EARTHJUSTICE * ALASKA COMMUNITY ACTION ON TOXICS * ENVIRONMENTAL HEALTH STRATEGY CENTER * ENVIRONMENTAL WORKING GROUP * LEARNING DISABILITIES ASSOCIATION OF AMERICA * SIERRA CLUB * UNION OF CONCERNED SCIENTISTS * UNITED STEEL, PAPER AND FORESTRY, RUBBER, MANUFACTURING, ENERGY, ALLIED INDUSTRIAL AND SERVICE WORKERS INTERNATIONAL UNION, AFL-CIO/CLC * WE ACT FOR ENVIRONMENTAL JUSTICE

Submitted online via *Regulations.gov* to dockets EPA–HQ–OPPT–2016–0736, EPA–HQ–OPPT–2016–0741, EPA–HQ–OPPT–2016–0723, EPA–HQ–OPPT–2016–0733, EPA–HQ–OPPT–2016–0735, EPA–HQ–OPPT–2016–0742, EPA–HQ–OPPT–2016–0743, EPA–HQ–OPPT–2016–0725, EPA–HQ–OPPT–2016–0732 and EPA–HQ–OPPT–2016–0737

Earthjustice, Alaska Community Action on Toxics, Environmental Health Strategy Center, Environmental Working Group, Learning Disabilities Association of America, Sierra Club, Union of Concerned Scientists, United Steel, Paper and Forestry, Rubber, Manufacturing, Energy, Allied Industrial and Service Workers International Union, AFL-CIO/CLC, and WE ACT for Environmental Justice — Petitioners and counsel for Petitioners in *Safer Chemicals, Healthy Families v. US EPA*, No 17-72260 (9th Cir.) — submit these comments in strong opposition to many of the approaches taken by the United States Environmental Protection Agency (EPA) in the Problem Formulations of the Risk Evaluations for the "first ten chemicals": asbestos, 1-bromopropane, carbon tetrachloride, 1, 4-dioxane, cyclic aliphatic bromide cluster (HBCD), methylene chloride, N-methylpyrrolidone, perchloroethylene, pigment violet 29, and trichloroethylene (together, problem formulations). We also oppose EPA's reliance, in the risk evaluation process for these chemicals, on its "Application of Systematic Review in TSCA Risk Evaluations" document (TSCA systematic review protocol),[1] which will likely result in the

[1] US EPA, *Application of Systematic Review in TSCA Risk Evaluations* EPA Document# 740-P1-8001 (2018).

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exclusion of meaningful information from EPA's risk evaluations in violation of TSCA section 26. If EPA continues to follow the approach it has laid out in the problem formulations, it will leave the public—and especially vulnerable groups like children, pregnant women, and workers—at ongoing unreasonable risk from the first ten chemicals that are being evaluated under the Toxic Substances Control Act (TSCA). These comments lay out how the problem formulations and TSCA systematic review protocol fail to comply with the language, intent, and purpose of TSCA.

Introduction

Many of the flaws with the problem formulations reflect applications of the illegal processes laid out in Procedures for Chemical Risk Evaluation Under the Amended Toxic Substances Control Act, 82 Fed. Reg. 33,726 (July 20, 2017), codified at 40 C.F.R. § 702.31 through § 702.51 ("Risk Evaluation Rule"). Our organizations have challenged the Risk Evaluation Rule, and this suit is pending before the U.S. Court of Appeals for the Ninth Circuit.[2] If the Ninth Circuit rules that the Risk Evaluation Rule is illegal in any manner that implicates processes, reasoning, or methodologies used in developing the problem formulations, EPA will have to revise the risk evaluations of the first ten chemicals to bring them into compliance with TSCA.

The overriding flaw in the problem formulations is that EPA is not taking a holistic approach to assessing risk, as TSCA mandates. Rather, EPA is excluding from its risk evaluations: hazards; exposure pathways; consideration of the impact of chemicals on vulnerable populations that were identified in the scopes of the risk evaluations of the first ten chemicals published in July 2017; and known or reasonably foreseen conditions of use. It is also

[2] *Safer Chemicals, Healthy Families v. US EPA*, No. 17-72260 (9th Cir. filed Aug. 10, 2017).

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adopting an impermissibly narrow view of the term "conditions of use," such that it excludes ongoing use and disposal of chemicals that are no longer manufactured for that use -- what EPA terms "legacy use" and "associated disposal" -- and ongoing exposures from disposals that initially occurred in the past (what EPA calls "legacy disposal"). Given this panoply of exclusions, the risk evaluations will not accurately characterize the true risk posed by "the chemical substance" under "the conditions of use," as required by TSCA section 6(b)(4).

Congress enacted TSCA in 1976 to give EPA authority to "look comprehensively at the hazards associated with [a] chemical" and to prevent harm to health and the environment through regulation of chemicals posing unreasonable risks. S. Rep. No. 94-698, at 2 (1976). While other federal environmental laws focus on specific media, such as air or water, before TSCA was adopted no federal law gave EPA authority to "look comprehensively" at the hazards of a chemical "in total." *Id.* Congress designed TSCA to fill these "regulatory gaps," S. Rep. No. 94-698, at 1, by adopting a comprehensive approach to chemical risk management that considered "the full extent of human or environmental exposure," H.R. Rep. No. 94-1341, at 6. This comprehensive approach is needed because individuals are often exposed to a chemical from multiple uses through a variety of exposure pathways. TSCA can effectively protect against chemical harm only if EPA evaluates *all hazards and all exposures* to a chemical substance. If EPA does not fully consider all known and reasonably foreseen hazards and exposures during a risk evaluation, the evaluation cannot accurately characterize the true risk posed by the chemical. If EPA fails to accurately characterize risk, it cannot identify and meaningfully manage unreasonable risks.

In addition to improper exclusions, the problem formulations are flawed by failure to rely on "information . . . that is reasonably available to the Administrator," within the meaning of

TSCA,[3] which EPA defines as "information that EPA possesses *or can reasonably generate, obtain and synthesize for use*" in the relevant timeframe.[4] Defying this requirement, many of the proposed exclusions from the risk evaluations are based on inappropriate conjecture and/or incomplete, ambiguous, and self-serving reports by a subset of manufacturers and processors to the effect that they have ceased manufacture. EPA should not rely on such representations because they may not provide complete information. Moreover, a decision to cease manufacture could be reversed at any time, and such resumption may be "reasonably foreseen." EPA must ascertain whether resumption of discontinued uses is reasonably foreseeable. Excluding conditions of use from risk evaluations based on a manufacturer's report that the chemical was discontinued will invite attempts to "game" the process. Even if, upon analysis of all reasonably available information, EPA concludes that re-commencement is not reasonably foreseen, it should not exclude discontinued conditions of use from final risk evaluations unless it also adopts a SNUR that ensures that EPA will receive notice and the opportunity to review -- and deny -- a proposal to re-commence manufacture for conditions of use that are not included in TSCA section 6(b) risk evaluations.

We urge EPA to revise its illegal approaches now, rather than waiting for a federal court to order the agency to make such revisions. Continuing down the current path, which will inevitably need to be revised to bring it in line with the plain meaning of TSCA, will only delay the process and jeopardize EPA's compliance with the timelines mandated by Congress.

A. The problem formulations violate TSCA by excluding known or reasonably foreseen "conditions of use" and "exposure pathways" of the first ten chemicals

[3] 15 U.S.C. § 2625(k).

[4] 40 C.F.R. § 702.3 (emphasis added).

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In conducting a TSCA section 6(b) risk evaluation, EPA must "determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors … under the conditions of use."[5] The directive to "determine whether *a chemical substance* presents an unreasonable risk" requires an evaluation of the chemical's total risk. And the phrase "under *the* conditions of use" unambiguously means *all* of the chemical's conditions of use. That EPA lacks the authority to pick and choose which conditions of use it includes in its TSCA section 6(b) risk evaluations is discussed in detail at pages 21-38 of Petitioners' Opening Brief in *Safer Chemicals, Healthy Families v. U.S. EPA*, No. 17-72260 (9th Cir. filed Apr. 16, 2018) ("Petitioners' Opening Brief"), a copy of which is attached hereto as Exhibit 1, and incorporated herein by reference.

A non-exhaustive sampling of the illegal exclusions proposed in the problem formulations follow.

1. Consumer product exclusions

The problem formulations indicate that EPA plans to exclude from its first ten risk evaluations exposures to chemicals resulting from their known presence in consumer products based on EPA's assertion that their presence is unintended or *de minimis*. These exclusions are not permitted. As one example, EPA plans to exclude consideration of exposure to 1,4-dioxane (a likely human carcinogen) when it is present in consumer products, such as detergents. EPA acknowledges that 1,4-dioxane is present in consumer products, but argues that it is present as a byproduct and that "contamination" is not an "intended" condition of use.[6] Similarly, EPA plans to exclude consideration of exposure to HBCD from its use in children's products, such as toys

[5] 15 U.S.C. § 2605(b)(4)(A).

[6] US EPA, *Problem Formulation of the Risk Evaluation for 1,4-Dioxane*, 18 (2018).

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and car seats, even though manufacturers reported to Washington State Department of Ecology (WSDE) that certain toys and car seats contained HBCD, and independent testing by WSDE confirmed the presence of HBCD in some products.[7] EPA's theory for exclusion is that HBCD was not intentionally added to these products as a flame retardant.

As explained more fully in Petitioners' Opening Brief, EPA's rationales for excluding these consumer exposures to 1,4-dioxane and HBCD are inconsistent with TSCA. These substances are "known" and/or "reasonably foreseen" to be present in consumer products, irrespective of whether they are "intended" to be there. The known and foreseeable presence of these substances in consumer products are "conditions of use" within the meaning of TSCA section 2(4) insofar as they are "circumstances . . . under which [the] chemical substance is . . . known, or reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of."[8] Under the statutory definition of "condition of use," it is irrelevant whether a chemical is present in a product unintentionally.

Additionally, EPA plans to exclude exposure to carbon tetrachloride (a probable human carcinogen) from sealants, adhesives, and arts and crafts products because it claims such uses present "de minimis exposure."[9] EPA may not exclude "de minimis" exposures from a risk evaluation because there is no way for EPA to determine which conditions of use will result in de minimis exposure or risk *before* conducting the evaluation whose very purpose is to assess the exposures and risks from those conditions of use. In other words, the risk evaluation is the

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[7] US EPA, *Problem Formulation for Cyclic Aliphatic Bromides Cluster*, 23-24 (2018). EPA also proposed to exclude ongoing uses of HBCD in commercial textiles simply on the basis that the use "appeared to be phasing out." *Id.* at 22. TSCA does not permit this.

[8] 15 U.S.C. § 2602(4).

[9] US EPA, *Problem Formulation of the Risk Evaluation for Carbon Tetrachloride,* 21 (2018).

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process that allows EPA to determine what levels of exposure to a given chemical are insignificant or de minimis. Any attempt to establish a de minimis level of exposure before completion of the risk evaluation would put the cart before the horse; EPA cannot know what is de minimis until it has completed its evaluation. Indeed, the problem formulation demonstrates just this problem. EPA has identified a set of exposures it deems de minimis, but there is no analysis of the actual exposures or the risk such exposures present. That analysis should be part of the risk evaluation that EPA is developing. Moreover, TSCA requires EPA to conduct risk evaluations that consider risks from multiple (sometimes relatively low-dose) exposures to the same chemical. EPA's proposal to exclude conditions of use that result in low exposures would prevent EPA from accurately evaluating total risks to vulnerable subpopulations like children, for whom low doses can pose significant risks, especially when they add up. *See Petitioners' Opening Brief*, at 37-38.

2. Environmental statute exclusions

Each of the problem formulations indicates that EPA plans to exclude exposure pathways on the grounds that such exposures are, or might someday be, regulated in some way under other environmental statutes (though not necessarily under a risk-based safety standard that excludes consideration of costs, as mandated by TSCA) under other environmental statutes.[10] Applying this new exclusion, which was not identified in the scopes of the first ten chemicals, EPA plans

[10] *See, e.g.*, US EPA, *Problem Formulation of the Risk Evaluation for Carbon Tetrachloride*, at 13; US EPA, *Problem Formulation for Cyclic Aliphatic Bromides Cluster*, at 13; US EPA, *Problem Formulation of the Risk Evaluation for 1,4-Dioxane*, at 37; US EPA, *Problem Formulation of the Risk Evaluation for 1-Bromopropane*, at 13. Each of these documents states that EPA will exclude exposure pathways under other environmental statutes, administered by EPA, which adequately assess and effectively manage exposures and for which long-standing regulatory and analytical processes already exist, i.e., the Clean Air Act (CAA), the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA) and the Resource Conservation and Recovery Act (RCRA).

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to exclude consideration of many well-known exposures of concern. This approach is antithetical to the statutory language, structure and purpose of TSCA, which requires EPA to evaluate chemicals under TSCA holistically and comprehensively. *See Petitioners' Opening Brief*, at 21-38.

For example, even though carbon tetrachloride is listed as a hazardous air pollutant under the CAA, emissions standards apply only to a limited list of industrial sources, and the emissions standards are based on maximum achievable control technology, rather than based on health or risk.[11] The standards often do not eliminate emissions, and the remaining emissions may present or contribute to unreasonable risks. For this reason, there is no justification for EPA to exclude ambient air exposures to carbon tetrachloride from the risk evaluations, as proposed.[12] EPA's assertion that "any risks [are] effectively managed when under the jurisdiction of the CAA" has no legal or scientific basis since the CAA provisions governing hazardous air pollutants do not establish a risk-based program. At a minimum, there is no basis for concluding that "unreasonable risk" within the meaning of TSCA, including consideration of potentially exposed and susceptible subpopulations, are "effectively managed" through CAA regulation.[13] Similarly, EPA cannot simply assume that risks are adequately addressed by RCRA. As EPA is well aware, the agency's RCRA regulations are riddled with exclusions and exemptions that limit RCRA's reach, including the protections offered by the Subtitle C "cradle to grave" hazardous waste requirements. Where those protections do not apply, there is no basis for EPA's claim that RCRA will sufficiently guard against risks.

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[11] 42 U.S.C. § 7412(d)(2).

[12] US EPA, *Problem Formulation of the Risk Evaluation for Carbon Tetrachloride*, at 43.

[13] *Id.* at 48.

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Moreover, even if regulations adopted under another environmental statute reduced exposure to a chemical, that exposure pathway must still be evaluated under TSCA unless **no** exposures are ongoing as a result of the regulation. As one of EPA's risk assessment handbooks explains, individuals may be exposed to chemicals "through more than one pathway. … [T]o achieve effective risk assessment and risk management decisions, *all* media and routes of exposure should be assessed."[14]

The 1,4-dioxane problem formulation illustrates why EPA's approach is so concerning. EPA indicates that it will exclude exposure to 1,4-dioxane from drinking water because this chemical is "currently being evaluated" under the SDWA.[15] EPA's proposal glosses over the fact that millions of people are currently drinking water contaminated with 1,4-dioxane, and will continue to do so for the foreseeable future.[16] Moreover, there is no certainty that EPA will ever take any measure under the SDWA to reduce these exposures. Even if EPA were to take some regulatory action under the SDWA, there is no way to know the level of continued exposure nor is there any assurance that the regulatory action will ensure "that the chemical substance . . . no longer presents [unreasonable] risk,"[17] as EPA would be required to ensure if such risks were identified as a result of the TSCA risk evaluation. Similar flaws are rampant in other problem formulations.

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[14] US EPA, *National Center for Environmental Assessment, Exposure Factors Handbook: 2011 Edition* 1-18 (2011) (emphasis added).

[15] US EPA, *Problem Formulation of the Risk Evaluation for 1,4-Dioxane*, at 43.

[16] *See* Declaration of Patricia D. Koman, Ph.D., M.P.P., In Support of Petitioners' Opening Brief, sworn April 13, 2018, submitted herewith as Exhibit 2; Declaration of Detlef Knappe, Ph.D. In Support of Petitioners' Opening Brief, sworn April 11, 2018, submitted herewith as Exhibit 3. These declarations were submitted by Petitioners in *Safer Chemicals, Healthy Families v. US EPA*.

[17] 15 U.S.C. § 2605(a).

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EPA's approach is counter to section 9 of TSCA, which governs EPA's options when laws other than TSCA, but that are administered by EPA, could eliminate or sufficiently reduce risks posed by chemical substances. Under section 9(b), EPA can choose to "protect against [a] risk" that has *already been identified in a TSCA risk evaluation* by using its non-TSCA authorities to manage the identified risks.[18] However this provision applies only *after EPA has completed a risk evaluation* and found unreasonable risk. Once an unreasonable risk determination is made, EPA can decide to "protect against such risk" under a law other than TSCA if it first "determines that a risk to health or the environment associated with a chemical substance or mixture could be eliminated or reduced to a sufficient extent by actions taken under the authorities contained in such other Federal laws."[19] The fact that EPA can look to other environmental statutes to "protect against [a] risk" identified in a TSCA risk evaluation, does not give EPA license to ignore exposures that *might be* reduced, in the future under a different law, when it conducts the TSCA risk evaluation.

In sum, TSCA does not permit EPA to exclude "conditions of use" or exposure pathways from a risk evaluation conducted under section 6(b), as proposed in the problem formulations. If EPA does not change course, such that these and other similar exclusions of conditions of use and their resulting exposures are reflected in the risk evaluations, the resulting risk evaluations will violate TSCA's plain text, structure, and purpose.

B. The problem formulations violate TSCA by excluding so-called legacy uses and associated disposals

Several of the problem formulations propose to exclude exposures from so-called "legacy uses," "associated disposal," and "legacy disposal" -- in other words, exposures from the

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[18] *See id.* § 2608(b)(1).

[19] *Id.*

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ongoing use and disposal of chemicals that are no longer manufactured for the use that is deemed "legacy." EPA asserts that these uses and disposals are not "conditions of use" within the meaning of TSCA. But this approach overlooks that the definition of "condition of use" includes "the circumstances . . . , under which a chemical substance is intended, known, or reasonably foreseen to be . . . used, or disposed of," irrespective of whether it is also manufactured, processed, or distributed in commerce. Because the TSCA definition of "conditions of use" uses a disjunctive "or" list, each lifecycle stage of a chemical, standing alone, is a condition of use, even if some of the chemical's lifecycle stages have been discontinued. EPA's proposed construction in the problem formulations robs the words "use" and "disposal" of their clear, independent role in the statute. For the reasons set forth in Petitioners' Opening Brief at 40-51, EPA's "rewriting [of TSCA's] unambiguous statutory terms" cannot stand. *Util. Air Regulatory Grp. v. EPA*, 134 S. Ct. 2427, 2445 (2014).

Not only is EPA's approach illegal under TSCA, it will also leave the population at significant risk of harm from toxic exposures. For example, in the problem formulation for HBCD, EPA proposes to exclude exposures to HBCD related to its use as a flame retardant in high impact polystyrene (HIPS) in electronic components. This is based on EPA's assertion that HBCD is no longer used in HIPS. However, until recently, HBCD was used extensively as an additive flame retardant in casings for electronics such as TVs, DVD players, and computers that were made of HIPS, and as a result, many people *continue to be exposed to HBCD* from electronics in their homes. Indeed, a recent study found a significant correlation between the number of electronics in the home and the amount of HBCD on people's hands (an exposure metric used to estimate dermal absorption and hand-to-mouth ingestion), indicating that

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electronics are a significant source of exposure for people.[20] EPA's problem formulation acknowledges these ongoing exposures. In the Executive Summary of the HBCD problem formulation, EPA states: "In indoor environments, there may also be exposures resulting from legacy uses of HBCD in articles (textiles, electronics and electrical products) containing HBCD."[21] Yet, inexplicably, EPA is proposing to exclude these consumer exposures from ongoing uses of products containing HBCD from the risk evaluations. This result is especially wrong-headed given that there is a robust marketplace for "used electronics" in this country, as is evident on eBay, craigslist, and the like. In light of the known ongoing exposures to HBCD from HIPS in electronics, it is unconscionable and illegal for EPA to exclude this exposure pathway from its risk evaluation.

EPA should modify the problem formulations to bring them into line with congressional intent that all exposures from use and disposal be addressed in section 6(b) risk evaluations so that evaluation and management of chemicals truly protects against unreasonable risk.

C. The problem formulations ignore known exposed and susceptible subpopulations

Under TSCA section 6(b), each risk evaluation must consider "whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors, *including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the*

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[20] Tay JH *et al.* Assessment of Dermal Exposure to Halogenated Flame Retardants: Comparison Using Direct Measurements from Hand Wipes with an Indirect Estimation from Settled Dust Concentrations. 115:285–94 (2018). Additional information about residential exposure to HBCD is set forth in the Declaration of Veena Singla, Ph.D. In Support of Petitioners' Opening Brief, sworn April 3, 2018, a copy of which is submitted herewith as Exhibit 4.

[21] US EPA, *Problem Formulation for Cyclic Aliphatic Bromides Cluster*, at 10.

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Administrator, under the conditions of use."[22] The statutory requirement to consider risks to potentially exposed or susceptible subpopulations runs throughout section 6(b). Despite this clear mandate, EPA's problem formulations propose to narrow the set of "susceptibilities" that would put certain subpopulations "at greater risk than the general population of adverse health effects from exposure,"[23] as compared to the Scope documents published in July 2017.

For 1-bromopropane, for example, in section 2.4.2.3 of the Scope, entitled "Potentially Exposed or Susceptible Subpopulations," EPA indicates that it considers pregnant women and infants to be vulnerable populations, referencing findings of developmental toxicity in a rodent study and indicating that the study is "representative of a sensitive subpopulation (i.e., adult women of childbearing age and their offspring)."[24] However, in the parallel section 2.4.2.3 of the Problem Formulation, EPA fails to reference a single vulnerable population. Rather, it states that "[i]n developing the hazard assessment, EPA will evaluate available data to ascertain whether some human receptor groups may have greater susceptibility than the general population to the chemical's hazard(s)."[25] In other words, without explanation, EPA no longer references adult women of childbearing age and their offspring as "sensitive subpopulations" when it comes to 1-bromopropane. This unexplained decision not to include adult women of childbearing age and their offspring as potentially exposed or susceptible subpopulation, despite being identified as such in the scope, is not permissible.

Similarly, for asbestos, EPA has removed age, pre-existing health conditions, genetic makeup/ genetic polymorphisms, co-exposure to other substances, early age at exposure,

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[22] 15 U.S.C. § 2605(b)(4)(A) (emphasis added).

[23] *Id.* § 2602(12).

[24] US EPA, *Scope of the Risk Evaluation for 1-Bromopropane,* 34 (2017).

[25] US EPA, *Problem Formulation of the Risk Evaluation for 1-Bromopropane*, at 45.

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smoking, and pre-existing respiratory conditions.[26] For TCE, it has removed life stage, gender-specific, genetic variation, race/ethnicity, preexisting health status, lifestyle factors and nutrition status from its list of factors that increase susceptibility to greater harm.[27] These inexplicable proposals to omit certain vulnerable populations from the risk evaluations are not permitted by TSCA. EPA must modify its approach to ensure that each of the problem formulations considers the greater exposures and greater susceptibilities of "potentially exposed and susceptible subpopulations," as the statute requires.

D. The problem formulations violate TSCA by excluding from their conceptual models conditions of use, exposure pathways, hazards, and potentially exposed and susceptible subpopulations that were included in the scope documents released in June 2017

Not only do the problem formulations describe an approach that would violate the *substantive* requirements of TSCA (insofar as they exclude known or reasonably foreseen hazards, exposure pathways, and conditions of use), moving forward with the new approach would violate the *procedures* mandated by TSCA. Specifically, TSCA section 6(b)(4)(D) precludes narrowing the hazards, exposures, conditions of use, and potentially exposed or susceptible subpopulations that were included in the scopes of the risk evaluations published in June 2017 (scopes). Under TSCA, after EPA initiates a risk evaluation, it must "publish *the scope of the risk evaluation to be conducted*, including the hazards, exposures, conditions of use, and the potentially exposed or susceptible subpopulations the Administrator expects to consider."[28] Nothing in TSCA authorizes EPA to issue a "problem formulation" document after

[26] US EPA, *Scope of the Risk Evaluation for Asbestos,* 35 (2017).

[27] US EPA, *Scope of the Risk Evaluation for Trichloroethylene,* 38 (2017).

[28] 15 U.S.C. § 2605(b)(4)(D) (emphasis added).

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the scoping process, and it certainly does not authorize EPA to use such a document to narrow the published scope of the risk evaluation.

EPA's approach is especially concerning because the parameters of "the scope of the risk evaluation" published pursuant to this section have legal consequences. For example, "the scope of the risk evaluation" determines the extent that EPA's actions preempt state actions involving the chemicals evaluated under TSCA section 6(b). Under TSCA section 18(b)(1), once EPA "defines the scope of a risk evaluation for a chemical substance under section 2605(b)(4)(D)," no State may establish a statute, criminal penalty, or administrative action prohibiting or restricting the manufacture, processing, distribution in commerce, or use of such chemical substance until EPA issues a risk evaluation or its time to do so expires. Under TSCA section 18(c)(2), federal preemption applies only to "the hazards, exposures, risks, and uses or conditions of use of such chemical substances included in the scope of the risk evaluation pursuant to section 2605(b)(4)(D) of this title."[29] If EPA establishes "the scope of the risk evaluation," but then narrows that scope — as it is proposing to do here — States would arguably be preempted from regulating hazards, exposures, and risks that EPA is not addressing in its risk evaluation, merely because these hazards, exposures and risks were (fleetingly) included in the Scope. This would undermine the right and ability of states to regulate to protect their citizens where EPA has chosen to stand to the side.

For this reason, EPA cannot now backtrack on the June 2017 scopes by excluding hazards, exposure pathways, susceptible populations and conditions of use that were included in the June 2017 scopes. Instead, EPA must analyze all of these factors and their contribution to the risk posed by the chemical substance.

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[29] *Id.* § 2617(c)(2).

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E. The problem formulations indicate that EPA is proposing to base the risk evaluations on unreliable or incomplete information in violation of TSCA

TSCA requires EPA to consider "information" relating to a chemical that is "reasonably available to the Administrator" throughout the risk evaluation process.[30] So that EPA can obtain and develop "the information necessary to fill knowledge gaps before making regulatory decisions,"[31] Congress expanded EPA's information-gathering authorities as part of the 2016 amendments to TSCA.[32]

1. Failure to rely on meaningful information

Despite the requirement that EPA rely on reasonably available information, the problem formulations suggest that EPA is relying on unfounded conjecture, incomplete, ambiguous, and self-serving reports by a subset of manufacturers and processors, or in some cases on the *absence* of information. This approach is incompatible with the TSCA requirements to base decisions on reasonably available information and the best available science.[33]

The HBCD problem formulation illustrates these concerns, which are present in the other problem formulations as well. EPA appears to be rejecting reliable evidence that HBCD continues to be used in consumer products, but with no justification. For example, EPA notes "[f]rom June 2012 to March 2017, the use of HBCD in children's clothing and blankets was self-reported 44 times by manufacturers and retailers to Washington State under state law."[34] Despite what appears to be clear evidence that HBCD is used in textiles, EPA inexplicably

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[30] *Id.* § 2625(k).

[31] H.R. Rep. No. 114-176, at 22 (2015).

[32] *See id.*; 15 U.S.C. §§ 2603(a)(1), (a)(2).

[33] *See id.* §§ 2625(h), (k).

[34] US EPA, *Problem Formulation for Cyclic Aliphatic Bromides Cluster,* at 22.

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proposes to exclude this use from the risk evaluation, stating that "[i]nformation gathered from research, industry and consumer product organizations has led EPA to believe that HBCD is no longer used in consumer textiles. Current use in consumer textiles has not been confirmed and EPA does not believe it is known, intended, or reasonably foreseen. Therefore, use in consumer textiles is not a condition of use under which EPA will evaluate HBCD."[35] Excluding uses based on conjecture that is inconsistent with clear evidence cannot be squared with the informational requirements and scientific standards in TSCA section 26.

In addition, EPA asserts that HBCD is no longer used in the production of flame retardants, EPS resins, high impact polystyrene, XPS masterbatch, motor vehicle upholstery, consumer textiles, and military, institutional and aviation textile applications. As a result, EPA plans to exclude these uses from the risk evaluation because it considers them not to be "conditions of use."[36] But these critical exclusions are based primarily on self-serving assertions from a subset of HBCD manufacturers, or the absence of information. For example:

- EPA states that "no information was identified that confirms use of HBCD in recycled HIPS for the purposes of flame retardancy. EPA, therefore, does not believe that this use is intended, known, or reasonably foreseen and is not a condition of use for HBCD." [37]
    - EPA cannot exclude uses based on the absence of information.
    - EPA cannot act based on "belief," rather than information.
    - It is irrelevant whether HBCD is present for purposes of flame retardancy.

- EPA states: "Albemarle Corporation, another historic manufacturer of HBCD, indicated that they stopped manufacturing HBCD flame retardants around 2016 and do not intend to resume the manufacture of HBCD-based flame retardants."[38]
    - What will ensure that Albemarle does not change its "intention" and resume manufacture? In the absence of a legal restriction on resumed manufacture, this intention should not be a basis of excluding uses from the risk evaluation.

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[35] *Id.*

[36] US EPA, *Problem Formulation for Cyclic Aliphatic Bromides Cluster*, at 24-25.

[37] *Id.* at 21.

[38] *Id.* at 20.

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- Even if Albemarle is true to its "intention," what will ensure that other manufacturers do not start the manufacture of HBCD-based or even HCBD containing flame retardants given the market "opening" by Albemarle's withdrawal?

- EPA states: "The EPS Industry Alliance (EPS-IA) which represents all major North American manufacturers (including Canada and Mexico) of EPS resin, reports that its members have phased out of the use of HBCD in the production of EPS resins."[39]
  - What assurance does EPA have that this "report" is accurate?
  - What about "non-major" manufacturers?

- EPA states that "Use of HBCD in High Impact Polystyrene (HIPs) appears to have ceased and EPA does not believe this use is intended, known, or reasonably foreseen."[40]
  - What does it mean that use "appears to have ceased"?
  - EPA cannot exclude uses based on belief, rather than information.

These are nothing more than speculative predictions about future events for which EPA has provided no evidence in support.

We also note that in the problem formulation for 1-bromopropane, EPA indicates that it will exclude many consumer uses of this substance, despite the fact that it is present in products that are generally available to consumers. EPA indicates that it will not consider consumer uses of 1-bromopropane as an adhesive because these products are "usually [sold] in amounts larger than consumers could use" and are sold through wholesale channels. EPA also indicates that it is excluding consumer use of 1-bromopropane as a brake cleaner and engine degreaser, despite the fact that many consumers do repair work on their own cars. EPA's theory is that 1-bromopropane has not been advertised for consumer use and expensive.[41] These evidence-less rationales for exclusion are not sufficient to conclude that consumers would not use this product.

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[39] *Id.* at 21.

[40] *Id.*

[41] US EPA, *Problem Formulation of the Risk Evaluation for 1-Bromopropane*, at 19.

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2. EPA cannot rely on uncertified chemical manufacturer's assertions that a product has been discontinued

Even if it were appropriate for EPA to exclude from its risk evaluations *truly discontinued* uses — and this would only be appropriate if there is no known, intended or reasonably foreseen ongoing use or disposal of the substance — EPA cannot conclude that a use is discontinued simply based on the agency's surmise that manufacture "appears" to have ceased, or that a manufacturer "indicated" that they are no longer making the substance. The fact that major manufacturers have ceased production does not mean that manufacture is not known or reasonably foreseeable, because it tells us nothing about minor manufacturers. Indeed, minor manufacturers can become major manufacturers once their larger competitors leave the business. Appearances, indications, beliefs, reports, and so on, do not constitute "information," and TSCA requires EPA to base its risk evaluations on "information."

For EPA to exclude a condition of use from its risk evaluation because use has discontinued, it must conduct an analysis based on all reasonably available information to confirm that re-commencement is not reasonably foreseen. And it must have in place a SNUR that prohibits the renewed manufacture and processing of all discontinued uses without notice to and review by EPA. Absent a meaningful analysis of whether resumption is reasonably foreseen, as well as SNURs that close the door on resumption, EPA would be excluding uses in the absence of reliable information.

3. EPA has failed to obtain all "reasonably available information" about asbestos and methylene chloride

The problem formulations for asbestos and methylene chloride indicate that EPA is not taking into account some of the most reliable information regarding the levels of workplace

exposure to these substances. Under OSHA, every employer whose employees are at risk of exposure to asbestos must conduct periodic exposure monitoring, including monitoring of employees who are, or may reasonably be expected to be exposed to airborne concentrations" over levels set by OSHA.[42] The same is true for methylene chloride.[43] Records of this medical monitoring must be retained for 30 years.[44] EPA should ask all employers subject to these mandates to submit these records to EPA so the agency can rely on them in its risk evaluations. As there is "reasonably available" information regarding actual workplace exposures to asbestos and methylene chloride, EPA is obligated to consider it under TSCA section 26(k).[45]

F. EPA should not rely on the TSCA systematic review protocol in the risk evaluations

The TSCA systematic review protocol describes how EPA intends to identify, evaluate, and integrate scientific information used in TSCA risk evaluations. We urge EPA not to utilize the approach laid out in this document in developing the risk evaluations for the first ten chemicals. TSCA does not permit reliance on this approach because it is not consistent with best practices for systematic review (as detailed in comments submitted during this comment period from the University of California San Francisco Program on Reproductive Health and the Environment, and others). Rather than laying out a method for evaluating the quality of evidence, this protocol will result in the exclusion of studies that may contain valid scientific data. TSCA requires EPA to conduct risk evaluations "us[ing] scientific information, technical procedures, measures, methods, protocols, methodologies, or models, employed in a manner

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[42] 29 C.F.R. § 1910.1001(d)(2)(i).

[43] *Id.* § 1910.1052(d).

[44] *Id.* § 1910.1020(d)(1)(i).

[45] 15 U.S.C. § 2625(k).

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consistent with the best available science"[46] and reasonably available information.[47] The TSCA systematic review document lays out a protocol that is inconsistent with this mandate by excluding information from EPA's consideration based on a single reporting or methodological limitation even when the study provides some valid and meaningful information. TSCA section 26(h), (i) and (k) reveal Congress's intent that EPA gather all reasonably available information and give it the appropriate weight taking into account limitations. EPA's new TSCA systematic review protocol is antithetical to TSCA section 26 insofar as it will entirely exclude meaningful, scientifically valid information based on single-flaw thresholds. It would be legal error for EPA to continue to rely on this approach as it moves forward with its risk evaluations.

CONCLUSION

For the foregoing reasons, TSCA requires EPA to modify the problem formulations so its risk evaluations encompass all conditions of use, including for uses and disposal of substances no longer manufactured for these purposes, address risks to all potentially exposed and susceptible subpopulations, and are based on all reasonably available information and a systematic review protocol that is established through a transparent and scientific process that meets globally established best practices.

Submitted this 16th day of August 2018 by:

Earthjustice

Alaska Community Action on Toxics

Environmental Health Strategy Center

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[46] *Id.* § 2625(h).

[47] *Id.* § 2625(k).

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Environmental Working Group

Learning Disabilities Association of America

Sierra Club

Union of Concerned Scientists

United Steel, Paper and Forestry, Rubber, Manufacturing, Energy, Allied Industrial and Service Workers International Union, AFL-CIO/CLC

WE ACT for Environmental Justice

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Exhibit 1

IN THE UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

Docket No. 17-72260
Consolidated with Docket Nos. 17-72501, 17-72968, 17-73290, 17-73383, 17-73390

SAFER CHEMICALS, HEALTHY FAMILIES et al.,

Petitioners,

v.

U.S. ENVIRONMENTAL PROTECTION AGENCY et al.,

Respondents.

IPC INTERNATIONAL, INC. et al.,

Respondents-Intervenors.

On Petition for Review of Final Rules of the U.S. Environmental Protection Agency

---

OPENING BRIEF OF PETITIONERS:

ALASKA COMMUNITY ACTION ON TOXICS; ALLIANCE OF NURSES FOR HEALTHY ENVIRONMENTS; ASBESTOS DISEASE AWARENESS ORGANIZATION; CAPE FEAR RIVER WATCH; ENVIRONMENTAL DEFENSE FUND; ENVIRONMENTAL HEALTH STRATEGY CENTER; ENVIRONMENTAL WORKING GROUP; LEARNING DISABILITIES ASSOCIATION OF AMERICA; NATURAL RESOURCES DEFENSE COUNCIL; SAFER CHEMICALS, HEALTHY FAMILIES; SIERRA CLUB; UNION OF CONCERNED SCIENTISTS; UNITED STEEL, PAPER AND FORESTRY, RUBBER, MANUFACTURING, ENERGY, ALLIED INDUSTRIAL AND SERVICE WORKERS INTERNATIONAL UNION, AFL-CIO/CLC; VERMONT PUBLIC INTEREST RESEARCH GROUP; and WE ACT FOR ENVIRONMENTAL JUSTICE

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CORPORATE DISCLOSURE STATEMENT

Pursuant to Federal Rule of Appellate Procedure 26.1, Petitioners Safer Chemicals, Healthy Families; Asbestos Disease Awareness Organization; Vermont Public Interest Research Group; Environmental Defense Fund; Alliance of Nurses for Healthy Environments; Cape Fear River Watch; Natural Resources Defense Council; Alaska Community Action on Toxics; Environmental Health Strategy Center; Environmental Working Group; Learning Disabilities Association of America; Sierra Club; Union of Concerned Scientists; WE ACT for Environmental Justice; and United Steel, Paper and Forestry, Rubber, Manufacturing, Energy, Allied Industrial and Service Workers International Union, AFL-CIO/CLC submit that they have no parent corporations and no publicly issued stock shares or securities. No publicly held corporation holds stock in any of the petitioners.

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PRELIMINARY STATEMENT

Toxic chemicals pervade our environment. Chemicals pollute our air, soil, and water, and contaminate our homes, workplaces, and consumer products.

Congress enacted the Toxic Substances Control Act (TSCA) in 1976 to give the U.S. Environmental Protection Agency (EPA or Agency) authority to "look comprehensively at the hazards associated with [a] chemical" and to prevent harm to health and the environment through regulation of chemicals posing unreasonable risks. S. Rep. No. 94-698, at 2 (1976). Nonetheless, the vast majority of chemicals in commerce have never been reviewed by EPA for safety and remain unregulated. This near-total failure to address chemical risks led Congress to amend TSCA in 2016, establishing a mandatory process to systematically evaluate and manage the risks of existing chemicals.

To implement this new mandate, Congress required EPA to issue two rules, known as the Framework Rules, establishing the processes by which EPA will prioritize chemicals for risk evaluations and then conduct those evaluations. The evaluation results—a finding of whether a chemical presents an unreasonable risk to health or the environment—dictate whether the Agency must ban, restrict, or otherwise regulate the chemical to prevent the risk.

Risk—the likelihood of harmful effects to human health or ecological systems—is determined by the toxicity of a chemical (i.e., its hazard) combined

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with how much contact (i.e., exposure) a person or ecological receptor has with the chemical.[1] Often, individuals are exposed to a chemical from multiple uses and through a variety of exposure pathways. Thus, TSCA can effectively protect against chemical harm only if EPA evaluates *all hazards and all exposures.* If EPA does not fully consider all known and reasonably foreseen hazards and exposures during a risk evaluation, the evaluation cannot accurately characterize the true risk posed by the chemical. Accordingly, the law requires EPA to examine broadly all of a chemical's "conditions of use," a term TSCA defines to encompass a chemical's entire lifecycle, starting with manufacture and processing, and continuing through distribution, use, and disposal.

EPA proposed the Framework Rules in January 2017 to implement Congress's mandate. The proposals complied with TSCA's requirement to comprehensively evaluate a chemical's hazards and exposures and make a holistic determination of whether the chemical presents an unreasonable risk of injury.

In the spring of 2017, a former chemical-industry advocate who had just been appointed by the new administration oversaw the final drafting of the Framework Rules. Following this appointment, EPA abruptly reversed course and adopted the approach favored by the chemical industry, in many instances revising

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[1] U.S. EPA, *About Risk Assessment*, https://www.epa.gov/risk/about-risk-assessment.

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the rules to match the chemical industry's comments word for word. In the final Framework Rules, EPA asserts unfettered discretion to exclude known or reasonably foreseen exposure pathways from consideration, thereby ignoring important contributors to a chemical's overall risk.

The Framework Rules unlawfully narrow the scope of risk evaluations by allowing EPA to exonerate chemicals based on only a partial review of known or reasonably foreseen uses and exposures. The Rules thereby threaten to leave the public—and especially vulnerable groups like children, pregnant women, and workers—inadequately protected from the potential risks of the thousands of chemicals to which individuals are exposed every day. Essential parts of the Rules violate Congress's unambiguous command to evaluate each chemical holistically and comprehensively, and those parts must be set aside.

STATEMENT OF JURISDICTION

Respondents EPA and Administrator Scott Pruitt (together, EPA) issued the Framework Rules pursuant to their authority under TSCA. 15 U.S.C. § 2605(b)(1)(A), (b)(4)(B); ER 1, 29.[2] The U.S. Courts of Appeals have jurisdiction to review the final Rules. 15 U.S.C. § 2618(a)(1)(B). Venue is proper in this Court because Petitioner Alaska Community Action on Toxics resides in

[2] Petitioners use "ER" to refer to the Excerpts of Record and "PA" to refer to Petitioners' Addendum of Declarations in Support of Standing.

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Alaska, and Petitioners Asbestos Disease Awareness Organization and Sierra Club reside in California. PA 5, 51, 321.

The Framework Rules were published on July 20, 2017, ER 1, 29, and issued for purposes of judicial review on August 3, 2017, *see* 40 C.F.R. § 23.5. Petitioners filed timely petitions for review in three Courts of Appeals on August 10 and 11, 2017. *See* 15 U.S.C. § 2618(a)(1)(A); Pet'rs' Joint Opp'n to Resps.' Mot. to Transfer 4-5, ECF No. 18 (listing petitions). All six petitions challenging the Rules were subsequently consolidated in this Court. Order, No. 17-1926 (4th Cir. Dec. 11, 2017), ECF No. 63; Order, No. 17-72260 (9th Cir. Jan. 3, 2018), ECF No. 34; *see* 28 U.S.C. § 2112(a)(3), (a)(5).

STATEMENT OF ISSUES PRESENTED

1. Congress directed EPA to conduct risk evaluations to determine whether "a chemical substance" presents an unreasonable risk of injury to health or the environment under "the conditions of use." 15 U.S.C. § 2605(b)(1)(A).

   a. Does TSCA grant EPA authority to pick and choose which conditions of use it will consider in prioritizing chemicals and conducting risk evaluations?

   b. Does TSCA permit EPA to conclude a risk evaluation without determining whether the chemical substance as a whole presents an unreasonable risk?

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c. Does TSCA permit EPA to determine that individual conditions of use do not present an unreasonable risk before completing its evaluation of the chemical substance as a whole?

2. Congress defined "conditions of use" as "the circumstances, as determined by the Administrator, under which a chemical substance is intended, known, or reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of." 15 U.S.C. § 2602(4). Has EPA unlawfully rewritten this definition by excluding a chemical's ongoing and future use and disposal from "conditions of use" if the chemical's manufacture, processing, and distribution for that specific use have been discontinued?

3. Congress directed EPA to consider all "reasonably available" information when making priority designations and conducting risk evaluations. 15 U.S.C. § 2625(k). Are the Framework Rules contrary to this mandate or arbitrary and capricious because they (a) penalize incomplete submissions by public commenters; (b) create thresholds for considering scientific information; (c) allow manufacturers to withhold relevant information about a chemical when requesting risk evaluations; and/or (d) fail to require EPA to consider during prioritization whether it has adequate information to conduct a risk evaluation?

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STATUTORY ADDENDUM

Petitioners attach a separate Statutory Addendum to their Opening Brief. 9th Cir. R. 28-2.7.

STATEMENT OF THE CASE

I. The Toxic Substances Control Act

A. The unfulfilled promise of the 1976 enactment

Congress enacted TSCA in 1976 to "prevent unreasonable risks of injury to health or the environment" from chemicals. S. Rep. No. 94-698, at 1; Pub. L. No. 94-469, 90 Stat. 2003 (codified at 15 U.S.C. § 2601 et seq.) (1976). Then-existing environmental laws were "clearly inadequate" to address the "serious risks of harm" to public health from toxic chemicals. H.R. Rep. No. 94-1341, at 7 (1976); *see* S. Rep. No. 94-698, at 3 ("[W]e have become literally surrounded by a man-made chemical environment. … [T]oo frequently, we have discovered that certain of these chemicals present lethal health and environmental dangers."). While other federal environmental laws focused on specific media, such as air or water, none gave EPA authority to "look comprehensively" at the hazards of a chemical "in total." S. Rep. No. 94-698, at 2.

Congress designed TSCA to fill these "regulatory gaps," S. Rep. No. 94-698, at 1, through a comprehensive approach to chemical risk management that considered "the full extent of human or environmental exposure," H.R. Rep. No.

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94-1341, at 6. However, the 1976 law proved ineffective at reducing risks to public health from toxic chemicals existing in commerce.

First, while TSCA section 6 required EPA to restrict unsafe chemicals, *see* 90 Stat. 2003, § 6(a), it did not establish a systematic process or schedule for evaluating whether chemicals present unreasonable risks of injury to health or the environment. As a result, EPA rarely restricted or banned existing chemicals, and these chemicals could remain in commerce indefinitely without any safety review by EPA. S. Rep. No. 114-67, at 4 (2015).

Second, EPA's use of section 6 was hampered by a court ruling invalidating EPA's 1989 ban on most uses of asbestos. *See Corrosion Proof Fittings v. EPA*, 947 F.2d 1201 (5th Cir. 1991). The court overturned EPA's asbestos rule on the grounds that EPA's cost-benefit analysis was flawed and that EPA failed to impose the "least burdensome" risk mitigation measure among available alternatives. *Id.* at 1215-17. Following this decision, EPA's section 6 rulemaking came to a standstill: EPA has not finalized a rule regulating an existing chemical under section 6 in nearly thirty years. S. Rep. No. 114-67, at 4. In fact, in the more than forty years since TSCA's enactment, EPA has only five times used its section 6 authority to ban, limit production of, or restrict the use of existing chemicals.[3]

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[3] *See* U.S. Gov't Accountability Office, *Chemical Regulation: Options Exist to Improve EPA's Ability to Assess Health Risks and Manage Its Chemical Review Program* 18 (June 2005), https://www.gao.gov/products/GAO-05-458.

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B. The 2016 amendments

In 2016, Congress overhauled TSCA by enacting the Frank R. Lautenberg Chemical Safety for the 21st Century Act (together with the 1976 law, the amended statute is referred to as TSCA). Pub. L. No. 114-182, 130 Stat. 448 (codified at 15 U.S.C. § 2601 et seq.) (2016). Congress affirmed that the intent of the original law—to give EPA "authority to look at the hazards [of chemicals] in total," S. Rep. No. 94-698, at 2—remained "intact." S. Rep. No. 114-67, at 7.

The 2016 amendments establish new requirements in section 6 for EPA to systematically evaluate the potential risks presented by existing chemicals. The Agency must now undertake a step-by-step process to (1) select, i.e., "prioritize" chemical substances needing evaluation based on their potential risk to health and the environment; (2) conduct "risk evaluations" of those prioritized chemicals, and some chemicals nominated by manufacturers, to determine whether they present unreasonable risks of injury to health or the environment; and (3) eliminate such risks by issuing rules regulating those chemicals. 15 U.S.C. § 2605(a)-(b).

Throughout the amendments to section 6, Congress used a new term, "conditions of use," to describe the circumstances EPA must consider when prioritizing chemicals for review and conducting risk evaluations. The statute broadly defines "conditions of use" as "the circumstances, as determined by the Administrator, under which a chemical substance is intended, known, or

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reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of." *Id.* § 2602(4). The amendments also clarified that EPA's "unreasonable risk" determination must be made "without consideration of costs" and removed the "least burdensome" requirement—modifying language that had doomed the asbestos ban. *Id.* § 2605(a), (b)(4)(A).

1. Prioritization

TSCA requires EPA to establish a "risk-based screening process," called prioritization, to guide EPA's selection of chemicals warranting full risk evaluation. Chemicals designated as "high-priority"—meaning they "may present an unreasonable risk of injury to health or the environment because of a potential hazard and a potential route of exposure under the conditions of use," *id.* § 2605(b)(1)(B)(i)—will undergo immediate risk evaluations. *Id.* § 2605(b)(3)(A). Chemicals designated as "low-priority"—a designation that must be based on "information sufficient to establish" that the chemical "does not meet the standard" for high-priority designation, *id.* § 2605(b)(1)(B)(ii)—will not undergo further review at that time. *Id.* § 2605(b)(1)(A).

2. Risk evaluations

Once EPA designates a chemical as high-priority, it must initiate a risk evaluation for that chemical and complete it within three years (with a possible six-month extension). *Id.* § 2605(b)(3)(A), (b)(4)(G). EPA must also conduct risk

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evaluations on some chemicals nominated by their manufacturer(s). *Id.* § 2605(b)(4)(C)(ii). Manufacturer-requested risk evaluations must follow the same process and meet the same requirements as EPA-initiated evaluations. *See id.* § 2605(b)(4)(C), (b)(4)(E)(ii).

Through each risk evaluation, EPA must

> determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors … under the conditions of use.

Id. § 2605(b)(4)(A). EPA must evaluate risks not only to the general population, but also to relevant "potentially exposed or susceptible subpopulation[s]." *Id.* These include groups such as "infants, children, pregnant women, workers, or the elderly," that, "due to either greater susceptibility or greater exposure," may face greater risks of harm than the general population from chemical exposures. *Id.* § 2602(12).

As an initial part of the evaluation, EPA must publish the "scope" of the evaluation, describing "the hazards, exposures, conditions of use, and the potentially exposed or susceptible subpopulations the Administrator expects to consider." *Id.* § 2605(b)(4)(D). EPA must also, among other requirements, "integrate and assess available information on hazards and exposures for the conditions of use of the chemical substance." *Id.* § 2605(b)(4)(F)(i). This is because characterizing exposure involves gathering information on the various

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conditions of use of a chemical to determine the potential pathways of exposure to the chemical and estimate the extent of exposure to people or environmental receptors, including the duration, intensity, frequency, and number of exposures. *Id.* § 2605(b)(4)(F)(iv); *see* ER 52-54. Characterizing hazard involves reviewing scientific studies to determine the nature and severity of the harms caused by the chemical. ER 54-56. Ultimately, the risk evaluation will combine EPA's exposure and hazard assessments to estimate the risk the chemical presents. ER 56-57.

3. Risk management rules

If EPA determines "that the manufacture, processing, distribution in commerce, use, or disposal of a chemical substance or mixture, or that any combination of such activities, presents an unreasonable risk" to health or the environment, EPA must issue a rule under section 6(a) to address the risk. 15 U.S.C. § 2605(a), (c)(1). This rule must impose restrictions or other requirements designed to eliminate the unreasonable risk. *Id.* § 2605(a). Such requirements may include full or partial bans on manufacture, processing, or distribution; warning labels; recordkeeping requirements; use restrictions; and prohibitions or limits on methods of disposal. *Id.*

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4. Obtaining information

TSCA requires EPA to consider information relating to a chemical that is "reasonably available to the Administrator" throughout the prioritization and risk evaluation processes. *Id.* § 2625(k). To allow EPA to obtain and develop "the information necessary to fill knowledge gaps before making regulatory decisions," H.R. Rep. No. 114-176, at 23 (2015), Congress expanded EPA's information-gathering authorities as part of the 2016 amendments. *See id.* at 22-23; 15 U.S.C. § 2603(a)(1), (a)(2).

II. History of the Framework Rules

Congress required EPA to issue the Framework Rules to implement the amendments to section 6. 15 U.S.C. § 2605(b)(1)(A), (b)(4)(B).

A. The proposed Rules

EPA issued the proposed Prioritization and Risk Evaluation Rules on January 17 and 19, 2017, respectively. ER 577, 60.

The proposed Rules complied with TSCA's mandate to take a comprehensive approach to chemical risk evaluation. EPA explained in the proposed Prioritization Rule that, "in response to clear statutory directives," it would "designate the priority of a 'chemical substance,' as a whole," rather than "a specific use or subset of uses of a chemical substance." ER 581. In the proposed Risk Evaluation Rule, EPA likewise construed TSCA to require it to conduct risk

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evaluations on "the chemical substance," "not [on] individual conditions of use." ER 63. EPA's focus on the total risk posed by each chemical informed critical aspects of the proposed Rules.

First, the proposed Rules required EPA to consider during both prioritization and risk evaluation "*all* known, intended, and reasonably foreseen activities associated with the subject chemical substance," i.e., "*all* … activities that constitute the conditions of use within the meaning of [the statutory definition]." *Id.* (emphases added); *see* ER 582, 588. EPA applied the requirement to evaluate all of a chemical's conditions of use to both EPA-initiated and manufacturer-requested risk evaluations. ER 60, 75-76. As a result, the proposed Risk Evaluation Rule required manufacturers requesting risk evaluations to provide EPA with "all [reasonably available] information that is necessary for EPA to conduct a risk evaluation addressing all the circumstances that constitute [the chemical's] conditions of use." ER 74.

Second, the proposed Risk Evaluation Rule required EPA to make a single, final risk determination of whether "the chemical substance presents an unreasonable risk of injury." ER 78, 63.

B. Influence of Dr. Nancy Beck over the final Framework Rules

Until at least April 12, 2017, EPA continued to interpret TSCA as requiring risk evaluations to "encompass all" of a chemical's conditions of use, and relied on

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that interpretation in denying several citizen petitions under TSCA. *See* 82 Fed. Reg. 17,601, 17,603 (Apr. 12, 2017).

Shortly thereafter, however, the Trump Administration appointed Dr. Nancy Beck as Deputy Assistant Administrator for EPA's Office of Chemical Safety and Pollution Prevention, which oversees the TSCA program. Since joining EPA in late April 2017, Dr. Beck has been the senior political appointee under the Administrator responsible for all aspects of EPA's implementation of TSCA. For the five years immediately before joining EPA, Dr. Beck was the Senior Director for Regulatory Science Policy at Respondent-Intervenor American Chemistry Council (ACC). MA 63.[4] A registered lobbying organization, ACC is the principal advocacy association representing the nation's largest and most influential chemical manufacturers. *See* MA 53, 67-68; ER 82.

As one of ACC's chief advocates regarding EPA's implementation of TSCA, Dr. Beck presented ACC's recommendations for the Framework Rules at an EPA public meeting on August 9, 2016, and signed ACC's August 2016 comments elaborating on its desired approach for the Rules. ER 79, 82. ACC and Dr. Beck urged EPA to focus on subsets of chemicals' conditions of use in its risk

[4] Petitioners use "MA" to refer to the Motion Appendix (ECF No. 43-2) filed with their Motion to Complete the Administrative Records. The Motion requests that the Court compel EPA to complete the administrative records with the documents identified in paragraphs 3 through 20 of the Marks Declaration, as well as additional documents that EPA omitted from its certified records.

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evaluations. ER 86; *see also* MA 13, 17-18 (showing Dr. Beck's participation in a November 2016 meeting at the Office of Management and Budget at which ACC recommended that EPA not evaluate all conditions of use and instead focus on those uses "that present the highest likelihood of potential concern"). ACC's March 2017 comments on the Framework Rules, written while Dr. Beck remained at ACC, repeated the same positions as Dr. Beck's previous comments, including that EPA need not "include 'all' conditions of use in any particular risk evaluation." ER 137; *see* ER 606-07. Because of this prior advocacy on ACC's behalf, EPA's ethics office "advised" Dr. Beck that she "cannot participate in any meetings, discussions, or decisions that relate to any individual ACC comment nor attend any meeting at which ACC is present." MA 88.

Nonetheless, after Dr. Beck's arrival at EPA, the Agency abruptly reversed its interpretation of TSCA's requirements. The final Framework Rules upend EPA's prior approach to risk evaluations and significantly narrow the Agency's interpretation of the meaning of "the conditions of use." This altered approach ignored recommendations and concerns raised by career agency staff. *See* MA 25-27, 29-30. Many of the changes to the proposed Rules mirror ACC's specific requests, in many instances word for word. *See* MA 528-539.

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C. The final Rules

The Framework Rules reject the comprehensive, substance-based approach of the proposed Rules.

First, EPA now asserts in the Risk Evaluation Rule that TSCA grants EPA "discretion" to exclude conditions of use from its risk evaluation of a chemical. ER 4. The Rule establishes no criteria for such exclusions. This pick-and-choose interpretation extends to the Rule's provisions allowing manufacturers to request risk evaluations limited to the conditions of use they wish to include. 40 C.F.R. § 702.37(b)(3); *see* ER 12.

Second, the Risk Evaluation Rule allows EPA to conduct piecemeal risk evaluations for a chemical, without determining whether the "chemical substance" poses an unreasonable risk. Instead, the Rule directs EPA to determine whether individual conditions of use in isolation pose unreasonable risks. 40 C.F.R. §§ 702.47 (EPA "will determine whether the chemical substance presents an unreasonable risk … *under each condition of uses* [sic] within the scope of the risk evaluation" (emphasis added)), 702.49(d); *see* ER 19.

Third, the Framework Rules rewrite the statutory definition of "conditions of use" to omit consideration of a chemical's ongoing and future uses and related disposals if manufacturing, processing, and distribution for those specific uses are no longer occurring. ER 4-5, 31. EPA misleadingly labels these omitted activities

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"legacy uses," "associated disposal," and "legacy disposal." ER 4-5.

The Rules also limit EPA's ability to collect and consider reasonably available information necessary to inform its decisions under TSCA.

III. Risk evaluation actions to date

In December 2016, EPA selected the first ten chemicals to undergo risk evaluations under the amended TSCA and began those evaluations. 81 Fed. Reg. 91,927 (Dec. 19, 2016); *see* 15 U.S.C. § 2605(b)(2)(A). EPA released the scopes for these ten chemicals contemporaneously with the final Framework Rules. MA 520-22. The scopes rely on EPA's revised interpretations of TSCA incorporated into the Framework Rules. *See* 82 Fed. Reg. 31,592, 31,593 (July 7, 2017).

STANDARD OF REVIEW

The standard set forth in the Administrative Procedure Act applies to the Court's review of EPA rules implementing TSCA. 15 U.S.C. § 2618(c)(1). Under this standard, courts must "hold unlawful and set aside" agency action and conclusions "found to be … arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." 5 U.S.C. § 706(2).

When reviewing whether an agency's interpretation of a statute is lawful, the Court follows the test established in *Chevron U.S.A. Inc. v. Natural Resources Defense Council, Inc.*, 467 U.S. 837 (1984). *City of L.A. v. U.S. Dep't of Commerce*, 307 F.3d 859, 868 (9th Cir. 2002). If Congress has spoken directly to

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the precise question at issue, the Court must give effect to Congress's unambiguously expressed intent. *Chevron*, 467 U.S. at 843 & n.9; *Akhtar v. Burzynski*, 384 F.3d 1193, 1198 (9th Cir. 2004). If the statute is silent or ambiguous, a court will defer to an agency's reasonable interpretation. *Chevron*, 467 U.S. at 843 & n.9.

In addition, agency action is arbitrary and capricious where an agency "entirely fail[s] to consider an important aspect of the problem" or fails to articulate a "'rational connection between the facts found and the choice made.'" *Motor Vehicle Mfrs. Ass'n of U.S. v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983) (quoting *Burlington Truck Lines v. United States*, 371 U.S. 156, 168 (1962)). A court's review of agency action, while "deferential," must be "thorough, probing, [and] in-depth." *Ranchers Cattleman Action Legal Fund United Stockgrowers of Am. v. U.S. Dep't of Agric.*, 415 F.3d 1078, 1093 (9th Cir. 2005) (internal quotation marks omitted).

SUMMARY OF ARGUMENT

1. EPA's claim of authority to exclude conditions of use and their resulting exposures from risk evaluations violates TSCA's plain text, structure, and purpose. The directive to "determine whether *a chemical substance* presents an unreasonable risk" requires an evaluation of the chemical's total risk. And the phrase "under *the* conditions of use" unambiguously means *all* of the chemical's

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conditions of use. Several provisions of TSCA confirm Congress's intent. First, when Congress intended EPA to act on fewer than all conditions of use, it expressly provided for such action. Second, Congress created a narrow exception allowing EPA to regulate certain chemicals based on previously completed risk assessments limited to a subset of conditions of use; this exception confirms that the new law otherwise requires comprehensive risk evaluations. Third, TSCA specifies in detail how EPA is to prioritize chemicals and evaluate their risks, but does not provide EPA with any criteria to eliminate conditions of use. Moreover, excluding conditions of use will frustrate TSCA's purpose of preventing unreasonable risks to health by underestimating risk, especially to vulnerable subpopulations. EPA's interpretation fails under *Chevron* and reflects arbitrary and capricious reasoning.

2. EPA also asserts authority to find that individual conditions of use, standing alone, do not present an unreasonable risk, and that it need not make a risk determination for a chemical substance as a whole. EPA's use-by-use approach cannot be reconciled with TSCA's requirement that EPA make a single, holistic risk determination on "a chemical substance."

3. EPA unlawfully rewrites the definition of "conditions of use" to omit a chemical's current and future use and disposal if the chemical's manufacture, processing, and distribution for that specific use are not ongoing. Congress's

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inclusion of "use" and "disposal" as "conditions of use" forecloses this construction. 15 U.S.C. § 2602(4). Moreover, Congress consciously allowed EPA to prioritize and evaluate chemicals that have not been manufactured in the ten years prior to passage of the TSCA amendments, i.e., chemicals that have *only* conditions of use ("use" and "disposal") that EPA claims it may omit from analysis. EPA's rewrite thus finds no support in the text or structure of TSCA.

4. The Framework Rules are inconsistent with EPA's duty to "take into consideration" all "reasonably available" information when prioritizing chemicals and conducting risk evaluations. 15 U.S.C. § 2625(k). For example, the Risk Evaluation Rule penalizes any "incomplete" public submissions, chilling public participation. The Rule also impermissibly limits the information manufacturers must provide when requesting a risk evaluation, allowing them to withhold relevant information about a chemical. These information-limiting provisions inhibit the scientifically sound decisions EPA is required to make under section 6.

5. Petitioners have standing to challenge the Framework Rules because their members face a credible threat of injury from EPA's unlawful approach to prioritizing chemicals and evaluating their risks. Petitioners also have informational standing to challenge the Risk Evaluation Rule, and some Petitioners have organizational standing to challenge that Rule.

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ARGUMENT

I. The Framework Rules violate TSCA's mandate that risk evaluations consider all of a chemical's conditions of use

Under TSCA, EPA must conduct risk evaluations to determine whether "*a chemical substance* presents an unreasonable risk … under *the conditions of use*." 15 U.S.C. § 2605(b)(4)(A) (emphases added). This directive expresses Congress's clear intent that EPA evaluate the risks posed by "a chemical substance" as a whole, taking into account all circumstances comprising "the conditions of use" of the chemical.

Ignoring Congress's unambiguous direction, the Framework Rules grant EPA unfettered "discretion" to pick and choose which conditions of use it will include in each risk evaluation. ER 4-5. In other words, EPA claims authority to "exclude certain activities that EPA has determined to be conditions of use" from risk evaluations. ER 4.[5] The Risk Evaluation Rule codifies this pick-and-choose approach by providing that the scope of each evaluation will "include" only "[t]he

[5] To the extent the Prioritization Rule authorizes EPA to exclude conditions of use from consideration when designating a chemical as high- or low-priority, the Rule is likewise unlawful. *See* ER 31 (referring to EPA's "discretion to 'determine' the conditions of use" for each chemical); *compare* 40 C.F.R. § 702.9(f) (basing proposed low-priority designations on "the proposed conclusion that the chemical substance meets the definition of Low-Priority Substance … *under the activities that [EPA] determines constitute conditions of use*" (emphasis added)), *with* ER 588 (basing low-priority designations on consideration of "all uses that [EPA] determines constitute conditions of use").

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condition(s) of use, as determined by the Administrator, *that the EPA plans to consider*," giving EPA carte blanche to exclude any conditions of use it chooses. 40 C.F.R. § 702.41(c)(1) (emphasis added). The Rule repeatedly refers to "the conditions of use *within* the scope of the evaluation," indicating that some conditions of use are outside the evaluation's scope. 40 C.F.R. §§ 702.41(a)(5), (a)(8), (a)(9), (c)(4)(i), (c)(4)(iii), (d)(2); 702.49(b), (c), (d) (emphasis added). Similarly, the Rule allows EPA to limit an evaluation requested by a manufacturer to those conditions of use "identified in the request," and other limited conditions of use that "warrant inclusion." *Id.* § 702.37(e)(3); *see id.* § 702.37(b)(3).

EPA points to a smorgasbord of potential exposure pathways it may exclude, while also leaving open the possibility of other exclusions as well. *See* ER 5 (asserting it may exclude a chemical's presence as an "impurity"), 183-85 (suggesting it may exclude use as an intermediate chemical during manufacturing, the incidental manufacturing of a chemical as a byproduct, and uses "where other agencies hold jurisdiction").

EPA's interpretation is not only contrary to the "particular statutory language at issue" and "the language and the design of the statute as a whole," *McCarthy v. Bronson*, 500 U.S. 136, 139 (1991) (quoting *K Mart Corp. v. Cartier, Inc.*, 486 U.S. 281, 291 (1988)), but also frustrates TSCA's purposes by ignoring exposures and underestimating risks posed by chemicals, *see Wilderness Soc'y v.*

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U.S. Fish & Wildlife Servs., 353 F.3d 1051, 1060 (9th Cir. 2003) (en banc). If EPA excludes conditions of use during prioritization and risk evaluations, it cannot fulfill TSCA's command to determine whether "a chemical substance" poses an unreasonable risk to health or the environment. 15 U.S.C. § 2605(b)(4)(A). The Court must give effect to Congress's "unambiguously expressed intent" by setting aside the provisions of the Framework Rules that reflect EPA's illegal approach. *Chevron*, 467 U.S. at 843.

A. TSCA's plain language requires EPA to include all conditions of use in prioritization and risk evaluations

The starting point for construing TSCA "is the language of the statute itself." *Grp. Life & Health Ins. Co. v. Royal Drug Co.*, 440 U.S. 205, 210 (1979).

1. TSCA requires priority designations and risk evaluations to focus on "a chemical substance" as a whole

Congress consistently used the phrase "a chemical substance" to describe the object of priority designations and risk evaluations. 15 U.S.C. § 2605(b)(1)-(4), (i) (using the phrase fourteen times). This language requires EPA to consider all hazards and exposures that contribute to the total risk presented by the chemical substance as a whole.

This whole-substance focus begins during prioritization. The definitions of high- and low-priority substances make clear that it is the "substance" that receives the designation, not selected uses. *See id.* § 2605(b)(1)(B). As EPA recognized in

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the Prioritization Rule, "[t]he statute is clear that EPA is to designate the priority of the 'chemical substance'—not a condition of use for a chemical substance." ER 31 (citing 15 U.S.C. § 2605(b)(1)(A)).

EPA must also conduct risk evaluations on "a chemical substance" as a whole. For example, TSCA provides that "[u]pon designating a chemical substance as a high-priority substance, the Administrator shall initiate a risk evaluation on *the substance*." 15 U.S.C. § 2605(b)(3)(A) (emphasis added). Similarly, the statute directs EPA to determine either that "*a chemical substance* presents" or "does not present an unreasonable risk." *Id.* § 2605(i)(1)-(2) (emphasis added). Congress also uses the phrase "a chemical substance" or "chemical substances" in many other places in TSCA's risk evaluation provisions. *See, e.g.*, *id.* § 2605(b)(4)(G) (setting deadlines for completing evaluation for "a chemical substance"), (b)(2)(A), (b)(2)(B), (b)(3)(A), (c)(1).

Together, these provisions show that "the statute requires" EPA to determine "whether a chemical substance, as a whole, presents an unreasonable risk or [sic] injury." ER 63-64. As EPA previously concluded, an interpretation allowing the Agency to evaluate "merely a subset of individual uses" is "a strained reading" of section 6(b). *Id.*

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2. The phrase "the conditions of use" means *all* conditions of use

By requiring EPA to determine whether a chemical substance presents an unreasonable risk "under *the* conditions of use," 15 U.S.C. § 2605(b)(4)(A) (emphasis added), TSCA is unambiguous: EPA's evaluation must include *all* conditions of use of the chemical. The "definite article 'the' particularizes the subject which it precedes," in contrast to the "indefinite or generalizing force of 'a.'" *In re Cardelucci*, 285 F.3d 1231, 1234 (9th Cir. 2002) (quoting Black's Law Dictionary 1477 (6th ed. 1990)). When "the" precedes a collective or plural noun, it is equivalent to "all." *E.g.*, *Dutcher v. Matheson*, 840 F.3d 1183, 1194 (10th Cir. 2016); *Kaufman v. Allstate N.J. Ins. Co.*, 561 F.3d 144, 155 (3d Cir. 2009); *Frazier v. Pioneer Americas LLC*, 455 F.3d 542, 546 (5th Cir. 2006). Accordingly, the phrase "the conditions of use" means *all* conditions of use.

When Congress intended EPA to act on fewer than all of a chemical's conditions of use, it used different words to convey that intent. *See SEC v. McCarthy*, 322 F.3d 650, 656 (9th Cir. 2003). Congress allowed EPA to grant exemptions from risk management rules for "a specific condition of use" of a chemical, 15 U.S.C. § 2605(g)(1); directed EPA to consider reasonably available alternatives when deciding whether to ban or restrict "a specific condition of use," *id.* § 2605(c)(2)(C); and permitted EPA to allow test marketing for "specific conditions of use" of new chemicals in some circumstances, *id.* § 2604(h); *see also*

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id. § 2613(b)(4)(B)(i) (referring to "a specific condition of use"). The Court "must assume that this difference in language is legally significant." *Spencer Enters., Inc. v. United States*, 345 F.3d 683, 689 (9th Cir. 2003).

B. EPA's conclusion that it may exclude conditions of use is contrary to TSCA's structure

Because courts "construe statutes, not isolated provisions," *King v. Burwell*, 135 S. Ct. 2480, 2489 (2015) (internal quotation marks omitted), "the words of a statute must be read in their context and with a view to their place in the overall statutory scheme," *FDA v. Brown & Williamson Tobacco Corp.*, 529 U.S. 120, 133 (2000) (internal quotation marks omitted).

1. EPA's pick-and-choose approach cannot be squared with the overall structure of TSCA

As EPA concluded in its proposed Risk Evaluation Rule, that TSCA "provides no criteria for EPA to apply" shows that the Agency does not have "license to choose among conditions of use." ER 64. The precision with which Congress prescribed EPA's implementation of section 6 supports this reading. Section 6 lays out detailed directions for EPA. *See* 15 U.S.C. § 2605(b)(1)(A) (mandating considerations for priority designations), (b)(4)(D) (identifying risk factors to include in a risk evaluation's scope), (b)(4)(F)(i)-(v) (detailing requirements for conducting risk evaluations); *see also id.* § 2605(a) (specifying possible risk management measures). These provisions indicate that Congress did

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not mean to allow EPA to exclude conditions of use from prioritization or risk evaluation without any criteria or instruction. *Cf. NRDC, Inc. v. EPA*, 863 F.2d 1420, 1432 (9th Cir. 1988) (invalidating regulatory procedure that "is wholly silent as to what factors the agency is to consider in granting exceptions" and provides "no discernible standard [for] limit[ing] th[at] discretion").

Indeed, when Congress intended EPA to exercise discretion under TSCA, it said so explicitly. *See, e.g.*, 15 U.S.C. §§ 2613(f) (granting EPA "[d]iscretion" in handling claims to protect confidential information), 2608(a) (instructing EPA, if it "determines, in the Administrator's discretion," that an unreasonable risk may be prevented under a federal law administered by another agency, to notify the agency), 2608(b), 2605(b)(4)(E)(iv)(II). That Congress purposefully included the language of discretion "in one section of the statute but omit[ted] it in another section of the same Act" shows that Congress did not intend EPA to use discretion to pick and choose which conditions of use to consider in prioritization and risk evaluation. *Hernandez v. Ashcroft*, 345 F.3d 824, 834 (9th Cir. 2003) (quoting *Andreiu v. Ashcroft*, 253 F.3d 477, 480 (9th Cir. 2001) (en banc)).

Underscoring that the pick-and-choose approach is inconsistent with TSCA's structure is EPA's suggestion that it may exclude "[u]ses where other agencies hold jurisdiction." ER 5. Congress is plainly aware, for example, that the Occupational Safety and Health Administration (OSHA) also has jurisdiction over

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worker safety, but section 6(b), when read with the definition of "potentially exposed or susceptible subpopulation," specifically requires EPA to evaluate the risks to workers. 15 U.S.C. §§ 2602(12), 2605(b)(4)(A). Further, section 9(c) permits concurrent EPA and OSHA regulation over working conditions. *See id.* § 2608(c). And, section 9 expressly contemplates that EPA may—only after it determines that a chemical presents an unreasonable risk—determine that the risk "may be prevented or reduced to a sufficient extent by action taken under a Federal law not administered" by EPA. *Id.* § 2608(a). These provisions show that Congress intended EPA to evaluate all conditions of use, even those potentially under the jurisdiction of other agencies. Indeed, where Congress intended to exclude uses of a chemical because they fall under the jurisdiction of another agency, it did so expressly. *See id.* § 2602(2)(B) (excluding from the definition of "chemical substance" uses regulated by other agencies under statutes such as the Food, Drug, and Cosmetic Act).

Similarly, EPA suggests that it may exclude conditions of use for reasons that bear no relationship to risk. *See* ER 5, 183-85. Such exclusions violate TSCA's requirement that EPA evaluate a chemical's risk "without consideration of costs or other nonrisk factors." 15 U.S.C. § 2605(b)(4)(A).

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2. TSCA's exception allowing certain partial risk evaluations confirms that comprehensive risk evaluations are the general rule

The express, limited exception Congress created to allow EPA to act on partial risk evaluations conducted prior to the 2016 TSCA amendments further confirms that Congress otherwise intended EPA to consider all conditions of use in risk evaluations. *See* 15 U.S.C. § 2625(*l*)(4). Section 26(*l*)(4) authorizes EPA to issue risk management rules for chemicals that, prior to the 2016 amendments, had been subject to partial risk evaluations based on a subset of conditions of use.[6] *Id.* Congress enacted this provision in direct response to concerns raised by EPA during the legislative process that partial risk evaluations were "simply not contemplated under the House and Senate bills." *See* MA 541. EPA noted that, absent this carve-out, the pending legislation would require EPA "to assess a chemical in its entirety, based on *all* conditions of use," and would preclude EPA from acting on its 2014 partial risk evaluations. *See* MA 540-42. Construing TSCA to allow EPA to conduct partial risk evaluations outside of this narrow carve-out, as the Framework Rules do, impermissibly renders section 26(*l*)(4) meaningless. *See Bilski v. Kappos*, 561 U.S. 593, 607-08 (2010). Although EPA now espouses a new view of this statutory language, its statement "to Congress …

[6] *E.g.*, trichloroethylene, 82 Fed. Reg. 7432, 7433 (proposed Jan. 19, 2017); methylene chloride and n-methylpyrrolidone, 82 Fed. Reg. 7464, 7465 (proposed Jan. 19, 2017).

at the very time it presented its own amendment to the Congress as one it urged for adoption … [is] more reliable." *United States v. One Bell Jet Ranger II Helicopter*, 943 F.2d 1121, 1126 (9th Cir. 1991).

C. Excluding conditions of use will frustrate TSCA's aim to prevent unreasonable risks to health from toxic chemicals

The meaning of statutory language "depends on context," including the statute's objectives. *Brower v. Evans*, 257 F.3d 1058, 1065 (9th Cir. 2001) (internal quotation marks omitted); *see Crandon v. United States*, 494 U.S. 152, 158 (1990). TSCA's overriding purpose is to eliminate "unreasonable risk[s] of injury to health or the environment" associated with chemicals, *see* 15 U.S.C. §§ 2601(b), 2605(a), by authorizing EPA to "look comprehensively at the hazards associated with the chemical," S. Rep. No. 94-698, at 2; *supra* p. 6. Congress amended TSCA to promote "effective implementation" of the 1976 law's objectives. *See* S. Rep. No. 114-67, at 2. Thus, the TSCA amendments reaffirm EPA's obligation to comprehensively evaluate the risks of chemicals, for example by defining "conditions of use" broadly to encompass a chemical's whole lifecycle and mandating that EPA protect vulnerable subpopulations. *See* 15 U.S.C. §§ 2602(4), 2605(b)(4)(A).

Preventing unreasonable risk from a chemical requires EPA to consider all sources and pathways of exposure. As one of EPA's risk assessment handbooks explains, individuals may be exposed to chemicals "through more than one

pathway. … [T]o achieve effective risk assessment and risk management decisions, *all* media and routes of exposure should be assessed." ER 248 (emphasis added). As public commenters explained, "a worker may be exposed to a chemical both at home and in the workplace, while an infant may be exposed to a chemical both through breast milk and through household dust." ER 253; *see also* ER 260. Additionally, an individual's exposure to a chemical through a single pathway (e.g., drinking water) may result from multiple uses of the chemical. *See* MA 29-30; ER 269, 272. "Even small exposures can add up over time to cause serious harm." ER 249. As EPA explained in the proposed Risk Evaluation Rule, if the Agency "were free to base its determination of whether a chemical substance, as a whole, presents an unreasonable risk … on merely a subset of individual uses, it could, for example, determine that a chemical substance with 10 known uses does not present an unreasonable risk of injury" after evaluating "a single one of those uses," while neglecting to evaluate other uses that may contribute to the chemical's risks. ER 63-64. This principle also explains why EPA must designate a chemical as high-priority if it lacks sufficient information to determine whether the chemical may present an unreasonable risk (including an unreasonable risk to vulnerable subpopulations). 15 U.S.C. § 2605(b)(2)(B). EPA cannot rule out the possibility that a chemical presents an unreasonable risk unless it has sufficient information on all conditions of use, because each condition of use

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may contribute to the chemical's total risk.

For the same reasons, excluding uses undermines the TSCA amendments' express commitment to protecting "potentially exposed or susceptible subpopulations," such as children, the elderly, and workers, from unreasonable chemical risks. *See* 15 U.S.C. § 2605(b)(1)(B)(i), (b)(4)(A), (b)(4)(F)(i). These subpopulations are defined by their "greater susceptibility or greater exposure" to chemicals, which may lead them to be "at greater risk than the general population of adverse health effects from exposure to a chemical." *Id.* § 2602(12). They face greater harm from low-level exposures, and may have more frequent exposures, from more sources, over time than the general population. *See, e.g.*, ER 275, 278 (children have "unique vulnerabilities to toxic chemicals," especially from "chronic, low-dose exposures that may occur at [developmentally] significant times"), 280-81, 284-87 (communities reliant on subsistence fishing and "wild foods" may face greater exposure to pollutants), 289, 290-91 (bio-accumulation of toxic chemicals in fish may increase exposure to individuals reliant on a "traditional subsistence diet"); *see also* ER 262-63, 298. To assess exposures to these vulnerable subpopulations in "real-world situations," EPA must consider "the totality of exposures from multiple pathways." ER 323 (citing U.S. EPA, Guidelines for Human Exposure Assessment, Risk Assessment Forum, Peer Review Draft (2016)).

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In sum, TSCA's text, structure, and purpose show that Congress spoke clearly to require EPA to include all conditions of use in making a priority designation and conducting a risk evaluation of a chemical substance.

D. EPA's asserted rationales in support of the pick-and-choose approach fail

1. The two statutory phrases EPA relies on do not grant it discretion to pick and choose

Neither of the two statutory phrases EPA plucks out of context grants it discretion to exclude conditions of use.

First, EPA's contention that the phrase "as determined by the Administrator" confers pick-and-choose authority is mistaken. *See* ER 4-5. This phrase merely confirms that EPA has a role in identifying the "circumstances" comprising a chemical's conditions of use under the statutory definition through factual investigation. *See* ER 4 (acknowledging that the "as determined by" phrase refers to a "largely … factual determination").

But EPA's role in "determin[ing]" the conditions of use is a limited one. The phrase "as determined by the Administrator" does not exist in a vacuum; the clause interrupts and modifies the rest of the definition. 15 U.S.C. § 2602(4). Thus, what EPA must "determine," i.e., identify by factual investigation, is bounded by the rest of the definition—the circumstances of a chemical's

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"intended, known, or reasonably foreseen" manufacture, processing, distribution, use, and disposal. *See id.* The phrase "as determined by" thus provides no authority for EPA to circumvent the statute's clear definition. *See U.S. Sugar Corp. v. EPA*, 830 F.3d 579, 631-32 (D.C. Cir. 2016) (rejecting reliance on statutory phrase "as determined by" to support "claim[ed] discretion"), *on reh'g en banc*, 671 F. App'x 822 (D.C. Cir. 2016), *and on reh'g en banc in part*, 671 F. App'x 824 (D.C. Cir. 2016).

Second, EPA cannot justify its pick-and-choose approach based on section 6(b)(4)(D), which requires EPA to "publish the scope of the risk evaluation …, including the hazards, exposures, conditions of use, and the potentially exposed or susceptible subpopulations the Administrator expects to consider." 15 U.S.C. § 2605(b)(4)(D). The phrase "expects to consider," understood in its ordinary meaning, does not provide discretion to pick and choose among the conditions of use. *See* Oxford American Dictionary 609 (3d ed. 2010) ("expect" means to "[r]egard (something) as likely to happen"); *supra* p. 27 (Congress used the word "discretion" when it meant to grant discretion). To the contrary, the term indicates only that EPA must describe the conditions of use it has identified through its fact-gathering. As EPA stated in the proposed rule, section 6(b)(4)(D) is "best read as directing the Agency to identify the uses and other activities that it has determined constitute the conditions of use, not as a license to choose among conditions of

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use." ER 64. If "expects to consider" were to grant EPA broad discretion to pick-and-choose and also modified all the preceding nouns, then EPA would also have broad discretion to exclude from the risk evaluation any hazards of the chemical (e.g., carcinogenic effects) that EPA chooses. But this interpretation is absurd.[7]

Moreover, contrary to EPA's assertions, TSCA's legislative history does not support the pick-and-choose approach. EPA relies heavily on a floor statement by a single senator to justify its interpretation, *see* ER 3, while ignoring a contradictory floor statement from four other senators, *see* 114 Cong. Rec. S3518-19 (daily ed. June 7, 2016). In light of the legislators' "contradictory account[s]," the statement of a single senator is not dispositive as to statutory meaning, especially when the statement is contrary to "clear statutory language." *NLRB v. SW Gen., Inc.*, 137 S. Ct. 929, 942-43 (2017); *Milner v. Dep't of Navy*, 562 U.S. 562, 572 (2011).

Even if TSCA were ambiguous, EPA's interpretation of the phrases "as determined by" and "expects to consider" as giving it carte blanche to exclude conditions of use is patently unreasonable. This is especially so because EPA's asserted discretion would be exercised even before conducting the evaluation that

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[7] Alternatively, under the rule of the last antecedent, the phrase "the Administrator expects to consider" does not even modify "conditions of use." *See Barnhart v. Thomas*, 540 U.S. 20, 26 (2003); *Nw. Forest Res. Council v. Glickman*, 82 F.3d 825, 832 (9th Cir. 1996), *as amended on denial of reh'g* (May 30, 1996).

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should answer how significant a risk the conditions of use actually present. If upheld, EPA's interpretation would give the Agency license to exclude *any* condition of use for *any* reason during (or even before) prioritization or risk evaluation. This irrational interpretation would undermine the integrity and protectiveness of those processes and cannot be squared with TSCA. Additionally, the pick-and-choose approach gives EPA license to implement TSCA in a manner wholly lacking in reasoned decision-making, rendering it arbitrary and capricious. *Cf. NRDC, Inc. v. EPA*, 863 F.2d at 1432.

2. EPA's view that it has unfettered discretion to exclude conditions of use is impermissible and lacks a rational basis

Implicitly conceding that Congress did not grant it unlimited discretion, EPA asserts that it intends to focus on evaluating "the conditions of use that raise greatest potential for risk." ER 3; *see* ER 180 (same); *see also* MA 17-18 (ACC handout urging EPA to limit risk evaluations to those conditions of use that "present the highest likelihood of potential concern"). EPA's non-binding intention cannot rescue the Framework Rules. First, no language in TSCA limits EPA to this "greatest potential for risk" focus. Nor does EPA point to any statutory terms that even arguably supply such a limitation.

Moreover, the Risk Evaluation Rule and the scopes for the first ten chemicals show that EPA intends to exclude conditions of use without any risk-based rationale (i.e., based on "nonrisk factors," *contra* 15 U.S.C. § 2605(b)(4)(A))

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and despite evidence that they do in fact present a serious potential for risk. For example, EPA indicates that it will exclude conditions of use of 1,4-dioxane when it is manufactured incidentally as a byproduct, a criterion with no connection to the level of risk presented, *see* 75 Fed. Reg. 49,656, 49,676 (proposed Aug. 13, 2010) (EPA "does not believe byproducts inherently pose lower exposures or risks than other manufactured chemical substances"), and that EPA itself has concluded falls within TSCA's jurisdiction, *see* 76 Fed. Reg. 50,816, 50,832 (Aug. 16, 2011). This exclusion of byproduct uses means that 1,4-dioxane's presence in many "commercial and consumer products," such as paints, household cleaners and detergents, and textile dyes, will not be evaluated, although these uses may present meaningful risks for some populations. MA 157, 170; ER 367; *cf.* ER 701. These excluded uses illustrate that EPA's "greatest potential for risk" rationale does not actually govern its exclusions.

In any event, focusing on only those conditions of use that EPA deems pose "the greatest potential for risk" is itself inconsistent with TSCA. The statute's plain terms require consideration of all conditions of use, not just the riskiest conditions. *See supra* pp. 23-26. There would be no way for EPA to determine soundly which conditions of use pose the greatest potential for risk *before* beginning the evaluation whose purpose is to assess the risks of those conditions of use. And it would be unreasonable to interpret the statute as allowing EPA to

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prioritize chemicals or conduct risk evaluations without considering risks from multiple (sometimes relatively low-dose) exposures to the same chemical. This exclusionary approach would prevent EPA from accurately evaluating total risks to vulnerable subpopulations like children, for whom low doses can pose significant risks, especially when they add up. *See supra* p. 32.

Likewise, EPA's "greatest potential for risk" theory is arbitrary and capricious because EPA has not provided a rational explanation to reconcile its pick-and-choose approach with TSCA's mandate to determine whether "a chemical substance" poses an unreasonable risk, including an unreasonable risk to vulnerable subpopulations, and to issue risk management rules to eliminate any such risks. *See State Farm*, 463 U.S. at 43.

Nor can EPA justify its pick-and-choose interpretation by reference to concerns about completing risk evaluations within "statutory deadlines." ER 3-4. This is not a legitimate excuse to disregard plain statutory language. *See Portland Gen. Elec. Co. v. Bonneville Power Admin.*, 501 F.3d 1009, 1026 (9th Cir. 2007). In any event, EPA has not explained its turnaround from its factual conclusion in the proposed Rule that including all conditions of use would be "manageable given the statutory deadlines." ER 64.

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II. EPA's use-by-use approach to risk determinations contravenes TSCA's requirement that EPA make a holistic risk determination for each chemical

EPA violates TSCA by asserting authority to determine the risk of individual conditions of use in isolation, not the chemical substance holistically. *See* 40 C.F.R. §§ 702.41(a)(9), 702.47, 702.49(d); ER 19. This aspect of the Risk Evaluation Rule flouts TSCA's command to determine whether "a chemical substance" presents an unreasonable risk, 15 U.S.C. § 2605(b)(4)(A), and defeats TSCA's purpose of preventing harms from toxic chemicals, *see supra* pp. 30-33. The holistic risk determination demanded by the statute must take into account that multiple exposures to the same chemical from different sources will increase risk. *See* 15 U.S.C. § 2605(b)(4)(F). If EPA considers each pathway to a chemical in isolation, as its Rule permits, it could determine that no single use poses an unreasonable risk, even where the totality of uses presents an unreasonable risk.

This use-by-use approach to risk determinations also cannot be squared with section 6(a), which requires EPA to issue a risk management rule if it determines that "any combination of" a chemical's "manufacture, processing, distribution in commerce, use, or disposal" presents an unreasonable risk. *Id.* § 2605(a). EPA cannot rule out the possibility that a combination of a chemical's conditions of use presents an unreasonable risk until after it has considered all of its conditions of use collectively. Sections 702.41(a)(9), 702.47, and 702.49(d) in the Risk

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Evaluation Rule are thus contrary to TSCA and must be set aside.

Under some circumstances EPA may determine that a particular use of a chemical *does* present an unreasonable risk before completing its risk determination. *See* 15 U.S.C. § 2605(a). This is because a "single use" may "present[] an unreasonable risk of injury for the population as a whole or for a susceptible subpopulation … regardless of the risk posed by other uses." ER 66. If EPA finds that a single use creates an unreasonable risk of harm, TSCA allows EPA to act quickly to protect public health, whether or not it has completed a risk determination for all uses, as EPA acknowledges. ER 15; *see* 15 U.S.C. § 2605(a), (b)(4)(A).

The converse, however, is not true. *See supra* pp. 30-33. Because the Risk Evaluation Rule allows EPA to determine that specific uses of a chemical do not pose an unreasonable risk before completing a comprehensive determination of the risks posed by the chemical, the Rule is contrary to law. *See Chevron*, 467 U.S. at 842-43.

III. EPA has unlawfully rewritten the statutory definition of "conditions of use" to omit certain uses and disposals

EPA rewrites Congress's unambiguous definition of "conditions of use" to significantly narrow the conditions of use the Agency will consider when making priority designations and conducting risk evaluations. ER 4, 5, 31. In contravention of the statutory definition, *see* 15 U.S.C. § 2602(4), EPA concludes

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that a chemical's ongoing use and disposal are *not* conditions of use if the chemical's manufacture, processing, or distribution for that specific use are not "prospective or on-going," ER 5. Moreover, EPA constricts the meaning of "disposal" to include only the one-time event when a chemical or product containing the chemical is placed in a landfill or other waste facility. Based on these contortions, EPA categorically omits from consideration three types of chemicals' conditions of use, which EPA misleadingly labels "legacy use," "associated disposal," and "legacy disposal." ER 4-5; *see* ER 31. This "rewriting [of TSCA's] unambiguous statutory terms" cannot stand. *Util. Air Regulatory Grp. v. EPA*, 134 S. Ct. 2427, 2445 (2014). Congress's clear definition controls the meaning of "conditions of use." *See Dig. Realty Tr., Inc. v. Somers*, 138 S. Ct. 767, 776 (2018); *United States v. Olson*, 856 F.3d 1216, 1223 (9th Cir. 2017).

A. A chemical's "conditions of use" include ongoing and future use and disposal under TSCA's plain language

TSCA's unambiguous text precludes EPA's conclusion that the term "conditions of use" ceases to apply to ongoing use and disposal once a chemical is no longer manufactured, processed, or distributed for a specific use. ER 4-5, 31. Although EPA asserts that TSCA is "ambiguous" and that "[n]o statutory text expressly addresses" the issue, ER 4, this is simply not so. A chemical's conditions of use include "the circumstances" under which the chemical is "known, or reasonably foreseen to be manufactured, processed, distributed in

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commerce, *used, or disposed of*." 15 U.S.C. § 2602(4) (emphasis added). Because the definition uses a disjunctive "or" list, each lifecycle stage of a chemical, standing alone, is a condition of use, even if some of the chemical's lifecycle stages have been discontinued. *See, e.g.*, *Horne v. Flores*, 557 U.S. 433, 454 (2009). EPA's construction robs the words "use" and "disposal" of their clear, independent role in the statute. The Court should reject EPA's attempt to "manufacture ambiguity" out of TSCA's plain language. *Aragon-Salazar v. Holder*, 769 F.3d 699, 706 (9th Cir. 2014).

Each of the three categories EPA concludes are *not* conditions of use falls squarely within the plain meaning of the definition. First, what EPA confusingly labels "legacy uses" includes ongoing and future uses of a chemical that is no longer manufactured, processed, or distributed for those specific uses. ER 4. Such uses are "circumstances" under which that chemical is "known" or "reasonably foreseen to be … used." 15 U.S.C. § 2602(4). For instance, notwithstanding that asbestos insulation is no longer produced in the United States, asbestos still insulates homes and buildings, is thus still *used* as insulation, and can become airborne if disturbed through remodeling or renovation. MA 111, 114-15; *see* 54 Fed. Reg. 29,460, 29,472-73 (July 12, 1989).

Second, so-called "associated disposal" refers to future disposals of a chemical relating to uses for which the chemical "is no longer manufactured,

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processed, or distributed." ER 4. This includes, for example, sending asbestos-containing debris from demolition of a building to a landfill. *See id.* Such disposals are "circumstances" under which a chemical is "known" or "reasonably foreseen to be … disposed of." 15 U.S.C. § 2602(4).

Third, so-called "legacy disposals" are "circumstances" under which a chemical is "known … to be … disposed of." *Id.* Contrary to EPA's assertion, these disposals are *ongoing*, not historical, activities. ER 4. "Disposal" of a chemical substance (including products containing that substance) is not a one-time occurrence when the substance or product is buried or placed in a landfill or other waste facility, but remains ongoing after the initial act of discard.

Although TSCA does not define "disposal," EPA previously defined the term in regulations implementing TSCA's requirement that EPA regulate disposal of a class of chemicals called polychlorinated biphenyls (PCBs). 15 U.S.C. § 2605(e); 40 C.F.R. § 761.3. EPA's regulations define disposal "very broadly to include any action that may be related to the ultimate disposition" of PCBs, including "accidental or intentional release of PCB[s] … to the environment." 43 Fed. Reg. 7150, 7150 (Feb. 17, 1978). EPA's "disposal" definition also includes "spills, leaks, and other uncontrolled discharges of PCBs as well as actions related to containing, transporting, destroying, degrading, decontaminating, or confining PCBs." 40 C.F.R. § 761.3. The ongoing activities of keeping the

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chemical "contain[ed] … or confin[ed]" are much broader than a one-time event. *Id.*

That disposal is not a one-time occurrence is also reflected in EPA's inclusion of "leaks, and other uncontrolled discharges" in its definition of disposal under TSCA. *Id.* Under EPA's regulations, disposal remains ongoing because PCB-contaminated soil can present ongoing and future risks if the substance leaks out of the containment or waste facility. *See In re Newell Recycling Co.*, 8 E.A.D. 598, TSCA Docket No. VI-659C (E.A.B. 1999), *aff'd*, *Newell Recycling Co. v. U.S. EPA*, 231 F.3d 204, 207-08 (5th Cir. 2000) (affirming EPA's rejection of claim that "PCB disposal is a one-time event"). For example, in *Environmental Defense Fund, Inc. v. EPA*, EPA acknowledged that PCB-containing "industrial waste and discarded end use products … in landfill sites … constitute[] a potential source of new free PCBs" that can be "a direct source of contamination for wildlife and humans." 636 F.2d 1267, 1270 (D.C. Cir. 1980) (quoting EPA Support Document).

In short, disposal of a chemical continues after it has been placed in a waste facility, and is a condition of use. 15 U.S.C. § 2602(4). The Court must set aside EPA's conclusion to the contrary.

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B. EPA's rewriting of the "conditions of use" definition is contrary to TSCA's structure and purpose

EPA's rewritten definition of "conditions of use" is inconsistent with the "overall statutory scheme" and purposes of TSCA. *See Brown & Williamson*, 529 U.S. at 133 (internal quotation marks omitted).

1. EPA's definition is at odds with TSCA's statutory scheme

First, EPA's interpretation ignores that when Congress amended section 6, it recognized that "inactive" chemicals could undergo prioritization and risk evaluation. As amended, section 8 of TSCA distinguishes between "active" chemicals, which had been manufactured or processed during the ten years prior to June 22, 2016, and "inactive" chemicals, which had not. 15 U.S.C. § 2607(b)(4)(A)(i)-(iii). In contrast, section 6 refers simply to "chemical substances," without reference to the date when the chemicals were last manufactured or processed. *Id.* § 2605. As the Senate Report accompanying an early version of the amended TSCA acknowledged, "there may be exposures of concern from substances that are not currently or no longer in commerce, and the section provides EPA authority to prioritize inactive substances that meet certain criteria." S. Rep. No. 114-67, at 11. The Court must presume that, by including the active/inactive distinction in section 8, but omitting the distinction in section 6, Congress acted intentionally. *See Russello v. United States*, 464 U.S. 16, 23 (1983). Thus, Congress intended EPA to prioritize, conduct risk evaluations on,

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and regulate chemicals with no recent manufacture or processing. Indeed, EPA itself rejected commenters' suggestion that EPA should not prioritize inactive chemicals. ER 32, 659. EPA's limited definition is at odds with Congress's deliberate scheme.

Second, EPA's interpretation would result in inconsistent treatment of identical activities based solely on whether manufacture or distribution is ongoing, a criterion that appears nowhere in section 6. For instance, under EPA's interpretation, a chemical's use in insulation constitutes a "condition of use" if the chemical is currently manufactured, processed, or distributed for use in insulation, but not otherwise. *See* ER 4; *compare* MA 229 (including as "condition of use" use of HBCD as insulation), *with* MA 114-115 (excluding from risk evaluation use of asbestos as insulation). This is so even if both uses present similar risks to public health. Omitting exposure scenarios from risk evaluations or prioritization decisions based on the happenstance of whether manufacturing, processing, or distribution for that specific use is ongoing is inconsistent with TSCA, as it involves considering a "nonrisk factor[]," just what TSCA prohibits. 15 U.S.C. § 2605(b)(1)(B), (b)(4)(A). These categorical omissions are capricious, in violation of TSCA.

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2. EPA's rewritten definition defeats TSCA's core purpose

EPA's three categorical omissions from the "conditions of use" definition, *see* ER 5, undermine TSCA's core aim to prevent unreasonable risks to health and the environment from toxic chemicals. *See* 15 U.S.C. §§ 2601(b), 2605(a)-(b). This statutory purpose is reflected both in the requirement that EPA regulate a chemical's use or disposal if either presents an unreasonable risk, and in EPA's broad authority to restrict "any manner or method" of a chemical's "use" or "disposal." *Id.* § 2605(a)(5)-(6). EPA's impermissible rewriting of the "conditions of use" definition will prevent it from making scientifically sound and health-protective decisions relating to priority designations and risk evaluations. Ongoing use and disposal of chemicals can pose significant risks that EPA must consider, even if the chemicals are no longer made, processed, or distributed for those uses.

EPA's ongoing risk evaluation of asbestos illustrates this point. Asbestos is no longer mined in the United States, few asbestos-containing products are still being imported, MA 111, and most asbestos-containing products are no longer being made, processed, or distributed. Yet large numbers of asbestos-containing products previously manufactured remain in use, including building materials such as insulation and flooring, and certain vehicle equipment. MA 114; *see also* MA 114-15 (identifying many discontinued asbestos-containing products with ongoing use and exposure, including floor tile, roofing felt, pipeline wrap, and more).

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Disposal of asbestos resulting from demolition, repair, or renovation of built structures or vehicle recycling is extensive, with disposal volumes totaling 25.6 million pounds in 2015. MA 116-17. Indeed, "the death rates from asbestos-caused diseases have remained constant," in part because of the "devastating health impact of asbestos in situ." ER 385. EPA's construction of "conditions of use" allows the Agency to ignore these health-threatening exposures in its risk evaluation. *See* MA 34 (Department of Health and Human Services urging EPA not to exclude "legacy uses" of asbestos, because such uses create "'new' hazardous exposure[s]" that pose significant risks to "fire fighters or building demolition [workers]").

Omitting ongoing use and disposal of chemicals no longer manufactured for those uses will also plague EPA's prioritization decisions. For example, when EPA considers whether to designate lead as high-priority, its analysis would be significantly under-inclusive if it omitted ongoing uses of lead-containing products—e.g., lead paint and lead-containing water pipes—that are no longer manufactured, but account for a substantial source of exposure to individuals. *See* 81 Fed. Reg. 60,304, 60,305 (proposed Sept. 1, 2016) (quoting CDC statement that "[l]ead-based paint and lead contaminated dust are the most hazardous sources of lead for U.S. children"); 56 Fed. Reg. 26,460, 26,470 (June 7, 1991) (contaminated drinking water contributes significantly to overall lead exposures); ER 699. EPA's

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erroneous omissions from lead's "conditions of use" would render its priority designation for lead grossly inadequate. Such omissions are at odds with the purposes of the 2016 TSCA amendments, which require consideration of populations with special vulnerabilities to chemicals, such as children.

C. EPA's contention that the "conditions of use" definition applies only prospectively is unreasonable

EPA's only justification for these categorical omissions is its specious contention that TSCA is "better interpreted to focus on the prospective flow of the chemical substance." ER 5.

First, as explained above, so-called legacy use, associated disposal, and legacy disposal are in fact ongoing and therefore prospective circumstances. *Supra* pp. 41-44.

Second, EPA's reliance on the passive infinitive phrase "to be" in the "conditions of use" definition is misguided. The definition plainly encompasses circumstances under which a chemical "is … *known* … to be … used, or disposed of." 15 U.S.C. § 2602(4) (emphasis added). The verb "to be" in this context describes a state of existence, i.e., that those circumstances of use and disposal are known to exist. For instance, lead pipes are "known to be used" in water distribution systems. This is true regardless of whether lead pipes continue to be manufactured or distributed.

Third, EPA's suggestion that it may have limited authority under TSCA to

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regulate use and disposal of discontinued products is both incorrect and irrelevant to the scope of risk evaluations conducted under section 6. ER 4. As discussed above, section 6(a) authorizes EPA to address risks from ongoing use and disposal of chemicals and products containing chemicals even in the absence of their ongoing manufacture, processing or distribution. 15 U.S.C. § 2605(a)(5)-(6).

Moreover, the possibility that EPA might identify an unreasonable risk that it lacks the tools to address, but that may be controlled by another agency, is not a valid reason to omit so-called legacy uses, associated disposal, and legacy disposal from risk evaluations and priority designations. TSCA section 9 expressly provides that, if EPA determines that a chemical presents an unreasonable risk that "may be prevented or reduced to a sufficient extent by action taken under a Federal law not administered by [EPA]," then EPA "shall" notify the other agency and ask whether the other agency will address the risk. *Id.* § 2608(a). The trigger for EPA to notify another agency under section 9(a) is a determination by EPA of unreasonable risk—a determination that can be made only *after* conducting a risk evaluation. *Id.* Congress thus anticipated that EPA's section 6(b) risk evaluations would include consideration of chemical exposures that may be most appropriately regulated by other agencies. EPA's approach would frustrate this deliberate statutory structure. *See supra* pp. 26-29.

Fourth, contrary to EPA's contention, *see* ER 5, the general presumption

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against construing a statute to be retroactive has no application to the question of statutory interpretation at issue. EPA's priority designations and risk evaluations do not "impair the rights a party possessed" in the past, "impose new duties with respect to transactions already completed," or impose any liability whatever. *See Landgraf v. USI Film Prods.*, 511 U.S. 244, 280 (1994).

In sum, considering the plain text of the "conditions of use" definition, the term's place in the statutory scheme, and TSCA's purposes, Congress unambiguously intended "conditions of use" to include ongoing and future uses and disposals of a chemical, even in the absence of ongoing manufacture, processing, and distribution for all or specific uses. EPA's categorical omission of so-called "legacy use," "associated disposal," and "legacy disposal" is unlawful and arbitrary. *See Chevron*, 467 U.S. at 842-43.

IV. The Framework Rules are inconsistent with EPA's obligation to base decisions on "reasonably available" information

TSCA requires EPA to consider all "reasonably available" information relating to a chemical when making prioritization decisions and conducting risk evaluations. 15 U.S.C. § 2625(k). The Framework Rules, however, preclude this consideration. The Prioritization Rule defines "reasonably available information" as "information that EPA possesses or can reasonably generate, obtain and synthesize for use, considering the deadlines … for prioritization and risk evaluation." 40 C.F.R. § 702.3; *id.* § 702.33 (same definition in Risk Evaluation

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Rule, but limited to risk evaluation deadlines). But the Rules include provisions that will prevent EPA from obtaining and developing the reasonably available information it needs—and is required to consider—to make legally and scientifically sound decisions under section 6. EPA also failed to consider how these provisions will inhibit its ability to develop needed information, "an important aspect of the problem." *State Farm*, 463 U.S. at 43.

A. The Risk Evaluation Rule will impermissibly chill the sharing of information by penalizing "incomplete" submissions by the public

Public participation plays a central role in EPA's efforts to obtain "reasonably available" information for risk evaluations. For example, EPA must provide notice of and allow public comment on draft risk evaluations. 15 U.S.C. § 2605(b)(4)(H); *see* 40 C.F.R. § 702.49(a). EPA also "encourage[s]" the public to provide comments and relevant information concerning manufacturers' requests for risk evaluations. 40 C.F.R. § 702.37(e)(4). Yet the Risk Evaluation Rule will deter public participation by placing commenters at peril of criminal punishment and civil penalties for submitting "incomplete" information. *Compare id.* § 702.31(d) (prohibiting "[s]ubmission to EPA of inaccurate, *incomplete*, or misleading information pursuant to a risk evaluation" (emphasis added)), *with* ER 73 (proposing penalties solely for incomplete submissions by manufacturers). This exceeds EPA's statutory authority and is unconstitutionally vague.

TSCA authorizes EPA to penalize only the "fail[ure] or refus[al] to comply

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with any requirement of [TSCA] or any rule promulgated, order issued, or consent agreement entered into" under the law. 15 U.S.C. § 2614(1). TSCA does not "require[]" members of the public to provide information to EPA. Thus, because 40 C.F.R. § 702.31(d) prohibits and threatens to penalize some voluntary information-sharing with EPA, it exceeds EPA's statutory authority and is invalid. *See City of Arlington v. FCC*, 569 U.S. 290, 297-98 (2013). It is also arbitrary and capricious for EPA to punish the public's submission of purportedly "incomplete" information, when the accumulated information EPA receives from individual commenters may well illustrate hazard or exposure patterns that would not come to light absent multiple submissions containing parts of the information. *Cf. NRDC, Inc. v. Pritzker*, 828 F.3d 1125, 1140 (9th Cir. 2016) (holding that agency acted contrary to law where it failed to consider how its choice to require "conclusive data" would result in underprotection of marine mammals by excluding potentially meaningful information).

In addition, by threatening members of the public with criminal and civil liability for providing incomplete information, section 702.31(d) runs afoul of the constitutional requirements of due process. A federal restriction violates due process protections when it is "so vague that it fails to give ordinary people fair notice of the conduct it punishes, or so standardless that it invites arbitrary enforcement." *Johnson v. United States*, 135 S. Ct. 2551, 2556 (2015). To

withstand scrutiny, section 702.31(d) requires the highest level of clarity because it touches on First Amendment activities of speech and petitioning the government, and subjects violators to criminal penalties. *Vill. of Hoffman Estates v. Flipside, Hoffman Estates, Inc.*, 455 U.S. 489, 498-99 (1982); *cf. Cal. Motor Transp. Co. v. Trucking Unlimited*, 404 U.S. 508, 510 (1972) (First Amendment protects petitioning).

Section 702.31(d) fails to meet this stringent standard. Members of the public and interested organizations, including Petitioners, would like to submit comments during EPA's TSCA risk evaluations. *Cf.* ER 442-80 (commenting on EPA's initial assessments under TSCA for three flame retardant clusters). But the Rule imposes criminal and civil liability for providing "incomplete" information, while providing no guidance regarding what would make a submission complete. That is unlawfully vague. *See State v. Mark Marks, P.A.*, 698 So. 2d 533, 534 (Fla. 1997) (statute criminalizing submission of "incomplete" demand letters is unconstitutionally vague for absence of guidance on meaning of "complete"); *cf. United States v. Crop Growers Corp.*, 954 F. Supp. 335, 345 (D.D.C. 1997) ("[W]here a statute or regulation imposes *no* duty whatever to disclose information, due process concerns require that criminal liability not be based on omission of such information." (citing *United States v. Murphy*, 809 F.2d 1427, 1431 (9th Cir. 1987))).

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The Rule's lack of clarity will not only subject individuals to arbitrary enforcement, it will "inevitably lead citizens to steer far wider of the unlawful zone … than if the boundaries of the forbidden areas were clearly marked." *See Grayned v. City of Rockford*, 408 U.S. 104, 109 (1972) (internal citations and quotation marks omitted). This chilling effect is unconstitutional. It will also undermine TSCA's intent by depriving EPA of information potentially relevant to its risk evaluations that would be "reasonably available," but for the vague threat of penalties.

Further, EPA did not consider the consequences of penalizing "incomplete" submissions, and did not even acknowledge that it had vastly expanded potential criminal liability as compared to the proposed rule. *See* ER 1-28. Imposing criminal and civil penalties without discussing these issues is arbitrary and capricious. *See Nat'l Parks Conservation Ass'n v. EPA*, 788 F.3d 1134, 1142-43 (9th Cir. 2015) (rejecting agency action where EPA did not "'cogently explain why it has exercised its discretion in a given manner'" (quoting *State Farm*, 463 U.S. at 48)).

B. The Framework Rules impermissibly use the factors in TSCA section 26(h) to screen, rather than weigh, information

The Risk Evaluation Rule also violates TSCA by limiting the information manufacturers must submit when requesting a risk evaluation to "[s]cientific information [that is] consistent with the scientific standards in 15 U.S.C. 2625(h)."

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40 C.F.R. § 702.37(b)(6). Section 26(h) requires that when EPA makes "a decision based on science," it must "consider as applicable" five factors to guide its decisions about the reliability of information. 15 U.S.C. § 2625(h). These factors include "the extent to which the information is relevant for [EPA's] use in making a decision about a chemical"; the "degree of clarity and completeness" with which the underlying data and analyses are documented; and "the extent to which the variability and uncertainty in the information … are evaluated and characterized." *Id.*

Section 702.37(b)(6) violates TSCA. It is both inconsistent with section 26(h) and contrary to section 26(k)'s mandate that EPA consider "reasonably available" information. *See* 15 U.S.C. § 2625(k).

First, section 702.37(b) impermissibly converts the section 26(h) considerations *EPA* must apply when weighing information into threshold requirements *manufacturers* must use to screen and limit the information they are permitted to submit to EPA. Nothing in the plain text of section 26(h) indicates that the factors are bright-line criteria for withholding information from EPA. To the contrary, each factor includes the phrase "degree of" or "extent to which," without identifying any threshold that would be disqualifying. This shows that Congress intended these factors to help EPA assess the weight information should be given based on its relative scientific reliability, not to create minimum

thresholds of reliability below which information must be withheld from EPA altogether. *Cf.* 15 U.S.C. § 2625(i) (directing EPA to make decisions "based on the weight of the scientific evidence"). EPA's conversion of these weight-of-the-evidence factors into a screening tool defies Congress's unambiguous intent.

Second, directing manufacturers to withhold information *the manufacturer decides* is not "consistent with" section 26(h) will prevent EPA from considering information relating to the chemical that is "reasonably available," in violation of section 26(k). For example, a manufacturer could decide that the documentation of "data, assumptions, … and analyses employed to generate the information" does not rise to the "degree of clarity and completeness," *id.* § 2625(h)(3), that makes it subject to disclosure under the Rule, 40 C.F.R. § 702.37(b)(6).[8] The withheld data, even if less than perfectly clear or complete, might have added to EPA's body of knowledge about the chemical. For this reason, section 702.37(b)(6) violates section 26(k)'s mandate that EPA consider reasonably available information. *Cf. Pritzker*, 828 F.3d at 1140 (rejecting agency's decision to rely on "screening criteria" that required "conclusive data" where such data were extremely difficult to obtain).

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[8] EPA provided no discernible standards for what it would mean for information to be "consistent with" "the degree of clarity" or any of these other weighing factors.

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The Prioritization Rule similarly incorporates an unlawful information screen. It states that during the prioritization process, EPA "expects to consider sources of information … consistent with the scientific standards in [section 26(h)]." 40 C.F.R. § 702.9(b). Just as EPA violated TSCA by directing manufacturers to withhold information that does not meet the section 26(h) "standards," EPA violated TSCA by erecting a "screen" that excludes some reasonably available information from EPA's prioritization process—rather than allowing EPA to weigh that information.

C. The Risk Evaluation Rule unlawfully and arbitrarily permits manufacturers to determine what information is relevant when requesting a risk evaluation

The Risk Evaluation Rule permits a manufacturer to withhold information critical to EPA's comprehensive evaluation of a chemical, if the manufacturer decides the information is not relevant to the specific conditions of use it is asking EPA to evaluate. Under the Rule, manufacturers must submit only "information that is relevant to whether the chemical substance, under the circumstances *identified by the manufacturer(s)*, presents an unreasonable risk." 40 C.F.R. § 702.37(b)(4) (emphasis added). This provision is contrary to TSCA and arbitrary and capricious.

To the extent the Rule allows EPA to limit risk evaluations to the conditions of use in the manufacturer's request, it rests on a faulty legal premise. As shown

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above, risk evaluations must address all of a chemical's conditions of use. *See supra* pp. 23-26. Without information on all conditions of use, EPA cannot conduct a full evaluation.

Allowing manufacturers to withhold information about chemicals also flouts the requirement that EPA base the requested risk evaluations on "reasonably available" information. 15 U.S.C. § 2625(k). Relevant information about a chemical's conditions of use in the manufacturer's possession is plainly "reasonably available." *Id.* Consistent with the proposed rule, ER 74, EPA must require manufacturers requesting risk evaluations to submit all such relevant information for all of a chemical's conditions of use.

The Rule is also arbitrary and capricious, for two reasons. First, EPA has given no justification for its choice to allow manufacturers to withhold information in their possession relevant to EPA's risk evaluations. *See Arrington v. Daniels*, 516 F.3d 1106, 1114 (9th Cir. 2008). Second, it is irrational to allow manufacturers to withhold relevant and reasonably available information from their risk evaluation requests, while requiring general public commenters to provide "complete" information or risk civil and criminal penalties. *See supra* pp. 52-55.

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D. EPA must consider during prioritization whether it has adequate information to conduct a risk evaluation

The Prioritization Rule does not require EPA to consider during the prioritization process whether it has adequate information about a chemical to conduct a risk evaluation; rather, EPA will consider only whether it has sufficient information "for purposes of prioritization" alone. 40 C.F.R. § 702.5(e); *see id.* § 702.5(b) (similar).[9] This limitation cannot be reconciled with the "reasonably available information" requirement. *See* 15 U.S.C. § 2625(k). By EPA's own definition, "reasonably available information" includes information EPA "possesses or can reasonably generate … considering [TSCA's] deadlines for prioritization *and risk evaluation*. 40 C.F.R. § 702.3 (emphasis added). Given this plain language, EPA's failure to consider what information it will need for risk evaluation during the prioritization phase violates TSCA and is arbitrary and capricious.

As a practical matter, it is important that EPA consider the information it needs for risk evaluation before beginning the prioritization process for a chemical. TSCA requires EPA to designate a chemical as low- or high-priority within twelve months of beginning the prioritization process, 15 U.S.C. § 2605(b)(1)(C). A high-

[9] In contrast, under the proposed rule EPA would have considered what information it needed for *both* prioritization and risk evaluation during the prioritization process. *See* ER 587.

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priority designation triggers further statutory deadlines for completing the risk evaluation. *See id.* § 2605(b)(3)(A), (b)(4)(G).

As EPA acknowledged in the proposed Rule, these deadlines may be too short for EPA to obtain needed information if it does not start gathering information before the risk evaluation commences. ER 583 ("EPA cannot assume that it will be able to require the generation of critical information during these time frames. … Tests necessary for risk evaluation, for example, could take months or years to develop and execute."). Analyzing certain hazards—such as developmental effects, neurotoxicity, and reproductive toxicity—typically requires longer-term testing; such information is particularly crucial to evaluate risks to vulnerable subpopulations such as infants, children, and pregnant women. *See* MA 653-56; *supra* p. 32; *cf.* ER 33 (noting that EPA may "need" to require "longer-term testing … to more completely consider the hazard characteristics and exposure pathways of a chemical").

Given the intertwined deadlines for prioritization and risk evaluation, if EPA does not consider the availability of information for risk evaluation before prioritization, EPA may be unable to obtain all "reasonably available" information that Congress required it to consider within the statutory timeframes. *See* 15 U.S.C. § 2625(k). This violates TSCA.

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V. Petitioners have standing

A. Petitioners have standing to bring this case on behalf of their members

Petitioners[10] have standing to challenge the Framework Rules on behalf of their members under the three-part test established in *Hunt v. Washington State Apple Advertising Commission*, 432 U.S. 333, 343 (1977). First, protecting their members from exposures to toxic chemicals is central to Petitioners' purposes. *E.g.*, PA 5-6, 43-45, 77-78, 206-11, 263-66, 384-86, 394-98, 424-29. Second, neither adjudication of the legal claims at issue nor the relief requested requires individual members' participation. *See Hunt*, 432 U.S. at 342-43.

Third, Petitioners' members would have standing to sue on their own behalf: EPA's unlawful approach to prioritization and risk evaluation injures the members by increasing the risk that they will suffer harm from exposure to toxic chemicals. *See NRDC, Inc. v. U.S. EPA*, 735 F.3d 873, 878-79 (9th Cir. 2013) (finding standing where organization showed a "credible threat" that members' children would be exposed to dangerous pesticide registered by EPA); *Cent. Delta Water Agency v. United States*, 306 F.3d 938, 948 (9th Cir. 2002) ("threat of injury" to

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[10] The membership-based Petitioners are: Alaska Community Action on Toxics, Alliance of Nurses for Healthy Environments, Cape Fear River Watch, Environmental Defense Fund, Environmental Health Strategy Center, Learning Disabilities Association of America, Natural Resources Defense Council, Sierra Club, Vermont Public Interest Research Group, United Steelworkers, and WE ACT for Environmental Justice.

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plaintiffs' crops from agency's planned water release schedule confers standing); *Hall v. Norton*, 266 F.3d 969, 976 (9th Cir. 2001).

1. Threat of harm from Risk Evaluation Rule

Petitioners' members experience a credible threat of health harms from ongoing exposure to chemicals that EPA is currently evaluating pursuant to the Risk Evaluation Rule, including asbestos, 1,4-dioxane, PERC, TCE, and HBCD. There is no doubt that Petitioners' members are exposed to these chemicals. *See, e.g.*, PA 200-03, 247-48, 294-96, 332-34. United Steelworkers' members, for instance, are exposed to asbestos when they repair, maintain, or replace equipment with asbestos-containing gaskets or insulation, and through the manufacture of chlorine and caustic soda in chlor-alkali plants. PA 387-88; *see* PA 518-23, 643-45. Cape Fear River Watch has members whose drinking water comes from a river with some of the highest documented levels of 1,4-dioxane contamination in the country, contamination that is not fully removed through water treatment. PA 62, 74; *see* PA 544-47. Alaska Community Action on Toxics' members are exposed to HBCD, which bio-magnifies in the arctic animals and fish that make up integral components of their diets. PA 15-18. The serious adverse health effects of each of these chemicals, even at low levels of exposure, are well established. PA 526, 616-21, 656-57, 680-83, 859-62.

These members face a credible threat, and reasonably fear, *NRDC v. U.S.*

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EPA, 735 F.3d at 878, that the flaws in EPA's Risk Evaluation Rule—e.g., exclusion of known or foreseeable exposures from risk evaluations, failure to make holistic risk determinations, deterring submission of all "reasonably available information"—will lead EPA to understate the risks posed by chemicals undergoing review. *See, e.g.*, MA 114-15 (excluding *in situ* uses of asbestos), 170 (excluding uses of 1,4-dioxane as a byproduct and impurity). If EPA understates risk, Petitioners' members will receive less protection than if the Rule complied with TSCA. *See, e.g.*, PA 18-23, 82-83, 212-15, 249, 273-76, 300-01, 329, 334, 387-91, 398-404. Although members attempt to remain vigilant to minimize their exposure, and incur costs to do so, they cannot completely avoid exposure to these chemicals. PA 39-40, 255-57, 291, 295-97, 332-33.

EPA's unlawful evaluation process thus threatens to increase the risk of members' exposure to chemicals like asbestos, HBCD, 1,4-dioxane, TCE, and PERC. These are exactly the types of risks Congress sought to reduce through TSCA, *see* 15 U.S.C. § 2601(b); *supra* pp. 6, 8, which "reinforc[es]" the conclusion that these injuries are cognizable for purposes of standing. *Baur v. Veneman*, 352 F.3d 625, 635 (2d Cir. 2003); *see also Covington v. Jefferson Cty.*, 358 F.3d 626, 638 (9th Cir. 2004).

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2. Threat of harm from Prioritization Rule

Petitioners' members are also reasonably concerned about the risks to their health from exposure to lead, a chemical not yet designated as high-priority, but included in the 2014 Workplan list of chemicals from which TSCA directs EPA to select high-priority chemicals. *See* ER 371. For example, members have credible concerns about their or their children's ongoing lead exposure through drinking water, household dust, and in occupational settings. PA 39-41, 251-53, 256-58, 325-29, 390-91, 420-22.

The cumulative, irreversible damage lead wreaks on the developing brains of children is undisputed. *See In re A Cmty. Voice*, 878 F.3d 779, 787 (9th Cir. 2017); PA 440-44. Especially at low levels of exposure, each additional exposure to lead can contribute to harming children's health. *See* PA 443. Adult lead exposure is also associated with adverse health outcomes. PA 444-45.

Because the Prioritization Rule allows EPA to omit conditions of use, including known, ongoing uses of lead, from its screening review, *see supra* pp. 42, 48-49; ER 31, EPA's designation of lead as high- or low-priority will not account for the full potential risk from lead. As a result, EPA's decision about whether lead "may present an unreasonable risk," including to vulnerable subpopulations like children and workers, will not conform to statutory requirements. *See* PA 277-82, 390-91, 433-34. If lead is not designated as high-

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priority, then EPA will not conduct an evaluation to determine whether lead presents an unreasonable risk that requires risk management under TSCA. Petitioners' members thus have reasonable concerns that if no risk evaluation is conducted for lead, they and their children will face an increased risk of ongoing harmful exposure.

Similarly, Petitioners' members are exposed to a variety of flame retardant chemicals, including polybrominated diphenyl ethers (PBDEs). PA 10, 80-83, 415-16. PBDEs are associated with cognitive and developmental harms in children. *See* PA 84-85, 268, 285-86. Several PBDEs are no longer produced or imported, but are still present in homes from so-called legacy uses. PA 83. Under the Prioritization Rule, EPA will ignore those uses and resulting exposures, and thus is more likely to designate these chemicals as low-priority despite PBDEs' well-recognized hazard and exposures.

3. These harms are traceable to the Framework Rules and redressable

Under the "relaxed" standards applicable here, these members' procedural injuries are traceable to the Framework Rules and will likely be redressed by a favorable decision by this Court. *See Cottonwood Envtl. Law Ctr. v. U.S. Forest Serv.*, 789 F.3d 1075, 1083 (9th Cir. 2015). Petitioners seek to enforce a statutorily required process for evaluating chemical risks, "the disregard of which could impair" their members' "separate concrete interest" in minimizing their exposure

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to harmful chemicals. *See Or. Nat. Desert Ass'n v. Dombeck*, 172 F.3d 1092, 1094 (9th Cir. 1998) (quoting *Lujan v. Defs. of Wildlife*, 504 U.S. 555, 572 (1992)); *see also Salmon River Concerned Citizens v. Robertson*, 32 F.3d 1346, 1355 (9th Cir. 1994) (finding causation and redressability where agency's deficient environmental analysis might cause environmental and health consequences to be overlooked).

A favorable decision by this Court would redress this injury, because it would compel EPA to assess chemical risks comprehensively, thereby requiring EPA to accurately determine whether a chemical presents an unreasonable risk and issue protective rules to eliminate any such risk. *See Idaho Conservation League v. Mumma*, 956 F.2d 1508, 1517-18 (9th Cir. 1992) (finding redressability where plaintiffs alleged that agency's failure to follow statutorily required procedures caused it not to recommend protecting wilderness areas, thereby opening the areas to future development); *see also N.Y. Pub. Interest Research Grp. v. Whitman*, 321 F.3d 316, 325-26 (2d Cir. 2003) (finding redressability where plaintiffs averred that Clean Air Act violations created uncertainties about whether plaintiffs were being exposed to harmful air pollution).

B. Petitioners have organizational and informational standing to challenge the Risk Evaluation Rule

Petitioners Environmental Working Group, Union of Concerned Scientists, Safer Chemicals Healthy Families, and Asbestos Disease Awareness Organization

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have standing because the organizations have suffered "both a diversion of [their] resources and frustration of [their] mission[s]." *Fair Housing Council of San Fernando Valley v. Roommate.com, LLC*, 666 F.3d 1216, 1219 (9th Cir. 2012) (internal quotation marks omitted). These organizations' missions will be frustrated by the Risk Evaluation Rule insofar as a core part of their work is providing their constituencies with accurate information about chemicals to which they are exposed. PA 52-54, 60, 229-31, 307; *see also* PA 364-65 (explaining that mission includes ensuring member-scientists have access to data). In this work, the groups and their members rely extensively on government information about the uses and health risks of chemicals, including information TSCA requires EPA to release. PA 59-60, 225, 344-47; 15 U.S.C. § 2605(b)(4)(C) (requiring EPA to "publish" final risk evaluations). TSCA aims to develop "adequate information" about the effects of chemicals on health and the environment, 15 U.S.C. § 2601(b)(1), and to "increase access" to that information, H.R. Rep. No. 114-176, at 16.

Because the Risk Evaluation Rule unlawfully allows EPA to exclude conditions of use and ignore the combined exposure from multiple uses of a chemical, the information it publishes concerning a chemical's "hazards and exposures" will be incomplete. *See* 15 U.S.C. § 2605(b)(4)(F)(i). This will frustrate these Petitioners' missions of creating and distributing accurate,

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comprehensive educational materials about chemical risks.

Instead of relying on EPA, the groups and their members will be forced to "expend additional resources that they would not otherwise have expended" on new research and data collection to close gaps in the government's data. *See* PA 230-31, 345-47. These injuries give rise to organizational standing. *See Nat'l Council of La Raza v. Cegavske*, 800 F.3d 1032, 1040 (9th Cir. 2015); *Am. Canoe Ass'n v. City of Louisa Water & Sewer Comm'n,* 389 F.3d 536, 544-47 (6th Cir. 2004); *Fair Housing Council*, 666 F.3d at 1219.

In addition, the Risk Evaluation Rule will prevent Petitioners and their members from "obtain[ing] information which must be publicly disclosed pursuant to the statute." *See Fed. Election Comm'n v. Akins*, 524 U.S. 11, 20-21 (1998); PA 21, 59-60, 75, 223-28, 281-82, 343-47, 385, 400-01. This informational injury also gives rise to standing. *See Friends of Animals v. Jewell*, 824 F.3d 1033, 1041 (D.C. Cir. 2016).

CONCLUSION

Petitioners respectfully request that this Court grant the petitions for review and set aside these rules "in part." 15 U.S.C. § 2618(c)(2). Vacatur, along with remand, is the presumptively appropriate remedy here. *See Cal. Wilderness Coal. v. U.S. Dep't of Energy*, 631 F.3d 1072, 1095 (9th Cir. 2011). Petitioners request that the Court vacate and remand the following provisions of the Framework

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Rules: 40 C.F.R. §§ 702.5(b), (e), 702.7(a), 702.9(b)-(c), (f), 702.31(d), 702.37, 702.41(a)(5), (a)(7)-(9), (b)(2), (c)(1), (c)(4)(i), (c)(4)(iii), (d)(2), 702.43(a)(1), 702.47, 702.49(b)(1), (c), (d), and the following portions of the preambles: Prioritization, IV.B (ER 31), IV.J (ER 34-34), and Risk Evaluation, III.B (ER 3-6), III.G (ER 10-13), III.H.1.d-e (ER 14-15), III.H.2 (ER 15-16), III.I.1 (ER 16), and III.I.6 (ER 19). Petitioners also respectfully request that the Court issue declaratory relief that TSCA requires priority designations and risk evaluations to consider all circumstances within the statutory definition of conditions of use.

April 16, 2018

Respectfully submitted,

/s/ Sarah C. Tallman

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STATEMENT OF RELATED CASES

Petitioners are unaware of any related cases within the definition of Circuit Rule 28-2.6.

Dated: April 16, 2018

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CERTIFICATE OF COMPLIANCE

This brief complies with the type-volume limitation of Fed. R. App. P. 32(a)(7)(B) because it contains 15,332 words, excluding the parts of the brief exempted by Fed. R. App. P. 32(a)(7)(B)(iii). This brief complies with the typeface requirements of Fed. R. App. P. 32(a)(5) and the type style requirements of Fed. R. App. P. 32(a)(6) because it has been prepared in a proportionally spaced typeface using Microsoft Office Word 2016 and 14-point Times New Roman font.

Dated: April 16, 2018

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CERTIFICATE OF SERVICE

I hereby certify that I electronically filed the foregoing with the Clerk of the Court for the United States Court of Appeals for the Ninth Circuit by using the appellate CM/ECF system on April 16, 2018.

I certify that all participants in the case are registered CM/ECF users and that service will be accomplished by the appellate CM/ECF system.

Dated: April 16, 2018

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ED_005636_00001081-00116

Exhibit 2

IN THE UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

SAFER CHEMICALS, HEALTHY FAMILIES et al., *Petitioners,* v. U.S. ENVIRONMENTAL PROTECTION AGENCY et al., *Respondents.* IPC INTERNATIONAL, INC. et al., *Respondents-Intervenors.*	Docket No. 17-72260 Consolidated with Docket Nos. 17-72501, 17-72968, 17-73290, 17-73383, 17-73390

DECLARATION OF PATRICIA D. KOMAN, PH.D., M.P.P.
IN SUPPORT OF PETITIONERS' OPENING BRIEF

I, PATRICIA D. KOMAN, do hereby affirm and state:

Introduction and Qualifications

1. I am a Research Investigator and Scientist at the University of Michigan School of Public Health, Environmental Health Sciences Department. In that role, I am responsible for conducting scientific research regarding how environmental contaminants affect human health. I am also the President and Senior Health Scientist at Green Barn Research Associates, Ann Arbor, Michigan. As a public health professional, I apply my scientific methods to study the effects of environmental and social factors on health.

2. I earned a Ph.D. (2016) in Environmental Health Sciences from the University of Michigan, School of Public Health, in Ann Arbor, Michigan. I earned a masters degree in public policy (1994) from the University of California at Berkeley. I earned a bachelors of arts with distinction, *Phi Beta Kappa* (1988), from the University of Virginia, Charlottesville, Virginia.

3. I have worked at the University of Michigan as a scientist since 2012. My work at the university is focused on the link between chemicals in our environment—including air pollutants, water contaminants, and consumer and industrial products—and human health, with a particular emphasis on vulnerable populations.

4. Previously, for 22 years, I served as a senior environmental scientist and program manager at the U.S. Environmental Protection Agency (EPA). There I conducted risk assessments and evaluated scientific literature about how the environment affects health from a variety of sources. I was awarded the Administrator's Award for Excellence for my health impact assessments and methodological advances. I have authored government reports with peer-reviewed methodologies. I earned four Gold Medals for exceptional service.

5. I have published articles in peer-reviewed scientific journals, including articles on the identification of vulnerable populations for protection from harm through health-based standards. I have authored numerous government

reports, such as Reports to Congress, *Federal Register* notices, staff summaries of scientific data (staff paper) and regulatory impact assessments.

6. I have presented testimony and comments to state and federal agencies on the regulation of toxic chemicals. I have organized and participated as an expert in educational programs with experts on chemical policy (including 1,4-dioxane) at the University of Michigan and the American Public Health Association annual meeting.

7. I have been invited by the State of Michigan Department of Environmental Quality to provide scientific input on hazardous chemical clean-up criteria and lead in drinking water issues related to the Flint water crisis. I managed an environmental educational program regarding water quality, with over 1,000 contacts with Flint residents and middle school students.

8. A more complete description of my educational and work experience, as well as a complete list of my publications, is attached to this declaration as Exhibit A.

9. By virtue of my training, experience, and knowledge of the pertinent scientific literature, I am considered by my peers as an expert in the public health impacts and sources of exposure to 1,4-dioxane.

10. All of the information set forth in this declaration is based upon my education, personal knowledge, experience, and my personal review of the

pertinent literature, including the documents listed as references at the end of this declaration.

Sources and Uses of 1,4-Dioxane (CASRN: 123-91-1)

11. 1,4-Dioxane is a chemical that contains four carbon atoms and two oxygen atoms in a ring.

12. 1,4-Dioxane is an industrial solvent manufactured in large quantities (up to 10 million lbs/year) for numerous industrial, commercial, and consumer uses. (Agency for Toxic Substances and Disease Registry 2012; Integrated Risk Information System 2013). In industrial use, 1,4-dioxane is a byproduct (a chemical formed as an incidental result) in manufacturing processes involving ethylene oxide, such as the production of the common plastic polyethylene terephthalate (PET), polyester, and ethyoxylated surfactants. The hazards posed by 1,4-dioxane are identical whether it is produced intentionally or as a byproduct.

13. 1,4-Dioxane is used as both a laboratory reagent and as an ingredient in the manufacture of a second industrial chemical (e.g., as an intermediate, an extraction medium for fats and oils, and as part of a polymerization catalyst that speeds up a chemical reaction). 1,4-Dioxane is also used in a wide variety of commercial and consumer products, including personal care products, detergents, waxes, and antifreeze. Other uses of 1,4-dioxane documented in Europe include commercial and consumer products such as lacquers, varnishes, paint strippers,

dyes, greases, cleaners and detergents, adhesives, cosmetics and deodorants (ECJRC 2002).

14. 1,4-Dioxane is also present as a contaminant in cosmetics, detergents, shampoos, pharmaceuticals, foods, agricultural and veterinary products and ethylene glycol-based antifreeze coolants, because it is a byproduct of manufacturing involving ethylene oxide (Agency for Toxic Substances and Disease Registry 2012). Although in the U.S. many manufacturers remove 1,4-dioxane through vacuum stripping in consumer cosmetics and household products, the U.S. Food and Drug Administration has stated 1,4-dioxane is still present in significant amounts in some products (ATSDR, 2012). In addition, tests conducted by the Campaign for Safe Cosmetics document concentrations of 1,4-dioxane in children's and adult bath products (Campaign for Safe Cosmetics, 2007). Products found to contain 1,4-dioxane include shampoo, conditioner, liquid hand soap, body wash, skin moisturizer, and baby lotion (Environment Canada, 2010).

15. The use and disposal of 1,4-dioxane in the past has led to environmental contamination that is contributing to ongoing exposures. Because 1,4-dioxane had been widely used as a stabilizer in certain chlorinated solvents, 1,4-dioxane is frequently found within groundwater contaminated with chlorinated solvents (Adamson et al. 2014; Knappe, D. Lopez-Velandia, C. Hopkins, Z. Sun 2016).

16. As of 2016, 1,4-dioxane had been identified at more than 34 sites on the EPA National Priorities List, the list of hazardous waste sites eligible for remediation under the federal Superfund program; it may be present (but samples were not analyzed for it) at many other sites (EPA 2016b).

17. These uses described in Paragraphs 12 through 16 above have led to widespread 1,4-dioxane exposure in the United States.

Environmental Fate and Transport

18. 1,4-Dioxane dissolves quickly and easily in water and is persistent. 1,4-Dioxane leaches readily from soil to groundwater, is miscible in water (meaning it dissolves completely), migrates rapidly in groundwater. In groundwater, 1,4-dioxane forms the leading edge of a pollution plume and travels much faster, farther, and more widely than other volatile organic compounds. Thus, 1,4-dioxane can rapidly reach drinking water or enter house basements through soil or groundwater intrusion, for example, contributing to exposures often before other pollutants are detected.

19. 1,4-Dioxane has been used at many industrial and federal facilities like military bases because of its widespread utility with other solvents.

20. Improper disposal or storage has caused 1,4-dioxane spills at military, defense contracting, and other industrial facilities (Integrated Risk Information

System 2013). Based on this history, unintentional releases and spills are reasonably foreseeable wherever the chemical is widely used.

Human Exposure to 1,4-Dioxane

21. As described below, human exposure to 1,4-dioxane is widespread as a result of its wide variety of uses. People come into contact with this substance through: drinking water, personal care products, household products, cosmetics, and occupational exposures, among other sources.

22. In the United States, humans are exposed to 1,4-dioxane primarily through ingestion of contaminated water and food and dermal contact with consumer products (Agency for Toxic Substances and Disease Registry 2012; ECJRC 2002; DHHS 2017).

23. Worker exposures include inhalation of vapors, skin absorption, ingestion, and skin and/or eye contact (Agency for Toxic Substances and Disease Registry 2012; ECJRC 2002; DHHS 2017; NIOSH 2010). The National Occupational Exposure Survey (conducted from 1981 to 1983) estimated that 430,000 workers, including 149,697 women, potentially were exposed to 1,4-dioxane (Boiano and Hull 2001; NIOSH 1990). Exposures occur during the production and use of 1,4-dioxane as a stabilizer or solvent (Agency for Toxic Substances and Disease Registry 2012; ECJRC 2002; DHHS 2017).

24. Exposures of 1,4-dioxane via drinking water are widespread and are documented back to the 1980s (Dietrich, A.M., D.S. Millington 1983; Stanton 2016; MDEQ 2018).

25. According to EPA's Toxic Release Inventory for 2014, 96,437 pounds of 1,4-dioxane were released to the air, 24,262 to surface water, and 422,943 pounds were transferred from the facility for off-site disposal (US EPA TRI Explorer, Release Chemical Report database, available at https://iaspub.epa.gov/triexplorer/tri_release.chemical). Total annual environmental releases of 1,4-dioxane reported by EPA's Toxics Release Inventory from 1988 to 2009 ranged from 0.3 million to 1.3 million pounds (DHHS 2017).

26. Based on drinking water sampling conducted under the direction of EPA, a significant portion of the municipal drinking water systems in the United States have 1,4-dioxane at levels associated with increased risk of serious health problems. Specifically, 2017 results from EPA's Third Unregulated Contaminant Monitoring Rule (UCMR3 at https://www.epa.gov/sites/production/files/2017-02/documents/ucmr3-data-summary-january-2017.pdf) indicate that over 6.9% of 4,905 public drinking water systems serving >10,000 people had concentrations of 1,4-dioxane above the EPA Reference Concentration of 35 micrograms/L, which signifies these populations could be likely to experience appreciable risk of deleterious effects (US

Environmental Protection Agency 2009; Integrated Risk Information System 2013).

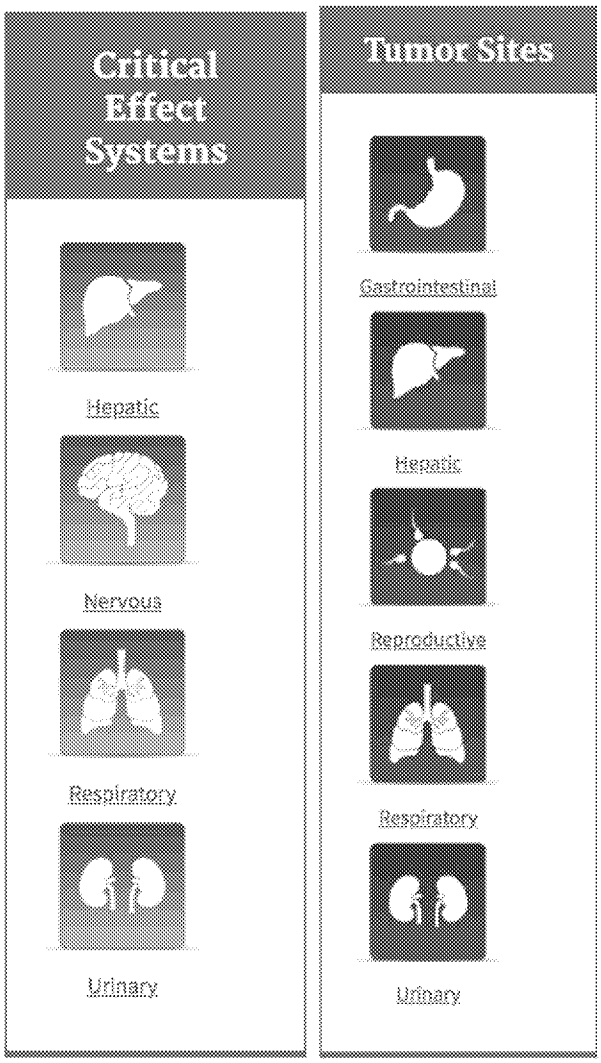
27. The EPA testing omits small public drinking water systems (i.e., systems serving <10,000 people), which account for about 27% of the U.S. Population (US Environmental Protection Agency 2017). Private wells are also not included in EPA's testing. Therefore, the UCMR3 results underestimate potential exposures (Sun, Lopez-Velandia, and Knappe 2016).

28. 1,4-Dioxane is present in a wide variety of consumer products, including household detergents, cosmetics/ toiletries, and foods (Integrated Risk Information System 2013). Based on an analysis of the ingredients in 15,000 cosmetic and other personal-care products, 22% of all such products may contain 1,4-dioxane (EWG 2017). Dermal contact is a relevant route of exposure. Cosmetics and personal care products have the potential to contribute significantly to exposures, since people are applying them directly to their bodies, often multiple times per day, every day (DHHS 2017).

Human Health Effects of 1,4-Dioxane

29. As described below, 1,4-dioxane is readily absorbable; distributes rapidly through the body, is likely to cause cancer in humans by all routes of exposure; and is associated with adverse reproductive effects. Long-term exposure to 1,4-dioxane may cause kidney and liver damage. Short-term exposure to high

levels of 1,4-dioxane may result in nausea, drowsiness, headache, and irritation of the eyes, nose and throat. The graphic below taken from the IRIS program summarizes for 1,4-dioxane exposure the four critical effect systems and the five tumor sites.



Summary of Critical Effect System and Tumor Sites for 1,4-Dioxane Exposure

Source: US EPA IRIS Program 2013

30. 1,4-Dioxane is readily absorbed through the lungs and gastrointestinal tract (Integrated Risk Information System 2013).

31. Distribution is rapid and uniform in the lung, liver, kidney, spleen, colon and skeletal muscle tissue (Agency for Toxic Substances and Disease Registry 2012).

32. 1,4-Dioxane is a likely human carcinogen. EPA has classified 1,4-dioxane as "likely to be carcinogenic to humans" by all routes of exposure (Integrated Risk Information System 2013). The U.S. Department of Health and Human Services (DHHS) states that 1,4-dioxane is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals (DHHS 2014). The National Institute for Occupational Safety and Health (NIOSH) considers 1,4-dioxane a potential occupational carcinogen (NIOSH 2010).

33. Short-term exposure to high levels of 1,4-dioxane may result in nausea, drowsiness, headache, and irritation of the eyes, nose and throat (Agency for Toxic Substances and Disease Registry 2012; Integrated Risk Information System 2013; NIOSH 2010; ECJRC 2002). An important feature of the scientific studies is a finding of consistent positive results in more than one type of animal model, which increases confidence in the results. Four inhalation studies in animals were identified in the literature; two, 13-week subchronic studies in laboratory animals (Kasai et al. 2009; Fairley, A; Linton, EC; Ford-Moore 1934) and two, 2-year chronic studies in rats (Kasai et al. 2009; Torkelson et al. 1974). Nasal, liver,

and kidney toxicity were the primary noncancer health effects of inhalation exposure to 1,4-dioxane in rodents.

34. 1,4-Dioxane is weakly genotoxic and its reproductive effects in humans are unknown; however, a developmental study on rats indicated that 1,4-dioxane may be slightly toxic to the developing fetus (Agency for Toxic Substances and Disease Registry 2012; Giavini, Vismara, and Broccia 1985). Studies in animal models have also reported that relatively high doses of 1,4-dioxane (1,000 mg/kg-day) during gestation can produce reduced fetal birth weights, which is an important marker for future health (Giavini, Vismara, and Broccia 1985).

35. Chronic studies reported the most sensitive effects in the liver and kidney in male Sherman rats from a high quality 2-year drinking water study (Kociba et al. 1974).

36. Long-term exposure to 1,4-dioxane may cause kidney and liver damage. (Agency for Toxic Substances and Disease Registry 2012; Integrated Risk Information System 2013; ECJRC 2002).

37. Due to concerns about the demonstrated serious health effects of 1,4-dioxane, 18 state health-based drinking water guidance values and federal occupational exposure limits have been established. EPA's IRIS database includes a chronic oral reference dose (RfD) of 0.03 milligrams per kilogram per day

(mg/kg/day) based on liver and kidney toxicity in animals, and a chronic inhalation reference concentration (RfC) of 0.03 milligrams per cubic meter (mg/m^3). (Integrated Risk Information System 2013). A chronic oral reference dose is a risk assessment benchmark or estimate of a daily oral dose to the human population (including accounting for sensitive subgroups and uncertainty) that is likely to be without an appreciable risk of deleterious non-cancer effects during a long-term period. A reference concentration is a similar risk assessment benchmark, referring to inhalation exposures.

38. Thus, people are exposed to 1,4-dioxane through multiple pathways including contaminated water, food, personal care products, and occupational exposures. The evaluation of the risks posed by these exposures must take into account the totality of those aggregate exposures in order to follow appropriate scientific procedures (National Academies of Sciences 2017; National Research Council 2009). Assessment of cumulative environmental exposures (e.g., to other chemicals) would also be recommended.

Conclusion

39. In my scientific opinion, 1,4-dioxane exposure may result in serious and in some cases permanent adverse health consequences for humans. These health effects are a cause for concern for current levels of 1,4-dioxane exposures. People are currently exposed via oral ingestion, inhalation and (to a lesser amount)

dermal contact pathways. Importantly, the risks posed by 1,4-dioxane are identical whether it is present by design or as a byproduct or contaminant. To fully assess the risks from 1,4-dioxane, a full consideration of the aggregate exposures must be undertaken.

Dated: April 13, 2018

Patricia Koman, Ph.D., MPP

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Exhibit A

to the Declaration of Patricia D. Koman, Ph.D., M.P.P.,
in Support of Petitioners' Opening Brief

Patricia D. Koman

524 3rd Street
Ann Arbor, MI 48103

tkoman@umich.edu
734-474-4711

Education

Doctor of Philosophy August 2016	University of Michigan, School of Public Health, Ann Arbor Environmental Health Sciences
Master of Public Policy May 1994	Graduate School of Public Policy, University of California, Berkeley
B.A. with Distinction May 1988	University of Virginia, Chemistry and Philosophy, *Phi Beta Kappa*; Louis Hammond Prize; Raven Society; Echols Scholar; Alpha Epsilon Delta science honorary society

Professional Experience

University of Michigan, School of Public Health, Ann Arbor, MI

(September 1, 2012 – present)

Research Investigator, Environmental Health Sciences (October 1, 2016 – present)
Interim Managing Director, Risk Science Center (September 1, 2016 – August 30, 2017)
Senior Project Manager, Dean's Office and Environmental Health Sciences Department (September 1, 2012 – August 31, 2016)

- Trained, mentored and developed scientists, faculty, and community members nationwide to communicate scientific data including evaluating epidemiologic studies with a variety of designs in regulatory decisions; team recommendations to Agency executives have been accepted, resulting in new research priorities, discussion in *Federal Register* records of decisions of additional data, and new and deeper involvement of medical sector stakeholders in environmental issues
- Initiated and led first School of Public Health (SPH) multi-disciplinary community-engaged project with Michigan Engaging Community Through the Classroom (MECC); co-investigator on three grants including 5-year $938,000 UM Third Century Transformative Learning grant for interdisciplinary engaged learning
- Conducted longitudinal secondary analysis of cohort data to examine the association between air pollution exposures with pulmonary function; performed an exposure assessment to assign air quality measurements to individual participants based on residential history and exam date; examined effect modification by obesity status of the relationship between air pollution exposure and lung function
- Principal investigator for MI-Environment cumulative environmental exposure vulnerability mapping and wildfire and health grants
- Developed environmental education curriculum and evaluation; as part of community-participatory process assisted with training of over 900 Flint residents about water quality and the drinking water system
- Led statewide training needs assessment of environmental health professionals to prepare public health workforce and target Michigan Public Health Training Center national course offerings, resulting in improved customer service competencies and skill in communicating complex issues to decision makers
- Provided expert consultation and testimony

- Michigan Department of Environmental Quality (MDEQ) Expert Panel to review water quality data from the city of Flint and recommendations with Michigan Governor Snyder's Flint Water Interagency Coordinating Council (FWICC) (2016- present)
- SPH Dean's Practice Advisory Committee (2012-2016)
- MDEQ technical advisory group for hazardous chemical clean-up standards (2013-14)

U.S. Environmental Protection Agency (June 1991 – August 30, 2012)

Environmental Scientist, Program Manager and Supervisor

- Office of Transportation and Air Quality, Ann Arbor, MI (2001 – August 30, 2012)
- Office of Air Quality Planning and Standards, Durham, NC (1994 – 2001)
- Region 9 Office, San Francisco, CA (June 1991 – 1994)

- Program Manager for Clean Ports USA: Achieved significant public health benefits by leading teams to reduce diesel emissions at U.S. seaports; in 5 years grew initiative to $100 million EPA grant program with projects on every coast and significant private investment
  - Developed Agency-wide multi-media marine ports strategy and budget request with EPA Administrator and Regional Administrators; communicated complex risk and exposure information to executives
  - Improved performance of 15-person cross-Agency multi-disciplinary team by creating new vision, managed operations and marketing campaign including web and print; supported 20 press announcements by top EPA executives and U.S. Senators; improved procedures for $125,000 public and technical information line to better communicate meaningful data to public
  - Forged key relationships with maritime industry, state and local agencies and other federal partners; developed regional networks by hosting technology conferences across the country; supported Agency executives' development of strategic plan in U.S., Taiwan, Panama and China
  - Initiated $2 million 6-party international partnership to develop prototype hydraulic hybrid yard hostler featuring EPA-patented technologies; displayed vehicle at international meetings by EPA Administrator; prototype tested in commercial service achieving emissions and fuel savings
  - Brought group to consensus over significant barriers as co-chair of Federal advisory workgroup under Mobile Source Technical Review Subcommittee
- Team leader of Implementation Strategies team responsible for budget formulation, communications and project implementation of the National Clean Diesel Campaign, developed web site with 80,000 hits and 40,000 copies of brochures describing health impacts of programs in the hands of clients each year; Charter developer of Clean School Bus USA nationwide public-private $150 million partnership measurably improving children's health

- Principal author of first Diesel Emissions Reduction Program Report to Congress; interpreting new legislative mandates; managed operations and improved software and web platform development of database to track, evaluate, and publicize projects; developed team with junior staff through coaching

- Program manager for multi-disciplinary scientific team conducting benefit-cost assessments of health and environmental improvements from major federal mobile source policies; authored air quality and public health justification for major rulemakings that withstood court challenges; worked with scientific advisory boards
  - Convened and led multi-disciplinary teams with annual budgets in excess of $500,000 to deliver complex modeling tasks on-time and under budget for Clean Air Act regulation of diesel emissions from heavy duty vehicles, nonroad equipment, and marine vessels while improving assessment methods and guiding research

- Principal author and team leader of landmark national air pollution standards for fine particulate matter under court ordered schedule; led 20-person multi-disciplinary scientific team and managed $1 million budget; analysis served as basis for policy that survived challenge to U.S. Supreme Court and became a top national priority for the EPA over the ensuing decade; required extensive evaluation of epidemiologic and air quality data

- As Air Toxics Center Director, supervised 11 engineers and specialists; managed all aspects of major Clean Air Act rulemaking; formulated and managed center's annual budget and resource request for 5-year plan

- As Coatings and Consumer Products Group Manager, supervised 12 engineers and Ph.D. scientists; responsible for personnel actions, health & safety and security policies for employees; managed all aspects of regulatory development and technical support for 28 new Clean Air Act actions; managed $2.3 million budget; advised senior management and prepared EPA witnesses for Congressional hearings; represented office to key stakeholders; briefed Congressional staff and the Office of Management and Budget staff; managed response to comment on six volume Report to Congress; interpreted legislation for first national rulemaking

SRI International, Research Analyst, Menlo Park, CA (1990 – 1991)
Conducted competitive assessments to create corporate strategies regarding environmental issues

ICF Incorporated, Analyst, Washington, DC (1988 – 1990)
Analyzed economic and technical impacts of broad array of environmental programs

Professional Honors and Awards

2017 National Center for Atmospheric Research Weather, Climate and Health Workshop Travel Scholarship
2017 University of Michigan "Road Scholar" Participant
2016 American Public Health Association Leadership Challenge Winner
2016 University of Michigan Graham Institute Dow Distinguished Interdisciplinary Sustainability Award
See for Yourself: What's in Your Water? Model Building
2015 University of Michigan Provost Teaching Innovation Prize
Michigan Engaging Community Through the Classroom (MECC)
2015 University of Michigan Graham Institute Dow Distinguished Interdisciplinary Sustainability Award
MI-Environment: Heat Stress Vulnerability Mapping
2014 University of Michigan, School of Public Health, Risk Science Fellowship
2014 University of Michigan Graham Institute Dow Distinguished Interdisciplinary Sustainability Award
MECC, Willow Run
2013 U.S. Health Resources and Services Administration and Association of Schools and Programs of Public Health "Promising Practice" recognition for MECC collaborative project teaching innovation
2012 Toastmasters International, Advanced Leadership – Silver
2011 Toastmasters International, Advanced Communication - Silver
2006 U.S. Environmental Protection Agency (EPA) Administrator's Award for Excellence
Economic Benefit Assessment Method Development
2007 U.S. EPA Gold Medal for Exceptional Service, Clean Diesel Initiative Team
2005 U.S. EPA Gold Medal for Exceptional Service, Clean Air Nonroad Diesel Rule Team
2004 U.S. EPA Silver Medal for Superior Service. Economic Benefits Methods Development
2003 U.S. EPA Bronze Medal for Commendable Service
2002 U.S. EPA Gold Medal for Exceptional Service, Heavy Duty Diesel Engine and Fuel Rule Team
2002 U.S. EPA Bronze Medal for Commendable Service
2001 U.S. EPA Role Model Award
1999 U.S. EPA Bronze Medal for Commendable Service
1998 U.S. EPA Gold Medal for Exceptional Service, Particulate Matter National Ambient Air Quality Standards
1997 U.S. EPA Bronze Medal for Commendable Service, Particulate Matter National Ambient Air Quality Standards Staff Paper

Grants

ACTIVE

1. University of Michigan Graham Institute Catalyst Grant. Atmospheric Modeling in Human Health & Climate Change Risk Assessment: Wildfire Smoke Exposures, $10,000 Principal Investigator (2017)

2. U.S. Environmental Protection Agency Environmental Education Grant, See for Yourself: What's in Your Water? Flint, Michigan $122,333, program manager and grant writer (2016-2017, PI Dvonch)

3. NIH/NIEHS Michigan Life Stages Environmental Exposures & Disease, NIEHS Center grant P30ES017885, University of Michigan, Co-Investigator, Integrated Health Sciences Core (2016, 5-year grant, PI Loch-Caruso)

4. University of Michigan, Third Century Transformative Learning Grant, Michigan Engaging Community Through the Classroom, $938,000 Co-Investigator (2015, 5-year grant, PI Norton)

COMPLETED

1. NIH/NIEHS Michigan Life Stages Environmental Exposures & Disease, NIEHS Center grant P30ES017885, University of Michigan, Pilot Grant: Climate and cardiopulmonary health: Does excess weight enhance risk? $5,600, Principal Investigator (2017)

2. NIH/NIEHS P30 ES017885 Community Outreach and Engagement Core (COEC) Supplement, 16-PAF08052, Environmental Justice Academy $100,000, Co-Investigator (2016, PI Schulz)

3. NIH/NIEHS Pilot grant, Michigan Life Stages Environmental Exposures & Disease P30ES017885, MI-Environment: Promoting Climate-Related Health within Michigan's Vulnerable Communities, $9,342 Co-Investigator (2016, PI Sampson)

4. University of Michigan, Graham Institute, Distinguished Interdisciplinary Sustainability Award, See for Yourself: What's in Your Water model development pilot, $5,000 Co-Investigator (2016, PI Olson)

5. University of Michigan President Fund, See for Yourself: What's In Your Water? Model Building, $3,600 Co-Investigator (2016, PI Daigger)

6. University of Michigan, Arts of Citizenship Award, MI-Environment: Hazard Proximity in Kent County, Michigan, $8,500 Principal Investigator (2015)

7. University of Michigan, Rackham Graduate Doctoral Candidate Award, $3,000 Principal Investigator (2015)

8. University of Michigan, Graham Institute, Distinguished Interdisciplinary Sustainability Award, MI-Environment: Climate Change and Heat Stress Vulnerability, $5,000 Co-Investigator (2015 PI O'Neill)

9. University of Michigan, Graham Institute, Distinguished Interdisciplinary Sustainability Award, Michigan Engaging Community Through the Classroom: Willow Run, $8,000 Co-Investigator (2014, PI Kellbaugh)

10. Michigan Public Health Training Center, Pilot Collaborative Project, Michigan Engaging Community Through the Classroom, $8,500 Principal Investigator (2013)

11. Rackham Graduate Student Award, University of Michigan, $1,500 Principal Investigator (2013)

Peer-Reviewed Publications

Koman PD, Mancuso P. 2017. Ozone exposure, cardiopulmonary health, and obesity: a substantive review. Chem. Res. Toxicol. acs.chemrestox.7b00077; doi:10.1021/acs.chemrestox.7b00077. ISSN 0893-228X. PMID 28574698 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5556919

Koman, P.D. K. Hogan, R. Mandell, N. Sampson, C.M. Coombe, Y. Hill-Ashford, M.M. Tetteh, D. Wilkins, R. Loch-Caruso, A. J. Schulz, T Woodruff. Air Pollution Exposure and Susceptibility of Pregnant Women: Disparities in Public Health Protection under the Clean Air Act (*Revision under review*)

Koman, P.D., J. Lam, T.J. Woodruff. The Promise and Perils of the Lautenberg Chemical Safety Act. (*Invited commentary manuscript, preparing resubmission)*

Norton, R.K., N.P. David, S. Buckman, **P.D. Koman**, Land Use Planning for Climate Change Adaptation on the Laurentian Great Lakes (*Revision under review*)

R.K. Norton, R. K., P. Fontaine, E.R. Gerber, G. Hohner, **P.D. Koman.** Pulling Aside Professional Blinders to Better Tackle Wicked Problems Through Multidisciplinary Community-Service Learning (*Revision under review*)

Manuscripts in Preparation

Koman, P.D., S.K. Park, C. Gronlund, D.J. Jacobs, Jr., P. Gordon-Larsen, P. Mancuso, M. O'Neill, Long-term Particulate Matter and Ozone Exposure and Pulmonary Function: Does Excess Weight Increase Risk? (Approved via CARDIA publication committee for submission, *manuscript in preparation*)

Koman, P.D., F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, R Goodspeed, M.S. O'Neill, A.J. Schulz. MI-Environment: Heat Stress Vulnerability in Michigan Communities (*Manuscript in preparation)*

French, NH, M Billmire, JT Dvonch, S Hoshiko, J Hutchninson, **P.D. Koman**, MS O'Neill, CE Reid, A Steiner, BJ Thelen, S Wu. Modeling Wildland Fire Smoke Exposure for Quantifying Human Health Associations (*First draft prepared)* (after first author, authors listed alphabetically)

Peer Reviewed Reports

1. "Report to Congress: Highlights of the Diesel Emissions Reduction Program, Energy Policy Act of 2005," US EPA Office of Air and Radiation report, EPA-420-R-09-006, August 2009 (Principal author)

2. "Study and Report to Congress on Section 183(e), Response to Comments" U.S. EPA, Office of Air and Radiation report, EPA-453/R-98-007, August 1998 (Managing director)

   The Section 183(e) Study is composed of six volumes:
   (1) Report to Congress (EPA–453/R–94–066–a)
   (2) Comprehensive Emissions Inventory (EPA–453/R–94–066–b)
   (3) Fate of Consumer Product VOC in Landfills (EPA–453/R–94–066–c)
   (4) Fate of Consumer Product VOC in Wastewater (EPA–453/R–94–066–d)
   (5) Economic Incentives to Reduce VOC Emissions from Consumer and Commercial Products (EPA–453/R–94–066–e)
   (6) Aerosol Products and Packaging Systems (EPA–453/R–94–066–f)

3. "Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information," U.S. EPA Office of Air and Radiation report, EPA-452\R-96-013, July 1996 (Principal author)

Government Reports with Peer Reviewed Methodologies

1. "MOVES Operating Mode Distribution Generator," U.S. EPA Office of Transportation and Air Quality, EPA-420-B-12-037, May 2012

2. "The National Clean Diesel Campaign (NCDC) 2005 Progress Report," U.S. EPA Office of Transportation and Air Quality, EPA-420-R-06-009, June 2006

3. "Regulatory Impact Analysis: Nonroad Diesel Engines and Fuel," (Chapter 2: Air Quality, Health and Welfare, and Chapter 9: Benefit-Cost Analysis), U.S. EPA Office of Air and Radiation report, May 2004

4. "Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder"(Chapter 2: Air Quality, Health and Welfare and Chapter 3: Industry Characterization) U.S. EPA Office of Air and Radiation report, EPA420-R-03-004, January 2003

5. "Regulatory Impact Analysis: Large SI/Recreational Vehicles Control," (Chapter 2: Air Quality, and Chapter 9: Benefit-Cost Analysis), U.S. EPA Office of Air and Radiation report, September 2002

6. "Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements," (Chapter VII: Benefit-Cost Analysis), U.S. EPA Office of Air and Radiation report, EPA420-R-00-026, December 2000

7. "2018 Milestone Benefits Assessment of BART Reductions in 9 Western States," U.S. EPA Office of Air Quality Planning and Standards report, http://www.epa.gov/ttn/ecas/regdata/Benefits/milestone.pdf August 2000

Translational Publications and Technology Demonstrations

1. **Koman, P.D.**, P. Goldberg, C. Klawuhn, M. Swain, P.D. Meadows, "Environmental Health Professionals Training Needs Assessment," University of Michigan, Office of Public Health Practice report, Ann Arbor, MI, 2014

2. Anthony, M., **Koman, P.D.**, Storton M. Revisiting the Campus Power Dilemma: A Case Study. Planning for Higher Education Journal. Vol 4. No. 1, http://www.scup.org/phe. December 2013

3. "Clean Ports USA: Navigating Toward Cleaner Air," US EPA, Office of Transportation and Air Quality, EPA-420-F-10-023, 2010

4. Federal Laboratory Consortium for Technology Transfer calendar, Hydraulic hybrid yard hostler featured as EPA's technology of the year, 2010 (Project initiator, work assignment manager, team leader for $2 million 6-party international partnership)

5. Prototype hydraulic hybrid yard hostler displays featuring EPA-patented technologies:
- US EPA Administrator press event, Port of New York and New Jersey, 2008
- Society of Automotive Engineers World Congress, Detroit, April 2009
- World Maritime Day Parallel event "Climate Change: A Challenge for IMO too! Responding to a Changing Environment" October 2009

6. "National Clean Diesel Campaign: Working Together for Cleaner Air," US EPA, Office of Transportation and Air Quality, EPA-420-F-09-063, 2009

7. "National Clean Diesel Campaign: State and Local Government Tools and Resources," U.S. EPA, Office of Transportation and Air Quality, EPA-420-F-09-070, 2009

8. "National Clean Diesel Campaign: Funding your Clean Diesel Project, " U.S. EPA, Office of Transportation and Air Quality, EPA-420-F-09-071, 2009

9. "Health Benefits Due to Emission Reductions Attributed to National Clean Diesel Campaign Scenarios," with Abt Associates, September 2007

10. **Koman, P.D.**, and Blubaugh, J. "Ports and Politics: Ports Working Together to Achieve Cleaner Air," pp. 25-27, Seaports, Winter 2007
http://www.aapaports.org/Publications/SeaportsDetail.cfm?itemnumber=3518#seaportsarticle7

11. **Koman, P.D.** "Common Goals," Bunkerspot Journal, Vol. 4, No. 1, February 2007

12. **Koman, P.D.** "Clean Ports USA: Navigating to Cleaner Air," Bunkerspot Journal, April 2006

13. "Reducing Idling for Clean Air," U.S. EPA, Office of Transportation and Air Quality, EPA-420-H-06-001, April 2006

14. "25 Million Reasons Why It's Important to Reduce Idling," U.S. EPA, Office of Transportation and Air Quality, EPA-420-F-06-018, April 2006

15. "Reducing School Bus Idling: The Key to a Healthier Ride Training Video," U.S. EPA, Office of Transportation and Air Quality, EPA-420-V-04-001 and EPA-420-CD-04-001, August 2004

16. Small, M, **Koman, P.D.**, Rodrieguez, M, Savage, M.K., "State Money Talks: State Assurance Funds are Shaping Compliance and Corrective Action," Soils, pp. 24- 33. April 1993

17. Small, M., **Koman, P.D.**, Rodriguez, M, Savage, M.K. State Assurance Funds and their Impact on Underground Storage Tank Compliance and Remediation. Edward J Calabrese and Paul T Kostecki (Ed.), Hydrocarbon Contaminated Soil, Vol. 3 (pp. 653-752). Lewis Publishers, Chelsea, MI. ISBN 1-56670-018-3 1993.

Conference Leadership

1. University of Michigan, School of Public Health, Inaugural Environmental Health Practice Workshop, "Health Equity at Industrial Scale – Lautenberg Chemical Safety Act Under the Trump Administration," Ann Arbor, MI (steering committee chairperson, panel moderator, March 28, 2017)

2. University of Michigan, School of Public Health, Environmental Health Sciences, 75th Anniversary Celebration (steering committee chairperson, February 2017)

3. University of Michigan, School of Public Health, Nursing Grand Rounds, Healthy Built Environment: Nursing Strategies at the Policy, Program, and Patient Levels, Ann Arbor, MI (steering committee member) http://miphtcdev.web.itd.umich.edu/trainings/healthy-built-environments-nursing-strategies-policy-program-and-patient-levels-0 April 4, 2016

4. University of Michigan, School of Public Health, Public Health Leadership Summit, Blue Skies with Green Allies: A Role for All Sectors in Environmental Health, Ann Arbor, MI (steering committee member) http://miphtcdev.web.itd.umich.edu/trainings/blue-skies-green-allies-role-all-sectors-environmental-health September 16, 2015

5. Clean Diesel 10: National Clean Diesel Campaign Tenth Anniversary Celebration, Washington, DC (steering committee chairperson, technical conference chairperson, staffed EPA Assistant Administrator Gina McCarty and EPA Office Director) October 19-20, 2010

6. U.S. EPA Regional Administrators' Leadership Forum: Ports and Sustainability Strategic Planning, Baltimore, MD (steering committee chairperson, staffed EPA Office Director) July 14, 2010

7. 2009 World Maritime Day Co-Located Event, New York, NY (steering committee member, staffed U.S. EPA Assistant Administrator Gina McCarty, assisted with award to International Maritime Organization Secretary General and recognition of Consul General for the Netherlands) October 16-18, 2009

8. U.S. EPA Diesel Emissions Reduction Act Regional Collaborative Leadership meeting, San Diego, CA, (Steering committee member) February 2009

9. U.S. EPA Regional Administrator's Leadership Forum: Goods Movement and Marine Ports Strategic Planning, New York, NY (Steering committee member, staffed EPA Office Director) September 2008

10. U.S. EPA National Clean Diesel Campaign Regional Leadership Forum, Baltimore, MD (Steering committee member) 2007

11. Clean Ships: Advanced Technology for Clean Air, San Diego, CA (Steering committee chairperson, technical conference chairperson, staffed EPA Assistant Administrator) February 7-9, 2007

12. U.S. EPA Regional Administrator's Leadership Forum: Implications of Port Operations and Growth, Ports Strategic Planning Retreat, Long Beach, CA (Steering committee chairperson, staffed Deputy EPA Administrator Marcus Peacock and EPA Regional Administrator Steve Johnson) September 6 -7, 2006

13. Clean Ports USA Technology Workshops, Seattle, WA; Duluth, MN; New York, NY; Philadelphia, PA; Houston, TX, 2005-2006 (managing director)

14. U.S. EPA National Clean Diesel Campaign, Policy Leaders Summit, Baltimore, MD, (steering committee member), February 2005

15. Clean Ports USA Summit, Corpus Christi, TX (Steering committee chairperson, conference chairperson), January 2005

Posters and Conference Proceedings

1. Sutton, P., J. Lam, **P.D. Koman**, T.J. Woodruff. The perils and promise of TSCA for protecting children from exposure to toxic environmental chemicals. American Public Health Association, Atlanta, GA, October 2017 (*abstract accepted for oral presentation*)

2. **Koman, P.D**. N. Sampson, R. Mandell, C.M. Coombe, M.M. Tetteh, Y. Hill-Ashford, D. Wilkins, R. Loch-Caruso, A. J. Schulz, T Woodruff. Air Pollution Exposure and Susceptibility in Pregnant Women: Improving Public Health Protection under the Clean Air Act. American Public Health Association, Atlanta, GA, October 2017 (*abstract accepted for oral presentation*)

3. **Koman, P.D.**, S. Bailey, E. DeLoney, D Moses, K. Keys, S. Cupal, M. Munroe-Younis, T. Dvonch. "Community Participatory Principals in Water Quality Environmental Education Program in Flint, MI" Genesee County Health Department Conference, Flint, MI, May 9, 2017

4. French, N.H., K. Anthony, K. Baker, M. Billmire, S. Hoshiko, J. Hutchinson, J. Johnson, **P.D. Koman**, B. Koziol, V. Limaye, J. McCarty, R. C. Owen, C. Reid, B. Thelen, S. Wu. Approaches and challenges to connecting exposure to air pollution from wildland fire emissions to health outcomes. Planetary Health and GeoHealth Annual Meeting, Boston, MA, April 29, 2017

5. **Koman, P.D.**, F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, K Hill-Knott, N.H. French, M.S. O'Neill, A.J. Schulz. MI-Environment Geospatial Analysis: Promoting Climate-Related Health within Michigan Vulnerable Communities. Planetary Health and GeoHealth Annual Meeting, Boston, MA, April 29, 2017

6. **Koman, P.D.**, F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, M.S. O'Neill, A.J. Schulz. MI-Environment: Climate and Health in Michigan. National Institute for Environmental Health Sciences (NIEHS) 50th Anniversary Research conference, Durham, NC, December 8, 2016

7. **Koman, P.D.**, F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, M.S. O'Neill, A.J. Schulz. MI-Environment: Promoting Climate-Related Health within Michigan Vulnerable Communities. American Public Health Association, Denver, CO, October 31, 2016

8. **Koman, P.D**. K. Hogan, K. Ferguson, R. Mandell, N. Sampson, C.M. Coombe, Y. Hill-Ashford, M.M. Tetteh, D. Wilkins, R. Loch-Caruso, A. J. Schulz, T Woodruff. Air Pollution Exposure and Susceptibility of Pregnant Women: Gender Disparities in Public Health Protection under the Clean Air Act. Social Determinants of Health Conference. George

Mason University School of Policy, Government and International Affairs. Arlington, VA. September 15, 2016

9. **Koman, P.D.** and P. Mancuso. Ozone exposure, obesity and occupational health. University of Michigan, School of Public Health, Center for Occupational Health & Safety Engineering symposium, Ann Arbor, MI, March 18, 2016

10. **Koman, P.D.** and P. Mancuso. Ozone exposure, obesity and cardiopulmonary health. University of Michigan, School of Public Health, Environmental Health Sciences Department Symposium, Ann Arbor, MI, January 22, 2016

11. **Koman, P.D.**, R. Adhikari, S.D. Adar, B.S. Kweon, P. Mohai, "Michigan School Children Proximity to Leaking Underground Storage Tanks and Hazardous Waste Treatment, Storage and Disposal Sites," American Public Health Association, Chicago, IL, November 4, 2015

12. Norton, R.K., P. Fontaine, E. Gerber, G. Hohner, **P.D. Koman**, J. Kosteva. "Generating Multidisciplinary Synergies across Community-Engaged Courses," University of Michigan, Center for Learning and Teaching Research conference, http://www.crlt.umich.edu/tip_winners, Ann Arbor, MI, May 5, 2015

13. **Koman, P.D.**, R. Adhikari, S.D. Adar, B.S. Kweon, P. Mohai, "Michigan School Children Proximity to Leaking Underground Storage Tanks and Hazardous Waste Treatment, Storage and Disposal Sites," University of Michigan, Environmental Health Sciences Department Symposium, Third Place poster award, Ann Arbor, MI, January 23, 2015

14. **Koman, P.D.,** P. Goldberg, C. Klawuhn, M. Swain, P.D. Meadows, "Environmental Health Professionals Training Needs Assessment," University of Michigan, Environmental Health Sciences Department Symposium, Ann Arbor, MI, January 23, 2015

15. Hill-Ashford, Y., **P.D. Koman**, K. Hogan, R. Mandell, A.J. Schulz, M. Tetteh, D. Wilkins, "Engaging community and academic partners in efforts to refine definitions of vulnerable populations: Detroit Reproductive Environmental Advocacy Matters (DREAM) Team," American Public Health Association conference, 299816, New Orleans, LA, November 17, 2014

16. Adar, S.D., M.S. Daskin, S.R. Gosman, **P.D. Koman**, B.S. Kweon, P. Mohai, "School Siting: Are Michigan Schools Safeguarding Children's Environmental Health," University of Michigan, MCubed Symposium, Ann Arbor, MI, October, 2014 (authors listed alphabetically)

17. Hogan K.A., M. Tetteh, R. Mandell, Y. Hill-Ashford, D. Wilkins, L. Nguyen, **P.D. Koman**, A.J. Schulz, C. Thomasson, S. Dernek, J. Jones, D. Ogunyemi, R. Loch-Caruso, "The DREAM Team and Clinical Allies Go to Washington: Environmental Reproductive Advocacy in Action," Michigan Community Health and Research Conference, Ann Arbor, MI, October 1, 2014

18. Thorpe, K., D. Thoe, **P.D. Koman**, "Michigan Engaging Community Through the Classroom: Willow Run Sustainability Project," University of Michigan, Undergraduate Research Opportunity Program (UROP) Symposium, Blue ribbon winner, Ann Arbor, MI, August 2014

19. Burke, M.N., **P.D. Koman**, P. Goldberg, C. Klawuhn, M. Swain, P.D. Meadows, "Environmental Health Professionals' Training Needs Assessment," University of Michigan, Undergraduate Research Opportunity Program (UROP) Symposium, Ann Arbor, MI, April 2014

20. Adar, S.D., M.S. Daskin, S.R. Gosman, **P.D. Koman**, B.S. Kweon, P. Mohai , "School Siting: Are Michigan Schools Safeguarding Children's Environmental Health," University of Michigan, MCubed Symposium, Ann Arbor, MI, November 15, 2013 (authors listed alphabetically)

21. **Koman, P.D.**, M. Arquero De Alarcon, P. Fontaine, C. Wilson, A. Yee, P. Barclay, M. Duchemin, N. Hall, A. Hing, Y. Mazloomdoost, E. Yu, D. Smith, P. Goldberg, D. Smith, D. Hawkins, P. Meadows, "Michigan Engaging Community

Through The Classroom. Collaborative community health impact assessment in the industrial landscapes of the Rust Belt: The Willow Run Project," Michigan Community Health and Research Conference, Ann Arbor, MI, March 19, 2013

22. Yee, A.K., **P.D. Koman**, M. Arquero de Alarcon, P. Barclay, M. Duchemin, P. Fontaine, P. Goldberg, N. Hall, A. Hing, Y. Mazloomdoost, E. Yu, D. Smith, D. Hawkins, C. Wilson, P. Meadows, "Michigan Engaging Community Through The Classroom. Community health and quality of life in the living industrial landscapes of the Rust Belt: The Willow Run Project," Poster and presentation at University of Michigan Rackham Graduate School Students of Color Conference, Ann Arbor, MI, March 22- 23, 2013

23. **Koman, P.D.**, C. Wilson, A. Yee, P. Barclay, M. Duchemin, N. Hall, A. Hing, Y. Mazloomdoost, E. Yu, D. Smith, P. Goldberg, P. Meadows, "Michigan Engaging Community Through The Classroom. Preliminary Health Impact Assessment." Poster and presentation at University of Michigan MECC final conference for project stakeholders, April 25, 2013; featured in AnnArbor.com news article

24. **Koman, P.D.**, Newstead, S., Keller, J., "Clean School Bus USA: Tomorrow's Buses for Today's Children," US EPA 3rd Annual Science Forum, Washington, DC June 2004

25. **Koman, P.D.**, Keller, J., Hubbell, B.J., "Reducing School Bus emissions: Successful solutions and practical applications," American Public Health Association 132rd Annual Meeting 5026.0 Disparities in Vulnerable Populations, Washington, DC, November 6-10, 2004

26. Hubbell, B., **P.D. Koman**, T. Fox, D. McCubbin, K. Davidson, P Dolwick. Health benefits of reducing particulate air pollution from nonroad diesel engines. Epidemiology. 15(4):S137. July 2004. ISSN: 1044-3983. DOI:1097/00001648-200407000-00355.

27. Hubbell, B., **P.D. Koman**, T. Fox, N.J. Possiel, G. Stella, B. Timin. Health benefits of reducing air pollution from heavy duty diesel engines. http://www.epa.gov/ttn/ecas/workingpapers/hddben.pdf, Research Triangle Park, NC, 2001

28. Hubbell, B.J., **Koman, P.D.**, Laurence, J., Heninger, B., Petro, A., Mills, J. and Haynes, R. "Integrated Forestry Ozone Regulatory Modeling System," Future Directions in Air Quality Research, North Carolina State University, Research Triangle Park, NC, February 12, 2001

29. Rogers, C.F., J.C. Chow, J.G. Watson, C.A. Cahill, S. Diaz , **P.D. Koman** , S. Sleva, R. Tropp, "Mineral Dust Contributions to Fine Particle Mass," Air & Waste Management Association, pp.168-176. January 1998

30. Small, M., Eklund, P., **Koman, P.D.** "Streamlining and Prioritizing Leaking Underground Storage Tank Site Corrective Action Programs," Proceedings of Air and Waste Management Conference, Accelerating Underground Storage Tank Corrective Action, Vol. 31, pp. 38-49, San Antonio, TX, March 1993

Preparation for Teaching

1. Participant, Graduate teaching certificate coursework, University of Michigan, Rackham Graduate School, Center for Research on Teaching and Learning, under mentorship of Dr. Phyllis Meadows, Health Management and Policy

    - Writing and Grading Exams virtual workshop, June 2015
    - Preparing Future Faculty Seminar, Spring Term 2015
    - Advanced Strategies for Inclusive Teaching workshop, March 2015
    - Graduate Student Instructor Orientation, January 2014

2. Syllabus design workshop. University of Michigan, Rackham Graduate School, Arts of Citizenship. Fall term 2014

3. Graduate Student Instructor Spring Board to Teaching seminar. University of Michigan, School of Public Health. Ann Arbor, MI. Fall 2013

Teaching, Training and Instruction

1. Practitioner roundtable for Rackham's Institute for Social Change introduction to public scholarship, "Working for Social Justice Inside and Outside Academia," University of Michigan, Rackham Graduate School, Ann Arbor, MI August 22, 2017

2. Master Class instructor, "Transportation Affects Health," Movin'On Michelin World Summit on Sustainable Transportation, Montreal, Canada, June 14, 2017

3. Guest lecture for Future Public Health Leaders program, for 40 undergraduate Center for Disease Control and Prevention scholars. "Environmental Health Sciences." University of Michigan, School of Public Health, Ann Arbor, MI, May 25, 2017

4. Curriculum co-developer, "Environmental Justice Academy" community-based participatory research partnership. Winter Term 2017

5. Curriculum developer and trainer, "See for Yourself: What's in Your Water" water quality and drinking water delivery system training for 500 community members and K-12 students in Flint, MI. Fall 2016 and Winter Term 2017

6. Assistant course instructor, PH600, Cross-disciplinary approaches to public health challenges, 4 credits, University of Michigan, School of Public Health, Associate Dean Phyllis Meadows. Winter Term 2016

7. Guest lecture for Future Public Health Leaders program, for 40 undergraduate Center for Disease Control and Prevention scholars. "Health Impact Assessment." University of Michigan, School of Public Health, Ann Arbor, MI. Associate Dean Phyllis Meadows. June 2015

8. Guest lecture for webinar, University of California San Francisco, Obstetrics, Gynecology and Reproductive Sciences, Reach the Decision Maker Fellows, for 50 health professionals, "Strategies for Effective Communication with the U.S. Environmental Protection Agency," Dr. Tracey Woodruff. June 2015

9. Guest lecture for Future Public Health Leaders program, for 40 undergraduate Center for Disease Control and Prevention scholars. "Environmental Health Sciences." University of Michigan, School of Public Health, Ann Arbor, MI. Associate Dean Phyllis Meadows. June 2015

10. Koman, P.D. "Climate Change and Human Health," Keynote. University of Michigan School of Public Health and Michigan Association for Local Public Health Day, Ann Arbor, MI, March 9, 2015 Available as Michigan Public Health Training Center on-line training: http://miphtcdev.web.itd.umich.edu/trainings/climate-change-and-human-health

11. Guest lecture for Future Public Health Leaders program, for 50 undergraduate Center for Disease Control and Prevention scholars. "Fundamentals of Health Impact Assessment." University of Michigan, School of Public Health, Ann Arbor, MI. Associate Dean Phyllis Meadows. July 2014

12. Invited trainer, University of California San Francisco, Obstetrics, Gynecology and Reproductive Sciences, Reach the Decision Maker Fellows, for 25 health professionals nationwide, "Making Your Case in Environmental Policy," Reach the Decision Maker Program, Washington, DC, Dr. Tracey Woodruff. May 2014

13. Guest lecture for webinar, University of California San Francisco, Obstetrics, Gynecology and Reproductive Sciences, Reach the Decision Maker Fellows, for 50 health professionals, "Effective Communication with the Environmental Protection Agency," Dr. Tracey Woodruff. June 2014

14. Guest lecture for Future Public Health Leaders program, for 50 undergraduate Center for Disease Control and Prevention scholars. "Introduction to Environmental Health Sciences." University of Michigan, School of Public Health, Ann Arbor, MI. Associate Dean Phyllis Meadows. June 2014

15. Guest lecture for 25 urban planning masters students, "Building Healthy Communities: Children's Environmental Health and Hazardous Substance Clean Up Criteria in Michigan." University of Michigan, Urban Planning Department. Ann Arbor, MI. UP 502 Environmental Planning, Issues and Concepts. Assistant Professor Ana Paula Pimental Walker. Fall 2013

16. Guest lecture for Future Public Health Leaders program, for 50 undergraduate Center for Disease Control and Prevention scholars. "Introduction to Environmental Health Sciences." University of Michigan, School of Public Health, Ann Arbor, MI. Associate Dean Phyllis Meadows. June 2013

17. Guest lecture on air quality and marine ports for masters students. University of Michigan, School of Public Health, Environmental Health Sciences. Ann Arbor, MI. EHS 572/SNRE 514 Environmental Impact Assessment. Professor Stuart Batterman. Fall 2012

18. Guest lecture for graduate students, "Ship Air Emissions and Controls," University of Michigan, College of Engineering, Naval Architecture and Marine Engineering. Ann Arbor, MI. Professor Jing Sun. Winter 2007

19. Trainer and course developer, "EPA Mobile Source Emissions software MOVES2010b Pilot Training Course." International Emissions Inventory Conference. 8-hour training, Tampa, FL. August 13, 2012

20. Trainer, "MOVES 3-Day Training Course," EPA Mobile Source Emissions Modeling 3-day computer-based training, Lansing, MI. May 2012

21. Trainer, "Effectively Communicating Key Messages," EPA's National Clean Diesel Campaign Regional Office Partners meeting. Washington, DC. December 9, 2005

Selected Presentations

1. **Koman, P.D.**, French, N.H., M.S. O'Neill, J.T. Dvonch, C. Reid, S. Hoshiko, K. Baker, M. Billmire, B. Thelen, S. Wu, A. Steiner. Atmospheric Modeling in Human Health & Climate Change Risk Assessment: Wildfire Smoke Exposures. Graham Institute external advisory board annual meeting, Ann Arbor, MI, April 13, 2017

2. **Koman, P.D.**, F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, M.S. O'Neill, A.J. Schulz. MI-Environment: Promoting Climate-Related Health within Michigan Vulnerable Communities. University of Michigan Environmental Epidemiology research seminar, Ann Arbor, MI, February 14, 2017

3. **Koman, P.D.**, F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, R Goodspeed, M.S. O'Neill, A.J. Schulz. MI-Environment: Heat Stress Vulnerability in Michigan Communities. Michigan University-wide Sustainability & Environment, Ann Arbor, MI, February 9, 2017

4. **Koman, P.D.** "Health Equity at Industrial Scale: What Every Public Health Professional Needs to Know about the Lautenberg Chemical Safety Act," California Department of Health research seminar, Richmond, CA, January 30, 2017

5. **Koman, P.D.,** M. Munroe-Younis. "See for Yourself: What's in Your Water?" Flint Neighborhood Recovery Resource Meeting, Flint, MI, January 5, 2017

6. **Koman, P.D.,** A. Jakkaraju, M. Halso, K. Heidecorn, C. Xi, T.M. Olson. "See for Yourself: What's In Your Water? Environmental Education Model Building." Environmental Water Resources Engineering Program Symposium, Ann Arbor, MI, October 21, 2016

7. **Koman, P.D.**, F. Romo, C. Gray, N. Sampson, S. Landfried, M. Battaglia, M.S. O'Neill, A.J. Schulz. MI-Environment: Promoting Climate-Related Health within Michigan Vulnerable Communities. American Public Health Association, Denver, CO, October 31, 2016

8. **Koman, P.D.** "See for Yourself: What's in Your Water?" Genesee County Steering Prevention Reducing Obesity Utilizing Teamwork (SPROUT), Genesse County Health Department, November 14, 2016

9. Panelist, Future Public Health Leaders program for 40 undergraduate Center for Disease Control and Prevention scholars, "Public Health Careers," University of Michigan, School of Public Health, Ann Arbor, MI. PI Associate Dean Phyllis Meadows. July 18, 2016

10. Norton, R.K., P. Fontaine, E. Gerber, G. Hohner, **P.D. Koman**, J. Kosteva. "Michigan Engaging Community Through the Classroom," University of Michigan, Center for Learning and Teaching Research conference, May 16, 2016

11. **Koman, P.D.,** keynote presentation, "Climate Change and Human Health" Genesee County Health Department 10th Annual Public Health Conference, Flint, MI, May 3, 2016

12. **Koman, P.D.**, F. Romo, S. Landfried, M O'Neill. "MI-Environment: Heat Vulnerability Mapping Interactive Tool" Michigan Lifestage Environmental Exposure & Disease Center pilot, Science Cafe, Detroit, MI, March 24, 2016

13. **Koman, P.D.**, Detroiters Working for Environmental Justice – "Communicating Climate Change and Health" interactive icebreaker activity at Climate Action Plan meeting in Detroit, MI

14. **Koman, P.D.,** invited panelist, "Engaging Community Partners," University of Michigan, Rackham Graduate School Arts of Citizenship Program training, Ann Arbor, MI, November 13, 2015

15. **Koman, P.D.,** invited speaker, "Climate Change and MI-Environment Heat Vulnerability Index: Opportunities for Research and Partnerships," University of Michigan, NIEHS Community Outreach & Engagement Core, Michigan Lifestage Environmental Exposure & Disease Center, Faculty and partners mobile meeting, Detroit, MI, November 13, 2015

16. F. Romo, M. Battaglia, **Koman, P.D.**, S. Landfried, M O'Neill, R. Goodspeed. "MI-Environment: Hazard Proximity in Kent County," Michigan Technology Research Institute, Ann Arbor, MI, October 30, 2015

17. **Koman, P.D.,** invited panelist, "Innovative Research," University of Michigan, Rackham Graduate School Donors Celebration Dinner, Ann Arbor, MI, October 9, 2015

18. Gronlund, C, **Koman, P.D.**, Cameron, L., Bryan, D. "Climate Change in Michigan: Human Health, Resilience, and Equity," Michigan Association for Local Public Health Premier Conference, Thompsonville, MI, October 7, 2015

19. **Koman, P.D.**, K. Huber, F. Romo, S. Landfried, R. Goodspeed, M O'Neill. "MI-Environment: Heat Vulnerability Mapping" NIEHS Community Outreach & Engagement Core, Michigan Lifestage Environmental Exposure & Disease Center, Stakeholder Advisory Board Meeting, Detroit, MI, July 22, 2015.

20. **Koman, P.D.,** national webinar, University of California San Francisco, Obstetrics, Gynecology and Reproductive Sciences, Reach the Decision Maker Fellows, for 50 health professionals, "Strategies for Effective Communication with the U.S. Environmental Protection Agency," June 2015

21. **Koman, P.D.**, P. Goldberg, C. Klawuhn, M. Swain, P.D. Meadows, "Michigan Environmental Health Professionals' Training Needs," Michigan Environmental Health Association conference, Traverse City, MI, March 20, 2015

22. **Koman, P.D.**, P. Goldberg, C. Klawuhn, M. Swain, P.D. Meadows, "The Future of Michigan Public Health Professionals: Strategic Directions and Training Needs," Michigan's Premier Public Health Conference, Michigan Association for Local Public Health, Bellaire, MI, October 22, 2014

23. **Koman P.D.**, "Risk Miscues and Mixed Messages: What is a Transportation Planner to Do?" 93rd Annual Transportation Research Board Conference, Washington, DC, January 12, 2014

24. **Koman, P.D**. and P. Mancuso, "Implications of Obesity Trends for Designating At-risk Populations in the Ozone and Particulate Matter National Ambient Air Quality Standards," American Public Health Association, 141st Annual Meeting, Boston, MA, November 4, 2013

25. **Koman, P.D.** "Understanding Michigan's Remediation and Redevelopment Program: What Every Public Health Official Needs to Know," Michigan's Premier Public Health Conference, Michigan Association for Local Public Health, Bay City, MI, October 17, 2013

26. **Koman, P.D.**, speaker and panel moderator, "Nonroad Engine Emissions Modeling," International Emissions Inventory Conference, Tampa, FL, August 16, 2012

27. **Koman, P.D.**, "Diesel Emissions Reduction Act Funding and Reauthorization," American Association of Port Authorities, Harbors, Navigation and Environment Committee Webinar, Charleston, SC, September 1, 2010

28. **Koman, P.D.**, "Diesel Emissions Reduction Act Reauthorization," Greenports and American Association of Port Authorities, Harbors, Navigation and Environment Committee Seminar, May 4-6, 2010

29. **Koman, P.D.**, keynote panel, "Future of the National Clean Diesel Campaign," Southeast Diesel Collaborative Annual Partners Meeting, Atlanta, GA, June 2009

30. **Koman, P.D.**, "Clean Ports USA," EPA Diesel Emissions Reduction Act Regional Collaborative Leadership meeting, San Diego, CA, February 2009

31. **Koman, P.D.**, "Sustainable Future - Hydraulic Hybrid Yard Hostler," U.S. – Taiwan Bilateral Environmental Cooperation meetings, and Taipei, Taiwan November 2008

32. **Koman, P.D.**, "Lessons from New York - Hydraulic Hybrid Yard Hostler," Pacific Ports Air Quality Conference, Kaohsiung, Taiwan, November 2008

33. **Koman, P.D.**, "U.S. Perspectives on Reducing Air Pollution from Ocean-Going Vessels," American Association of Port Authorities Conference, Panama City, Panama, May 2008

34. **Koman, P.D.**, "National Clean Diesel Campaign," Faster Freight - Cleaner Air, Los Angeles, CA, March 2008

35. **Koman, P.D.**, moderator and panel speaker, "Clean Ports USA: Reducing Emissions from Marine Engines," Faster Freight - Cleaner Air, Los Angeles, CA, March 2008

36. **Koman, P.D.**, "Communication and Outreach," EPA National Clean Diesel Campaign Regional Leadership Forum, Baltimore, MD, 2007

37. **Koman, P.D.**, "Clean Ports USA: Navigating to Cleaner Air," EPA National Clean Diesel Campaign Regional Leadership Forum, Baltimore, MD 2007

38. **Koman, P.D.**, "Clean Ports USA: Great Ideas for the Great Lakes," Great Lakes Ports Association Directors' Meeting, Cleveland, OH, June 2006

39. **Koman, P.D.**, "Clean Ports USA: Navigating toward Cleaner Air," State and Territorial Air Pollution Program Administrators (STAPPA) / Association of Local Air Pollution Control Officers (ALAPCO) annual meeting, Madison, WI, May 21-25, 2005

40. **Koman, P.D.**, "Clean Ports USA," National Association of Waterfront Employers' annual executives meeting, Charlotte, NC, April 2005

41. **Koman, P.D.**, "Clean Ports USA," Clean Ports USA Summit, Corpus Christi, TX, January 26, 2005

42. **Koman, P.D.**, "Clean School Bus USA Demonstration Projects," National Retrofit Conference, Washington, DC, June 2004

43. **Koman, P.D.**,"Clean School Bus USA," Maricopa Association of Governments, Phoenix, AZ, March 2004

44. **Koman, P.D.**, keynote speaker, "Moving the Air Toxics Program Forward," American Forest and Paper Association Conference, Research Triangle Park, NC, April 1999

45. **Koman, P.D.**, keynote speaker, "Pollution Prevention in EPA's Industrial Surface Coating National Emission Standards for Hazardous Air Pollutants," National Pollution Prevention Roundtable, Cincinnati, OH, May 1998

46. **Koman, P.D.**, "Ten Year Surface Coating National Emission Standards for Hazardous Air Pollutants," Air Toxics Implementation Workshop, Research Triangle Park, NC, August 1997

47. Trainer for nationally broadcast program (answering live questions from air pollution regulators, industry representatives, and other participants) regarding the final decision to revise the ozone and particulate matter (PM) national ambient air quality standards (NAAQS), July 1997

48. **Koman, P.D.**, keynote plenary address, "Proposed Revisions to the PM NAAQS," Air and Waste Management Association (AWMA) Utilities and Acid Rain Conference, Phoenix, AZ, January 1997

49. **Koman, P.D.**, plenary speaker, "Proposed Revisions to the PM NAAQS," American Forest and Paper Association Conference, Research Triangle Park, NC, February 1997

50. National spokesperson for proposed revisions to the PM NAAQS at Air and Waste Management Association public seminars, January and February 1997, at the following locations:

- Atlanta, GA	- New York, NY
- Chicago, IL	- Phoenix, AZ
- Hartford, CT	- Pittsburgh, PA
- Los Angeles, CA	- Research Triangle Park, NC

51. Presenter to Japanese and Russian delegation regarding the proposed revisions to the ozone and PM NAAQS, Research Triangle Park, NC, 1997

52. Lead presentation with in-depth 3-hour question-and-answer session at WESTAR meeting for Western State and local air pollution officials regarding proposed revisions to the PM NAAQS, Palm Springs, CA, December 1996

53. Trainer for seminar broadcast nationally (answering questions faxed in from air pollution regulators, industry representatives, and other participants) regarding proposed revisions to the Ozone and PM NAAQS, December 1996

54. Small, M., Eklund, P., **Koman, P.D.** "Streamlining and Prioritizing Leaking Underground Storage Tank Site Corrective Action Programs," US EPA National Underground Storage Tank Conference, Washington, DC, March 1993

Affiliations

- International Society for Environmental Epidemiology (2015- present)
- International Epidemiology Association (2016- present)
- American Public Health Association (2004, 2012- present)
- Michigan Engaging Community Through the Classroom Advisory Committee (2013- present)
- Mentor, Reach the Decision Makers program, University of California at San Francisco (2013 – 2016)
- Navigation Guide Group, University of California at San Francisco Program on Reproductive Health and the Environment (2012 – present)
- American Association of Port Authorities, Harbors Navigation and Environment Committee (associate member, 2005- 2011)

Exhibit 3

IN THE UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

SAFER CHEMICALS, HEALTHY FAMILIES et al., *Petitioners,* v. U.S. ENVIRONMENTAL PROTECTION AGENCY et al., *Respondents.* IPC INTERNATIONAL, INC. et al., *Respondents-Intervenors.*	Docket No. 17-72260 Consolidated with Docket Nos. 17-72501, 17-72968, 17-73290, 17-73383, 17-73390

DECLARATION OF DETLEF KNAPPE, PH.D., IN SUPPORT OF PETITIONERS' OPENING BRIEF

I, DETLEF KNAPPE, do hereby affirm and state:

Introduction and Qualifications

1. I am an environmental engineer. I hold a B.S. in Civil Engineering from the University of Illinois at Urbana-Champaign (1989). I received M.S. (1991) and Ph.D. (1996) degrees in Environmental Engineering from the University of Illinois at Urbana-Champaign.

2. I am a Professor in the Department of Civil, Construction, and Environmental Engineering at North Carolina State University in Raleigh. I teach two graduate courses (Chemical Principles of Environmental Engineering;

Physical-Chemical Water Treatment Processes) and one undergraduate course (Environmental Chemistry and Microbiology).

3. My research focuses on (1) developing and evaluating physical-chemical treatment processes for the control of trace organic contaminants (e.g., carcinogenic volatile organic contaminants, 1,4-dioxane, fluorochemicals, endocrine-disrupting chemicals, antibiotics, and other pharmaceutically active compounds), and (2) developing information about the effects of reactive and unregulated wastewater contaminants on drinking water quality and treatment—information that is not provided under the federal Clean Water Act or Safe Drinking Water Act.

4. I am a member of the Drinking Water Committee of the United States Environmental Protection Agency's Science Advisory Board. I am also a member of the Science Advisory Board of the North Carolina Department of Environmental Quality and the North Carolina Department of Health and Human Services

5. I serve as a Trustee for the Water Science and Research Division of the American Water Works Association, and am a member of the Association's Activated Carbon Standards Committee and the Organic Contaminants Research Committee.

6. A more complete description of my educational and work experience, as well as a complete list of my publications, is appended as Exhibit A.

7. By virtue of my engineering training, my research, my professional service, and knowledge of pertinent scientific literature, I consider myself—and others in the field consider me to be—an expert on trace organic contaminants and their effects on drinking water quality and treatment.

8. All of the information set forth in this declaration is based upon my education, personal knowledge, and experience.

What is 1,4-dioxane?

9. 1,4-Dioxane is an organic compound produced for commercial purposes. It is also a manufacturing by-product.

10. In the past, the dominant commercial use of 1,4-dioxane was for the stabilization of certain solvents. The use of 1,4-dioxane as a solvent stabilizer has decreased since 1995 when production of one such solvent was phased out under the Montreal Protocol (an international treaty) because of its ozone depletion potential.

11. Currently, 1,4-dioxane is used as a chemical reactant, solvent, and processing aid in many industries, such as textile processing, specialty chemical manufacturing (e.g., pharmaceuticals, pesticides), recycling, wood pulping,

manufacturing of polyethyleneterephthalate (PET) plastics, cellulose acetate, resins, waxes, and fats.[1]

12. 1,4-Dioxane can also be produced as a by-product in manufacturing processes, including production of polyester and surfactants used in detergents and shampoos.

13. 1,4-Dioxane is an impurity in some consumer products, including detergents, waxes, varnishes, and personal care products such as shampoos and cosmetics.

14. Reliable current 1,4-dioxane production volumes in the United States are not available because much of the information is considered confidential business information. Furthermore, there is no reliable information on the volume of by-products generated.

15. There is no federal drinking water standard for 1,4-dioxane.

16. Several states have developed drinking water standards or guidelines for 1,4-dioxane.

17. In North Carolina, a narrative surface water quality standard exists. 15A NCAC 02B .0208 states that "for carcinogens, the concentrations . . . shall not

[1] U.S. EPA, Rep. No. EPA-HQ-OPPT-2016-0723, Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: 1,4-Dioxane (2017), https://www.epa.gov/sites/production/files/2017-02/documents/14-dioxane.pdf.

result in unacceptable health risks and shall be based on a Carcinogenic Potency Factor. An unacceptable health risk for cancer shall be considered to be more than one case of cancer per one million people exposed (one-in-a-million risk level)." For 1,4-dioxane, the one-in-a-million risk level corresponds to a concentration of 0.35 μg/L (or parts per billion).

How widespread is 1,4-dioxane contamination of drinking water in the U.S.?

18. The U.S. Environmental Protection Agency (EPA) assessed the occurrence of 1,4-dioxane in U.S. drinking water as part of the Third Unregulated Contaminant Monitoring Rule (UCMR3).[2] Between January 1, 2013, and December 31, 2015, more than 36,000 drinking water samples were collected across the United States and submitted for 1,4-dioxane analysis. These samples came from almost 5,000 public water systems in the United States, each of which serves more than 10,000 people. Nationwide, 1,4-dioxane was detected in 21.9% of public water systems, and 1,4-dioxane levels exceeded 0.35 μg/L—the one-in-a-million risk level—in 6.9% of public water systems. More than 75% of all 1,4-dioxane detections in U.S. drinking water were associated with **groundwater** sources.

[2] *See* U.S. EPA, Occurrence Data for the Unregulated Contaminant Monitoring Rule, https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule#3.

19. Compared to the entire United States, 1,4-dioxane occurs more frequently in North Carolina drinking water. Between January 1, 2013, and December 31, 2015, as part of the UCMR3, more than 1,300 drinking water samples were collected across North Carolina and submitted for 1,4-dioxane analysis. These samples came from 151 public water systems that serve more than 10,000 people. In North Carolina, 1,4-dioxane was detected in 30.5% of public water systems, and 1,4-dioxane levels exceeded 0.35 μg/L in 15.9% of public water systems. More than 95% of all 1,4-dioxane detections in North Carolina were associated with **surface water** sources.

How does 1,4-dioxane enter drinking water sources?

20. Most drinking water in the United States is produced from groundwater or surface water.

21. 1,4-Dioxane can enter groundwater from leaking underground storage tanks that contain(ed) solvents stabilized with 1,4-dioxane, from unlined landfills, and from wastewater lagoons.

22. 1,4-Dioxane can enter surface water through municipal and industrial wastewater treatment plant discharges.

23. The concentration of 1,4-dioxane in U.S. municipal wastewater discharges is typically found at levels that are associated with the use of consumer

products such as laundry detergents and shampoos. These levels generally range from 0.3 to 3 μg/L.[3]

24. In many communities, industrial wastewater is pre-treated and discharged to the municipal sewer. Because 1,4-dioxane is an unregulated contaminant, its possible presence is typically not considered when pre-treatment programs evaluate the discharge from an industrial wastewater treatment plant to a municipal sewer system.

25. If an industrial wastewater discharge to a municipal sewer contains high levels of 1,4-dioxane, it will elevate the 1,4-dioxane concentration of the wastewater reaching the municipal wastewater treatment plant. Municipal wastewater treatment plants cannot effectively remove 1,4-dioxane. Therefore, 1,4-dioxane concentrations will be high in the discharge of municipal wastewater treatment plants that receive industrial wastewater with elevated 1,4-dioxane concentrations.

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[3] Staci Massey Simonich et al., Probabilistic analysis of risks to US drinking water intakes from 1,4-dioxane in domestic wastewater treatment plant effluents, 9 Integ. Envtl. Assess. Mgmt. 554 (2013), https://setac.onlinelibrary.wiley.com /doi/epdf/10.1002/ieam.1448; Detlef R. U. Knappe et al., U. N.C. Water Res. Research Inst., Rep. No. 478, Occurrence of 1,4-Dioxane in the Cape Fear River Watershed and Effectiveness of Water Treatment Options for 1,4-Dioxane Control (2016), https://repository.lib.ncsu.edu/bitstream/handle/1840.20/34331/UNC-WRRI-478.pdf?sequence=1&isAllowed=y [hereafter Cape Fear Report].

26. In 2015, in North Carolina, the Department of Environmental Quality and North Carolina State University monitored 1,4-dioxane concentrations in the Cape Fear River watershed. Monthly samples were collected from October 2014 to October 2015 and analyzed. Discharges of three municipal wastewater treatment plants were found to be significant sources of 1,4-dioxane. The highest 1,4-dioxane concentrations (up to 1,700 μg/L) were observed in the headwaters of the Cape Fear River watershed just downstream of the three wastewater treatment plant discharges. Median 1,4-dioxane concentrations decreased in a downstream direction with increasing distance from the identified sources. However, the concentration of 1,4-dioxane stayed above the one-in-a-million risk level throughout the watershed.

How persistent is 1,4-dioxane in aquatic systems?

27. The molecular structure of 1,4-dioxane makes it stable and relatively immune to environmental degradation as it moves through a watershed.

28. Watershed monitoring data for the Cape Fear River basin in North Carolina are consistent with the persistent nature of 1,4-dioxane. Monthly monitoring in two rivers over a one-year period (October 2014-October 2015) demonstrated that mass flows of 1,4-dioxane remained stable over a 200-km-stretch of the Cape Fear River that had no substantial 1,4-dioxane inputs.[4] Similar

[4] Cape Fear Report.

results showing no losses of 1,4-dioxane were observed over a 120-km-stretch of the Deep River.

How can 1,4-dioxane be removed in drinking water treatment plants?

29. 1,4-Dioxane is not removed in conventional surface water treatment plants. Conventional surface water treatment processes include: (1) coagulation, (2) flocculation, (3) solid-liquid separation (e.g., sedimentation, filtration), and (4) disinfection with free chlorine. A 2014 North Carolina State University study of two drinking water treatment plants in the Cape Fear River watershed showed no removal of 1,4-dioxane.[5] For the Pittsboro plant, the finished drinking water contained 1,4-dioxane at levels 25 times the one-in-a-million risk level. For the Fayetteville plant, the finished drinking water contained 1,4-dioxane at levels 7 times the one-in-a-million risk level.

30. 1,4-Dioxane is also not well removed by many advanced treatment technologies, including activated carbon adsorption, air stripping, and most oxidation processes (including treatment by chlorine).

31. There are some advanced treatment options that can remove 1,4-dioxane from drinking water, such as ultraviolet light in combination with hydrogen peroxide or ozone. Data from our laboratory suggest that implementing

[5] *Id.*

such treatment required to lower 1,4-dioxane to safe levels in the Cape Fear River basin would be very costly.

32. Advanced treatment with ozone at a drinking water treatment plant in Wilmington, North Carolina was insufficient to lower the 1,4-dioxane concentration to the one-in-a-million risk level (0.35 μg/L). Ozone treatment may also create undesirable by-products in some water systems.

33. Reverse osmosis membranes may partially remove 1,4-dioxane, but may need to be coupled with other advanced treatment to achieve safe levels. Such treatment is very costly compared to conventional treatment.

How many North Carolinians drink water with elevated 1,4-dioxane levels?

34. Surface water in the Cape Fear River basin serves as a source of drinking water for approximately 1.5 million North Carolinians. Of the approximately 1.5 million residents, about 1 million receive drinking water with 1,4-dioxane concentrations above the one-in-a-million risk level.

What can affected residents do?

35. To date, no point-of-use (pitcher, faucet, under-sink, refrigerator) or point-of-entry (whole house) filters have been certified for 1,4-dioxane removal.

36. Pitcher and refrigerator filters were evaluated at North Carolina State University for their 1,4-dioxane removal effectiveness. Overall, commercially available point-of-use treatment devices exhibited limited effectiveness for 1,4-

dioxane removal from tap water, especially under variable 1,4-dioxane concentrations.[6]

37. In a field study involving six under-sink reverse osmosis filters, 1,4-dioxane was removed to concentrations below the one-in-a million risk level (0.35 μg/L) in communities served by Cape Fear River water in North Carolina. These filters are prohibitively costly for some homeowners.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Detlef Knappe, Ph.D.

4/11/18
Date

[6] *Id.*

Exhibit A

to the Declaration of Detlef Knappe, Ph.D.
in Support of Petitioners' Opening Brief

Curriculum Vitae

Name: Detlef R. U. Knappe **April 3, 2018**

I. Brief Resume

Name Detlef Knappe

1. Education background:

Ph.D., Environmental Engineering in Civil Engineering, 1996, University of Illinois, Urbana, IL.
M.S., Environmental Engineering in Civil Engineering, 1991, University of Illinois, Urbana, IL.
B.S., Civil Engineering, 1989, University of Illinois, Urbana, IL. Highest honors.

2. Professional experience:

Professor, 2008-present, NC State University, Department of Civil, Construction, and Environmental Engineering
Visiting Scholar, Spring 2013, US Environmental Protection Agency, Research Triangle Park, NC
Associate Professor, 2002-2008, NC State University, Department of Civil, Construction, and Environmental Engineering
Visiting Scholar, Fall 2005, Swiss Federal Institute of Technology (ETH), EAWAG, Switzerland
Assistant Professor, 1996-2002, NC State University, Department of Civil Engineering
Graduate Research and Teaching Assistant, 1991-1995, University of Illinois, Environmental Engineering in Civil Engineering, IL
University Fellow and Graduate Research Assistant, 1989-1991, University of Illinois, Environmental Engineering in Civil Engineering, IL

3. Scholarly and creative activities:

Refereed Activity	*Number*
Book Chapters	2
Journal Articles	48 (+1 submitted)
Research Reports	14

Non-Refereed Activity	*Number*
Conference Papers	60
Conference Abstracts	87
Invited Presentations	56

4. Membership in professional organizations

American Chemical Society, 1999-present
American Geophysical Union, 1998-2008

American Society of Civil Engineers, 1987-present
American Water Works Association, 1989-present
Association of Environmental Engineering and Science Professors, 1996-present
Engineers Without Borders, 2008-present
International Water Association, 1996-present

5. Scholarly and professional honors

Best paper award for our 2016 publication in ES&T Letters, 2017
NSF Science Nation video of our 1,4-dioxane research in the Cape Fear River watershed, 2015
Thesis advisor for the 1st place winner in the American Water Works Association Academic Achievement Award competition for the best Master's Thesis, 2013
Outstanding Teacher Award (NCSU College of Engineering), 2011
Advisor for the winner of the Best Student Paper Award at the American Water Works Association Water Quality Technology Conference, 2007
Thesis advisor for the 2nd place winner in the American Water Works Association Academic Achievement Award competition for the best Master's Thesis, 2007
AWWA Water Science & Research Division Best Poster Award, 2006
Bill Horn Kimley-Horn Faculty Award, NC State University, 2003
AWWA Water Science & Research Division Best Paper Award, 2001
Young Civil Engineer Achievement Award, University of Illinois, 2000
Thesis Advisor for the 2nd place winner in the AEESP/Montgomery Watson Master's Thesis Award Competition, 1999
University of Illinois Fellowship, 1989-1991
Bronze Tablet Recipient, University of Illinois, 1989
Ira O. Baker Prize, Department of Civil Engineering, University of Illinois, 1989
A. Epstein Award, Department of Civil Engineering, University of Illinois, 1989
Chi Epsilon, 1988-present
Tau Beta Pi, 1988-present

6. Professional service on campus

Department RPT Committee Member 2014-2016, Chair 2016-present
Global WaSH Cluster Hire Search Committee, 2015-present
Department ABET Assessment Committee for Laboratory Outcomes Member, 2001-2015, Chair 2015-present
Department EB V/Oval Lab Committee Member 2008-2010, 2016-present
Department Equipment and Facilities Committee Member 1998-2002, 2013-2016, Chair 2002-2012
WREE Group Coordinator, Fall 2011-Spring 2012
Department Head Search Committee Member, 2004 and 2009-2010
Department Awards Committee Member, 2007-2011
Department Sustainability Task Force Member, 2008-2010
WRRI Director Search Committee Co-Chair, 2008-2009
Department Compact Planning Committee Member, Spring 2007
Water Resources and Environ. Engrg. Seminar Series Teleconference Coordinator, 1998-2004
Department Faculty Search Committee Member, 1997, 1999, 2007

Department Open House Committee Chair, 1998-1999
Department Open House Committee Member, 1997-1998
Department Flower Fund Chair, 1996-1997
College Welcome Presenter, 2001
Department Representative for Summer Orientation, 1998-2000
Technical Advisory Committee Member for Engineers without Borders (NCSU Student Chapter), 2006-present

7. Professional service off campus

Committee Appointments
NC Science Advisory Board, Member, 2017-present
EPA Science Advisory Board, Member, Drinking Water Committee, 2016-present
Trustee, AWWA Water Science and Research Division, 2016-present
AEESP Lectures Committee Member, 2008-2016, Subcommittee Chair for lecturer selection at the AWWA Annual Conference, 2014-2016
AWWA Publications Award Committee Member, 2013-present
AWWA Activated Carbon Standards Committee Member, 2003-present
AWWA Regeneration Standards Subcommittee Chair, 2005-2007
AWWA Organic Contaminants Research Committee Member, 2000-2005, 2007-present
AWWA Carcinogenic Volatile Organic Compounds Working Group, 2011-2014
AWWA Particulate Contaminants Research Committee Member, 2001-2005

Journal Editorship
Topic Editor, Drinking Water Engineering and Science (Open Access Journal), 2011-present
Associate Editor, Water Science and Technology, 2009-2013

Conference Organization
Organizer for special topic session "GenX and Emerging Contaminants of Concern," NC Water Resources Research Institute Annual Conference, 2018
Organizer for special topic session "Effects of Perfluoroalkyl Substances on Drinking Water Quality and Treatment," AWWA Annual Conference, 2017
Organizer for special topic session "Water Treatment with Superfine Powdered Activated Carbon for Organics Removal," AWWA Water Quality Technology Conference, 2015
Organizer for special topic session "Activated Carbon Adsorption," AWWA Annual Conf., 2013
Co-organizer of ACS Symposium "Advances in Adsorption Processes," 2007-2008

Review
Peer reviewer for journals, conference abstracts, and research proposals (NSF, NIH, EPA, Water RF, EREF, WRRI, Research Council of Norway, U.S.-Israel Binational Science Foundation), 1991-present
Project Advisory Committee Member for WateReuse Foundation project, 2015-present
Project Advisory Committee Member for AwwaRF/Water RF research projects, 1997-2011

II. TEACHING AND MENTORING OF UNDERGRADUATE AND GRADUATE STUDENTS

A. Teaching Effectiveness

Courses Taught, Enrollment, and Student Evaluations for the Past Three Years

Semester	Course Code	Enrollment	Student Evaluations*, §
Spring 2015	CE 771	12	4.8 (4.4)
Fall 2015	CE 378	28	4.7 (4.1)
	CE 574	16 8‡	4.6 (4.5) 5.0 (4.5) ‡
Spring 2016	CE 771	6	4.3 (4.5)
Fall 2016	CE 378	30	4.4 (4.1) – partially taught by Amie McElroy, I served as her teaching mentor
	CE 574	15	4.8 (4.5)
Spring 2017	CE 771	10	4.8 (4.6)
Fall 2017	CE 378	30	4.5 (4.0)
	CE 574	19 3‡	4.1 (4.5) not evaluated
Spring 2018	CE 771	6	ongoing

* Evaluation is the average response to "Overall, the instructor was an effective teacher" with a choice of 1 through 5. A response of 5 represents "strongly agree."
§ Departmental average is shown in parentheses.
‡ Engineering Online section

Summary of Peer Evaluations of Teaching

Dates: 10/17/17, 10/19/17, and 10/22/17
Faculty Member: Detlef Knappe
Peer Reviewers: Joel Ducoste and Sankar Arumugam
Course No. and Name: CE 378 – Environmental Chemistry and Microbiology

Evaluation:

"Very well" and "Adequately" were the only boxes that were checked on the Class Observation and Course Materials Checklists (apart from "Not applicable"). *What worked well in the class*: "Good pace." "Good discussion of how to organize oral presentation." "I attended a laboratory session. The instructor started off the class reminding students of today's assignment, then helped them get started on the required measurements. The lab was well organized and appeared to be appropriately stocked with the required supplies and equipment. All students arrived promptly and were focused on their work. Everyone appeared to understand what was going on." "Attention was given to each lab group." "Good preparation for oral presentations. Good presentation, illustrations of what is good and bad was helpful. Clear review of quiz solution." *What could have been improved*: "Rework slides from others (remove big blackouts) to get students more involved in discussion." "The

instructor and several students were not initially wearing safety glasses." "Consider asking student reading newspaper to not attend class as it may set tone for others." "Perhaps write out definition of accuracy and precision and then illustrate by example." "Ask students to critique slides." Comments on course materials: " Course materials are clear and well organized. Lab experiments are clear and easy to follow. Course covers basic environmental laboratory techniques that will be useful for those that go on to do laboratory research." "Clear course description and expectations." "Well organized handouts."

B. Instructional Development

Presented a class on critiquing research papers in the CE610 Research Methods class led by Dr. Ranjithan, Fall 2015, Spring 2016, Fall 2016.

Participated in discussions that led to a new Sustainable Engineering Design course, an interdisciplinary course between CCEE and Architecture. First offered in Spring 2012. Lead: Dr. Ranjithan in CCEE and Dr. Hill in Architecture. Provide lecture on water conservation each year.

Developed course content for CE 378 (Environmental Chemistry and Microbiology). Emphasizes fundamental concepts of chemistry and microbiology as they apply to (1) characterizing water and air quality and (2) finding engineering solutions to improve water and air quality. The course integrates theory and hands-on laboratory experiments. First offered Fall 2010.

Co-developed (with Dr. Joel Ducoste) course content for CE 373, a new introductory Environmental Engineering course (Spring 2002). I am continuing to develop lecture, homework, and project materials for CE 373 to enhance the sustainable engineering content for this course. For example, students are completing group projects related to green building design and construction practices. During the summer of 2009, Joe DeCarolis, Francis de los Reyes, Morton Barlaz and I re-designed the content of CE 373; in particular, concepts of engineering for sustainability were introduced.

Revised course content for CE 374, a junior-level environmental engineering laboratory course that introduces students to analytical techniques for the assessment of water and air quality. Both through Education and Technology Fee funds and matching funds from the College of Engineering, equipment was obtained that (1) introduces students to modern analytical techniques employed in environmental engineering practice and (2) strengthens the process engineering component of this course. Using the new equipment, experiments were developed that introduced students to common unit operations in water and wastewater treatment through hands-on experiences. Formal laboratory report requirements were designed to improve students' technical writing skills, and an oral presentation component was added in the Fall 2003 semester to give students an opportunity to present experimental results in verbal form using appropriate visual aids.

Modified notes for and taught a CE 381 laboratory session on viscosimetry on a semesterly basis (Spring 1997 – Spring 1999).

Completely revised course material for CE 484, a senior-level undergraduate course that introduces students to the design of unit operations for the treatment of water and wastewater. Design concepts for both physicochemical and biological treatment processes are presented and supplemented by field trips to local water and wastewater treatment plants. In the Fall 2000 semester, I introduced a technical writing and presentation assignment that gave student groups the opportunity to research a current topic in water and wastewater treatment (e.g. algal toxins, endocrine disruptors). In their course evaluation forms, students commented nearly unanimously that they enjoyed the assignment despite nearly equally unanimous comments that the assignment represented a substantial time-commitment. By requiring student groups to complete project milestones throughout the semester, they completed this open-ended assignment effectively and with enthusiasm. I was also pleasantly surprised by the quality of the students' final papers and presentations.

Participated in an *ad-hoc* committee to revise CE 574. The course action form and syllabus were changed to expand the environmental chemistry component of this course. Over the course of the Fall 2012 and Fall 2013 semesters, I updated course content and adopted a new textbook.

Completely revised course material for CE 672 (last offered in Spring 1998, currently not offered), an advanced graduate level course that focuses on the application of mass transfer concepts for the treatment of water and waste. Covered topics include activated carbon adsorption, ion exchange, gas transfer, and membrane treatment processes.

Completely revised course material for CE 771 (formerly CE 571), a graduate level course that focuses on the application of fundamental physicochemical principles to the design of common unit processes used in the treatment of water and waste. Covered topics include sedimentation, coagulation/flocculation, filtration, oxidation/reduction, disinfection, softening, adsorption, and membrane treatment. Offered CE 771 (formerly CE 571) through the Engineering Online program to students as far away as Washington State and Qatar.

Co-developed course material for CE 796C (Environmental Behavior of Organic Contaminants), an advanced graduate level course, in which students apply principles of environmental organic chemistry to predict the partitioning of contaminants among environmental media and to model chemical and biological transformation processes. Initial offering: Spring 07.

Coordinated effort to organize graduate course offerings in the process engineering area (Spring 2003). Course action forms for CE 571, CE 574, CE 771, and CE 774 were updated, and CE 573 was added.

Attended the College of Engineering Teaching Effectiveness Workshop conducted by Richard Felder and Rebecca Brent, McKimmon Center, NCSU, August 12-14, 1996. Began to enhance my courses by (1) incorporating more group activities, (2) addressing different learning styles, and (3) developing more problems that address higher level thinking.

C. Mentoring Activities

Undergraduate Academic Advising

I continue to serve as an academic advisor to approximately 10-20 undergraduate students in each academic year. Also mentored Parks Scholars.

Direction of Undergraduate Research (in chronological order)

Student	Program	Period
Tiffany Tang	BS (NCSU)	F 2017 – present
Julia O'Brian[*]	BS (NCSU)	Su 2017
Asma Idries	BS (NCSU) – co-advised with D. Call	Mar. – May 2017
Rachel Scroggins	BS (NCSU) – co-advised with D. Call	Mar. – May 2017
Nancy Lee McLean[*]	BS (NCSU)	Sp 2017 – present
John Merrill[*,‡]	BS (NCSU)	Sp 2015 – present
Ally Patrick[*]	BS (NCSU)	Su 2014
Sara Troutman[*,☺]	BS (NCSU) – co-advised with Ranjithan	F 2013 – Sp 2015
Caroline LaFave	BS (NCSU)	Sp 2014
Rodniqua Minor[*,☺]	BS (NCSU)	Sp 2013 – Sp 2014
Justin Davenport[*,☺]	BS (NCSU)	Sp 2013 – Sp 2014
Dustin Rhodes[*]	BS (NCSU)	Sp/Su 2012
Benjamin Lord[‡]	BS (NCSU)	Sp 2012
Katie Dorety[*]	BS (NCSU)	Sp 2011
Evan Ged[*,☺]	BS (NCSU)	F 2010/Sp 2011
Ross Varin[*,☺,Δ]	BS (NCSU) – co-advised with de los Reyes	F 2010/Sp 2011
Ruth Small[*,☺]	BS (NCSU)	Sp 2010
Susan Dunn[*,☺,§]	BS (NCSU)	F 2009
Leigh-Ann Bender[*,☺]	BS (NCSU)	Sp/Su 2010
Maggie Hennessy[*,☺]	BS (NCSU)	Sp/Su 2009
Oksana Popovski[*,#,☺]	BS (NCSU)	Sp/Su 2009
Mary Waligora[*,‡,☺]	BS (NCSU)	Sp 2008 - Sp 2010
Martin Srb[*]	IAESTE[**]	Su 2007
Catherine M. Hoffman[*]	REU (NSF)	Su 2006
Laura E. Chambers[*,#]	REU (NSF)	Su/F 2003
Laurissa E. Hoyle[*,#,§]	REU (NSF)	F 2002/Sp 2003
Maria Pinzón[+]	Summer Research Experience (NSF)[&]	Su 2002
Travis B. Wagner[*,§]	BS (NCSU)	Sp/Su 2001
Anette Olsson[+]	BS (University of Lund, Sweden)	Sp 2001
Jon C. Williams[+,§]	BS (NCSU)	Su 2000/2001
Jun-Sang Lee[*]	BS (ChungBuk National Univ., S. Korea)	Su/Fall 1999
Jin-Man Kim[*]	BS (ChungBuk National Univ., S. Korea)	Su/F 1999
Patricia A. Quinlivan[*,§]	BS (NCSU)	Sp/Su 1999
Laurel E. Wright[*,§]	BS (NCSU)	Sp/Su 1999
Adrienne M. Sheats	Ravenscroft High School Intern	May 1999
Alper O. Savas[+,§]	BS (METU, Turkey)	Su 1998

Jenny Parmar[*, §]	BS (NCSU)	Sp 1998
Heather A. Marek[*]	REU (NSF)	Su 1997
Alper O. Savas[*, §]	BS (METU, Turkey)	Su 1997

[*] Students worked on externally funded projects
[@] Cost-shared with COE/CCEE undergraduate research funds
[Δ] Co-advised with F.L. de los Reyes
[#] Co-advised with M.A. Barlaz
[‡] Student was recipient of an NCSU undergraduate research award
[**] International Association for the Exchange of Students for Technical Experience
[§] Students subsequently enrolled in the graduate Civil Engineering program at NCSU
[+] Students worked on unfunded projects to collect screening data for research proposals
[&] The North Carolina Minority Graduate Education Program is funded by NSF and includes the "Intensive Research and Training Program," which has two primary components: the "Academic Year Research Experience" (ARE) and the "Summer Research Experience" (SRE).

Graduate Committees (Chair/co-chair)

Student	**Degree**	**Committee Role**	**Graduation Date**
S. Park	PhD	co-chair	anticipated Sp 22
C. Zhang	PhD	chair	anticipated Sp 20
A. McElroy[^]	PhD	chair	anticipated Sp 18
Z. Hopkins	PhD	chair	anticipated Sp 17
B. Yuncu	PhD	chair	Fa 10
J. M. Saquing	PhD	co-chair	Fa 09
A. A. Rossner	PhD	chair	Fa 08
A. C. Baeza[*, +]	PhD	chair	Fa 08
C. Chun	PhD	co-chair	Su 07
Y. Chen	PhD	co-chair	Su 03
L. Li	PhD	co-chair[§]	Su 02
B. Wu	PhD	co-chair[§]	Su 02

[^] GAANN Fellow
[*] NSF Graduate Research Fellow
[+] NWRI Fellow
[§] I served as primary research advisor, but I was not able to chair PhD committees because of my associate membership in the Graduate Faculty

M. Fitzstevens	MS	co-chair	anticipated Su 18
O. Hounwanou	MS	chair	anticipated Sp 18
C. Maness	MS	chair	Sp 17
C. Lopez Velandia	MS	chair	Su 16
J. Moreno Barbosa	MS	chair	Su 16
R. S. Ingham	MS	chair	Su 14
A. C. Greune	MS	chair	Su 14
V. U. Edeback	MS	chair	Su 14
E. C. Arevalo	MS	chair	Sp 14
A. M. Reinert	MS	chair	Sp 13
M. E. Fotta	MS	chair	Su 12
L. M. Dudley	MS	chair	Sp 12

S. E. Dunn*, +	MS	chair	Fa 11
A. Mastropole	MS	chair	Su 11
Q. Deng	MS	chair	Su 10
A. Viswakumar	MS	chair	Sp 10
V. Mandapaka	MS	co-chair	Fa.08
I. A. Mezzari+	MS	chair	Sp.06
L. A. Mitchell	MS	chair	Sp.05
A. A. Rossner	MS	chair	Su.04
T. B. Wagner	MS	chair	Su.03
P. A. Quinlivan*	MS	chair	Su.01
C. M. Taylor	MS	chair	Sp.00
S. R. Gandy	MS	chair	Sp.00
N. Rastogi	MS	chair	Fa.99
R. C. Belk	MS	chair	Sp.99
D. S. Briley+	MS	chair	Fa.98
A. H. Rike	MS	chair	Sp.98

* NSF Graduate Research Fellow
+ Thesis Award Winner (AWWA, AEESP)

Graduate Committees (Member)

Student	**Program**	**Graduation Status**
A. Hess	PhD (Process Eng. – ETH Zurich)	ongoing
Q. Cheng	PhD (CE)	ongoing
M. Bentley	PhD (CE – U. Colorado, Boulder)	ongoing
A. Beciragic	PhD (ESE – UNC-CH)	ongoing
H. Chmielewski	PhD (OR)	ongoing
B. Hess	PhD (BAE)	ongoing
K. Grzebyk	PhD (ESE – UNC-CH)	ongoing
J.M. Tillotson	PhD (CE)	ongoing
S. Safavizadeh	PhD (CE)	completed
E. Gillispie	PhD (SSC)	completed
K. Shimabuku	PhD (CE – U. Colorado, Boulder)	completed
E. Bailey	PhD (ESE – UNC-CH)	completed
J. Kearns	PhD (CE – U. Colorado, Boulder)	completed
J. Won	PhD (CE)	completed
J.R. Lang	PhD (CE)	completed
A.D. Lindsay	PhD (NE)	completed
X. Wang	PhD (CE)	completed
F. de la Cruz	PhD (CE)	completed
D. Kempisty	PhD (CE – U. Colorado, Boulder)	completed
A. Kennedy	PhD (CE – U. Colorado, Boulder)	completed
A. Sobremisana	PhD (CE)	completed
X. He	PhD (CE)	completed
J. Oh	PhD (CE)	completed
Q. Chow	PhD (CE – U. Illinois, Urbana)	completed

C. Corwin	PhD (CE – U. Colorado, Boulder)	completed
S. M. Alpert	PhD (CE)	completed
S. Velten	PhD (CE – ETH Zurich)	completed
T. M. Kunberger	PhD (CE)	completed
C. Mota	PhD (CE)	completed
I. Lou	PhD (CE)	completed
M. Badruzzaman	PhD (CE – Ariz. State)	completed
L. Schideman	PhD (CE – U. Illinois, Urbana)	completed
D. Liu	PhD (CE)	completed
Y. Liu	PhD (CE)	completed
E. Solano	PhD (CE)	completed
K. Clay	MS (MEAS)	completed
J. Babuin-Nickels	MS (MEAS)	completed
A. Berglund	MS (CE)	completed
J. B. Wahlen	MS (CE)	completed
S. R. Farling	MS (CE)	completed
F. J. Hurley	MS (CE)	completed
K. Fogle	MS (CE)	completed
B. Karami	MS (CE)	completed
J. Lang	MS (CE)	completed
L. Bao	MS (CE)	completed
J. P. Kaplan	MS (ESE – UNC-CH)	completed
M. Vazquez	MS (CE)	completed
E. Gallimore	MS (CE)	completed
C. Bowker	MS (CE)	completed
R. Prevost	MS (CE)	completed
Y. Bi	MS (Soil Science)	completed
L. Wellborn	MS (CE)	completed
K. Jang	MS (CE)	completed
J. H. Martin II	MS (BAE)	completed
V. L. Nguyen	MS (CE)	completed
A. Sadri	MS (CE)	completed
G. Gulez	MS (CE)	completed
J. C. Williams	MS (CE)	completed
C. Long	MS (CE)	completed
N. Bartholomew	MS (Soil Science)	completed
A. C. Baeza	MS (CE)	completed
J. Liao	MS (CE)	completed
D. C. Hopkins	MS (CE)	completed
J. C. Ihnatolya	MS (CE)	completed
V. A. Ortiz	MS (CE)	completed
K. M. Aragona	MS (CE)	completed
R. J. Fairweather	MS (CE)	completed
D. M. Giachini	MS (CE)	completed
D. K. Peplinski	MS (CE)	completed
M. T. Pelton	MS (CE)	completed

J. K. Rash	MS (CE)	completed
M. R. Sanchez	MS (CE)	completed
J. B. Stillman	MS (CE)	completed
M. B. Vergonio	MS (CE)	completed

MCE Project Advisor

I. A. Mezzari	MCE	Sp.09
A. O. Savas	MCE	Sp.03
J. M. Chambers	MCE	Fa.99
G. C. Rucker	MCE	Sp.97

External PhD Thesis Reviewer

Lionel Ho	University of South Australia	Fall 2004

Graduate Academic Advising

In addition to the MS and PhD students, for whom I serve as research and academic advisor, I continue to serve as an academic advisor to approximately 2 MCE students (courses-only program) and 2 MCEZ students (Engineering Online program) in each academic year.

Hosting of Visiting Scholars

Zihong Fan, Lecturer, Chongqing Technology and Business University, March 2017 – August 2018. Research Topic: Cyclodextrin-enhanced adsorption of disinfection by-product precursors.

Mary Jo Weiss-Errico, PhD Student, Florida International University, January-February 2018. Research Topic: Functionalization of graphene oxide for targeted PFAS removal.

Geert Aschermann, PhD Student, TU Berlin, November 2017 – February 2018. Research Topic: Factors controlling PFAS desorption from activated carbon.

Josh Kearns, PhD Student, CU-Boulder; Director, Aqueous Solutions (A non-profit organization with the mission to enable households and communities to ensure the safety of their drinking water in a sustainable and self-reliant manner.) April – October 2008, Jan. 2013-May 2017. Research Topic: Effect of char preparation on adsorptive pesticide removal from drinking water.

Guangqian Wu, PhD Student and Lecturer, Nanjing Forestry University, June 2014-March 2015. Research Topic: Adsorption of 1,4-dioxane on graphene and carbonaceous resins.

Dr. Zhang Hua, Assistant Professor from Tongji University, August 2011 – August 2012. Research Topic: Organic contaminant sorption to municipal solid waste constituents. Co-directed by Drs. Barlaz and Knappe

Dr. Qingdong Qin, post-doctoral researcher at Southeast University in Nanjing, China. Dr. Qin spent 6 months at NCSU to conduct research on activated carbon adsorption processes. April – September 2011.

Dr. Koichi Ohno, Assistant Professor, Laboratory of Environmental Risk Engineering, Hokkaido University, Sapporo, Japan. Dr. Ohno spent a 10-month sabbatical at NCSU and conducted research on activated carbon adsorption processes. March 2009 – January 2010.

Silvana Velten, PhD Candidate, EAWAG (Swiss Federal Institute of Aquatic Science and Technology), February – August 2007. Research Topic: The effects of natural organic matter preloading on physicochemical properties of granular activated carbon and polar organic contaminant removal efficiency.

Dr. Hang-Bae Jun, Assistant Professor, ChungBuk National University, South Korea, January 1999 – January 2000. Research Topic: Optimization of Coagulation Conditions for the Removal of Algae from Drinking Water. Funding Agency: Korean Science and Engineering Foundation. The collaboration resulted in the publication of one peer-reviewed paper. Dr. Jun was promoted to Associate Professor at ChungBuk University after his stay at NC State University.

Advising of Post-Doctoral Research Associates

Dr. Nadine Kotlarz, August 2017 – present. Research Topics: Human biomarkers for emerging PFASs; water treatment options for emerging PFASs

Dr. Yue Zhi, August 2017 – present. Research Topic: Nanoparticles for the recovery of phosphate from waste

Dr. Mei Sun, April 2013 – December 2015. Research Topics: Adsorptive removal of fluorinated alternatives from drinking water, biological sulfide potential. Co-directed by Drs. Barlaz and Knappe. Current position: Assistant Professor, University of North Carolina at Charlotte.

Dr. Jovita Saquing, August 2009 – August 2010. Research Topic: Contaminant Fate and Transport in Municipal Solid Waste. Co-directed by Drs. Barlaz and Knappe. Current position: Post-doctoral research associate, University of Delaware.

Dr. Erik Rosenfeldt, August 2006 – July 2007. Research Topic: New Techniques to Quantify Assimilable Organic Carbon Concentrations and Microbial Regrowth in Drinking Water Distribution Systems. Current position: Director of Applied Research, Hazen and Sawyer.

Dr. Shannon Bartelt-Hunt, July 2004 – December 2005. Research Topic: Assessment of the Behavior of Chemical and Biological Contaminants in Landfills. Co-directed by Drs. Barlaz and Knappe. Current position; Professor, University of Nebraska at Omaha.

Advising of Student Groups

I have served and continue to serve as research group advisor and technical advisory committee member for the NCSU Student Chapter of Engineers Without Borders. Fall 2006 – present.

Master's and Doctoral Theses Directed and Being Directed

PhD Theses

1. Bingyan Wu. 2002. Factors controlling alkylbenzene sorption and desorption in municipal solid waste. Ph.D. Thesis (co-chair with Dr. M.A. Barlaz).*

2. Lei Li. 2002. Effects of activated carbon surface chemistry and pore structure on the adsorption of trace organic contaminants from aqueous solution. Ph.D. Thesis (co-chair with Dr. M.A. Barlaz).*

3. Ye Chen. 2003. Effects of Aging on the Bioavailability of Toluene Sorbed to Municipal Solid Waste Components. Ph.D. Thesis (co-directed with Dr. M.A. Barlaz)

4. Chen Chun. 2007. Quantifying Anti-Strip Additive in Asphalt Binders and Mixes. Ph.D. Thesis (co-directed with Dr. A.A. Tayebali).

5. A. Carolina Baeza. 2008. Removal of pharmaceutical and endocrine disrupting chemicals by sequential photochemical and biological oxidation processes. Ph.D. Thesis (Carolina Baeza's work was supported by a NSF Graduate Research Fellowship and a NWRI fellowship).

6. Alfred A. Rossner. 2008. Removal of polar and emerging organic contaminants by alternative adsorbents. Ph.D. Thesis.

7. Jovita Saquing. 2009. Sorption Behavior and Persistence of Organic Contaminants in Landfills. Ph.D. Thesis (co-directed with Dr. M.A. Barlaz).

8. Bilgen Yuncu. 2010. Removal of 2-Methylisoborneol and Geosmin by High-Silica Zeolites and Powdered Activated Carbon in the Absence and Presence of Ozone. Ph.D. Thesis.

9. Zachary Hopkins. Expected 2017. Advanced oxidation and reduction processes for the control of emerging ether contaminants in drinking water (tentative title). Ph.D. Thesis.

10. Amie McElroy. Expected 2018. Degradation of 1,4-dioxane by monooxygenase-producing microorganisms (tentative title). Ph.D. Thesis.

11. Chuhui Zhang. Expected 2020. Total oxidizable precursor assay for the characterization of environmental samples contaminated with perfluoroalkyl ether acids (tentative title). PhD Thesis.

12. Sol Park. Expected 2022. Electrically assisted adsorption of short-chain perfluoroalkyl acids.

[*] I served as primary research advisor, but I was not able to chair PhD committees because of my associate membership in the Graduate Faculty

MS Theses

1. Andrew H. Rike. 1998. The impacts of algae and extracellular organic matter on coagulant demand and trihalomethane and dichloroacetonitrile formation potential. M.S. Thesis.

2. David S. Briley. 1999. Optimization of coagulation conditions for the removal of algae in conventional water treatment. M.S. Thesis. (David Briley's thesis received 2nd place in the AEESP/Montgomery Watson Master's Thesis Award Competition).

3. Robert C. Belk. 1999. On-line monitoring tools for detecting algae in natural waters. M.S. Thesis.

4. Neerja Rastogi. 1999. Effects of Potassium Permanganate Preoxidation on Algae Removal and Finished Water Quality. M.S. Thesis.

5. Steven R. Gandy. 2000. Effectiveness of Dissolved Air Flotation and Microsand-Enhanced Flocculation for the Removal of Algae from Drinking Water. M.S. Thesis.

6. Caleb M. Taylor. 2000. Relationships between Physical and Chemical Characteristics of Municipal Solid Waste and its Sorptive Properties. M.S. Thesis. (co-directed with Dr. M.A. Barlaz)

7. Patricia A. Quinlivan. 2001. The Effects of Activated Carbon Surface Chemistry and Pore Structure on the Adsorption of Methyl Tertiary-Butyl Ether and Trichloroethene from Natural Water. M.S. Thesis. (Patricia Quinlivan's work was supported by a NSF Graduate Research Fellowship).

8. Travis B. Wagner. 2003. Factors controlling hydrophobic organic contaminant sorption to and desorption from municipal solid waste. M.S. Thesis. (co-directed with Dr. M.A. Barlaz)

9. Alfred A. Rossner. 2004. Adsorption of methyl tertiary-butyl ether on high-silica zeolites: effects of adsorbent characteristics and natural organic matter on adsorption isotherms. M.S. Thesis.

10. Lisa A. Mitchell. 2005. Factors controlling desorption rates of hydrophobic organic contaminants from municipal solid waste. M.S. Thesis.

11. Isabella A. Mezzari. 2006. Predicting the adsorption capacity of activated carbon for organic contaminants from fundamental adsorbent and adsorbate properties. M.S. Thesis. (Isabella Mezzari's thesis received 2nd place in the 2007 AWWA Academic Achievement Awards Master's Thesis Competition).

12. Venkata Mandapaka. 2008. Effect of prolonged heating on asphalt-aggregate bond strength. M.S. Thesis (co-directed with Dr. A.A. Tayebali).

13. Anjali Viswakumar. 2010. Development of a gas chromatography-tandem mass spectrometry method for the simultaneous analysis of 19 taste and odor compounds. M.S. Thesis.

14. Qianru Deng. 2010. Removal of biochemically active compounds by powdered activated carbon adsorption processes. M.S. Thesis.

15. Angela Mastropole. 2011. Evaluation of available scale-up approaches for the design of GAC contactors. M.S. Thesis.

16. Susan Dunn. 2011. Effect of powdered activated carbon base material and size on disinfection by-product precursor and trace organic pollutant removal. M.S. Thesis.

17. Leigh-Ann Dudley. 2012. Removal of perfluorinated compounds by powdered activated carbon, superfine powdered activated carbon, and anion exchange resins. M.S. Thesis.

18. Meredith Fotta. 2012. Effect of granular activated carbon type on adsorber performance and scale-up approaches for volatile organic compound removal. M.S. Thesis.

19. Allison Reinert. 2013. Granular activated carbon adsorption of micropollutants from surface water: Field-scale adsorber performance and scale-up of bench-scale data. M.S. Thesis.

20. Elisa Arevalo. 2014. Removal of Perfluorinated Compounds by Anion Exchange: Factors Affecting Resin Performance and Regeneration. M.S. Thesis.

21. Rachel Ingham. 2014. Henry's Law and Freundlich adsorption constants for carcinogenic volatile organic contaminants. M.S. Thesis.

22. Viking Edeback. 2014. Treatment Options for Disinfection Byproduct Control in Drinking Water Sources with Elevated Bromide Levels. M.S. Thesis.

23. Amber Greune. 2014. Bromide Occurrence in North Carolina and the Relationship between Bromide Concentration and Trihalomethane Formation. M.S. Thesis.

24. Jonathan Moreno Barbosa. 2016. Evaluation of Freundlich Adsorption Constants for VOCs at Regulatory Relevant Concentrations. M.S. Thesis.

25. Catalina Lopez Velandia. 2016. Occurrence of 1,4-dioxane in the Cape Fear River Watershed and Effectiveness of Point-Of-Use Treatment Options for 1,4-dioxane Control. M.S. Thesis.

26. Clark Maness. 2017. Control of Regulated and Unregulated Disinfection Byproducts by Granular Activated Carbon : Effects of Bromide, Iodide, and Pre-Chlorination. M.S. Thesis.

27. Obatayo Hounwanou. Effect of soil properties on turbidity control strategies for stormwater treatment (tentative title). M.S. Thesis. Expected August 2018.

III. SCHOLARSHIP IN THE REALMS OF FACULTY RESPONSIBILITY

A. Scholarly Accomplishments

Book Chapters

1. Summers, R.S.; D.R.U. Knappe; and V.L. Snoeyink. "Chapter 14 – Adsorption of Organic Compounds." In *Water Quality and Treatment*, 6th ed., J.K. Edzwald (Ed.), McGraw-Hill: New York, NY, 2011.

2. Knappe, D.R.U. "Chapter 9 - Surface Chemistry Effects in Activated Carbon Adsorption of Industrial Pollutants." In *Interface Science in Drinking Water Treatment – Theory and Applications*, Newcombe, G. and Dixon, D. (Eds.), Academic Press: Oxford, UK, 2006.

Refereed Journal Publications

1. Hopkins, Z.R., Sun, M., DeWitt, J.R., and Knappe, D.R.U. "Recently detected drinking water contaminants: GenX and other per- and polyfluoroalkyl ether acids." *Journal AWWA*, accepted (invited).

2. Hess, B.J.; P. Kolar, J.J. Classen, D. Knappe, and J.J. Cheng. "Evaluation of waste eggshells for adsorption of copper from water." *Transactions of the ASABE*, accepted.

3. Kennedy, A.M., Reinert, A.R., Knappe, D.R.U., and Summers, R.S. "Prediction of Full-Scale GAC Adsorption of Organic Micropollutants." *Environmental Engineering Science*, 34(7): 496-507, 2017.

4. Sun, M., Arevalo, E., Strynar, M.J., Lindstrom, A.B., Richardson, M., Kearns, B., Smith, C., Pickett, A., and Knappe, D.R.U. "Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina." *Environmental Science and Technology Letters*, 3(12): 415-419, 2016.

5. Sun, M., Lopez-Velandia, C., Knappe, D.R.U. "Determination of 1,4-dioxane in the Cape Fear River watershed by heated purge-and-trap preconcentration and gas chromatography–mass spectrometry." *Environmental Science and Technology*, 50(5): 2246–2254, 2016.

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12. Kovalova, L.; Knappe, D.R.U.; Lehnberg, K., Kazner, K., and Hollender, J. "Removal of highly polar micropollutants from wastewater by powdered activated carbon." *Environ. Sci. Poll. Res.*, 20(6): 3607-3615, 2013.

13. Chen, Y.; D.R.U. Knappe; and M.A. Barlaz. "The Effect of Aging on the Bioavailability of Toluene Sorbed to Municipal Solid Waste Components." *Chemosphere*, 90(2): 251-259, 2013.

14. Matsui, Y.; Yoshida, T.; Nakao, S.; Knappe, D.R.U.; and Matsushita, T. "Characteristics of Competitive Adsorption between 2-Methylisoborneol and Natural Organic Matter on Superfine and Conventionally Sized Powdered Activated Carbons." *Water Research*, 45(16): 4741-4749, 2012.

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Technology – Water Supply, 5(5): 83-91, 2005.

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49. Merle, M.; Knappe, D.R.U.; Pronk, W.; Vogler, B.; and von Gunten, U. "Assessing breakthrough of micropollutants in full-scale granular activated carbon adsorbers with rapid small-scale column tests and a novel pilot-scale sampling approach." *Water Research* (submitted March 12, 2018).

Peer-Reviewed Final Reports*

1. Stanford, B., D. Knappe, R.S. Summers, S.D. Richardson, and E.R.V. Dickenson. GAC Control of Regulated and Emerging DBPs of Health Concern. Water Research Foundation: Denver, Colorado, in review.

2. Cotton, C., D.R.U. Knappe, K. Linden, J. Brown, G. Upadhyaya, and P. Ponturo. Evaluation of cVOC Removal Efficiencies by Various Technologies. Water Research Foundation: Denver, Colorado, in review.

3. Knappe, D.R.U., R.S. Ingham, J. Moreno Barbosa, S. Troutman, D. Kempisty, T. Daugherty, and R.S. Summers. Henry's Law and Freundlich adsorption constants for carcinogenic volatile organic contaminants. Water Research Foundation: Denver, Colorado, 2017.

4. Chowdhury, Z., K.L. Porter, J. Collins, C. Francis, S. Sriboonlue, D. Cornwell, R. Brown, and D.R. U. Knappe. Survey of Existing VOC Treatment Installations. Water Research Foundation: Denver, Colorado, 2016.

5. R.S. Summers, D. Kempisty, T. Daugherty, and D. Knappe. Removal of volatile organic contaminants (VOCs) from drinking water via granular activated carbon treatment. Water Research Foundation: Denver, Colorado, 2015.

6. Dudley, L.A., E.C. Arevalo, and D.R.U. Knappe. Removal of perfluoroalkyl substances by powdered activated carbon adsorption and anion exchange. Water Research Foundation: Denver, Colorado, 2015.

7. Summers, R.S., A.M. Kennedy, D.RU. Knappe, A.M. Reinert, M.E. Fotta, A.J. Mastropole, C.J. Corwin, and J. Roccaro. Evaluation of Available Scale-up Approaches for the Design of GAC Contactors. Water Research Foundation: Denver, Colorado, 2014.

8. Dunn, S.E. and D.R.U. Knappe. Disinfection By-Product Precursor and Micropollutant Removal by Powdered Activated Carbon. Water Research Foundation: Denver, Colorado, 2013.

9. Ducoste, J.J., D.R.U. Knappe; and S.M. Alpert. Evaluation of Computational Fluid Dynamics (CFD) for Modeling UV-Initiated Advanced Oxidation Processes. Water Research Foundation: Denver, Colorado, 2011.

10. Knappe, D.R.U.; B. Yuncu; and Qianru Deng. *Removal of 2-Methylisoborneol and Geosmin by High-Silica Zeolites and Zeolite-Enhanced Ozonation*. Water Research Foundation: Denver, Colorado, 2010.

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13. Knappe, D.R.U.; L. Li; P.A. Quinlivan; and T.B. Wagner. *Effects of Activated Carbon Surface Chemistry and Pore Structure on the Adsorption of Trichloroethene and Methyl Tertiary-Butyl Ether from Natural Water*. American Water Works Association Research Foundation: Denver, Colorado, 2003, 74 pages.

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* Final reports for research projects funded by the Water Research Foundation (formerly the

American Water Works Association Research Foundation or AwwaRF) undergo peer review by a project advisory committee comprised of two to four members from academia and environmental engineering practice. Reports are published by the Foundation and are the principal product for Foundation subscribers.

Conference Presentations (with papers)

1. Lopez-Velandia, C. and D.R.U. Knappe. "1,4-Dioxane: Occurrence, sources, and treatment options for an emerging surface water contaminant." In *Proc. of the AWWA Annual Conference*, Chicago, IL, Jun. 19-22, 2016.

2. McElroy, A., M. Hyman, C. Smith, and D. Knappe. "Biological Degradation of 1,4-Dioxane at Drinking Water Relevant Concentrations." In *Proc. of the AWWA Water Quality Technology Conference*, Salt Lake City, UT, Nov. 15-19, 2015.

3. Sun, M., C. Lopez-Velandia, A. Eaton, and D.R.U. Knappe*. "1,4-Dioxane in North Carolina Surface Water: Occurrence Data and Regulatory Framework." In *Proc. of the AWWA Water Quality Technology Conference*, New Orleans, LA, Nov. 16-20, 2014.

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6. Knappe, D.R.U.*, A.C. Greune, and V.E. Edeback. "Uncovering the Trends of Increasing Bromide in North Carolina's Surface Waters: Sources and Impacts on Brominated DBPs throughout the State." In *Proc. of the AWWA Annual Conference*, Boston, MA, Jun. 8-12, 2014. (Invited Presentation)

7. Kennedy, A.*, A.M. Reinert, D.R.U. Knappe, and R. S. Summers. "Understanding and Predicting the Adsorption of Trace Organic Micropollutants by Granular Activated Carbon." In *Proc. of the AWWA Water Quality Technology Conference*, Long Beach, CA, Nov. 3-7, 2013.

8. Knappe, D.R.U.* "New Directions For PAC in Water Treatment." In *Proc. of the AWWA Annual Conference*, Denver, CO, Jun. 9-13, 2013.

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12. Kennedy, A.*, A. Reinert, R.S. Summers, I. Ferrer, M. Thurman, and D.R.U. Knappe. "Scale-Up of the GAC Adsorption of Trace Organic Compounds." In *Proc. of the AWWA Water Quality Technology Conference*, Toronto, ON, Nov. 4-7, 2012.

13. Fotta, M.E., J. Roccaro, and D.R.U. Knappe*. "Scale-Up Of Granular Activated Carbon Adsorbers For Volatile Organic Compound Removal From Groundwater: Effect Of Carbon Type." In *Proc. of the AWWA Water Quality Technology Conference*, Toronto, ON, Nov. 4-7, 2012.

14. Reinert, A.M. *, A. Kennedy, I. Ferrer, M. Thurman, R.S. Summers, and D.R.U. Knappe. "Comparing scale-up approaches to predict granular activated carbon adsorber performance for micropollutant removal." AWWA Annual Conference, Dallas, TX, June 10-14, 2012.

15. Dudley, L.M. *, M. Strynar, A. Lindstrom, L. McMillan, and D.R.U. Knappe. "Removal of perfluorinated compounds by powdered activated carbon: Effect of adsorbent and background water characteristics." AWWA Annual Conference, Dallas, TX, June 10-14, 2012.

16. Dunn, S.E., B. Yuncu, E. Ged, and D.R.U. Knappe*. Combined disinfectant byproduct precursor and micropollutant removal with superfine powdered activated carbon. In *Proc. of the AWWA Water Quality Technology Conference*, Phoenix, AZ, Nov. 13-17, 2011, 11 pages.

17. Corwin, C.J., A. Kennedy, J. Cardenas*, R.S. Summers, A. Mastropole, and D.R.U. Knappe. Impact of DOC, EBCT and Pretreatment on the GAC Adsorption of Trace Organic Contaminants. In *Proc. of the AWWA Water Quality Technology Conference*, Phoenix, AZ, Nov. 13-17, 2011, 6 pages.

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24. C. Baeza and D.R.U. Knappe.* Characterization of oxidation products formed in UV/H_2O_2 processes: Biochemical activity and biodegradation potential. *AWWA Research Symposium Emerging Organic Contaminants*, Austin, TX, Feb. 12-13, 2009, 6 pages.

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26. E. Rosenfeldt,* C. Baeza, and D.R.U. Knappe. Removal of Biochemically Active Compounds from Wastewater Effluent Using UV/H_2O_2 Treatment. *23rd Annual WateReuse Symposium*, Dallas, TX, Sept. 7-10, 2008, 9 pages.

27. S. Velten*; S. Meylan, M. Boller; and D.R.U. Knappe. Changes in physical characteristics and MTBE adsorption capacity of granular activated carbon during operation of a pilot-scale adsorber. In *Proc. of the 4th IWA Young Water Professionals International Conference*, Berkeley, CA, July 16-18, 2008, 8 pages.

28. B. Yuncu* and D. R.U. Knappe. Removal of 2-methylisoborneol and geosmin with high-silica zeolites. In *Proc. of the AWWA Water Quality Technology Conference*, Charlotte, NC, Nov. 4-8, 2007, 11 pages.

29. E.J. Rosenfeldt*; C. Baeza; and D.R.U. Knappe. Application of a flow cytometry method to quantify bacterial regrowth and assimilable organic carbon in distribution systems. In *Proc. of the AWWA Water Quality Technology Conference*, Charlotte, NC, Nov. 4-8, 2007, 7 pages.

30. A. Rossner* and D.R.U. Knappe. Adsorption of trimethoprim and sulfamethoxazole on alternative adsorbents. In *Proc. of the AWWA Water Quality Technology Conference*, Charlotte, NC, Nov. 4-8, 2007, 6 pages.

31. C. Baeza* and D.R.U. Knappe. Removal of an antimicrobial compound by sequential photochemical and biological oxidation processes. In *Proc. of the AWWA Water Quality Technology Conference*, Charlotte, NC, Nov. 4-8, 2007, 5 pages.

32. Barlaz, M.A.*; J. Saquing; I. Mezzari; and D.R.U. Knappe. Simulation and Modeling of the Fate and Transport of Chemical Warfare Agents in Laboratory-Scale Landfills. *11th International Waste Management and Landfill Symposium*, Cagliari, Italy, Oct. 1-5, 2007, 7 pages.

33. Alpert, S.M.*; D.R.U. Knappe; and J. Ducoste. "The Use of Computational Fluid Dynamics (CFD) to Model UV-Initiated Advanced Oxidation Processes." In *Proc. of the IOA - IUVA World Congress*, Los Angeles, CA, August 27-29, 2007, 14 pages.

34. Alpert, S.M.*; D.R.U. Knappe, and J. Ducoste. "Incorporation of Micromixing Models Within CFD Simulations Describing UV-Initiated Advanced Oxidation Processes." In *Proc. of the AWWA Annual Conference*, Toronto, ON, June 24-28, 2007, 14 pages.

35. Mezzari, I.A. *; T.F. Speth; and D.R.U. Knappe. "Predicting the Adsorption Capacity of Activated Carbon for Organic Contaminants from Adsorbent and Adsorbate Properties." In *Proc. of the AWWA Annual Conference*, San Antonio, TX, June 11-15, 2006, 13 pages.

36. C. Baeza* and D.R.U. Knappe. "Removal of Sulfonamides and Associated Antimicrobial Activity by UV Photolysis and UV/H_2O_2 Processes." In *Proc. of the AWWA Annual Conference*, San Antonio, TX, June 11-15, 2006, 5 pages. (This presentation received the 2006 AWWA Water Science & Research Division Best Poster Award).

37. Mezzari, I.A.; T.F. Speth; and D.R.U. Knappe*. "Predicting the Adsorption Capacity of Activated Carbon for Emerging Organic Contaminants from Fundamental Adsorbent and Adsorbate Properties." *Carolina Environmental Program: 2006 Symposium - Safe Drinking Water: Where Science Meets Policy*, Chapel Hill, NC, March 16-17, 2006, 14 pages.

38. Knappe, D.R.U. * and A.A. Rossner. "Effectiveness of High-Silica Zeolites for the Adsorption of Methyl Tertiary-Butyl Ether from Natural Water." 3rd IWA Leading-Edge Conference & Exhibition on Water and Wastewater Treatment Technologies, Sapporo, Japan, June 6-8, 2005. Accompanying paper published in *Water Science and Technology – Water Supply*, 9 pages.

39. Rossner, A.A. * and D.R.U. Knappe. "Adsorption of MTBE on Alternative Adsorbents." In *Proc. of the AWWA Annual Conference*, Orlando, FL, June 13-17, 2004, 13 pages.

40. Hepplewhite, C.; G. Newcombe *; and D.R.U. Knappe. "Predicting PAC Doses for the Removal of Algal Metabolites: How Can NOM Characterisation Techniques Help Us?" In *Proc. of the Australian Water Association 20th Annual Convention*, Perth, Australia, April 6-9, 2003, 10 pages.

41. Knappe, D.R.U. *; L. Li; and P.A. Quinlivan. "Suggestions for Selecting Activated Carbons for Drinking Water Treatment." In *Proc. of the 2002 NC AWWA/WEA Conference*, Winston-Salem, NC, Nov. 17-20, 2002, 8 pages.

42. Newcombe, G. *; C. Hepplewhite; and D.R.U. Knappe. "NOM and MIB, who wins in the competition for activated carbon adsorption sites?" *6th International Symposium on Off-*

Flavours in the Aquatic Environment, Barcelona, Spain, October 7-10, 2002. Accompanying paper published in *Water Science and Technology*.

43. Knappe, D.R.U. *; L. Li; and P.A. Quinlivan. "Going Beyond Iodine Number and BET Surface Area – Suggestions for Selecting Activated Carbons Based on Pore Structure and Surface Chemistry." In *Proc. of the AWWA Annual Conference*, New Orleans, LA, June 16-20, 2002, 8 pages.

44. Newcombe, G.*; J. Morrison; C. Hepplewhite ; and D.R.U. Knappe. "In the (Adsorption) Competition between NOM and MIB, Who is the Winner and Why?" *2001 World Water Congress*, Berlin, Germany, October 15-19, 2001. Accompanying paper published in *Water Science and Technology: Water Supply* 2(2): 59-67, 2002, 9 pages.

45. Quinlivan, P.A.*; L. Li; and D.R.U. Knappe. "Effects of Activated Carbon Surface Chemistry and Pore Structure on the Adsorption of Methyl Tertiary-Butyl Ether and Trichloroethene from Natural Water." In *Proc. of the AWWA Annual Conference*, Washington, DC, June 17-21, 2001, 14 pages.

46. Chambers, J.M.* and D.R.U. Knappe. "Coagulation Strategies for Algae Removal from a Piedmont Reservoir." In *Proc. of the NCAWWA/WEA Annual Conference*, Charlotte, NC, Nov. 13-14, 2000, 10 pages.

47. Rastogi, N. and D.R.U. Knappe*. "Treatment of Algae-Laden Waters with Potassium Permanganate: A Case Study for the Taste and Odor Causing Species *Synura petersenii*." In *Proc. of the AWWA Annual Conference*, Denver, CO, June 11-15, 2000, 11 pages.

48. Belk, R.C.*; D.R.U. Knappe; W.D. Frazier; E. Hannon; and H. Glasgow. "Detection of Algae in Drinking Water Sources by On-line Measurements." In *Proc. of the AWWA Water Quality Technology Conference*, Tampa, FL, Oct. 31 – Nov. 4, 1999, 22 pages.

49. Jun, H.B.*; B.D. Lee; Y.J. Lee; and D.R.U. Knappe. "Practical Approaches to Mitigate Filter Clogging in Conventional Water Treatment Plants." In *Proc. of the AWWA Water Quality Technology Conference*, Tampa, FL, Oct. 31 – Nov. 4, 1999, 10 pages.

50. Rastogi, N.; S.R. Gandy; and D.R.U. Knappe*. "Achieving Effective Algae Removal Prior to Filtration: Comparison of Conventional Treatment and Microsand-Enhanced Flocculation." In *Proc. of the AWWA Water Quality Technology Conference*, Tampa, FL, Oct. 31 – Nov. 4, 1999, 19 pages.

51. Barlaz, M.A.*; F.D. Sanin; and D.R.U. Knappe. "Biological and Chemical Transformations of Hazardous Organic Chemicals During Refuse Decomposition." *7th International Waste Management and Landfill Symposium*, Cagliari, Italy, Oct. 4-8, 1999, 12 pages.

52. Briley, D.S.* and D.R.U. Knappe. "Optimization of Coagulation Conditions for the Removal of Algae." In *Proc. of the AWWA Annual Conference*, Dallas, TX, June 21-25, 1998, 12 pages.

53. Knappe, D.R.U. *; D.S. Briley; and N. Rastogi. "Strategies for Algae Removal in Conventional Treatment." In *Proc. of the AWWA Annual Conference*, Dallas, TX, June 21-25, 1998, 16 pages.

54. Knappe, D.R.U. *; V.L. Snoeyink; P. Roche; M.J. Prados; and M.M. Bourbigot. "The Effect of GAC Service Time on the Adsorption of Periodic Episodes of Atrazine." In *Proc. of the AWWA Annual Conference*, Atlanta, GA, June 15-19, 1997, 24 pages.

55. Knappe, D.R.U. *; B.E. Greene; V.L. Snoeyink; and F.W. Pogge. "Predicting the Adsorption Capacity of Powdered Activated Carbon for Atrazine and Alachlor at Trace Levels in Missouri River Water." In *Proc. of the AWWA Water Quality Technology Conference*, Boston, MA, November 17-21, 1996, 12 pages.

56. Snoeyink, V.L. *; T.E.T. Gillogly; D.R.U. Knappe; and J.R. Elarde. "Optimal Use of Powdered Activated Carbon for Pesticide and Taste and Odour Removal." In *Proc. of the Annual Conference of the Australian Water and Wastewater Association*, May 1996, 4 pages.

57. Knappe, D.R.U. *; V.L. Snoeyink; Y. Matsui; M.J. Prados; and M.M. Bourbigot. "Determining the Remaining Life of a Granular Activated Carbon (GAC) Filter for Pesticides." *IWSA Specialized Conference on Activated Carbon in Drinking Water Treatment*, Amsterdam, The Netherlands, September 27-28, 1994; published in *Water Supply*, vol. 14 (2): 1-14, 1996, 14 pages.

58. Knappe, D.R.U. *; V.L. Snoeyink; M.J. Prados; M.M. Bourbigot; and K. Alben. "Determining the Life of Fresh and Operating GAC Filters for Atrazine." In *Proc. of the AWWA Annual Conference*, Anaheim, CA, June 18-22, 1995, 20 pages.

59. Snoeyink, V.L.* and D.R.U. Knappe. "Evaluation of Pilot and Full Scale Granular Activated Carbon Performance Data." In *Proc. of the AWWA Annual Conference*, New York, New York, June 19-23, 1994, 11 pages.

60. Knappe, D.R.U. *; V.L. Snoeyink; M.J. Prados; M.M. Bourbigot; and G. Dagois. "Adsorption of Atrazine by Powdered Activated Carbon." In *Proc. of the AWWA Annual Conference*, San Antonio, Texas, June 6-10, 1993, 24 pages.

* indicates presenter

Conference Presentations (with abstracts)

1. Kotlarz, N., Hopkins, Z., and Knappe, D.R.U. Can hydrogen peroxide enhance 1,4-dioxane oxidation by ozone in Cape Fear River water and lower bromate formation? *255th ACS National Meeting*, New Orleans, LA, March 18-22, 2018.

2. Hopkins, Z.R., McCord, J., Strynar, M., Lindstrom, A., and Knappe D.R.U. Detection and Treatment of Per- and Polyfluoroalkyl substances in the Cape Fear River basin of North

Carolina. *255th ACS National Meeting*, New Orleans, LA, March 18-22, 2018.

3. McElroy, A., Hyman, M.R., and Knappe, D.R.U. Locally enriched cultures can cometabolize 1,4-dioxane at drinking water relevant concentrations. *255th ACS National Meeting*, New Orleans, LA, March 18-22, 2018.

4. Hopkins, Z. and Knappe, D.R.U. Treatment Of 1,4-Dioxane In Surface Water By Ozone And Advanced Oxidation Processes. AWWA Annual Conference. Philadelphia, PA, June 11-14, 2017.

5. Knappe, D.R.U., Dudley, L.A., Arevalo, E., Strynar, M., Lindstrom, A., and PFAS Removal by Activated Carbon Adsorption & Anion Exchange. AWWA Annual Conference. Philadelphia, PA, June 11-14, 2017.

6. Sun, M., Dudley, L.A., Arevalo, E., Strynar, M., Lindstrom, A., and Knappe, D.R.U. Removal of traditional and emerging perfluoroalkyl substances by powdered activated carbon adsorption and anion exchange. AWWA Water Quality Technology Conference. Indianapolis, IN, November 13-17, 2016.

7. Cuthbertson, A.A., Kimura, S.Y., Richardson, S.D., Knappe, D., Seidel, C., Summers, R.S., Stanford, B., and Dickenson, E. Use of Granular Activated Carbon (GAC) for Controlling Emerging Disinfection By-Products (DBPs). AWWA Water Quality Technology Conference. Indianapolis, IN, November 13-17, 2016.

8. Castellano, L., Hopkins, Z., and Knappe, D.R.U. Analysis of 1,4-dioxane and carcinogenic VOCs at sub-mg/L levels by gas chromatography-triple quadrupole mass spectrometry. AWWA Water Quality Technology Conference. Indianapolis, IN, November 13-17, 2016.

9. Sun, M., L.A. Dudley, M. Strynar, A. Lindstrom, and D. Knappe. "Adsorption of traditional and emerging perfluoroalkyl substances by powdered activated carbon." *251st ACS National Meeting*, San Diego, CA, March 13-17, 2016.

10. Knappe, D., C. Lopez-Velandia, Z. Hopkins, and M. Sun. "Occurrence of 1,4-dioxane in North Carolina surface water and evaluation of possible treatment options." *251st ACS National Meeting*, San Diego, CA, March 13-17, 2016.

11. Sun, M., C. Lopez-Velandia, and D.R.U. Knappe. Using heated purge-and-trap and gas chromatography-mass spectrometry to quantify 1,4-dioxane in the Cape Fear River watershed in North Carolina. AWWA Water Quality Technology Conference. Salt Lake City, UT, November 15-19, 2015.

12. Dunn, S.E., A. Viswakumar, B. Yuncu, D. Rhodes, E. Ged, and D.R.U. Knappe. "Superfine powdered activated carbon for the removal of disinfection byproduct precursors and organic micropollutants. AWWA Water Quality Technology Conference. Salt Lake City, UT, November 15-19, 2015.

13. Moreno-Barbosa, J., K. Porter, J. Collins, J. Roccaro, and D. Knappe. "Implications of potential new regulatory scenarios for the removal of carcinogenic volatile organic compounds by granular activated carbon." North Carolina AWWAWEA Annual Conference. Raleigh, NC, November 16, 2015. Received 1st Prize in the Best Poster Award Competition and was therefore invited for presentation at the *AWWA Annual Conference* in Chicago, June 19-22, 2016.

14. Lopez-Velandia, C., M. Sun, and D.R.U. Knappe. "1,4-Dioxane: Occurrence and treatment options for an emerging surface water contaminant." North Carolina AWWAWEA Annual Conference. Raleigh, NC, November 16, 2015. Received 2nd Prize in the Best Poster Award Competition.

15. Lopez-Velandia, C., M. Sun, and D.R.U. Knappe. "1,4-Dioxane: Occurrence, sources, and treatment options for an emerging surface water contaminant." SETAC North America 36th Annual Meeting. Salt Lake City, UT, November 1-5, 2015.

16. Sun, M.*, E. Arevalo, L.A. Dudley, A.B. Lindstrom, M.J. Strynar, and D.R.U. Knappe. "Adsorption of perfluoroalkyl substances, including a fluorinated alternative, by powdered activated carbon." FLUOROS 2015 An International Symposium on Fluorinated Organics in the Environment. Golden, CO, July 12-14, 2015.

17. Stanford, B.D.*, A.M. Reinert, E. Rosenfeldt, M. Bishop, and D.R.U. Knappe. "A Hybrid Approach to Granular Activated Carbon: A Model to Balance Cost with Water Quality Objectives and DBP Compliance." AWWA Annual Conference, Anaheim, CA, June 5-8, 2015.

18. C. Lopez-Velandia*, M. Sun, and D.R.U. Knappe. "1,4-Dioxane Occurrence in the Cape Fear River Watershed of North Carolina and Point-of-Use Treatment Options for 1,4-Dioxane Control." NSF WORKSHOP: Fostering Advances in Water Resource Protection and Crisis Communication, Lessons Learned from Recent Disasters. Sheperdstown, WV, May 27-29, 2015.

19. M. Sun* and D.R.U. Knappe. "Rapid Analysis of 1,4-Dioxane in Water by Heated Purge-and-Trap Gas Chromatography-Mass Spectrometry." NSF WORKSHOP: Fostering Advances in Water Resource Protection and Crisis Communication, Lessons Learned from Recent Disasters. Sheperdstown, WV, May 27-29, 2015.

20. Chmielewski, H.*, S. Troutman, D.R.U. Knappe, and R. Ranjithan. "Modeling Future Performance of Water Pumping and Treatment Options." World Environmental & Water Resources Congress, Austin, TX, May 17-21, 2015.

21. A.B. Lindstrom*, M.J. Strynar, R.L. McMahen, L. McMillan, and D.R.U. Knappe. "Municipal Waste Water Treatment Plant Biosludge Applications and Perfluoroalkyl Acid Surface Water Contamination in North Carolina." NCAWWA-WEA 14th Annual Spring Conference, Wilmington, NC, April 12-14, 2015.

22. Lopez-Velandia, C., M. Sun, and D.R.U. Knappe. "1,4-Dioxane - A Contaminant of Emerging Concern for NC Drinking Water Providers." *WRRI Annual Conference*, Raleigh, NC, March 18-19, 2015.

23. A.B. Lindstrom*, A.B., M.J. Strynar, L. McMillan, D. Knappe, E. Arevalo, S. Wing, A. Lowman, M. Serre, and P. Jat. "Surface Disposal of Waste Water Treatment Plant Biosoilds – an Important Source of Perfluorinated Compound Contamination in the Environment?" SETAC North America, Vancouver, BC, Canada, November 9-13, 2014.

24. Arevalo, E.C.*, L.A. Dudley, A.M. Reinert, M. Strynar, A. Lindstrom, L. McMillan, and D.R.U. Knappe. "Occurrence of Perfluorinated Compounds in the Cape Fear River Basin and Effectiveness of Treatment Approaches." *93rd NC AWWA/WEA Annual Conference*, Concord, NC. November 10-13, 2013. Received 1st Prize in the Best Poster Award Competition and was therefore invited for presentation at the *AWWA Annual Conference* in Boston, June 8-12, 2014.

25. Chmielewski, H.*, Troutman, S., Knappe, D. & Ranjithan, R. "Optimizing Multiple Objectives in Future Water Treatment and Distribution Decisions." 16th Annual Water Distributions Systems Analysis Symposium at the World Environmental & Water Resources Congress, Portland, OR, June 1-5, 2014.

26. Ingham, R.* and D.R.U. Knappe. "Henry's Law Constants and Freundlich Adsorption Constants for Carcinogenic Volatile Organic Compounds." *WRRI Annual Conference*, Raleigh, NC, March 19-20, 2014.

27. Greune, A.C.* and D.R.U. Knappe. "Bromide Occurrence in North Carolina Surface Waters." *93rd NC AWWA/WEA Annual Conference*, Concord, NC. November 10-13, 2013.

28. Edeback, V.U.* and D.R.U. Knappe. "Use of Rapid Small-Scale Column Tests to Assess Full Scale Granular Activated Carbon Adsorber Design Options for Disinfection Byproduct Precursor Control." *93rd NC AWWA/WEA Annual Conference*, Concord, NC. November 10-13, 2013.

29. Ingham, R.* and D.R.U. Knappe. "Evaluation of Henry's Law Constants for Carcinogenic Volatile Organic Compounds." *93rd NC AWWA/WEA Annual Conference*, Concord, NC. November 10-13, 2013.

30. Dudley, L.A., Q. Deng, P. Kaplan, Y. Liu, H. Weinberg, and D.R.U. Knappe*. "Removal of Emerging Contaminants with Water Treatment Processes Commonly Used in North Carolina." *WRRI Annual Conference*, Raleigh, NC, March 20-21, 2013

31. Fotta, M.E.*, J. Roccaro, and D.R.U. Knappe. "Effect of Carbon Type, Reactivation, and Empty Bed Contact Time on Granular Activated Carbon Performance for Volatile Organic Compound Removal." *South Carolina Environmental Conference*, Myrtle Beach, SC, March 10, 2013.

32. Reinert, A.* and D.R.U. Knappe. "Comparing Scale-Up Approaches to Predict Granular Activated Carbon Adsorber Performance for Micropollutant Removal." *92nd NC AWWA/WEA Annual Conference*, Raleigh, NC. November 11-14, 2012. Received 2nd Prize in the Best Poster Award Competition.

33. Chowdhury, Z.*, J. Shaw, D.R.U. Knappe, J. Roccaro, K. Randazzo, and A. Roberson. "What are the Impacts of a cVOC Group Regulation?" *AWWA Water Quality Technology Conference*, Toronto, ON, Nov. 4-7, 2012.

34. Fotta, M.E.*, J. Roccaro, and D.R.U. Knappe. "Effect of Activated Carbon Type on Scale-Up of Adsorbers for Volatile Organic Compound Removal from Groundwater." *AWWA Annual Conference*, Dallas, TX, June 10-14, 2012.

35. Dudley, L.M.*, M. Strynar, A. Lindstrom, L. McMillan, and D.R.U. Knappe. "Removal of perfluorinated compounds by powdered activated carbon and anion exchange resins." *2012 WRRI Annual Conference and NCWRA Symposium*, Raleigh, NC. March 27-28, 2012. Received 3rd Prize in the Best Poster Award Competition.

36. Dudley, L.M., M. Strynar, A. Lindstrom, L. McMillan, and D.R.U. Knappe*. "Removal of perfluorinated compounds by powdered activated carbon: Effect of base material and particle size." *AWWA Water Quality Technology Conference*, Phoenix, AZ, Nov. 13-17, 2011.

37. Fotta, M.E.*, A. Reinert*, and D.R.U. Knappe. "Evaluation of Scale-Up Approaches for the Design of Granular Activated Carbon Contactors." *91st NC AWWA/WEA Annual Conference*, Concord, NC. November 13-16, 2011.

38. Dudley, L.M.*, M. Strynar, A. Lindstrom, L. McMillan, and D.R.U. Knappe. "Removal of Perfluorinated Compounds by Powdered Activated Carbon: Effect of Base Material and Particle Size." *91st NC AWWA/WEA Annual Conference*, Concord, NC. November 13-16, 2011.

39. Mastropole, A.*, Fotta, M., Kennedy, A., Thurman, M.E., Ferrer, I., Summers, R.S., and Knappe, D.R.U. "Scale-Up Approaches for the Design of GAC Contactors: Emerging Contaminant Mixtures at Environmentally Relevant Concentrations." *AWWA Annual Conference*, Washington, DC, Jun. 12-16, 2011.

40. Dunn, S.E.* and D.R.U. Knappe. "Effect of powdered activated carbon base material and size on disinfection byproduct precursor removal." *Engineering Day at the NC Legislature*, Raleigh, NC. April 27, 2011. Winning poster in the Grand Challenges Competition for Providing Access to Clean Water. Also winner of People's Choice Award.

41. Ged, E.* and D.R.U. Knappe. "Effectiveness of superfine powdered activated carbon for the removal of sulfamethoxazole." *20th Annual NC State Undergraduate Research Symposium*, Raleigh, NC. April 12, 2011. Poster was selected as one of four winners in the Engineering category.

42. Dunn, S.E.* and D.R.U. Knappe. "Effect of powdered activated carbon base material and size on disinfection byproduct precursor removal." *2011 WRRI Annual Conference and NCWRA Symposium*, Raleigh, NC. March 22-23, 2011. Received 2nd Prize in the Best Poster Award Competition.

43. Dudley, L.M., Q. Deng, M. Hennessy, and D.R.U. Knappe*. "Treatment Options for the Removal of Emerging Pollutants of Concern." *2011 WRRI Annual Conference and NCWRA Symposium*, Raleigh, NC. March 22-23, 2011.

44. Deng, Q., K. Ohno, and D.R.U. Knappe. "Removal of pharmaceuticals from drinking water by powdered activated carbon." *89th NC AWWA/WEA Annual Conference*, Raleigh, NC. November 15-18, 2009.

45. B. Yuncu and D.R.U. Knappe. "Removal of taste and odor compounds in drinking water with zeolite-enhanced ozonation." *89th NC AWWA/WEA Annual Conference*, Raleigh, NC. November 15-18, 2009. Received 1st Prize in the Best Poster Award Competition.

46. Waligora, M.C. and D.R.U. Knappe. "Starch-based polymers as a green coagulant aid alternative for the treatment of drinking water." *89th NC AWWA/WEA Annual Conference*, Raleigh, NC. November 15-18, 2009.

47. I.A. Mezzari,* J. Saquing, D.R.U. Knappe, and M.A. Barlaz. "Development of a Fate and Transport Model for Organic Chemicals in Landfills." *The 5th Intercontinental Landfill Research Symposium*, Copper Mountain Conference Center, CO, Sept. 10-12, 2008.

48. M. Srb,* C. Baeza, and D.R.U. Knappe. "Kinetics of Sulfonamide Removal by Low-Pressure UV Photolysis and UV/H_2O_2 Advanced Oxidation Processes. *IWA World Water Congress and Exhibition*, Vienna, Austria, Sept. 7-12, 2008.

49. S. Velten,* D.R.U. Knappe, and M. Boller. "Effects of Natural Organic Matter Preloading on Physical Characteristics and Remaining MTBE Adsorption Capacity of Granular Activated Carbon." *IWA World Water Congress and Exhibition*, Vienna, Austria, Sept. 7-12, 2008.

50. D.R.U. Knappe* and C. Baeza. "UV/H_2O_2 Oxidation of Antimicrobial Compounds: Biochemical Activity and Biodegradability of Oxidation Intermediates." *5th IWA Leading-Edge Conference & Exhibition on Water & Wastewater Technologies*, Zurich, Switzerland, June 1-4, 2008.

51. B. Yuncu and D.R.U. Knappe.* "Use of high-silica zeolites for the targeted removal of taste and odor compounds from drinking water." *235th ACS National Meeting*, New Orleans, LA, April 6-10, 2008.

52. R.S. Summers,* D. Dani; B. Zachman; C. Corwin; N. Blute; M. McGuire; and D.R.U. Knappe. "MTBE Adsorption: Evaluating EBCT, competition, and fouling." *235th ACS National Meeting*, New Orleans, LA, April 6-10, 2008.

53. C. Baeza* and D.R.U. Knappe. "Removal of antimicrobial compounds and their associated biochemical activity by UV photolysis and UV/H_2O_2 processes." *233rd ACS National Meeting*, Chicago, IL, March 25-29, 2007. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 47, No. 1.

54. Rossner, A.* and D.R.U. Knappe. "MTBE adsorption kinetics on alternative adsorbents and packed bed adsorber performance." *233rd ACS National Meeting*, Chicago, IL, March 25-29, 2007. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 47, No. 1.

55. Mezzari, I.A.; T.F. Speth; and D.R.U. Knappe.* "Prediction of organic contaminant adsorption isotherms on activated carbons." *233rd ACS National Meeting*, Chicago, IL, March 25-29, 2007. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 47, No. 1.

56. Rossner, A.; S.A. Snyder; and D.R.U. Knappe.* "Adsorption of emerging organic contaminant mixtures by alternative adsorbents." *233rd ACS National Meeting*, Chicago, IL, March 25-29, 2007. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 47, No. 1.

57. Mezzari, I.A.* and D.R.U. Knappe. "Predicting the Adsorption Capacity of Activated Carbon for Emerging Organic Contaminants from Fundamental Adsorbent and Adsorbate Properties." *86th NC AWWA/WEA Annual Conference*, Greensboro, NC. November 12-15, 2006. (Poster won 1st place in best poster competition).

58. Rossner, A.* and D.R.U. Knappe. "Adsorption kinetics of MTBE on alternative adsorbents." *86th NC AWWA/WEA Annual Conference*, Greensboro, NC. November 12-15, 2006.

59. Bartelt-Hunt, S. L., Barlaz, M. A., Knappe, D. R. U. and P. Kjeldsen. "Fate of Chemical Warfare Agents and Toxic Industrial Chemicals in Landfills," *4th Intercontinental Landfill Research Symposium*, Gallivare, Sweden, June 14 – 16, 2006.

60. Baeza, C.* and D.R.U. Knappe. "Removal of an Antimicrobial Compound by Sequential Photochemical and Biological Oxidation Processes." *85th NC AWWA/WEA Annual Conference*, Greensboro, NC. November 13-16, 2005. (Poster won 2nd place in best poster competition).

61. D.R.U. Knappe.* "Activated Carbon Characteristics and the Prediction of Aqueous-Phase Adsorption Isotherms." Invited presentation at the *230th ACS National Meeting*, Washington, DC, August 28 – September 1, 2005.

62. Bartelt-Hunt, S. L.*, Barlaz, M. A., Knappe, D. R. U. and P. Kjeldsen. "Assessment of the Behavior of Chemical Warfare Agents in Landfills." *AEESP Frontiers Conference*, Potsdam, NY, July 25 – 27, 2005.

63. Barlaz, M. A., Bartelt-Hunt, S. L., Knappe, D. R. U. and P. Kjeldsen. "Assessment of the Behavior of Chemical Warfare Agents in Landfills." *SWANA Landfill Symposium*, Boulder,

CO, June 6 – 9, 2005.

64. Chen, Y., Knappe, D. R. U. and M. A. Barlaz.* "The Effect of Aging on the Bioavailability of Toluene Sorbed to Municipal Solid Waste Components," *The 3rd Intercontinental Landfill Research Symposium*, Lake Toya, Japan, Nov. 30 – Dec. 2, 2004.

65. Rossner, A.A.* and D.R.U. Knappe. "Adsorption of MTBE on Alternative Adsorbents." *83rd NC AWWA/WEA Conference*, Greensboro, NC, Nov. 16-19, 2003.

66. Knappe, D.R.U. *; L. Li; P.A. Quinlivan; and G. Newcombe. "Recent Advances in Characterizing GAC Performance." Invited presentation at the IWA-sponsored *Global Conference on Leading Edge Water and Wastewater Treatment Technologies*, Noordwijk/Amsterdam, The Netherlands, May 26-28, 2003.

67. Zhang, Z.*; M.A. Barlaz; and D.R.U. Knappe. "Factors Affecting the Bioavailability of Tetrachloroethylene Sorbed to Municipal Solid Waste Components." *103rd General Meeting of the American Society for Microbiology*, Washington, DC, May 18-22, 2003.

68. Chen, L. *; M.A. Nanny; D.R.U. Knappe; T.B. Wagner; and N. Ratasuk. "Chemical Characterization and Sorption Capacity of Degraded Newsprint from a Landfill." *225th ACS National Meeting*, New Orleans, LA, March 23-27, 2003. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 43, No. 1.

69. Wu, B.; D.R.U. Knappe *; and M.A. Barlaz. "Modeling Toluene Desorption from Municipal Solid Waste Components." *2002 Fall Meeting of the American Geophysical Union*, San Francisco, CA, December 6-10, 2002.

70. Zhang, Z.; L.E. Hoyle; D.R.U. Knappe*; and M.A. Barlaz. "Interactions between Hydrophobic Organic Contaminants and Dissolved Organic Matter in Methanogenic Leachate." *2nd Intercont. Landfill Research Symposium*, Asheville, NC, Oct. 13-16, 2002.

71. Zhang, Z.*; M.A. Barlaz; and D.R.U. Knappe. "Factors Affecting the Bioavailability of Tetrachloroethene Sorbed to Municipal Solid Waste Components." *2nd Intercontinental Landfill Research Symposium*, Asheville, NC, Oct. 13-16, 2002.

72. Wu, B., Knappe, D. R. U. and M. A. Barlaz. "Factors Controlling Alkylbenzene Sorption and Desorption to Municipal Solid Waste." *2nd Intercontinental Landfill Research Symposium*, Asheville, NC, Oct. 13-16, 2002.

73. Chen, Y. *; M.A. Barlaz; and D.R.U. Knappe. "Effect of Aging on the Bioavailability of Toluene Sorbed to Municipal Solid Waste Components." *Bioremediation and Biodegradation - Current Advances in Reducing Toxicity, Exposure and Environmental Consequences*, Pacific Grove, CA, June 9-12, 2002.

74. Knappe, D.R.U. * and L. Li. "Predicting the Adsorption Capacity of Activated Carbon from Fundamental Adsorbent and Adsorbate Properties." Invited presentation at the *IWA Workshop on Biological Activated Carbon Filtration*. Delft, The Netherlands, May 29-31,

2002.

75. Knappe, D.R.U.*; L. Li; and P.A. Quinlivan. "Activated Carbon Surface Chemistry and Pore Structure Effects on Adsorption of Volatile Organic Compounds from Natural Water." *2001 World Water Congress*, Berlin, Germany, October 15-19, 2001. (Abstract accepted for platform presentation, but trip was cancelled as a result of the Sept. 11 tragedies).

76. Newcombe, G.*; J. Morrison; C. Hepplewhite ; and D.R.U. Knappe. "Predicting PAC Doses for the Removal of Algal Metabolites: How Can NOM Characterization Techniques Help Us?" *AwwaRF/Cooperative Research Centre for Water Quality and Treatment/Vivendi Workshop: Relating NOM Characteristics to Improve Water Treatment Process Selection and Performance*, Berlin, Germany, October 10-12, 2001.

77. Li, L.*; P.A. Quinlivan; and D.R.U. Knappe. "Effects of Activated Carbon Surface Chemistry and Pore Structure on the Adsorption of MTBE from Natural Water." *222nd ACS National Meeting*, Chicago, IL, August 26-30, 2001. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 41, No. 2.

78. Wu, B.*; C.M. Taylor; D. R.U. Knappe; M.A. Barlaz; and M.A. Nanny. "Factors Controlling Alkylbenzene Sorption to Municipal Solid Waste." *222nd ACS National Meeting*, Chicago, IL, August 26-30, 2001. In *Abstracts of Papers of the American Chemical Society – Division of Environmental Chemistry*, Vol. 41, No. 2.

79. Wu, B.; C.M. Taylor; M.A. Barlaz; D.R.U. Knappe*; and M.A. Nanny. "Effects of Anaerobic Sorbent Degradation on the Sorption of Toluene and *o*-Xylene to municipal solid waste components." *2001 International Containment & Remediation Technology Conference and Exhibition*, Orlando, FL, June 10-13, 2001.

80. Barlaz, M.A. and D.R.U. Knappe*. "The Effects of Aging and Sorbent Decomposition on the Bioavailability of Toluene and *o*-Xylene in Solid Waste." *1999 US EPA Bioremediation Research Program Review*, Bloomingdale, IL, Nov. 2-4, 1999.

81. Barlaz, M.A.*; F.D. Sanin; and D.R.U. Knappe. "The Fate of Toluene and Dichloroethane in a Superfund Landfill." *In Situ and On-Site Bioremediation 5th International Symposium*, San Diego, CA, April 19-22, 1999.

82. Rastogi, N.; S.R. Gandy; and D.R.U. Knappe*. "Removal of Algae from Drinking Water by Conventional Treatment and Microsand-Enhanced Flocculation." *Annual NC Water Resources Research Conference*, Raleigh, NC, March 25, 1999.

83. Sanin, F.D.; M.A. Barlaz; and D.R.U. Knappe*. "Toluene Sorption, Humification, and Biodegradation in Excavated Refuse, a High Organic Carbon Sorbent." *AGU Spring Meeting*, Boston, MA, May 26-29, 1998.

84. Knappe, D.R.U.* "Strategies for Algae Removal in Drinking Water Treatment." *Annual NC Water Resources Research Conference*, Raleigh, NC, April 1, 1998.

85. Knappe, D.R.U. *; Y. Matsui; V.L. Snoeyink; P. Roche; M.J. Prados; and M.M. Bourbigot. "Predicting the Adsorption Capacity of Powdered Activated Carbon for Micropollutants." *American Carbon Society Workshop: Carbon Materials for the Environment*, Charleston, SC, June 9-12, 1996.

86. Snoeyink, V.L.* and D.R.U. Knappe. "Optimal Use of Powdered Activated Carbon for Pesticide Removal." *Second EPA National Drinking Water Treatment Technology Transfer Workshop*, Kansas City, MO, August 12-14, 1996.

87. Knappe, D.R.U. *; V.L. Snoeyink; F.S. Cannon; and R.G. Lee. "The Effect of Calcium on the Thermal Regeneration of Granular Activated Carbon." *AWWA Annual Conference*, Philadelphia, PA, June 23-27, 1991.

* indicates presenter

Invited Presentations

1. Knappe, D.R.U. Impacts of fluorochemical production and use on drinking water quality in North Carolina. University of Rhode Island, Kingston, RI, April 20, 2018.

2. Sun, M., Arevalo, E., Strynar, M., Lindstrom, A., and Knappe, D.R.U. Occurrence and control of legacy and emerging perfluoroalkyl substances in North Carolina. *255th ACS National Meeting*, New Orleans, LA, March 18-22, 2018. (Awards Session)

3. Knappe, D.R.U., Rossner, A.A., Dudley, L.A., and Sun, M. Factors controlling the adsorption of ionizable organic compounds to activated carbon. *255th ACS National Meeting*, New Orleans, LA, March 18-22, 2018.

4. Sun, M., Lopez-Velandia, C., McElroy, A., and Knappe, D.R.U. Rapid and sensitive method for the determination of 1,4-dioxane analysis in a wide range of aqueous matrices. *255th ACS National Meeting*, New Orleans, LA, March 18-22, 2018.

5. Hopkins, Z., Merrill, J., Sun, M., Arevalo, E., Lindstrom, A., Strynar, M., and Knappe, D.R.U. Impacts of perfluoroalkyl ether acids on drinking water quality in North Carolina. Emerging Contaminants Summit. Westminster, CO, March 6-7, 2018.

6. Knappe, D.R.U. Impacts of fluorochemical production and use on drinking water quality in North Carolina. University of Colorado – Boulder, Boulder, CO, October 6, 2017.

7. Sun, M., Arevalo, E., Dudley, L.A., Strynar, M., Lindstrom, A., and Knappe, D.R.U. Legacy and emerging per- and polyfluoroalkyl substances are challenging small (and large) surface water treatment systems in North Carolina. 14th Annual USEPA Drinking Water Workshop Cincinnati, OH, August 22, 2017

8. Knappe, D.R.U., Mezzari, I.A., and Speth, T.F. Combining the Polanyi-Dubinin-Manes framework with molecular models to predict adsorption isotherms of aqueous organic

contaminants on activated carbons. *252nd ACS National Meeting*, Philadelphia, PA, August 21-25, 2016.

9. Dudley, L.A., Sun, M., Arevalo, E., Lindstrom, A., Strynar, M., and Knappe, D.R.U. Factors controlling the adsorption of perfluoroalkyl substances by powdered activated carbon. *252nd ACS National Meeting*, Philadelphia, PA, August 21-25, 2016.

10. Greune, A. and Knappe, D.R.U. Effect of bromide discharges on source water bromide levels and disinfection by-product formation in North Carolina. *252nd ACS National Meeting*, Philadelphia, PA, August 21-25, 2016.

11. Knappe, D.R.U. Keynote: Activated carbon adsorption processes in the USA: Developments in research and application. Workshop: Adsorption in der Wasseraufbereitung: Renaissance einer bewährten Technologie, 27. Mülheimer Wassertechnisches Seminar, Mülheim, Germany, June 15, 2016.

12. Knappe, D.R.U. Water treatment options for perfluoroalkyl substances. Tsinghua University, Beijing, China, May 25, 2016.

13. Knappe, D.R.U., L.A. Dudley, E. Arevalo, M. Sun, M. Strynar, and A. Lindstrom. Water treatment options and challenges for perfluoroalkyl substances and fluorinated alternatives. *251st ACS National Meeting*, San Diego, CA, March 13-17, 2016.

14. Knappe, D. "Polanyi-Dubinin-Manes model framework to predict adsorption isotherms of aqueous organic contaminants on activated carbons." *37th International Activated Carbon Conference*, Orlando, FL, February 25-26, 2016.

15. Knappe, D. "Considerations for large and small utilities for addressing emerging contaminants from upstream sources." *Freshwater in the North Carolina Coastal Plain: Understanding and Preparing for 21st Century Challenges*. New Bern, NC, February 19, 2016.

16. Knappe, D.R.U.*, L.A. Dudley, E. Arevalo, A.B. Lindstrom, and M.J. Strynar. "Adsorption of perfluoroalkyl substances by powdered activated carbon." Clemson University, March 13, 2015.

17. Knappe, D.R.U. Carcinogenic volatile organic contaminant (cVOC) group rule. Charlotte Water Training Institute, Charlotte, NC, February 5, 2015.

18. Knappe, D.R.U. UCMR3 Update for North Carolina. Charlotte Water Training Institute, Charlotte, NC, February 5, 2015.

19. Knappe, D.R.U. Thoughts about the safety of our drinking water: Emerging surface water quality and drinking water treatment challenges in North Carolina Lunch and learn, West Raleigh Rotary Club, Oct. 17, 2014.

20. Knappe, D.R.U. Unregulated Data Communications Workshop - Recent North Carolina Research and Associated Data. City of Raleigh, Sept. 16, 2014.

21. Knappe, D.R.U. UCMR3 Update for North Carolina. NCWOA 2014 Remote Lab Tech Day, Winston-Salem, NC, August 27, 2014.

22. Knappe, D.R.U.*, A.C. Greune, and V.E. Edeback. "Uncovering the Trends of Increasing Bromide in North Carolina's Surface Waters: Sources and Impacts on Brominated DBPs throughout the State." In *Proc. of the AWWA Annual Conference*, Boston, MA, Jun. 8-12, 2014.

23. Knappe, D.R.U. Emerging surface water quality and water treatment challenges in North Carolina. CCEE Department Lunch and Learn, June 5, 2014.

24. Knappe, D.R.U.* and J. Fireline. "Fracking 101 - Shale Gas Extraction using Horizontal Drilling and Hydraulic Fracturing." *NC-AWWA/WEA Lab Technology Day*, Raleigh, NC, May 6, 2014.

25. Knappe, D.R.U. Adsorptive Removal of Micropollutants from Drinking Water Using Granular Activated Carbon and Superfine Powdered Activated Carbon. Technical University of Dresden, Germany, May 28, 2013,

26. Knappe, D.R.U. Adsorptive Removal of Micropollutants from Drinking Water Using Granular Activated Carbon and Superfine Powdered Activated Carbon. Technical University of Berlin, May 24, 2013.

27. Knappe, D.R.U.* and J. Fireline. "Bromide Occurrence in the Cape Fear River Basin." *Triad Area Utilities Meeting*, Greensboro, NC, April 11, 2013.

28. Knappe, D.R.U.* and J. Fireline. "Fracking 101 - Shale Gas Extraction using Horizontal Drilling and Hydraulic Fracturing." *92nd NC AWWA/WEA Annual Conference*, Raleigh, NC. November 11-14, 2012.

29. Knappe, D.R.U. "Disinfection byproducts in drinking water: Human health risks and risk management options." Genetic and Environmental Mutagenesis Society (GEMS) Meeting, Research Triangle Park, NC. April 24, 2012.

30. Knappe, D.R.U. "Control of Disinfection Byproduct Formation with Activated Carbon." Disinfection Byproducts Workshop, NC Public Water Supply Section, Division of Water Resources, Raleigh, NC. April 19, 2012.

31. Knappe, D.R.U. "Suffolk County Water Authority VOC Case Study." AWWA Carcinogenic Volatile Organic Contaminant Workshop, Suffolk County Water Authority, Long Island, NY. March 28, 2012.

32. Knappe, D.R.U. "Granular Activated Carbon Adsorption: Opportunities for Process Optimization." Suffolk County Water Authority, Long Island, NY. June 16, 2011.

33. Knappe, D.R.U. "Algal Performance Issues for Water Treatment Plants." Emerging Water Quality Issues Committee - Algae Workshop, AWWA Annual Conference, Washington, DC. June 12, 2011.

34. Knappe, D.R.U. "Emerging Contaminants and Water Scarcity – Perspectives from North Carolina and Beyond." Keynote address – Emerging Contaminants Research: Implications for Water Treatment, Wastewater Treatment, and Utility Planning. Hazen & Sawyer Workshop, Cary, NC. February 17, 2011.

35. Knappe, D.R.U. "Staying Ahead of the Curve – Advanced Treatment Technologies for Water Reuse." Public Health – Reclaim to Sustain Workshop, NCAWWA-WEA, Raleigh, NC, Mar. 9, 2010

36. Knappe, D.R.U. "Disinfection byproducts: Do current regulatory approaches in the U.S. effectively reduce risk?" Workshop EULA 2010, Universidad de Concepcion, Concepcion, Chile, January 8, 2010.

37. Knappe, D.R.U. "Treatment Options for Water Reclamation." Invited presentation, Public Health & Reclaimed Water Workshop, NC DENR, Raleigh, NC, Aug. 27, 2009.

38. Knappe, D.R.U. "Removal of Pharmaceuticals and EDCs by Oxidation and Adsorption." Invited seminar, Dept. of Environmental and Molecular Toxicology, NC State University, Raleigh, NC, Oct. 14, 2008.

39. Knappe, D.R.U. "Removal of Pharmaceuticals and Endocrine Disrupting Chemicals by Oxidation and Adsorption." *NC/GA/SC Watershed Symposium & Drinking Water Technology Forum*, Concord, NC, Sept. 17-19, 2008.

40. Knappe, D.R.U. "Adsorptive and Oxidative Removal of Trace Organic Pollutants." Invited seminar at the Technologiezentrum Wasser, University of Karlsruhe, Germany, May 29, 2008.

41. Knappe, D.R.U. "Emerging Issues and Technologies in Water and Wastewater Treatment." Invited presentation, WRRI Advisory Committee Meeting, Raleigh, NC, May 13, 2008.

42. Knappe, D.R.U.* "Activated Carbon Characteristics That Matter for Organic Micropollutant Removal from Drinking Water." Invited presentation at the workshop "Advances in the Use of Activated Carbon." *AWWA Water Quality Technology Conference*, Charlotte, NC, Nov. 4-8, 2007.

43. Knappe, D.R.U.* "Removal of Wastewater-Derived Organic Contaminants and Their Associated Biochemical Activity by Low Pressure UV/H_2O_2 Treatment." Invited presentation at the workshop "Advanced Oxidation Technologies in Water Treatment: Fundamentals and Applications." *AWWA Water Quality Technology Conference*, Charlotte,

NC, Nov. 4-8, 2007.

44. Knappe, D.R.U.* "Activated Carbon Characteristics and the Prediction of Aqueous-Phase Adsorption Isotherms." Invited presentation at the *230th ACS National Meeting*, Washington, DC, August 28-September 1, 2005.

45. Knappe, D.R.U.* "*A priori* Prediction of Adsorption Isotherms on Activated Carbons." Invited seminar, Dept. of Civil and Environmental Engineering, University of Illinois, Urbana, April 25, 2006.

46. Knappe, D.R.U.* "Activated Carbon Adsorption Processes – Effects of Adsorbent Properties on the Removal of Trace Organic Contaminants." Invited lecture, Dept. of Urban Environmental Engineering, Hokkaido University, June 2, 2005.

47. Knappe, D.R.U.* "Predicting Adsorption Isotherms from Fundamental Adsorbent and Adsorbate Properties." Invited presentation at EAWAG: Swiss Federal Institute for Environmental Science and Technology, Dübendorf, Switzerland, June 3, 2004.

48. Knappe, D.R.U.* "Strategies for Algae Detection and Removal in Water Treatment." Invited presentation at the Jordan Lake Stakeholder Meeting, NC A&T State University, Greensboro, NC, January 29, 2004.

49. Knappe, D.R.U.*; L. Li; P.A. Quinlivan; and G. Newcombe. "Recent Advances in Characterizing GAC Performance." Invited presentation at the IWA-sponsored *Global Conference on Leading Edge Water and Wastewater Treatment Technologies*, Noordwijk/Amsterdam, The Netherlands, May 26-28, 2003.

50. Glasgow, H.B.*; J.M. Burkholder; B.W. Touchette; L.C. Ehrlich; D.R.U. Knappe; and E.H. Allen. "Impacts of Toxigenic Cyanobacteria on North Carolina Waterways." Invited Presentation at a NCDENR and NCPH-sponsored workshop entitled *Blue Green Algae and Public Water Supplies*, Hickory, NC, February 19, 2003; Asheville, NC, February 25, 2003; Statesville, NC, February 26, 2003.

51. Knappe, D.R.U. * and L. Li. "Predicting the Adsorption Capacity of Activated Carbon from Fundamental Adsorbent and Adsorbate Properties." *IWA Workshop on Biological Activated Carbon Filtration*. Delft, The Netherlands, May 29-31, 2002.

52. "Teleconference on Taste & Odor in Drinking Water: Operational Tools and Techniques for Identification and Control." University of North Carolina at Chapel Hill, May 21, 2001.

53. Knappe, D.R.U. * "Strategies for Algae Detection and Algae Removal in Water Treatment." Duke University, Durham, NC, February 26, 2001.

54. Knappe, D.R.U. *; D.S. Briley; and N. Rastogi. "Optimized Treatment to Minimize the Impacts of Algae on Finished Water Quality." *Annual NC AWWA & WEA Conference*, Research Triangle Park, NC, November 8-11, 1998.

55. Knappe, D.R.U. *; D.S. Briley; and N. Rastogi. "Optimized Treatment to Minimize the Impacts of Algae on Finished Water Quality." *Conference of the Canadian Water and Wastewater Association*, Quebec City, Quebec, October 28-30, 1998.

56. "Teleconference on Adsorption and Membrane Treatment Technologies: Applications to Water Utilities in North Carolina." UNC-Chapel Hill, July 24, 1997.

* indicates presenter

Honors and Awards

1. Advisor for the 1st and 2nd prize winners at the student poster award competition at the *97th NCAWWA/WEA Annual Conference*, November 2017.

2. Best paper award for our 2016 publication "Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina" in *ES&T Letters*, 2017

3. Advisor for the 3rd prize winner in Engineering at the NCSU Graduate Research Symposium, March 23, 2016.

4. Advisor for the 1st and 2nd prize winners at the student poster award competition at the *95th NCAWWA/WEA Annual Conference*, November 2015.

5. NSF Science Nation video of our 1,4-dioxane research in the Cape Fear River watershed, 2015

6. Advisor for the 1st prize winner at the student poster award competition at the *93rd NCAWWA/WEA Annual Conference*, 2013.

7. Thesis advisor for the 1st place winner in the 2013 American Water Works Association Academic Achievement Award competition for the best Master's Thesis (Annual national competition. Award was given for Susan Dunn's MS thesis entitled "Effect of powdered activated carbon base material and size on disinfection by-product precursor and trace organic pollutant removal").

8. Advisor for the 2nd prize winner at the student poster award competition at the *92nd NCAWWA/WEA Annual Conference*, 2012.

9. Advisor for the 3rd prize winner at the student poster award competition at the *WRRI Annual Conference and NCWRA Symposium*, 2012.

10. Thank a Teacher Recipient, Fall 2011.

11. Outstanding Teacher Award, NC State University, 2011.

12. Advisor for a winning poster at the *20th Annual NC State Undergraduate Research Symposium*, 2011.

13. Winning poster in the Grand Challenges Competition for Providing Access to Clean Water, College of Engineering, NC State University, 2011. Poster was also winner of People's Choice Award at Engineering Day at the NC Legislature.

14. Advisor for the winner of the Best Student Paper Award at the American Water Works Association Water Quality Technology Conference, 2007

15. Thesis advisor for the 2nd place winner in the 2007 American Water Works Association Academic Achievement Award competition for the best Master's Thesis (Annual national competition. Award was given for Isabella Mezzari's MS thesis entitled "Predicting the adsorption capacity of activated carbon for organic contaminants from fundamental adsorbent and adsorbate properties").

16. AWWA Water Science & Research Division Best Poster Award, 2006 (Award for best research poster at the Annual AWWA Conference and Exhibition)

17. Bill Horn Kimley-Horn Faculty Award for excellence in graduate and undergraduate teaching and other accomplishments, Department of Civil, Construction, and Environmental Engineering, NC State University, 2003.

18. AWWA Water Science & Research Division Best Paper Award, 2001 (Annual award presented by the American Water Works Association for the best research paper published in Journal AWWA – the award was given for the paper entitled "Atrazine Removal by Preloaded GAC" that appeared in the October 1999 issue).

19. Young Civil Engineer Achievement Award, University of Illinois, 2000 (Annual award presented by the University of Illinois Civil and Environmental Engineering Alumni Association to three outstanding alumni).

20. Thesis advisor for the 2nd place winner in the 1999 AEESP/Montgomery Watson Master's Thesis Award Competition (Annual national competition. Award was given for David Briley's MS thesis entitled "Optimization of coagulation conditions for the removal of algae in conventional water treatment").

B. Research Project Record

Sponsored Research

1. **Title:** Assessing Impact Of Drinking Water Exposure To Genx (hexafluoropropylene Oxide Dimer Acid) In The Cape Fear River Basin, North Carolina. PI: Hoppin, J. Co-PIs: Smart, R.; Knappe, D.; May, K. Agency: National Institute of Environmental Health Sciences

(NIEHS) ($311,399; 11/1/17-10/31/18).

2. **Title:** Collaborative Research: Eager: Tailored Sorbents For The Removal Of Emerging Per- And Polyfluorinated Alkyl Substances From Water. PI: Knappe, D.R.U. Agency: National Science Foundation ($35,000; 9/15/17-8/31/18). An equal amount of funding was awarded to Kevin O'Shea, Dept. of Chemistry, Florida International University.

3. **Title:** Electrically Assisted Sorption and Desorption of Per- and Polyfluoroalkyl Substances. PI: Call, D. Co-PI: Knappe, D.R.U. Agency: Strategic Environmental Research and Development Program ($200,000; 5/16/18-5/16/19).

4. **Title:** Field Demonstration and Comparison of Ex-Situ Treatment Technologies for Poly- and Perfluoroalkyl substances (PFASs) in Groundwater. PI. Knappe, D.R.U. Agency: Water Research Foundation (Prime: Department of Defense)($200,011; 5/16/18-5/16/20).

5. **Title:** Center for Human Health and the Environment. PI: Smart, R.C. Co-PIs: many. Agency: National Institutes of Health ($4,754,972; 4/20/15-3/31/19).

6. **Title:** Occurrence of Pesticides in North Carolina Private Drinking Water Wells and Identification of Point-of-Use Treatment Options. PI: Knappe, D.R.U. Co-PIs: LePrevost, C.; de los Reyes, F. Agency: North Carolina Water Resources Research Institute ($120,000; 3/1/18 – 2/28/20).

7. **Title:** Cometabolic Degradation of 1,4-Dioxane in Biologically Active Carbon Filters with Locally Enriched Biota. PI: Knappe, D.R.U (for PhD student Amie McElroy). Agency: North Carolina Water Resources Research Institute ($10,000; 3/1/18 – 2/28/19).

8. **Title:** Design and Application of Cyclodextrin-Based Materials for the Treatment of Legacy and Emerging Perfluoroalkyl Acids. PI: Knappe, D.R.U (for PhD student Zachary Hopkins). Agency: North Carolina Water Resources Research Institute ($10,000; 3/1/18 – 2/28/19).

9. **Title:** EAGER; GOALI: Perfluoroethercarboxylic acids – a new class of drinking water contaminants. PI: Knappe, D.R.U. Agency: National Science Foundation ($89,849; 9/1/15-8/31/16).

10. **Title:** Development of Appropriate Technologies to Treat Drinking Water Co-Contaminants Associated with Chronic Kidney Disease of Unknown Origin. PI: Knappe, D.R.U. Co-PIs: Hoppin, J., Duckworth, O., Polizzotto, M. Agency: NCSU-RISF ($25,000; 1/1/17-12/31/17).

11. **Title:** RAPID; GOALI: Sources of 1,4-Dioxane in the Cape Fear River Watershed of North Carolina and Treatment Options for 1,4-Dioxane Control. PI: Knappe, D.R.U. Agency: National Science Foundation ($50,000; 8/15/14-7/31/15).

12. **Title:** The Effects of Contaminated Soil and Groundwater on Subsurface Utilities, Surface Water and Drainage. PI: Pour-Ghaz, M. Co-PIs: Gabr, M.; Knappe, D.R.U. Agency: NC Dept. of Transportation ($345,381; 8/1/16-7/31/18).

13. **Title:** Generation of Biodegradation - Sorption Barriers for Munitions Constituents. PI: Borden, R.C. Co-PI: Knappe, D.R.U. Agency: US Army Corps of Engineers ($820,000; 3/30/11 – 3/30/16).

14. **Title:** 1,4-Dioxane in North Carolina Drinking Water Sources: Occurrence and Treatment Options. PI: Knappe, D.R.U. Agency: North Carolina Urban Water Consortium ($120,531; 5/15/14 – 5/14/16).

15. **Title:** Evaluation of Flocculants: Optimizing Characteristics and Screening Methods. PI: McLaughlin, R. Co-PI: Knappe, D.R.U. Agency: North Carolina Department of Transportation ($199,523; 8/16/14 – 8/15/16).

16. **Title:** GAC Control of Regulated and Emerging DBPs of Health Concern. PI: Knappe, D.R.U. Agency: Hazen & Sawyer – Prime: Water Research Foundation ($89,998; 2/5/15 – 3/18/17).

17. **Title:** Numerical Modeling of Post-Remediation Impacts of Anaerobic Bioremediation on Groundwater Quality. PI: Borden, R.C. Co-PI: Knappe, D.R.U. Agency: Strategic Environmental Research and Development Program (SERDP) ($506,874; 3/22/11-3/22/15).

18. **Title:** Evaluation of cVOC Removal Efficiencies by Various Technologies. PI: Knappe, D.R.U. Agency: ARCADIS – Prime: Water Research Foundation ($105,000; 10/1/13 – 9/30/15).

19. **Title:** Evaluation of Henry's Law Constant and Freundlich Adsorption Constant for VOCs. PI: Knappe, D.R.U. Agency: Water Research Foundation ($100,000; 10/1/12 – 9/1/15).

20. **Title:** Survey of Existing Volatile Organic Compound (VOC) Treatment Installations. PI: Knappe, D.R.U. Agency: ARCADIS – Prime: Water Research Foundation ($60,000; 10/1/12 – 9/30/14).

21. **Title:** Bromide Occurrence In North Carolina Drinking Water Sources And Effect On Disinfection By-product Formation. PI: Knappe, D.R.U. Agency: North Carolina Water Resources Research Institute and Urban Water Consortium ($87,964; 3/1/13 – 11/28/14).

22. **Title:** New water Treatment Technology Utilizing Non-Thermal Plasma Technology. PI: Shannon, S. (NE, NCSU), co-PI: Knappe, D.R.U. Agency: NCSU Chancellor's Innovation Fund ($72,213; 7/15/13-7/14/14).

23. **Title:** Removal of perfluorinated compounds by powdered activated carbon blends, superfine powdered activated carbon, and magnetic anion exchange resins PI: Knappe, D.R.U. Agency: Water Research Foundation ($150,000; 1/1/11 – 12/31/13).

24. **Title:** Effectiveness of sub-micrometer sized powdered activated carbon for the combined removal of disinfection by-product precursors and trace organic pollutants. PI: Knappe, D.R.U. Agency: Water Research Foundation ($150,000; 10/1/09 – 10/31/12).

25. **Title:** Evaluation of scale-up approaches for the design of GAC contactors. PIs: Summers, R.S. (University of Colorado) and Knappe, D.R.U. Agency: Water Research Foundation ($350,000; 5/1/10 – 10/31/12, NCSU budget is $155,000 plus $20,000 cash contribution from Suffolk County Water Authority).

26. **Title:** Treatment Options for the Removal of Emerging Pollutants of Concern. PI: Knappe, D.R.U. Agency: Urban Water Consortium ($52,919; 1/15/09 – 12/31/10).

27. **Title:** Protecting Receiving Waters: Removal of Biochemically Active Compounds from Wastewater by Ozonation and Activated Carbon Adsorption Processes PI: Knappe, D.R.U. Agency: NC Water Resources Research Institute ($50,000; 3/1/09 – 12/31/10).

28. **Title:** Development of an analytical method for taste and odor compounds and application to NC drinking water sources and finished waters. PI: Knappe, D.R.U. Agency: NC Water Resources Research Institute ($50,000; 3/1/08 – 8/31/09).

29. **Title:** Assessment Landfill Gas Pathway – Laboratory Simulation of Partitioning of Chemical and Biological Contaminants under Anaerobic Decomposition in a Landfill. PI: Barlaz, M. A.; co-PIs: Knappe, D.R.U. and de los Reyes, F.L. Agency: U.S. Environmental Protection Agency ($700,000, 9/1/04 – 12/31/09).

30. **Title:** Decision Support Tool Guidance Document for Management of Debris from Incidents of National Significance. PI: Barlaz, M. A.; co-PIs: Knappe, D.R.U. and de los Reyes, F.L. Agency: Eastern Research Group ($60,282, 9/5/08 – 4/29/09).

31. **Title:** Evaluation of Computational Fluid Dynamics (CFD) for Modeling UV-Initiated Advanced Oxidation Processes. PI: Ducoste, J.; co-PI: Knappe, D.R.U. Agency: American Water Works Association Research Foundation ($150,000; 1/1/06 – 5/15/09).

32. **Title:** Removal of 2-Methylisoborneol and Geosmin with High-Silica Zeolites and Zeolite-Enhanced Ozonation. PI: Knappe, D.R.U. Agency: American Water Works Association Research Foundation ($150,000; 2/1/06 – 5/15/09).

33. **Title:** Impact of UV Location and Sequence on By-Product Formation. PI: Knappe, D.R.U. Agency: NC Water Resources Research Institute Subcontract – primary sponsor is AwwaRF ($21,899; 1/1/08 – 12/31/08).

34. **Title:** Protecting Receiving Waters: Removal of Biochemically Active Compounds from Wastewater by Sequential Photochemical and Biological Oxidation Processes. PI: Knappe, D.R.U. Agency: NC Water Resources Research Institute ($50,000; 3/1/07 – 8/31/08).

35. **Title:** Effect of Prolonged Heating on the Asphalt-Aggregate Bond Strength of HMA Containing Liquid Antistrip Additives. PI: Tayebali, A.A. (NCSU), co-PI, Knappe, D.R.U. Agency: NC Department of Transportation ($163,790; 7/1/06 – 6/30/08).

36. **Title**: High-Silica Zeolites for the Removal of Polar Organic Contaminants from Drinking Water - Development of a 'Green' Adsorption/Regeneration System. PI: Knappe, D.R.U.

Agency: American Water Works Association Research Foundation ($150,000; 2/15/03 – 2/14/06).

37. **Title**: Predicting Single-Solute Adsorption Isotherms for Non-Regulated Contaminants from Fundamental Adsorbent and Adsorbate Properties. PI: Knappe, D.R.U. Agency: U.S. Environmental Protection Agency ($65,000; 8/16/03 – 9/30/06).

38. **Title**: Sequestration Mechanisms and Bioavailability of Tetrachloroethene and Toluene in Solid Waste. Co-PIs: Barlaz, M.A. (NCSU), Knappe, D.R.U. (NCSU) and M. A. Nanny (University of Oklahoma). Agency: National Science Foundation ($566,560; 9/1/01 – 8/31/05). The two co-PIs at NCSU have equal responsibility for this project; University of Oklahoma is a subcontractor.

39. **Title**: Assessment of the Behavior of Chemical and Biological Contaminants in Landfills. PI: Barlaz, M. A. (Knappe, D. R. U. and de los Reyes, F. are also working on this project). Agency: U.S. Environmental Protection Agency. ($100,000, 12/1/03 – 6/30/05).

40. **Title**: Quantifying Anti-Strip Additive in Asphalt (Binders and Mixes). PI: Tayebali, A.A. (NCSU), co-PI, Knappe, D.R.U. Agency: NC Department of Transportation ($111,914; 7/1/03 – 12/31/04).

41. **Title:** Effects of Activated Carbon Surface Chemistry and Pore Structure on the Adsorption of Methyl Tertiary-Butyl Ether and Trichloroethene from Natural Waters. PI: Knappe, D.R.U. Agency: American Water Works Association Research Foundation ($149,985; 1/1/99 – 4/01/02).

42. **Title:** The Effects of Aging and Sorbent Decomposition on the Bioavailability of Toluene and Xylene in Solid Waste. Co-PIs: Barlaz, M.A. (NCSU) and Knappe, D.R.U. Agency: U.S. Environmental Protection Agency ($425,000; 10/1/98 – 3/31/02). The two co-PIs had equal responsibility for this project.

43. **Title:** Optimization of Treatment to Mitigate Impacts of Algae and Algae Control on Finished Water Quality, PI: Knappe, D.R.U., Co-PIs: S. Liehr (NCSU) and J. Burkholder (NCSU). Agency: American Water Works Association Research Foundation and the North Carolina Urban Water Consortium (AWWARF $299,442 plus $24,886 supplement, NC Urban Water Consortium $33,000; in-kind contributions $99,064; 12/1/96 – 5/15/00).

Unsponsored and independent research

1. **Title:** Treatment Strategies for the Combined Removal of VOCs and 1,4-Dioxane from Suffolk County Groundwater (Students: H. Chmielewski and S. Troutman, supported through DHS Fellowship to H.C.), ongoing with S. Ranjithan.

2. **Title:** Advanced Oxidation Technologies for the removal of pharmaceutically active compounds from drinking water (Student: A. Carolina Baeza, supported through an NSF

Graduate Research Fellowship and an NWRI Fellowship), completed Dec. 2009.

3. **Title:** Employing artificial neural networks and genetic algorithms to optimize turbidity and natural organic matter removal in drinking water treatment (Student: A. O. Savas, in collaboration with Dr. S. Ranjithan)

4. **Title**: Adsorption of methyl tertiary-butyl ether on high-silica zeolites (Students: A. Olsson, J. Williams)

5. **Title**: Implementation of an HPLC method to quantify trace levels of hydroxydesethylatrazine in deionized, distilled water and in tap water (Student: G. C. Rucker)

C. Cross-Disciplinary Activities

1. Member of NCSU's Center for Human Health and the Environment. Participated in the development of a time-sensitive R21 proposal that was selected for funding. Currently working on a Superfund Research Center proposal.

2. Successfully developed a collaborative NSF EAGER proposal with Kevin O'Shea in the Department of Chemistry at Florida International University.

3. Member of a team of researchers that developed a successful GRIP proposal entitled "Water Sustainability through Nanotechnology: Nanoscale Science and Engineering at the Solid-Water Interface."

4. Participated in preparation of NSF NRT Proposal "NRT: Resilience of Infrastructure Systems and the Environment (RISE)." (not selected for funding).

5. Member of NCSU Research Network on Water Solutions (ReNeWS).

6. Participated in writing NSF ERC Proposal "RENEE: Resilient Nutrients, Energy, and Environment." Lead: Arizona State University (not selected for funding).

7. Organizer of "Activated Carbon Adsorption" Session at the 2013 AWWA Annual Conference. Denver, CO, June 9-13, 2013.

8. Submitted Chancellor Innovation Fund (CIF) proposal with Dr. S. Shannon (NCSU, Nuclear Engineering). Spring 2012 (not selected for funding), revised and re-submitted in Spring 2013 and selected for funding.

9. Participated in developing a Sustainable Research Networks preproposal that was submitted to NSF. Collaboration between multiple units at NCSU (primarily CCEE and Architecture) and at other universities (US, international). Fall 2011, not selected for funding.

10. Participated in developing a proposal to the Superfund Hazardous Substance Research and Training Program of the National Institute of Environmental Health Sciences (NIEHS). Focus is on health effects associated with trichloroethylene contamination of drinking water at Camp Lejeune. Lead: Jerry LeBlanc, Dept. Head of Environmental & Molecular Toxicology, NCSU (Spring 2010, not selected for funding on first attempt).

11. Developed a joint research proposal with Dr. Howard Weinberg (UNC-CH, ESE) that was selected for funding by the Urban Water Consortium.

12. Gave a presentation about emerging issues and technologies in water and wastewater treatment to the WRRI Advisory Committee, Raleigh, NC, May 13, 2008.

13. Co-organizer of the ACS Symposium "Advances in Adsorption Processes" to be held at the 235th National Meeting & Exposition of the American Chemical Society, New Orleans, LA, April 6-10, 2008.

14. Session co-organizer and invited participant at the NSF-funded Workshop on Models for Sustainable Landfills. March 16-18, 2008, Lewes, DE.

15. Collaborated with Drs. Howard Weinberg (UNC-CH, ESE) and Karl Linden (U. Colorado - Boulder) on a research proposal that was submitted to the American Water Works Association Research Foundation to study disinfection byproduct and assimilable organic carbon formation in UV/H_2O_2 processes. Project was approved for funding and began 1/1/08).

16. IGERT proposal team member (Proposal Title: Globally Engaged Leaders in Innovative Structures & Systems for Climate-Friendly Buildings), Fall 2007

17. Participant at NCSU-EPA Office of Research and Development Meeting to integrate NCSU and EPA research initiatives. April 9, 2007, Research Triangle Park, NC.

18. Invited participant at the NSF-sponsored workshop "Advancing the Quality of Water" to develop future directions in water-quality related research. March 10-12, 2004, Chapel Hill, NC.

19. Collaborated with Dr. Jaap Folmer in the Chemistry Department at NC State University on an NSF-funded project to determine glass transition temperatures for isolated biopolymers and biopolymer composites using differential scanning calorimetry (DSC) to better understand organic contaminant diffusion in municipal solid waste components.

20. Collaborated with Dr. Mark A. Nanny in the School of Civil Engineering & Environmental Science at the University of Oklahoma on an NSF-funded project. Used nuclear magnetic resonance spectroscopy and pyrolysis GC/MS to characterize interactions between xenobiotics and humic substances at the molecular level. In January 2004, a second proposal was submitted with Dr. Nanny, Dr. Morton Barlaz (NCSU, CCEE), and Dr. Neal Blair (NCSU, MEAS) to the biocomplexity program of the National Science Foundation (not

selected for funding).

21. Initiated contact with Dr. JoAnn Burkholder in the Botany Department at NC State University to collaborate on research investigating the removal of algae and algal metabolites from drinking water. Developed a joint proposal that was selected for funding by the American Water Works Association Research Foundation and the Urban Water Consortium.

IV. EXTENSION AND ENGAGEMENT WITH CONSTITUENCIES OUTSIDE THE UNIVERSITY

A. Accomplishments

1. Invited speaker at national and regional workshops, teleconferences, community forums, and other functions
   - Invited panelist at community forums in Wilmington, Brunswick County, and Fayetteville to discuss impacts of GenX on drinking water quality (June 2017 – present)
   - Invited speaker at local seminar series (e.g. Fearrington Village, SAS, 2018)
   - NCAWWA-WEA, Invited Panelist, 2017 Seminar – Wastewater Regulatory Trends and Emerging Issues, Raleigh, NC, June 1, 2017.
   - Chatham Conservation Partners (1,4-dioxane in Pittsboro's drinking water, January 21, 2016).
   - Pittsboro Town Council (1,4-dioxane in Pittsboro's drinking water, September 28, 2015).
   - NC Waterworks Operator Association (hydraulic fracturing, May 6, 2014; UCMR3, August 27, 2014; organics removal, September 23, 2015).
   - Charlotte Water Training Institute, Charlotte, NC, February 5, 2015.
   - Lunch and learn (NCSU, June 5, 2014), West Raleigh Rotary Club (October 17, 2014)
   - Unregulated Data Communications Workshop - Recent North Carolina Research and Associated Data. City of Raleigh, Sept. 16, 2014.
   - Proactive Assessment & Implementation of Future Water Treatment Optimization Goals for Greensboro, Greensboro, NC, May 21, 2014.
   - Bromide Occurrence in the Cape Fear River. Fayetteville Public Utilities Commission, April 10, 2014.
   - Bromide and 1,4-Dioxane in the Cape Fear River Watershed. Triad Area Utilities Meeting, Greensboro, February 5, 2014.
   - AWWA carcinogenic volatile organic contaminants working group. April 30, 2013
   - Triad Area Utilities Meeting. April 11, 2013.
   - NC Public Water Supply Section Disinfection Byproducts Workshop. April 19, 2012.
   - AWWA carcinogenic volatile organic contaminants working group. March 28, 2012.
   - Suffolk County Water Authority, Long Island, NY. June 16, 2011.
   - Hazen & Sawyer Workshop: Emerging Contaminants Research: Implications for Water Treatment, Wastewater Treatment, and Utility Planning. Keynote address. February 17, 2011.
   - NCAWWA-WEA Public Health – Reclaim to Sustain Workshop, March 9, 2010.
   - NC DENR Workshop Public Health & Reclaimed Water, August 27, 2009.
   - Updated NC water utilities on ongoing research in our laboratory. North Carolina Urban Water Consortium Meeting, Charlotte, NC, March 20, 2008.
   - Design Your Own Education Experience (Continuing Education for Practicing Engineers), CCEE Extension Program, Dec. 4, 2007.
   - AWWA Workshop "Advances in the Use of Activated Carbon." Charlotte, NC, November 4, 2007.
   - AWWA Workshop "Advanced Oxidation Technologies in Water Treatment." Charlotte, NC, November 4, 2007.

- Teleconference "Taste & Odor in Drinking Water: Operational Tools and Techniques for Identification and Control." University of North Carolina at Chapel Hill, May 21, 2001.
- Teleconference "Adsorption and Membrane Treatment Technologies: Applications to Water Utilities in North Carolina." University of North Carolina at Chapel Hill, July 24, 1997.

2. Our research on emerging contaminants has been featured by a number of national news services (e.g., PBS News Hour, Washington Post, Chemical & Engineering News, The Intercept) as well as local news outlets (Wilmington Star News, Fayetteville Observer, Carolina Health News, WRAL, WUNC, WHQR). The most impactful article was a June 8, 2017 article by Vaughn Hagerty in the Wilmington Star News, which brought the GenX contamination into the public eye.

3. Assembled stakeholder group consisting of state regulators, drinking water providers, and wastewater discharges to begin to eliminate 1,4-dioxane contamination of drinking water sources in North Carolina. The NCSU research team is meeting regularly with the stakeholder group to provide data updates and to discuss next steps.

4. Our 1,4-dioxane research was featured in an NSF Science Nation video (http://www.nsf.gov/news/special_reports/science_nation/capefearwatershed.jsp). Published May 4, 2015.

5. Provided information to National Public Radio reporter Elizabeth Shogren about 1,4-dioxane occurrence in North Carolina surface water, story aired on March 26, 2014.

6. Taught CE 771 (formerly CE 571) through the Engineering Online program in Fall 1997, Spring 2000, Spring 2002, Spring 2004, Spring 2006, Spring 2008, Spring 2012, Spring 2014, Spring 2016.

7. Taught CE 574 through the Engineering Online program in Fall 2011, Fall 2013, Fall 2015.

B. Program Impacts

Our research on per- and polyfluoroalkyl substances (PFAS) provided the impetus for dramatic decreases in PFAS levels in the drinking water of more than 200,000 residents living in the lower Cape Fear River basin. These improvements resulted in part from voluntary actions by The Chemours company as well as actions mandated by the North Carolina Department of Environmental Quality (DEQ).

As a result of our research on 1,4-dioxane, a working group was formed that includes representatives from DEQ, drinking water providers impacted by 1,4-dioxane, wastewater managers from communities with elevated 1,4-dioxane levels in wastewater, and NCSU researchers. Results of our research informed the working group about the location of 1,4-dioxane discharges and led to the initiation of voluntary source reduction efforts in communities from where 1,4-dioxane originates. In addition, DEQ is considering to revise NPDES discharge permits for municipal wastewater treatment plants in municipalities in

which wastewater contains high levels of 1,4-dioxane. Lowering 1,4-dioxane concentrations in the Cape Fear River watershed is expected to improve the drinking water quality of more than one million North Carolinians.

To maintain licensure, Professional Engineers need to satisfy continuing professional development requirements. By engaging with Professional Engineers at workshops designed to meet continuing professional development requirements, I am able to inform practicing engineers about current research results and technological developments in the water treatment arena. Furthermore, by offering my graduate physico-chemical water treatment course through the Engineering Online program, I am providing opportunities for practicing engineers to further their education.

V. TECHNOLOGICAL AND MANAGERIAL INNOVATION

A. Accomplishments

1. Patent: Very high frequency (VHF) driven atmospheric plasma sources and point of use fertigation of irrigation water utilizing plasma production of nitrogen bearing species. Patent number: 9475710; Inventors: Steven C. Shannon, Detlef Knappe, Brandon Byrns, Daniel Wooten, Alexander Lindsay. October 2016.

2. Collaboration with Hazen and Sawyer, CDM-Smith, Tighe & Bond, and other consulting firms to develop water treatment solutions for PFAS removal.

3. Collaboration with HDR to identify sources of perfluoroalkyl substances in the drinking water supply of the City of Greensboro, NC

4. Collaboration with the Suffolk County Water Authority to assess the effectiveness of granular activated carbon for the removal of perfluoroalkyl substances from ground water

5. Collaboration with Malcolm Pirnie/ARCADIS and the Los Angeles Department of Water and Power to assess treatment options for carcinogenic volatile organic compounds in light of future regulatory scenarios (Spring 2012-present)

6. Research collaborations with drinking water treatment plants across the U.S. (Philadelphia Water Department, Contra Costa Water District, Southern Nevada Water Authority, Central Lake County Joint Action Water Agency, Suffolk County Water Authority, Los Angeles Department of Water and Power, Louisville Water Company, Colorado Springs Utilities, Manatee County Utilities, Kern County Water Authority, and several utilities in North Carolina)

7. Collaboration between the Malcolm Pirnie, Inc. and the University of Colorado, Boulder, to evaluate the effectiveness of activated carbon for the treatment of MTBE-contaminated drinking water wells (Summer 2006, Spring 2007).

8. Prepared reports for AwwaRF that cover such topics as activated carbon selection criteria, algae removal strategies, and MTBE removal strategies.

9. In the Spring 2007 semester, undergraduate and graduate students participated in a study evaluating the effects of switching disinfectants on distribution system water quality for the cities of Raleigh and Cary, NC.

10. I have answered via e-mail and telephone many adsorption- and algae-related questions from water treatment plants and consulting firms across in the US and Canada. I have also provided interested parties with relevant publications of journal articles and conference proceedings.

B. Program Impact

I consider technology transfer an important component of my research and education programs. By engaging with constituencies outside the university, the research results obtained in my research group are being applied by practicing engineers to help improve the quality of drinking water both locally and nationally.

VI. SERVICE TO THE UNIVERSITY AND PROFESSIONAL SOCIETIES

A. Department:

1. Reappointment, Promotion, and Tenure (RPT) Committee Member (Fall 2014 – 2016), Chair (2017 – present).

2. Equipment and Facilities Committee Chair (Fall 2002 – 2012), Equipment and Facilities Committee Member (Fall 1998 – Spring 2002, Fall 2013 - present)
   - Allocated funds among teaching laboratories in the department
   - Prepared annual expenditure reports
   - Prepared "Facilities" section of ABET self-study questionnaire.

3. ABET Assessment Committee for Laboratory Outcomes Member (Fall 2001 - 2015), Chair (Fall 2015 – present)

4. WREE Group Coordinator (Fall 2011 – Spring 2012)

5. Department Head Search Committee member (Spring 2004 – December 2004, Fall 2009 – Spring 2010)

6. Global WaSH Cluster Search Committee member (Fall 2015 – 2018)

7. Awards committee member (Fall 2007 – Spring 2011)

8. EB V/Oval committee member (Fall 2008 – 2010, 2016 – present)

9. Steering committee member for the Department's sustainability task force (Fall 2007 – May 2010)

10. Compact Planning Committee Member (Spring 2007)

11. Search Committee Member for Program Head in Coastal Sustainability and Resilience at the University of North Carolina Coastal Studies Institute (Fall 2007 – Spring 2008)

12. Water Resources and Environmental Engineering Seminar Series Teleconference Coordinator (Fall 1998 - 2004)
    Successfully applied to host distinguished lecturers (AEESP Distinguished Lecturers, Kappe Lecturers) during this time period.

13. Water Resources and Environmental Engineering Faculty Position Search Committees
    Member (Spring 1999)
    Chair (Fall 1997)

14. Open House Committee
    Chair (Fall 1998 – Spring 1999)
        Coordinated Fall 1998 Open House and Spring 1999 Engineering Open House representation of the Civil Engineering Department.
    Member (Fall 1997 - Spring 1998)
    Participant (Spring 1997, Fall 1997, Fall 1999)

15. Flower Fund Chair (Fall 1996 - Summer 1997)

16. Participated in the 2001 "College Welcome"

17. Participated in the Water Resources and Environmental Engineering Spring Symposium (annually starting in Spring 2001)

18. Participated in Air & Waste Management Association Open House (Spring 1998, Spring 1999, Spring 2000)

B. College:

1. Department Representative for Summer Orientation (Spring 1998 – Summer 2000)

2. Occasional guest lecturer for E101 (last in October 2010)

C. NCSU Committees:

1. Technical Advisory Committee member and research advisor for the NCSU Student Chapter of Engineers Without Borders – Advising students, who are working on water supply

projects in Bolivia and Sierra Leone (Fall 2006-present).

2. Faculty Advisor for NC Safewater Student Chapter (2011-present)

3. Mentor for NCSU Global Health Case Competition (April 2010, April 2011).

4. Search committee co-chair for director position of Water Resources Research Institute (March 2008 – March 2009).

5. Mass Spectrometry Users Committee (Spring 1999-2003)

D. State and Regional activities and committee work:

1. NC Science Advisory Board, Member, 2017-present

2. Science Fair Judge at the North Carolina School of Science and Math, Feb. 2012

3. Science Night at Hunter Elementary School. Demonstrated water treatment technologies to K-5 students, April 2010, March 2014.

4. Presented research results from on-line monitoring studies for the detection of algae and bench-scale studies that evaluated the removal of algae from drinking water to members of the North Carolina Urban Water Consortium. February 19, 1998, Greensboro, NC; February 25, 1999, High Point, NC; February 15, 2001, Raleigh, NC. A related presentation was given at a Jordan Lake Stakeholders meeting (January 29, 2004, Greensboro, NC).

5. Provided technical information to the Johnston County Utilities Department (Amanda Bader and Timothy Broome, Smithfield, NC) to improve algae control and treatment strategies (March 2001).

6. Technical review committee member for the expansion/upgrade of the Greenville, NC, water treatment plant.

7. Collaboration with NC water treatment plants on externally funded research projects.

8. Provided technical information to Dave Pritchett of Jamestown Engineering. The information was in regard to the design of an activated carbon adsorption system for the town of Aberdeen, NC, where the pesticide lindane was found in the water supply. Also provided information to the local newspaper on the same topic.

E. National and international activities and committee work:

1. EPA Science Advisory Board, Member, Drinking Water Committee, 2016-present

2. Trustee, AWWA Water Science and Research Division, 2016-present

3. Member, Technical Advisory Council for PFAS Focus Area, The Water Research Foundation, 2017-present.

4. Topic Editor for the Open Access Journal Drinking Water Engineering and Science. January 2011 – present.

5. Associate Editor for Water Science & Technology. March 2009 – February 2013.

6. Member of the Lectures Committee of the Association of Environmental Engineering and Science Professors (AEESP). May 2008 – present. Subcommittee chair for AEESP speaker selection at the AWWA Annual Conference, 2014 – present.

7. Invited member of the American Water Works Association (AWWA) working group for carcinogenic volatile organic compounds. 2011 – 2014.

8. Invited member of the AWWA Publications Award Committee. 2013 – present.

9. External scientific peer reviewer for the State of California Water Resources Control Board Staff Report for "Proposed amendments to statewide water quality control plans for trash." Summer 2014.

10. Co-organizer of the ACS Symposium "Advances in Adsorption Processes" to be held at the 235th National Meeting & Exposition of the American Chemical Society, New Orleans, LA, April 6-10, 2008.

11. Invited member of the American Water Works Association (AWWA) Activated Carbon Standards Committee. The purpose of this committee is to develop and maintain standards and related manuals on adsorptive characteristics of activated carbon for water treatment. June 2003 – present.

    I chaired the Regeneration Standards subcommittee, which was charged with revising AWWA Standard B605 – Standard for Reactivation of Granular Activated Carbon (sent out for balloting in March 2006, revised standard was published by AWWA in 2007).

12. Project Advisory Committee member for the American Water Works Association Research Foundation (AwwaRF). Project Title: Removal of Pesticides and their Degradates by Adsorptive Processes. Peer-review of proposal, project reports and final report. Fall 2006 – Fall 2011. Research team from Technologie-Zentrum Wasser (TZW) in Karlsruhe, Germany.

13. Member of the AWWA Organic Contaminants Research Committee. The purpose of this committee is to assess research results concerning organic contaminant occurrence, behavior, and control in treatment; to point out implications for water supply through seminars and committee reports; and to define research needs. June 2000 – 2005, June 2007 - present.

14. Invited member of the AWWA Particulate Contaminants Research Committee. The purpose of this committee is to identify, evaluate, and communicate research needs, develop ideas for research projects, encourage basic and applied research, and disseminate research results, with a primary focus on particulate contaminants. June 2001 – 2005.

15. Project Advisory Committee member for the American Water Works Association Research Foundation (AWWARF). Project Title: Development of molecular reporters for monitoring *Microcystis* activity and toxicity. Peer-review of project reports and final report. Summer 2001 – 2005. Research team from the University of Tennessee.

16. Project Advisory Committee member for the American Water Works Association Research Foundation (AWWARF). Project Title: Treatability of algal toxins using oxidation, adsorption, and membrane technologies. Peer-review of project reports and final report. Spring 2002 – 2006. Research team: City of Cocoa, FL, and CH2M Hill.

17. Invited Lecturer, Summer School Course on "Presence of Organic Micro-Contaminants in Water: Characterization, Effects And Treatment Alternatives." Environmental Science Doctorate Program, Universidad de Concepcion, Concepcion, Chile, January 4-12, 2010.

18. Invited participant of an international group of researchers to compare experimental and mathematical modeling techniques used to determine the micropore size distribution of carbonaceous adsorbents. October 2002 – 2003.

19. Project Advisory Committee member for AwwaRF. Project Title: The use of oxidants to minimize passage of pathogenic particles through granular media filters. Peer-review of project reports and final report. Summer 2000 – Summer 2003. Research team from Johns Hopkins University.

20. Project Advisory Committee member for AWWARF. Project Title: Characterization of the polar fraction of NOM with respect to DBP formation. Participated in writing of RFP and selection of proposal, peer-review of project reports and final report. Spring 1997 – Spring 2001. Research team members from University of Colorado-Boulder, U.S. Geological Survey, and Metropolitan Water District of Southern California.

21. Peer reviewer for:
    ACS book chapter (Disinfection by-products)
    Adsorption
    AIChE Journal
    Carbon
    Environmental Engineering Science
    Environmental Pollution
    Environmental Science and Technology
    Environmental Science and Technology Letters
    Industrial & Engineering Chemistry Research
    Journal American Water Works Association
    Journal of Colloid and Interface Science
    Journal of Environmental Engineering-ASCE

Journal of Environmental Quality
Journal of Hazardous Materials
Journal of Infrastructure Systems-ASCE
Journal of Material Cycles and Waste Management
Journal of Membrane Science
Journal of Water Supply: Research and Technology-AQUA
Separation Science and Technology
Water Research
Water Science and Technology

I review ~10 manuscripts per year.

22. Peer reviewer for the following funding agencies:
    Water Research Foundation
    Water Reuse Research Foundation
    The Research Council of Norway (2014, 2015)
    National Science Foundation (CAREER panel, CBET Standard Grants Program, Major Research Instrumentation Program)
    U.S. Environmental Protection Agency Grants Program
    U.S. Environmental Protection Agency Graduate Fellowship Program
    U.S. Environmental Protection Agency SBIR Program
    Environmental Research and Education Foundation
    American Chemical Society – Petroleum Research Fund
    US Army Research Office

23. Peer reviewer for the ASCE Environmental Engineering Conference, IWA World Congress, ACS National Meeting.

Exhibit 4

IN THE UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

SAFER CHEMICALS, HEALTHY FAMILIES et al., *Petitioners,* v. U.S. ENVIRONMENTAL PROTECTION AGENCY et al., *Respondents.* IPC INTERNATIONAL, INC. et al., *Respondents-Intervenors.*	Docket No. 17-72260 Consolidated with Docket Nos. 17-72501, 17-72968, 17-73290, 17-73383, 17-73390

DECLARATION OF VEENA SINGLA, Ph.D.
IN SUPPORT OF PETITIONERS' OPENING BRIEF

I, Veena Singla, declare as follows:

Introduction and Qualifications

1. I am the Associate Director of Science and Policy at the University of California, San Francisco Program on Reproductive Health and the Environment. My research focuses on: indoor environmental quality; understanding exposure pathways for chemicals used in consumer products and building materials; and the mechanisms by which cumulative exposures can lead to adverse health outcomes, especially for vulnerable populations such as workers, pregnant women and young children. The phrase "cumulative exposures" refers to the combination of

exposures to: chemicals during critical windows of development; multiple chemicals; and non-chemical stressors. Through education and communication about relevant research results, I seek to ensure that chemical evaluation methods such as risk assessment and alternatives assessment incorporate current science on exposure pathways, biological susceptibility, the social determinants of health and other relevant fields. I am speaking on behalf of myself in this matter and not as a representative of my employer.

2. I received a Ph.D. from University of California, San Francisco in Developmental and Cellular Biology, and completed a post-doctoral fellowship at Stanford University. My graduate and postdoctoral research focused on how genes control the ways in which cells communicate in vertebrate and invertebrate systems, and the proteins, hormones and small molecules that carry out intra- and inter-cellular signaling. I also studied the developmental origins of disease—the idea that if normal cell signaling during development is disturbed by genetic and/or environmental factors, these perturbations can result in disease and dysfunction later in life.

3. I worked for several years as a Senior Scientist with the Green Science Policy Institute (GSPI), and then served as a Staff Scientist at the Natural Resources Defense Council (NRDC). At GSPI and NRDC, I worked on environmental health science and policy issues relevant to how chemicals in the

environment affect human health. This work included analysis and characterization of flame retardant chemicals in the indoor and built environment, human exposure pathways throughout the chemical lifecycle (i.e., from manufacture, through use and ultimate disposal), and human health hazards. I also completed analysis on the environmental fate, exposure and toxicity properties of the class of halogenated flame retardants which includes hexabromocyclododecane (HBCD), and submitted in-depth scientific and technical comments to the U.S. Environmental Protection Agency (US EPA) on their alternatives assessment evaluation of HBCD.

4. I have extensive experience reviewing data and information from scientific studies and government reports. I have published multiple peer-reviewed articles on the science and policy of flame retardant chemicals in scientific journals. In 2012, I co-authored an article published in Building Research and Information which focused on HBCD.[1]

5. As a recognized expert in the field of human health and the built/indoor environment, I was invited to the first U.S. Green Building Council Summit on Green Building and Human Health in 2012, and to present at a national conference for Occupational and Environmental Medicine Physicians in 2016.

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[1] Babrauskas V, Lucas D, Eisenberg D, Singla V, Dedeo M, Blum A. Flame retardants in building insulation: a case for re-evaluating building codes. Build Res Inf. 2012;40(6):738–55.

6. I have presented invited testimony and/or comments on flame retardant chemicals to the US EPA, the Alaska and California legislatures, the Consumer Product Safety Commission, the International Code Council and the San Francisco Board of Supervisors.

7. By virtue of my education, training, and research, and my knowledge of the pertinent scientific literature, I am considered an expert on the sources of human exposure and effects on human health of the flame retardant HBCD. A more complete description of my education and work experience, as well as a complete list of my publications, is attached to this declaration as Exhibit A.

8. The statements in this declaration are scientifically accurate to the best of my knowledge and ability.

Health Hazards of HBCD

9. HBCD is a manmade chemical containing bromine, carbon and hydrogen. US EPA has identified HBCD as one of the first ten chemicals to undergo risk evaluation under the Toxic Substances Control Act (TSCA). EPA's risk evaluation of HBCD covers three related chemicals, which EPA refers to as the "cyclic aliphatic bromides cluster." This cluster of three chemical includes two Chemical Abstract Services Registry Numbers (CASRN) that identify HBCD[2]; and

[2] HBCD is identified by CASRN 3194-55-6 and 25637-99-4. 3194-55-6 is the most accurate CASRN to use for the HBCD technical mixture. However, it has

one CASRN for a substance with no known uses.[3]

10. Much of the information on the toxicity of HBCD comes from studies in laboratory animals. This is so for at least two reasons. First, it is unethical to intentionally expose human subjects to hazardous substances. Second, data from toxicological studies in whole animals, usually rodents, are highly relevant for predicting a chemical's toxicity in humans. For example, every agent that is known to cause cancer in humans is carcinogenic in animals when adequately tested,[4] and almost one-third of human carcinogens were identified after carcinogenic effects were found in well-conducted animal studies.[5] This almost complete concordance across species is seen because animals and humans have the same genetic, metabolic, and systemic processes that affect the biology of disease induction and progression. It is for this reason that animal tests, conducted in accordance with

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historically also been referred to with the CAS RN 25637-99-4, and is referenced with this number in a variety of regulatory documents and authoritative lists.

[3] US EPA (2017) Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Cyclic Aliphatic Bromide Cluster (HBCD).

[4] IARC Monographs Preamble, http://monographs.iarc.fr/ENG/Preamble/.

[5] Huff J. Predicting chemicals causing cancer in animals as human carcinogens. Occup Environ Med. 2010 Oct;67(10):720.

Maronpot RR, Flake G, Huff J. Relevance of animal carcinogenesis findings to human cancer predictions and prevention. Toxicol Pathol. 2004 Mar-Apr;32 Suppl 1:40-8. Review.

Huff J. Chemicals and cancer in humans: first evidence in experimental animals. Environ Health Perspect. 1993 Apr;100:201-10. Review.

strict guidelines for the welfare and use of research animals, are required by regulatory bodies before new pharmaceutical drugs can be tested in humans.[6] In summary, animal experiments provide information on chemical toxicity that is directly applicable to understanding human disease.

11. HBCD causes liver toxicity in animal studies, including increased liver weight, inflammation and accumulation of fat. This liver toxicity occurs when animals are exposed to HBCD as adults or prenatally (before they are born).[7] These kinds of changes are associated with liver damage and disease such as non-alcoholic fatty liver disease, which can lead to cirrhosis and even liver failure.[8]

12. HBCD causes thyroid toxicity in animal studies, and studies in humans reported associations between HBCD exposures and effects on thyroid

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[6] Page R, Baneux P, Vail D, Duda L, Olson P, Anestidou L, Dybdal N, Golab G, Shelton W, Salgaller M, Hardy C. Conduct, Oversight, and Ethical Considerations of Clinical Trials in Companion Animals with Cancer: Report of a Workshop on Best Practice Recommendations. J Vet Intern Med. 2016 Mar-Apr;30(2):527-35.

Workman P, Aboagye EO, Balkwill F, Balmain A, Bruder G, Chaplin DJ, Double JA, Everitt J, Farningham DA, Glennie MJ, Kelland LR, Robinson V, Stratford IJ, Tozer GM, Watson S, Wedge SR, Eccles SA; Committee of the National Cancer Research Institute. Guidelines for the welfare and use of animals in cancer research. Br J Cancer. 2010 May 25;102(11):1555-77.

[7] US EPA (2017). Scope of the Risk Evaluation for Cyclic Aliphatic Bromides Cluster (hereinafter, "EPA HBCD Scope Document").

[8] Kim, W., 2002. Burden of liver disease in the United States: Summary of a workshop. Hepatology, 36(1), pp.227–242. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12085369.

hormones.[9] Normal thyroid hormone levels and function, especially during the prenatal period, are essential for healthy brain development. Prenatal exposures to chemicals that cause thyroid toxicity can, in effect, scramble thyroid hormone signals, leading to abnormal brain development and health impacts such as loss of cognitive capacity/IQ, attention, learning, memory and motor or coordination problems.[10] In adults, thyroid hormones help maintain normal physiology and metabolism. Perturbations can lead to hyper- or hypo-thyroid disease.

13. HBCD causes neurotoxicity to the developing brain in animal studies. HBCD exposures in young animals caused changes in movement and brain function, and these effects persisted into adulthood. It is believed that thyroid toxicity may be one mechanism by which HBCD causes these effects. HBCD exposure also caused changes in hearing and the functioning of the critical neurotransmitter dopamine.[11] Dopamine is involved in brain processes including response to reward and addiction.

14. HBCD causes reproductive toxicity in animal studies, with reduced fertility and fewer successful pregnancies seen in females.[12]

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[9] EPA HBCD Scope.

[10] Zoeller TR. Environmental chemicals targeting thyroid. Horm. 2010;9(1):28–40.

[11] EPA HBCD Scope Document.

[12] EPA HBCD Scope Document.

15. As stated above, the results of these animal toxicology studies indicate HBCD's toxicity to humans. According to US EPA, HBCD "can reasonably be anticipated to cause developmental and reproductive effects in humans and is highly toxic to aquatic and terrestrial organisms."[13] These health hazards are especially of concern for women of reproductive age, fetuses, infants and young children because the developing reproductive and nervous system is particularly vulnerable to disruption by toxic chemicals.[14] Just as low-level lead exposures that would not harm an adult can be highly poisonous to a child, HBCD exposures during critical windows of a child's brain and reproductive system development

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[13] 81 FR 85440 Nov 28, 2016. Addition of Hexabromocyclododecane (HBCD) Category; Community Right-to-Know Toxic Chemical Release Reporting.

[14] Grandjean P, Bellinger D, Bergman A, Cordier S, Davey- Smith G, Eskenazi B, et al. The Faroes statement: human health effects of developmental exposure to chemicals in our environment. Basic Clin Pharmacol Toxicol 2008;102:73–5.

Crain DA, Janssen SJ, Edwards TM, Heindel J, Ho SM, Hunt P, et al. Female reproductive disorders: the roles of endocrine-disrupting compounds and developmental timing. Fertil Steril 2008;90:911–40.

Diamanti-Kandarakis E, Bourguignon J-P, Giudice LC, Hauser R, Prins GS, Soto AM, et al. Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement. Endocr Rev. 2009 Jun;30(4):293–342.

Gore AC, Chappell VA, Fenton SE, Flaws JA, Nadal A, Prins GS, et al. EDC-2: The Endocrine Society's Second Scientific Statement on Endocrine-Disrupting Chemicals. Endocr Rev. 2015 Dec;36(6):E1–150.

Bennett D, Bellinger DC, Birnbaum LS, Bradman A, Chen A, Cory-Slechta DA, et al. Project TENDR: Targeting Environmental Neuro-Developmental Risks The TENDR Consensus Statement. Environ Health Perspect. 2016 Jul 1;124(7).

can be toxic to this susceptible population at levels that may not harm other populations.

HBCD is a Persistent, Bioaccumulative and Toxic Chemical

16. According to US EPA, "[B]ased on the available bioaccumulation and persistence data, EPA has determined that HBCD should be classified as a persistent, bioaccumulative, and toxic (PBT) chemical…"[15] Persistence in the environment means that HBCD does not break down after it is released into the environment. Bioaccumulation means that HBCD builds up in wildlife and people, accumulating to higher and higher levels in the body as it moves up the food chain. Because HBCD is harmful to the health of living organisms, as described above, it is considered toxic.

17. HBCD is designated as a persistent, bioaccumulative and toxic chemical (also knowns as a PBT or POP, persistent organic pollutant) by the Stockholm Convention[16] and US EPA's Toxics Release Inventory.[17]

Sources and Uses of HBCD

[15] 81 FR 85440 Addition of Hexabromocyclododecane (HBCD) Category; Community Right-to-Know Toxic Chemical Release Reporting.

[16] Stockholm Convention. SC-6/13: Listing of hexabromocyclododecane

[17] 81 FR 85440 Addition of Hexabromocyclododecane (HBCD) Category; Community Right-to-Know Toxic Chemical Release Reporting

18. The total volume of HBCD manufactured or imported in the U.S. in 2015 was between 1 and 10 million pounds. It is added as a flame retardant to building materials, electronics, floor coverings, furniture, and fabrics.[18]

19. The major use of HBCD (90% of production volume) is in building insulation, specifically expanded and extruded polystyrene materials.[19] Existing buildings in the U.S. contain 66-132 million pounds of HBCD.[20]

20. HBCD is a semi-volatile organic chemical which is also used additively in plastic materials and on textiles. For example, HBCD is added to plastic cases (high-impact polystyrene (HIPS)) used for televisions, computers, printers and other electronics; and as a coating on fabrics including furniture upholstery and curtains.[21]

21. HBCD can migrate out of products and partition into air and dust in

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[18] EPA HBCD Scope Document.

[19] Babrauskas V, Lucas D, Eisenberg D, Singla V, Dedeo M, Blum A. Flame retardants in building insulation: a case for re-evaluating building codes. Build Res Inf. 2012;40(6):738–55.

EPA HBCD Scope Document.

[20] Safer Chemicals, Healthy Families et al. Comments to the U.S. Environmental Protection Agency (EPA) on the Scope of its Risk Evaluation for the TSCA Work Plan Chemicals: CYCLIC ALIPHATIC BROMIDE CLUSTER or HEXABROMOCYCLODODECANE (HBCD). March 15, 2017. https://healthybuilding.net/uploads/files/saferchemicals-hbcd.pdf

[21] Stubbings WA, Harrad S. Extent and mechanisms of brominated flame retardant emissions from waste soft furnishings and fabrics: A critical review. Environ Int. 2014 Oct;71:164–75.

the occupied spaces of buildings.[22] HBCD is found in the dust of homes, commercial buildings, vehicles, airplanes, schools, daycares and college dormitories.[23]

22. HBCD is released to air, water, and land during the chemical's manufacture, processing, and use in products, as well as with the recycling and disposal of such products.[24] Environmental monitoring studies find significantly

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[22] Weschler, C.J. & Nazaroff, W.W., 2008. Semivolatile organic compounds in indoor environments. Atmospheric Environment, 42(40), pp.9018–9040.

Rauert C, Lazarov B, Harrad S, Covaci A, Stranger M. A review of chamber experiments for determining specific emission rates and investigating migration pathways of flame retardants. Atmos Environ. 2014;82:44–55.

[23] US EPA, 2015. TSCA Work Plan Chemical Problem Formulation and Initial Assessment: Cyclic Aliphatic Bromides Cluster Flame Retardants. Office of Chemical Safety and Pollution Prevention, EPA Document# 743-D1-5001, pg. 26

Harrad, S. et al., 2010. Dust from U.K. primary school classrooms and daycare centers: The significance of dust as a pathway of exposure of young U.K. children to brominated flame retardants and polychlorinated biphenyls. Environmental Science and Technology, 44(11), pp.4198–4202.

Harrad, S. & Abdallah, M.A.-E., 2011. Brominated flame retardants in dust from UK cars – Within-vehicle spatial variability, evidence for degradation and exposure implications. Chemosphere, 82(9), pp.1240–1245.

Dodson RE, Rodgers KM, Carey G, Cedeno Laurent JG, Covaci A, Poma G, et al. Flame Retardant Chemicals in College Dormitories: Flammability Standards Influence Dust Concentrations. Environ Sci Technol. 2017 Apr 13;acs.est.7b00429.

Mitro SD, Dodson RE, Singla V, Adamkiewicz G, Elmi AF, Tilly MK, et al. Consumer Product Chemicals in Indoor Dust: A Quantitative Meta-analysis of U.S. Studies. Environ Sci Technol. 2016;acs.est.6b02023.

[24] EPA HBCD Scope Document.

higher levels of HBCD in the air, water, sediment, soil and animals near facilities that manufacture, process (including recycling) and dispose of HBCD and/or products containing HBCD.[25]

23. Because HBCD is persistent in the environment, it is subject to long-range transport and is found in the air of urban and remote environments; surface and ocean water; soil, sediment and sewage sludge; in marine and freshwater fish; and in animals including marine mammals, birds and their eggs.[26]

24. Environmental releases result in contamination of food with HBCD. HBCD is found in peanut butter, fish, poultry and pork products purchased at U.S. grocery stores.[27] HBCD also contaminates traditional foods such as wild fish and

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[25] Covaci A, Gerecke AC, Law RJ, Voorspoels S, Kohler M, Heeb N V, et al. Hexabromocyclododecanes (HBCDs) in the environment and humans: A review. Environ Sci Technol. 2006 Jun;40(12):3679–88.

Zhu H, Zhang K, Sun H, Wang F, Yao Y. Spatial and temporal distributions of hexabromocyclododecanes in the vicinity of an expanded polystyrene material manufacturing plant in Tianjin, China. Environ Pollut. 2017 Mar;222:338–47.

Stubbings WA, Harrad S. Extent and mechanisms of brominated flame retardant emissions from waste soft furnishings and fabrics: A critical review. Environ Int. 2014 Oct;71:164–75.

[26] Law RJ, Covaci A, Harrad S, Herzke D, Abdallah MA-E, Fernie K, et al. Levels and trends of PBDEs and HBCDs in the global environment: Status at the end of 2012. Environ Int. 2014 Apr;65:147–58.

Stockholm Convention Persistent Organic Pollutants Review Committee. (2010) Risk profile on hexabromocyclododecane. UNEP/POPS/POPRC.6/13/Add.2

[27] Schecter A, Szabo DT, Miller J, Gent TL, Malik-Bass N, Petersen M, et al. Hexabromocyclododecane (HBCD) Stereoisomers in U.S. Food from Dallas, Texas. Environ Health Perspect. 2012 May 31;120(9):1260–4.

marine mammals relied on by arctic, indigenous and other communities for some portion of their diets.[28]

Human Exposure to HBCD

25. Because HBCD is not bound to the materials to which it is added and because it is semi-volatile, HBCD migrates out of products into indoor air and dust.[29] It can migrate in three ways: (1) as a vapor or gas, with subsequent inevitable attachment to house dust; (2) physical abrasion of particles from the treated product directly into dust; and (3) direct contact between the surface of the treated product and dust.[30]

Schecter A, Haffner D, Colacino J, Patel K, Päpke O, Opel M, et al. Polybrominated diphenyl ethers (PBDEs) and hexabromocyclodecane (HBCD) in composite U.S. food samples. Environ Health Perspect. 2010 Mar;118(3):357–62.

[28] de Wit CA, Herzke D, Vorkamp K. Brominated flame retardants in the Arctic environment - trends and new candidates. Sci Total Environ. 2010;408(15):2885–918.

Arctic Monitoring and Assessment Program. (2016) AMAP Assessment 2016: Chemicals of Emerging Arctic Concern.

Suk WA, Avakian MD, Carpenter D, Groopman JD, Scammell M, Wild CP. Human exposure monitoring and evaluation in the Arctic: The importance of understanding exposures to the development of public health policy. Environ Health Perspect. 2004;112(2):113–20.

[29] EPA HBCD Scope Document.

[30] Rauert C, Lazarov B, Harrad S, Covaci A, Stranger M. A review of chamber experiments for determining specific emission rates and investigating migration pathways of flame retardants. Atmos Environ. 2014;82:44–55.

Rauert C, Kuribara I, Kataoka T, Wada T, Kajiwara N, Suzuki G, et al. Direct contact between dust and HBCD-treated fabrics is an important pathway of source-to-dust transfer. Sci Total Environ. 2016 Mar;545–546:77–83.

26. This HBCD-contaminated dust moves away from treated products through the air and settles down, coating the surface of floors, carpets and indoor objects. Studies find ubiquitous HBCD contamination of indoor environments including cars, homes, schools, and other buildings; across studies, HBCD is detected in 92-100% of indoor dust samples.[31] Because people spend more than 90% of their time indoors in the U.S.,[32] indoor exposures are particularly important for the general population.

27. HBCD enters the bodies of adults and children in the general population when people: breathe in contaminated air; touch products containing HBCD or put such products in their mouths; touch, breathe in, or accidentally ingest contaminated indoor dust; drink contaminated water; and eat contaminated food.

28. Young children who crawl, play on the floor, and put their hands in their mouths have greater exposure to contaminated indoor dust compared to adults, and their exposure to HBCD via dust would be elevated.[33] HBCD also

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[31] Mitro SD, Dodson RE, Singla V, Adamkiewicz G, Elmi AF, Tilly MK, et al. Consumer Product Chemicals in Indoor Dust: A Quantitative Meta-analysis of U.S. Studies. Environ Sci Technol. 2016;acs.est.6b02023.

[32] Klepeis, N. E.; Nelson, W. C.; Ott, W. R.; Robinson, J. P.; Tsang, A.M.; Switzer, P.; Behar, J. V.; Hern, S. C.; Engelmann, W. H. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J. Exposure Anal. Environ. Epidemiol. 2001, 11 (3), 231–252.

[33] US EPA. Exposure Factors Handbook.

contaminates breastmilk, and diet is the major source of HBCD exposure for infants.[34, 35] Further, recent testing found HBCD in children's car seats,[36] and data indicates that baby products are an important contributor to children's exposure for other flame retardants.[37] Children have 3-15 times higher levels of exposure to other kinds of flame retardant chemicals compared to adults; because the exposure pathways are similar, children are also at risk for higher exposures to HBCD.[38]

29. Subsistence populations rely on natural resources to provide some portion of their diet. These populations, including many indigenous communities, consume significantly more and different types of fish compared to the general

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[34] EPA HBCD Scope Document.

[35] Fromme H, Becher G, Hilger B, Völkel W. Brominated flame retardants – Exposure and risk assessment for the general population. Int J Hyg Environ Health. 2015;219(1):1–23.

[36] Ecology Center 2016. Children's Car Seat Study 2016- Report. Available: http://www.ecocenter.org/healthy-stuff/pages/childrens-car-seat-study-2016-report

[37] Hoffman K, Butt CM, Chen A, Limkakeng AT, Stapleton HM. High Exposure to Organophosphate Flame Retardants in Infants: Associations with Baby Products. Environ Sci Technol. 2015 Dec 15;49(24):14554–9.

[38] Lunder S, Hovander L, Athanassiadis I, Bergman Å. Significantly Higher Polybrominated Diphenyl Ether Levels in Young U.S. Children than in Their Mothers. Environ Sci Technol. 2010 Jul 1;44(13):5256–62.

Butt CM, Congleton J, Hoffman K, Fang M, Stapleton HM. Metabolites of Organophosphate Flame Retardants and 2-Ethylhexyl Tetrabromobenzoate in Urine from Paired Mothers and Toddlers. Environ Sci Technol. 2014 Sep 2;48(17):10432–8.

population, and thus their exposures to HBCD via diet would be elevated.[39]

30. The environmental monitoring studies cited above find significantly higher levels of HBCD in the air, water, sediment, soil and animals near facilities that historically or currently produce, process, recycle or dispose HBCD or HBCD-containing products. Given these higher levels, it is likely that communities near such facilities would have elevated exposures to HBCD. Because HBCD is persistent in the environment, HBCD levels around such facilities would be expected to remain elevated even if the facility no longer produces or processes HBCD.

31. Because HBCD is persistent and bioaccumulative, environmental releases will manifest in continued contamination of water, crops, livestock and wild foods.[40] These sources will result in ongoing human exposures, likely for many decades into the future. Evidence from other persistent and bioaccumulative chemicals demonstrates that after production bans, human exposure initially

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[39] US EPA. Exposure Factors Handbook, Chapter 10: Intake of Fish and Shellfish.

Suk WA, Avakian MD, Carpenter D, Groopman JD, Scammell M, Wild CP. Human exposure monitoring and evaluation in the Arctic: The importance of understanding exposures to the development of public health policy. Environ Health Perspect. 2004;112(2):113–20.

[40] Harrad S, Diamond ML. New Directions: Exposure to polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs): Current and future scenarios. Atmos Environ. 2006 Feb;40(6):1187–8.

declines, but then remains steady because of ongoing exposures from existing products, diet, etc.[41]

32. Workers who manufacture or process HBCD, or handle HBCD-containing products such as building materials, would have additional sources of HBCD exposure through skin contact and inhalation of contaminated air and dust. As buildings with HBCD-containing insulation are remodeled, rehabilitated and demolished, existing insulation that is recycled or landfilled will lead to worker exposures and environmental contamination.[42] For example, a 2012 study in Environmental Science and Technology found that cutting building insulation boards releases microscopic particles containing HBCD that could be inhaled deep into the lung.[43] Furniture, electronics and other products containing HBCD will

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[41] Zota AR, Linderholm L, Park J-S, Petreas M, Guo T, Privalsky ML, et al. Temporal Comparison of PBDEs, OH-PBDEs, PCBs, and OH-PCBs in the Serum of Second Trimester Pregnant Women Recruited from San Francisco General Hospital, California. Environ Sci Technol. 2013 Oct 15;47(20):11776–84.

Parry E, Zota AR, Park J-S, Woodruff TJ. Polybrominated diphenyl ethers (PBDEs) and hydroxylated PBDE metabolites (OH-PBDEs): A six-year temporal trend in Northern California pregnant women. Chemosphere. 2018;195:777–83.

[42] Babrauskas V, Lucas D, Eisenberg D, Singla V, Dedeo M, Blum A. Flame retardants in building insulation: a case for re-evaluating building codes. Build Res Inf. 2012;40(6):738–55.

[43] Zhang H, Kuo Y-Y, Gerecke AC, Wang J. Co-release of hexabromocyclododecane (HBCD) and Nano- and microparticles from thermal cutting of polystyrene foams. Environ Sci Technol. 2012 Oct;46(20):10990–6.

also contribute to worker exposures and environmental contamination as they are recycled and disposed.[44] In this way, workers may be exposed to HBCD through their handling of HBCD-containing products at the end of the products' life. Additionally, workers would have elevated exposures to HBCD because on-the-job exposures occur in addition to the HBCD exposures they experience at home and via diet, etc., that are also experienced by the general population.

Risks from Aggregate and Cumulative Exposures

33. In general, the equation ***Hazard x Exposure = Risk*** is a simplified representation of the risk assessment calculation. In US EPA's risk evaluation of HBCD under the Toxic Substances Control Act, HBCD's health hazards will be considered in conjunction with the dose, or exposure, of HBCD received into the body to calculate the total health risk presented by HBCD. Therefore, if the hazard or the exposure is understated, then the risk will be understated.

34. It is not possible to determine, *a priori*, which use(s) of a chemical carry the highest risk(s) without a comprehensive examination of the chemical's hazards and exposures. For example, the volume of a chemical put into a particular use is often used as a surrogate to estimate potential exposure—the higher-volume the use, the higher the potential exposure. But this simplistic assumption does not

[44] Stubbings WA, Harrad S. Extent and mechanisms of brominated flame retardant emissions from waste soft furnishings and fabrics: A critical review. Environ Int. 2014 Oct;71:164–75.

always hold true. In the case of HBCD, 90% of the production volume is used in building insulation, and 10% of production volume is used in other applications including electronics cases and textiles. The simplistic assumption would be that building insulation uses contribute most to human exposures for the general population. But if we consider indoor HBCD exposures, data shows that actually, furniture and electronics contribute significantly to indoor levels of HBCD through the migration pathways described above.[45] Specifically, HBCD levels in dust were significantly higher: near a television containing HBCD compared to other areas in a room;[46] and in college dormitories adhering to stricter flammability standards that result in more furniture being treated with flame retardants, including HBCD.[47] In fact, the highest levels of HBCD ever measured in indoor dust in the U.S. were found in college dormitories, an exposure that would not be accounted

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[45] Rauert C, Lazarov B, Harrad S, Covaci A, Stranger M. A review of chamber experiments for determining specific emission rates and investigating migration pathways of flame retardants. Atmos Environ. 2014;82:44–55.

Rauert C, Kuribara I, Kataoka T, Wada T, Kajiwara N, Suzuki G, et al. Direct contact between dust and HBCD-treated fabrics is an important pathway of source-to-dust transfer. Sci Total Environ. 2016 Mar;545–546:77–83.

[46] Harrad S, Abdallah MAE, Covaci A. Causes of variability in concentrations and diastereomer patterns of hexabromocyclododecanes in indoor dust. Environ Int. 2009 Apr;35(3):573–9.

[47] Dodson RE, Rodgers KM, Carey G, Cedeno Laurent JG, Covaci A, Poma G, et al. Flame Retardant Chemicals in College Dormitories: Flammability Standards Influence Dust Concentrations. Environ Sci Technol. 2017 Apr 13;acs.est.7b00429.

for if only exposures from the highest volume use were considered.

35. HBCD enters people's bodies from many sources including indoor and outdoor environments, products, water and food. All of these sources contribute to the total dose, or exposure, of HBCD in the body. Excluding any known source of exposure—for example from food—will underestimate total exposure, and thus underestimate the total risk of HBCD.

36. Exposures can be also underestimated by failing to consider the actual duration of the exposure. For example, children would experience almost continuous HBCD exposure throughout the day as they move between home, cars and school or daycare. Assuming children are exposed to HBCD only 8 hours a day would underestimate their exposure and underestimate risk. Further, multiple exposure spikes over time (known as "repeated dose" exposures) can have a sensitizing effect, resulting in a more severe reaction to a second, third or fourth exposure than occurred to the first. If the effects of multiple exposures are not considered, risk would be underestimated.

37. Underestimation of exposure is especially consequential for the sub-populations of women of reproductive age, fetuses, infants and young children who have greater biological susceptibility to HBCD toxicity, and thus could experience harm at lower levels of HBCD exposure than other populations.

Conclusion

38. HBCD is a persistent, bioaccumulative and toxic chemical that presents threats to human and environmental health. A person's risk of suffering harm from exposure to HBCD depends on the totality of a person's exposures from all sources, including from existing products *in situ* in buildings and disposal of such products. If EPA fails to account for all sources and uses, risk to populations including workers, communities, subsistence populations, women, fetuses, infants and children would be underestimated. In that case, one or more of these populations could suffer health harms as a result of HBCD exposures, including but not limited to liver damage, infertility, decreased IQ, and attention problems.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on April 3, 2018.

Veena Singla

Exhibit A

to the Declaration of Veena Singla, Ph.D.
in Support of Petitioners' Opening Brief

VEENA SINGLA, PH.D.

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San Francisco, CA 94108
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veena.singla@gmail.com

EDUCATION

From	To	Institution	Degree	Major	PhD Advisor
08/1997	05/2001	University of California, Berkeley	B.S.	Chemistry	
09/2003	09/2010	University of California, San Francisco	PhD	Cell Biology	Jeremy Reiter
04/2011	05/2012	Stanford University	Postdoctoral Fellowship		

OTHER POSITIONS

From	To	Institution	Position	Department
09/2008	12/2011	University of San Francisco	Adjunct Professor	Biology
04/2010	08/2010	KQED Public Media for Northern California	Education Intern	QUEST
05/2012	10/2013	Green Science Policy Institute	Senior Scientist	
01/2014	6/2017	Natural Resources Defense Council (NRDC)	Staff Scientist	Health and Environment Program

HONORS AND AWARDS

Year	Name	Organization
2001	High honors (Summa cum laude)	UC Berkeley Chemistry Department
2004	Graduate Research Fellowship	National Science Foundation
2006	Richard Fineberg Memorial Teaching Award	UC San Francisco
2008	Scholarship recipient	Phi Beta Kappa Association of Northern California
2009	Outstanding poster presentation	California Academy of Sciences Evolution Symposium

PROFESSIONAL ORGANIZATIONS

From	To	Organization
07/2014	Present	American Chemical Society

SERVICE TO PROFESSIONAL ORGANIZATIONS

From	To	Organization	Role
01/2013	Present	Californians for Toxic-Free Fire Safety Coalition	Co-lead

09/2014	Present	Healthy Babies, Bright Futures Integrated Flame Retardant Campaign	Steering Committee member

INVITED PRESENTATIONS

Category	Year	Organization	Role	Type
International	2007	FASEB Biology of Cilia and Flagella International Meeting	Speaker	Podium
Regional	2011	Green Campus Energy Efficiency Summit	Speaker	Podium
National	2014	14th Annual Workshop on Brominated and Other Flame Retardants	Speaker	Podium
National	2014	Green Chemistry Clearinghouse	Speaker	Panel
National	2014	American Chemical Society National Meeting	Speaker	Panel
National	2014	Health and Environmental Funders Network meeting	Speaker	Panel
National	2015	Green Chemistry Clearinghouse	Speaker	Panel
National	2015	SXSW Eco	Speaker	Panel
Other	2016	UCSF Grand Rounds	Speaker	Podium
National	2016	Toxic Substances in the Workplace and the Environment Conference	Speaker	Podium
Regional	2016	Environmental Chemistry Laboratory Seminar Series, California Department of Toxic Substances Control	Speaker	Podium
National	2016	Society of Environmental Journalists Annual Conference	Speaker	Panel

PROFESSIONAL DEVELOPMENT ACTIVITIES
UCSF Becoming an Effective Science Teacher (BEST) and Teaching Apprenticeship Program (TAP) courses

SERVICE ACTIVITIES SUMMARY
My service activities have focused on providing career development mentorship for graduate students interested in science policy and communication.

Category	From	To	Organization	Role
UCSF Campuswide	04/2010	04/2011	UCSF Green Campus (Alliance to Save Energy)	Team leader
Other University	2011	2011	Stanford Splash! Education Program	Class leader
UCSF Campuswide	09/2010	2014	UCSF Graduate Student Internships for Career Exploration	Alumnus advisor- Participate in roundtables/ panels at bi-annual events
UCSF Campuswide	09/2014	Present	UCSF Motivating INformed Decisions (MIND) Program	Mentor (conduct about 1 informational interview/ month)

COMMUNITY AND PUBLIC SERVICE

From	To	Organization	Role
1999	2001	UC Berkeley Disabled Students Program	Tutor
1999	2001	South Berkeley YMCA	Volunteer
2008	2009	Golden Gate Parks Conservancy	Volunteer
2011	2011	California Academy of Sciences	Volunteer

CONTRIBUTIONS TO DIVERSITY
As manager of NRDC's internship program, I expanded our recruitment efforts to include more diverse Bay Area schools such as Touro University and University of San Francisco (USF), both majority minority institutions. I have guest lectured at Touro every year since 2013 and we hosted our first USF intern in 2017.

TEACHING SUMMARY
I am an experienced educator with significant curriculum development, evaluation and teaching experience. I use an evidence-based approach to teaching drawing from research in science education, cognitive science and psychology. I have experience working with diverse student populations, including minority, low-income and disabled.

FORMAL TEACHING

University	Year	Class	Department	Role
UCSF	2004-05	Biochemistry Fundamentals and Cancer Block	Medical School	Teaching assistant
University of San Francisco	2008	Introductory Biology	Biology	Laboratory teaching assistant
University of San Francisco	2009	Advanced Genetics	Biology	Lecturer and curriculum development
University of San Francisco	2010	"The Science of Life" Biology for non-majors	Biology	Lecturer and Laboratory Instructor, curriculum development
Stanford University	2011-12	Core Molecular Biology Laboratory (Bio 44X)	Biology	Laboratory instructor, curriculum development, and evaluation

MENTORING SUMMARY
I have served as the primary mentor for undergraduate, master's, and pre-doctoral students as well as physician fellows in internships ranging from 1 month- 1 year.

Student	Year	Current Position	Mentor Type	Role
Nichole Johnston (Undergraduate intern)	2013	Graduate student, Biochemistry, Yale University	Research, project, career mentor	Full-time mentor, 3 months, meetings once a week

Student	Year	Current Position	Mentor Type	Role
Biruk Tammru (MPH candidate)	2014	Design Researcher at Gobee Group	Research, project, career mentor	Full-time mentor, 3 months, meetings once a week
Raj Puri (MD fellow)	2014		Project mentor	Full-time mentor, 1 month, meetings once a week
Jacqueline Levere (Undergraduate intern)	2014		Research, project, career mentor	Full-time mentor, 3 months, meetings once a week
Lee Ann Hill	2015	Associate, Environmental Health at PSE Healthy Energy	Research, project, career mentor	Full-time mentor, 3 months, meetings once a week
Yi Krystal Lin (MD fellow)	2015	Physician, The Permanente Medical Group	Research and project mentor	Full-time mentor, 1 month, meetings once a week
Anna Reade (predoctoral student)	2016	Senate Fellow, California Council on Science and Technology	Research, project, career mentor	Full-time mentor, 3 months, meetings once a week
Shuchi Aggarwal (MD fellow)	2016	Resident Physician in Occupational and Environmental Medicine at UCSF	Project mentor	Full-time mentor, 1 month, meetings once a week
Alex Shi (MPH candidate)	2016		Research, project, career mentor	Full-time mentor, 3 months, meetings once a week
Lucia Ruiz (MPH candidate)	2017		Research, project, career mentor	Full-time mentor, 3 months, meetings once a week
Monica Kaitz (MD fellow)	2016-17		Research and project mentor	Meetings once a month; one publication completed and another in progress

RESEARCH AND CREATIVE ACTIVITIES SUMMARY

I have developed, secured funding for, and managed strategic new research initiatives on chemical exposures in the indoor environment and vulnerable populations. These include multiple collaborative, interdisciplinary research projects at the intersection of environmental health and policy.

At Green Science Policy Institute, I led a multi-disciplinary team of fire scientists (from Lawrence Berkeley National Laboratory and industry) and environmental health and policy experts (from UC Berkeley and non-governmental organizations (NGOs)) to publish the first-of-its-kind paper on flammability standards, building codes and toxic chemicals in the built environment.

Recently, I led a team of seven scientists investigating consumer product chemicals in the indoor environment, bringing together academic, NGO, and medical researchers from George Washington University, Silent Spring Institute, Harvard School of Public Health and UCSF. I provided the vision and funding for the project, resulting in a publication in a leading journal and extensive media coverage.

RESEARCH AWARDS

Category	Role	Funding Source	Date	Total Direct Costs	Project Description
Past	Project lead	NRDC Science Center	2015-16	$50,000	A quantitative meta-analysis of consumer product chemicals in U.S. indoor dust
Past	Project co-lead	Healthy Babies, Bright Futures	2015	$10,000	Risk assessment of flame retardant chemical clusters
Past	Project co-lead	Ziering Family Foundation	2015	$10,000	Risks of the pesticide chlorpyrifos
Past	Project co-lead	Healthy Babies, Bright Futures	2016	$15,000	Evaluation of flame retardant chemical data
Current	Project co-lead	Healthy Babies, Bright Futures	2017	$15,000	Evaluation of flame retardant chemical data

PEER-REVIEWED PUBLICATIONS

1. Corbit, K.C., Aanstad, P., **Singla, V.**, Norman, A.R., Stainier, D.Y., Reiter, J.F. (2005) Vertebrate Smoothened functions at the primary cilium. *Nature*. 437 (7061): 1018-1021
2. **Singla, V.** and Reiter, J.F. (2006) The primary cilium as the cell's antenna: signaling at a sensory organelle. *Science*. 313 (5787): 629-633
3. **Singla, V.**, Hunkapiller, J., Santos, N., Seol, A.D., Norman, A.R., Wakenight, P., Skarnes, W.C., Reiter, J.F. (2010) Floxin, a resource for genetically engineering mouse ESCs. *Nature Methods*. Jan;7(1):50-2.
4. **Singla, V.**, Romaguera-Ros, M., Garcia-Verdugo, J.M., Reiter, J.F. *Ofd1*, a human disease gene, regulates the length and distal structure of centrioles. (2010) *Developmental Cell* Mar 16; 18(3): 410-424.
5. Hunkapiller, J., **Singla, V.**, Seol, A.D., Reiter, J.F. (2011) The ciliogenic protein Oral-Facial-Digital 1 regulates the neuronal differentiation of embryonic stem cells. *Stem Cells and Development*. May;20(5):831-41
6. Babrauskas, V., Lucas, D., Eisenberg, D., **Singla, V.**, Dedeo, M., Blum, A. (2012). Flame retardants in building insulation: a case for re-evaluating building codes. *Building Research & Information*, 40(6), 738–755. doi:10.1080/09613218.2012.74453
7. Brownell, S. E., Hekmat-Scafe, D.S., **Singla, V.**, Seawell, P.C., Conklin-Imam, J.F., Eddy, S.L., Stearns, T., Cyert, M.S. (2015) A high-enrollment course-based undergraduate research experience improves student conceptions of scientific thinking and ability to interpret data. *CBE Life Sciences Education*, 14(2), 14-ar21. doi: 10.1187/cbe.14-05-0092
8. Hekmat-Scafe, D.S., Brownell, S.E., Seawell, P.C., Malladi, S., Conklin-Imam, J.F., **Singla, V.**, Bradon, N., Cyert, M.S., Stearns, T. (2016) Using yeast to determine the functional consequences of mutations in the human p53 tumor suppressor gene: An introductory course-based undergraduate research experience in molecular and cell biology. *Biochemistry and Molecular Biology Education*. doi: 10.1002/bmb.21024
9. Mitro, S.D., Dodson, R.E., **Singla, V.**, Adamkiewicz, G., Elmi, A.F., Tilly, M.K., Zota, A.R. (2016) Consumer product chemicals in indoor dust: A quantitative meta-analysis of U.S. studies. *Environmental Science & Technology*. doi: 10.1021/acs.est.6b02023

10. Zota, A.R., **Singla, V.**, Adamkiewicz, G., Mitro, S.D., and Dodson, R.E. (2017) Reducing chemical exposures at home: opportunities for action. *Journal of Epidemiology and Community Health*. (In press)

CONFERENCE ABSTRACTS

1. Poster presentation (2009) Evolution Symposium, **California Academy of Sciences**, San Francisco, CA. *Awarded prize for outstanding poster presentation*
2. Poster presentation. (2008) **American Society for Cell Biology Meeting**, San Francisco, CA.
3. Poster presentation (2005) **EMBL Workshop on Centrosomes and Spindle Pole Bodies**, Heidelberg, Germany.
4. Poster presentation (2005) **Society for Developmental Biology Meeting**, San Francisco, CA.