations

Micronuclei formation

DNA strand breaks

Precursor changes, biomarkers and induction of mammary gland tumors

Modification of existing long-term cancer bioassays* redesigned to evaluate mammary gland endpoints, and:

include whole mounts of mammary tissue

include in utero exposures

assess effects over the whole lifespan

use an animal strain appropriate to the exposure and the endpoint

Cell cycle changes in breast epithelial cells

Cell proliferation

Decreased apoptosis

Endocrine disruption

Estrogenic activity (e.g., Uterotrophic assay)

Androgenic activity (e.g., Hershberger assay)

Developmental changes in female and male mammary gland tissue (e.g. TEB formation, ductal branching, ER and AR levels)

Reproductive changes in males and females (e.g., AGD, nipple retention, altered cyclicity, pubertal timing)

Altered circulating hormone levels (e.g. steroid or peptide hormones)

Breast Cancer & Chemicals Policy Recommendations

Chemical toxicity testing—and the public policies that require it—can inform breast cancer prevention efforts by identifying chemicals that may raise the risk of breast cancer.

1. Chemical testing relevant to breast cancer should include the following endpoints:
   - *Genotoxicity*
   - *Cell cycle changes*
   - *Endocrine disruption (e.g., estrogenicity)*
   - *Altered mammary gland development*

2. Design and conduct toxicity tests to consider:
   - *Timing of exposure*
   - *Underlying susceptibility factors*

Breast Cancer & Chemicals Policy Recommendations

3. Research needs:
- Further elucidate biological pathways
- Adapt current methods to increase relevance for breast cancer
- Develop and validate new toxicity tests – HTS screening methods

4. Apply a similar process to other disease endpoints to develop a comprehensive approach to identifying chemicals of concern.

Breast Cancer & Chemicals Policy Recommendations

Panel recommended an approach, not specific tests

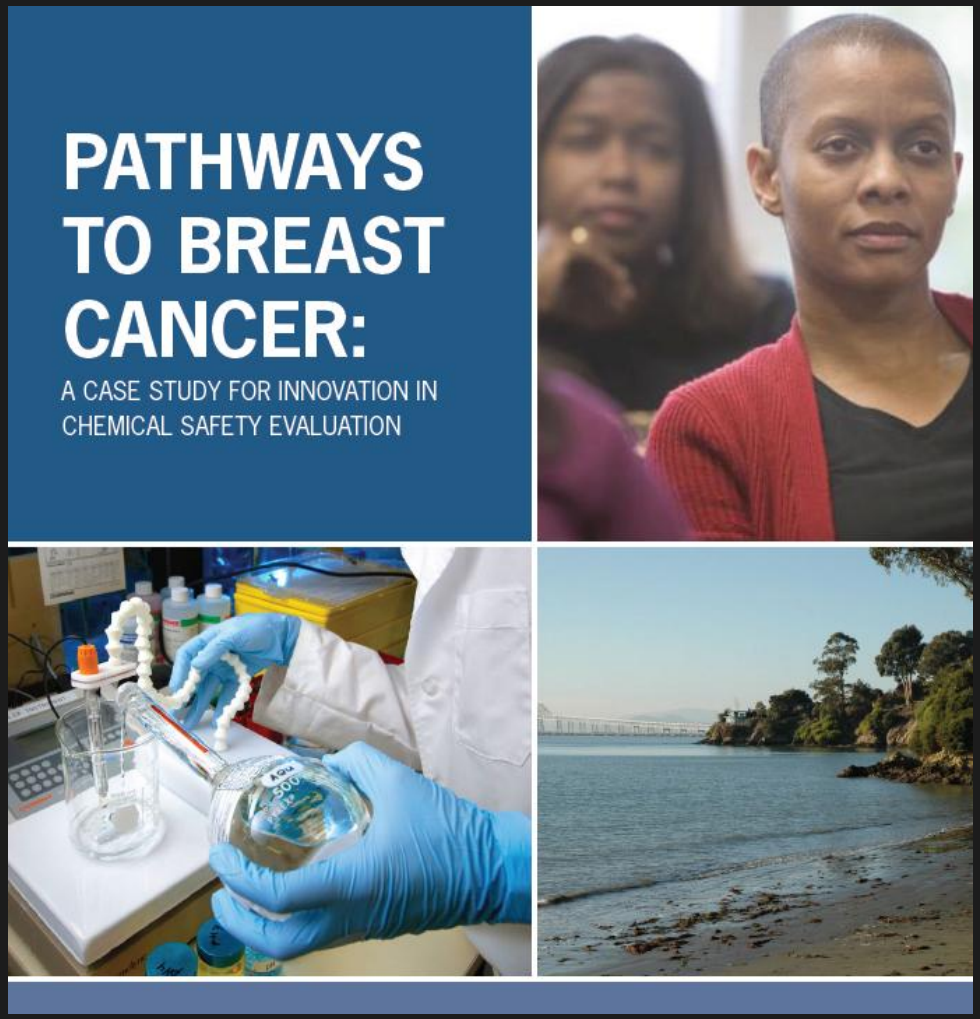
- The field of toxicity testing is rapidly evolving
- Best practices can evolve with emerging tests

High throughput screens are under development

- Promise of testing thousands of chemicals
- Potential to evaluate many possible metabolites

Medium throughput screens using human breast tissue

- Research methods could be adapted for toxicity testing to replace some animal studies (e.g., for mammary gland development effects)



Final report: http://coeh.berkeley.edu/greenchemistry/cbcrp.htm

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