Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in
Green and Sustainable Chemistry

A more ethical chemistry

Rick Reibstein

The evolution of chemical mastery is something of which the human race can be justly proud. However, it has produced toxic byproducts, causing concern to reduce impacts. Because of the success of greener and safer alternatives the industry now has a new responsibility: to investigate whether better alternatives are feasible, and continuously evolve to impose less risk. Leaders are developing these practices of ethical commerce.

Chemicals law in the US was successfully evolving to foster prevention, but this has stalled. Using chemicals that carry risks gives rise to responsibilities that go beyond complying with existing law. Working to dismantle environmental protections is unethical participation in democracy. A more ethical chemistry is necessary to reduce significant risks to biological life on earth. The chemical industry should accept the need for accountability and voters should support innovative forms of environmental governance which better inform them and which prevent risks.

Addresses
Department of Earth and Environment, Boston University, 685 Commonwealth Ave, Boston, MA 02215, USA

Corresponding author: Reibstein, Rick (rreibste@bu.edu)

Current Opinion in Green and Sustainable Chemistry 2017, **8**:36–44

This review comes from a themed issue on **New Business Models**

Edited by **Joel A Tickner**, **Piergiuseppe Morone** and **Valentina Tartiu**

https://doi.org/10.1016/j.cogsc.2017.09.004

A problem for the industry

The public is concerned about the chemical industry: it is concerned about contamination of land, air, water, impacts on children, and growing evidence that toxic chemicals are spreading and building up. In our bodies this has many effects that go beyond the health of the individual, including reproductive, affecting the future of humanity, and neurotoxic, affecting our thinking and our behavior.

When concerns suddenly arise, as when Alar was found in apples, Thalidomide was seen to deform infants, asbestos cases started to win, the danger of PCBs were understood, and the core at Three Mile Island melted down, profits can quickly disappear. Trust is an intangible asset that is hard to evaluate, hard to see until its loss affects operations or sales. A new consumer movement to buy safer, greener products has stimulated the development of ever more alternatives, threatening businesses that fail to keep pace with trends toward greater environmental responsibility. The success of current deregulatory politics also threatens existing interests, which may experience an erosion of trust because of the perception that they do not share or respect the public's concerns about chemical risks. The industry would be better positioned for a future of more informed and responsible consumers by more aggressively pursuing safer products and processes, and by adopting a more ethical participation in democracy that accepts strong systems for accountability. Focusing political action on improving regulatory and judicial oversight rather than reducing legal pressures would strengthen the stimulus to continuously improve and better meet the needs of consumers. The adoption of ethical politics should be the next great step for responsible actors in the industry.

Many people in the industry embrace responsibility. There are leaders in responsible production, distribution, and design, but industry political work to dismantle governance obscures their achievements. The industry as a whole risks being perceived as irresponsible unless more voices within it are raised in support of bettering, rather than simply reducing, governmental authority over their operations.

Strong compliance systems allow companies to derive the benefits of the status of being law-abiding. Weakening mechanisms of accountability reduces the ability of corporations to defend against claims that they pursue interests antithetical to that of the public. Without mechanisms to ensure responsibility, the industry cannot effectively claim to be responsible. Without trust markets corrode.

Better regulation, not less, is capable of resolving conflicts. Effective regulation fosters approvals to operate and reduces fears of products and operations. This reduces the need for advertising budgets to counter negative public perceptions. Intelligent regulation prompts the improvements we need, that result in safer environments. Accepting the responsibility for continuous improvement is a better resolution of conflicts concerning chemical risks than the arguments we now have over risk acceptability. The industry should accept the evolution of law that recognizes and manifests a responsibility to prevent harm, and work to evolve ever safer products, reducing risks where

feasible. It cannot produce confidence in its safety by reducing regulatory pressure for this evolution, but only by assisting in the establishment of truly effective and reasonable means to prompt the development society needs.

From pride and dependency to ethical participation in democracy

The industry often expresses a pride about how central it is to modern living. In 1937, chemical industry leader Arthur Hixson wrote that the industries "render a service that touches practically every activity" in which people are engaged, and that the ordinary person should be awakened "to the realization that he is utterly dependent upon these industries not only for the necessities and luxuries of life, but also for his very existence." [1] The American Chemistry Council has similar information on its website today. But dependency does not of itself create trust. Recently the European Association for Chemical and Molecular Sciences formed a working group on ethics in chemistry. The group has identified the objective of convincing chemists "of their role in the ethical, legal and social implications (ELSI) of research." The need for this effort was described in a recent paper by workgroup members that noted that "Chemistry and enactors depend on public trust and support in its institutional and societal justification and performance. Therefore, it is also (but not only) the chemists' responsibility to create trust through a high degree of credibility and reliability as experts when it comes to (public) discourses on risks and benefits of science and technology or the ethical and social implications of scientific and technological progress." [2].

Modern chemistry represents, as Barry Commoner pointed out in 1971, "probably the most rapid burst of creativity in human history." But he also noted that the new technology was like a two-legged stool: "well founded in physics and chemistry, but flawed by a missing third leg — the biology of the environment." [3] The contamination of our world is a fact. Because it "is almost impossible and economically infeasible to remove dissolute pollution from the environment" once dispersed [4], it is necessary to try to prevent toxic wastes from being created, but progress toward cleaner, safer chemistry is too slow. Experts have found that the "unacceptable" burden of cancer and many environmental and occupational exposures "could have been prevented" [5]. And this preventable burden is enormous: it is estimated that in just one year (2012) "1.3 million lives and 43 million disability-adjusted life-years were lost" due to exposures to just some selected chemicals [6].

Recognitions of the importance of ethical and social responsibility, in addition to scientific credibility, should include support for government action to more effectively address the contamination of the environment in which we live. Yet many in the industry have actively worked to reduce it. A prime example of this is the effort to preempt state toxics laws in the recent amendments to the U.S. Toxic Substances Control Act (TSCA). It is at the state level that chemicals policy has been developing in the U.S. during recent decades. Narrowing the public's protections to those provided by the federal government reduces the vitality of this nation's democracy, and gives the industry one entity to deal with. Funding cuts or industry appointees within the relevant agencies could significantly free the industry from oversight. If the public perceives industry's political efforts as having reduced important protections, consumers and voters may respond, causing both negative political and commercial consequences for certain chemical actors.

A bad reputation can be costly. Union Carbide is no more, Monsanto is written about as a "hated company" [7], and Exxon seems to feel it must run frequent advertisements about the jobs it provides to counter negative public attitudes. The story of how the lead industry worked to forestall regulation, beginning in the 1920's and continuing for decades, and marketed lead pipes for water after it was clear this would have public health impacts [8], is now told to illustrate the danger of political activity by an industry producing a hazardous product. The poisoning was not just of children, but of our political system.

The purpose of democratic systems is to find the right balance of interests, rights and perspectives that can inspire trust in the resolution. The industry deserves to have a place at the table, to be heard, to be indeed respected. But domination of the process erodes acceptance of the outcome and runs counter to the premises of mutual self-governance. When too much money, advertising, legal expertise and lobbying is evident, distrust of the entity that seeks a dominating influence is inevitable.

The story of lead has also made clear that uncontrolled dispersion of toxics is a cost imposed on all of society, not just its victims. Many studies have shown that it increases crime, reduces property values, increases health costs, and has many other impacts on entire communities that are shared by everyone. The average cost of increasing a child's blood lead level by only 1 μg/dL has been estimated as $50,000 [9], and we see such damage as reduced IQ, reduced brain volume [10] and altered executive function in the brain [11]. Clearly a society with healthier brains is of benefit to everyone. Our common health is our common wealth.

If the industry accepts its responsibility concerning such risks, what should it do? Accelerating programs for transforming to greener chemistry, to safer substitutes in

ingredient and process, for all known and potential toxic and hazardous substances would be one step to take, to reduce both public concerns and demand for regulations that the industry considers burdensome. But companies should also consider that there is an ethical way to participate in democratic processes. Seeking dominance in policy-making has produced the image of an industry that does not respect the legitimate concerns relating to toxic dispersion. Many responsible people in the industry do not deserve this, but they are not as visible as those working for deregulation.

Regulations cost time and effort to produce and are the gift of previous societies. The industry should recognize a responsibility to keep them in place. The industry should accept the idea of a watchdog over it. This political position does not preclude lobbying to improve regulations. It does not preclude defense against negative connotations. It does not preclude expressing pride in accomplishments or benefits provided to society. But it should preclude weakening accountability to the point of meaninglessness and working to reduce the capacity to govern, which prevents the development of the innovative policies we need, to foster greener production.

Two different responses to reputational risk

In 2014 the Environmental Working Group reported that "Dow, Dupont, BASF, 3M, Honeywell and Koch Industries and the companies they hire to lobby Congress spent $48.6 million last year to lobby legislators, up from $39.6 million in 2010. These six companies and the American Chemistry Council, the industry trade association, spent $63 million on lobbying last year, up from $49.7 million in 2010." [12] Columnist Nicholas Kristof asked in the *New York Times*, referring to endocrine disruptors, "why we allow the chemical industry — by spending $100,000 on lobbying per member of Congress — to buy its way out of effective regulation…". He noted that "the industry's deceit marks a replay of Big Tobacco's battle against regulation of smoking." [13] In 2015 the Union of Concerned Scientists also compared the industry's aims to those of the tobacco industry, to "deny the science, bring in its own experts to counter the evidence, launch misleading advertising campaigns, and pressure decision makers to abandon restrictions on the chemical's use." [14] Court documents recently released concerning the potential causation by glyphosphate of non-Hodgkin's lymphoma included an email from a Monsanto executive discussing how the company could write scientific articles and then find researchers to "just edit & sign their names…" [15]. In January, 2016 the *New York Times* magazine section featured pollution and deception concerning perfluorinated compounds: "When a 1993 interoffice memo announced that a viable substitute had been found, "that appeared to be less toxic and stayed in the body for a much shorter duration of time", Dupont decided against it because "The risk was too great: Products manufactured with PFOA were an important part of DuPont's business, worth $1 billion in annual profit." [16] In 2012 the *Chicago Tribune* began reporting on deceptive campaigns promoting the use of flame retardants ("Playing with Fire"). Not long afterward, the rules were changed so they would no longer be required in furniture, and environmental groups and concerned parents started talking about purchasing products that do not contain these chemicals. Relational ethics includes whether industry will acknowledge or deny that it imposes risks; whether it attacks opponents personally; and whether it uses its money to have excessive weight in policy-making.

Greater respect for the regulatory system, and working to improve rather than degrade it, shows respect for the public, and would probably create less friction and fewer legal and reputational costs. Well-designed rules are good for everyone concerned, including the regulated community. Many who have studied environmental regulation have found its impacts beneficial for the regulated community itself. For example, it reduces the number of products that "would have ultimately failed", a "compensating effect" for imposed costs "from increased safety, health, or environment quality." [17] Michael Porter's famous hypothesis that well-designed regulation could be good for the regulated community retains vitality [18], and as illustrated below, innovative programs for environmentally conscious production, such as those for pollution prevention or cleaner production, have proven this concept. The benefits of federal regulations in general are significant, estimated by the General Accounting Office to be from $141 billion to $691 billion annually, with estimated annual costs of only $42.4 billion to $66.3 billion, and environmental regulations are especially good investments: EPA regulations account for 60 to 82 percent of the benefits but only 43 to 53 percent of the costs [19].

Consumers are alarmed about toxic body burden, plastics in the ocean, damage to their children's brains and endocrine systems, and the continued failure to clean up environmental contamination. If chemical companies should act to reverse the decline in public trust that their activity in the public sphere has caused, by supporting governance and accountability, the public would likely take notice of the more responsible posture. This could translate into consumer support and be worth far more than the most expensive advertising campaign. There is a solid business justification for placing profit-making values in the context of the public interest and the public's right to processes that best determine that interest.

Efficient aspects of the evolution that was happening

Legal mechanisms, particularly those put in place by states, were causing a beneficial evolution in the chemical industry, and should be revived. The approach of preventing pollution by making things out of less toxic materials addresses the root cause of so many environmental and public health impacts. This is far more efficient than continuing with current practice and trying to manage toxic byproducts that could have been avoided. Lowering toxic inputs permanently reduces impacts over the entire life of the product. It is far more efficient to redesign for safety than to just continue to manage wastes that have been unnecessarily created.

Governance was once moving in this direction and actions that were taken to implement this concept were extraordinarily effective. In 1990 every state in the United States had established a "pollution prevention assistance" program, where government employees actually helped companies — usually for free - to reduce their use of toxic materials and the creation of problematic wastes. Half the states had some kind of pollution prevention law, which stimulated in various ways the examination by companies and others of safer alternatives. In that year, Congress affirmed what the states had demonstrated, passing the Pollution Prevention Act, declaring that "pollution should be prevented or reduced at the source whenever feasible". Analysis of reports from sixty-some such programs — all small, many with just a few staff - found that a decade of activities prevented more than 167 billion pounds of pollution and conserved 4 billion gallons of water, and that "during the period 1998 to 2000, 13 Pollution Prevention (P2) programs with a total average budget of $1.9 million annually reported total cost savings equal to $404 million." [20].

The states have demonstrated how environmental law may be improved and how it can benefit the regulated community. Surveys of companies required to do toxics use reduction planning by the Massachusetts law, considered one of the strongest, found that businesses saved millions of dollars beyond the costs of compliance, the opposite of the conventional assumption that environmental regulations are costly and burdensome [21]. The program has been credited by numerous companies for helping them to attain valuable certifications, retain or acquire new customers, develop new products, and increase production efficiencies, all benefits far beyond avoided waste management costs, the expected value of pollution prevention [22].

These benefits have been achieved through a sophisticated mix of governance strategies, many more friendly than conventional command and control: flexible planning regulation, one-on-one assistance, education and training, third-party and senior officer certification, and fees sufficient to resource the program. Surprisingly, the estimated hundreds of millions of pounds of reductions reported by companies came about without requiring the reduction of any toxics use [23]. Instead, the law requires that companies perform a good faith effort to examine their opportunities for reducing toxics use. The law respects regulated entities, treating companies as competent and smart, ready to make the right decisions and see the efficiency of a focus on the root cause of their pollution, workplace safety, and consumer acceptance problems — the decision to use a toxic material. There are many such examples of law that has benefits for the regulated community as well as the public and the shared environment. By creating greater awareness of choices for better product and process design these laws prompt continuous improvement. Beneficial innovation for cleaner technologies can be efficiently fostered by requirements to examine safer choices: "Unlike traditional technology assessment, Technology Options Analysis does not require absolute quantification of all the variables: one has only to demonstrate, in a *comparative* manner, that one technology is better or worse than another in performance, health, safety, ecological effects, and so forth." [24] Options assessment is one example of how regulation can efficiently stimulate the evolution toward safer alternatives that will be of universal benefit, but industry participation in policy-making has slowed the evolution of chemical policy in this direction. Intentional ethics includes whether companies adopt the responsibility to examine options for safer production.

Relational ethics includes whether they honor the customer's right to know. In the 1980's workers' right to know about the hazards of materials they use on the job began to be recognized at law and in practice, and it has become global. Some developments reflect the pressure to evolve such a right concerning consumers. Maine's attorney general advises consumers that "In the past when you purchased a home directly from the homeowner the doctrine of *caveat emptor* ("let the buyer beware") applied. Today the law offers more protection… a home owner… must disclose in writing any known defects, whether the home has hazardous materials." [25] Many states have required disclosure of hazardous products — a search on the database of state chemical laws and policies of the Lowell Center for Sustainable Production revealed 28 [26]. Some have moved to require more information about hazardous facilities or wastes. Architects and builders and consumers of all kinds are concerning themselves with constituents but there is as yet no effective system of informing consumers about what is in what they buy. This benefits those who sell more dangerous products, while effective consumer right to know would benefit those who would sell safer products.

The evolution of these forms of law has effectively stopped. There has been an industry role in opposing that evolution, through lobbying for cutting funds to environmental agencies or limiting their authorities, suing them, and funding groups that claim government operations are inefficient and a limitation on freedom, which has helped retard the policy development we need. The Massachusetts and New Jersey laws pioneering materials accounting were going to be adopted by many other states, then they were not; it was to be built into the Toxics Release Inventory and then it wasn't. National chemical industry funding created and has helped support the Massachusetts Chemistry and Technology Alliance, which has repeatedly tried to repeal the state's Toxics Use Reduction Act. Meanwhile, other chemical companies have produced greener products in response to government solicitation of environmentally preferable products.

Which is the face of the industry? Because of this question, participants in the chemical industry must now ask themselves if they can demonstrate a commitment to ethical participation in democracy. They can generate trust by respecting the right to know, supporting innovative governance to foster safer products and processes, and ensuring a fundamental level of safety that includes restrictions where necessary.

The prompt of innovation arrested

The Toxic Substances Control Act as amended by the 2016 Lautenberg Act preempts, to a large degree, further state governance of the chemical industry. This occurred although Attorneys General from several states wrote to Congress that "TSCA reform should not interfere with the authority of states to continue to establish requirements under such longstanding laws." [27] Except for some state laws that may continue to operate, most states cannot impose new restrictions on chemicals without a waiver from EPA. If significant progress is to occur, it must now happen at the federal level, and the opportunity to implement Justice Brandeis's vision of states as "laboratories of democracy", to let them try different approaches so we can better learn how best to govern ourselves, has been greatly diminished.

Because we are now dependent on the federal government for progress, it is important that EPA's Office of Chemical Safety and Pollution Prevention recently reported to Congress that it will need to hire outside help [28] to accomplish its duties under TSCA. Subsequent to that report the new Administration announced its intention to cut EPA's budget by a quarter. There are fees authorized by the act, but the language of the section allows the Administrator to choose not to impose the fee [29]. Without the robust ability of states to regulate chemicals and with a weak federal presence, chemical companies are without effective checks and balances, which increases the likelihood that risks will become manifest.

A recipe for stasis

While efforts to develop regulation that would prevent harm have been weakened, laws that provide an incentive for companies to behave ethically, because of concern over liability, are also having lowered impact. Our understanding of the harm caused by the dispersion of substances not compatible with living things and systems calls for new legal forms of response, but their development has been stalled. For example, plaintiffs suing in private actions in the US must meet a high degree of proof in asserting causation of their injury by actions of defendants. The case of *Sindell v Abbott*, concerning cancers caused by the miscarriage preventative diethylstilbesterol [30], provided an example of a legal approach more suitable to the age of mass consumption, in which the chain of production may not be traceable from provider to victim, and where the evidence of harm may not surface for many years. The court articulated a concept of "market share" apportionment of liability to replace the requirement that a plaintiff prove harm by a specific defendant. Although the court observed that the "manufacturer is in the best position to discover and guard against defects in its products and to warn of harmful effects; thus, holding it liable for defects and failure to warn of harmful effects will provide an incentive to product safety", this approach has not been widely adopted. Nor has the principle of strict liability, which obviates the need for extensive proofs that the injury was caused by the fault of the defendant, been applied to many dangerous substances and activities. The liability of producers is limited by the failure of the law of private actions to evolve.

Plaintiffs are under a high burden even when the specific defendant can be identified. They must pay for expert witnesses who pass judicial approval and can counter the expert witnesses that wealthy defendants can often more easily pay for. They must make their case when many hazardous substances do not leave "fingerprint" injuries and there are many potential causes of the harm experienced. Toxic tort law imposes a scientific standard of proof, instead of the lower "preponderance" of evidence standard (characterized as "more likely than not"), distorting "the balance of interests historically protected by the legal system… too many victims of toxic torts… cannot win legal redress for their injuries." [31].

Our legal system imposes little effective general responsibility to reduce such impacts as toxic body burden, the cost of managing household hazardous wastes, and chronic damage to ecosystems. Product liability and our environmental statutes do impose

responsibilities for creating dangerous products but generally they are triggered after a problem has occurred. Regulations are largely reactive, "postmarket", or as in the case of Environmental Impact Statements, only reveal impacts and do not necessarily prevent them. Legal philosopher Carl Cranor writes: "A company neither ensures that its products are safe nor fully assures others that they are free from externalities, especially risks. In effect, the company foists off costs and consequences on others, who must bear them, subsidizing the market price of the product" [32].

The Supreme Court held in the 1980 *Benzene* case that the Occupational Safety and Health Administration (OSHA) could not impose a rule requiring companies to reduce carcinogenic risks to the extent feasible, but had to determine a safe limit — which assumes that our scientific capacity is sufficient to this task, that agencies have adequate resources, and that all chemicals have a safe limit that can be discerned [33]. OSHA had attempted to impose a feasible reduction standard because carcinogens are not regarded as having a threshold below which there is no concern. The approach required by the court, of allowing government action up to the point of a safety threshold, instead of the concept that an actor who creates risks should attempt to reduce it when reduction is feasible, results in a static, compromise solution, rather than one of continuous improvement.

Another form of stasis has resulted from the 1991 case *Corrosion Proof Fittings v. EPA*, in which the court vacated EPA's use of the authority to ban toxics under TSCA, finding that before a ban can be instituted, less onerous alternatives must be evaluated and compared [34]. This is one reason it has been often stated that chemicals are "innocent until proven guilty".

Risk assessment techniques have focused on individual impacts, one at a time, instead of cumulative impacts. California has found that "While this approach has been effective in control-ling media-specific exposures in the past, it does not account for exposure to multiple pollutants from multiple sources." [35] Joseph Guth has pointed out the law needs to have "the goal of maintaining the functioning ecological systems that we are so dependent upon." [36] EPA, the National Research Council, and a Presidential Commission have all made the same point [37].

Cost-benefit analysis has been criticized by many as a poor method for assessing intangibles such as our view of the value of life, (for example environmental attorney Michael Baram's characterization of implicit quantification of intangible decision-criteria as "intellectually and morally irresponsible" [38]), or for ensuring a just distribution of benefits and impacts [39]. The basic outcome of this form of reasoning is that "a person can kill another person if it would cost too much to avoid killing her." [40] The very act of performing cost-benefit analysis employs a "discount rate" to convert future benefits to present values, privileging the present moment over the interests of future generations. By looking only to present-day preferences we do not capture what people "believe we owe to future generations" [41]. Because they are based on what we know at the time, quantitative methods cannot capture what we don't know we don't know.

Industry should support the evolution of the common law as well as regulation, because the potential liability for imposing unnecessary risks will provide a necessary discipline and rigor to the profession of making and using chemicals, generating trust and higher quality products.

A matter of rights and values

Testing for contaminants has identified hundreds of known toxicants in our bodies, concrete evidence that our system of law is failing to protect us [42]. The Environmental Working Group's evaluation of the exposure of newborns found 287 chemicals in umbilical cord blood: 180 that cause cancer in humans or animals, 217 toxic to the brain and nervous system, and 208 that cause birth defects or abnormal development in animal tests [43]. As one writer put it, we are engaged in a "giant chemistry experiment" that treats people as guinea pigs [44]. Research on human subjects in the university setting is now strictly governed by ethical concepts that require anticipation of potential harm and the obtaining of informed consent, but no such ethical principle has been applied to these wider exposures without consent.

Does the average consumer know they can have respiratory damage from exposure to spray foam [45], that the commonly used antibacterial triclosan is now "in breast milk, in blood, in babies just born, in dust, in water?" [46] Do they know that the nano-engineered forms of silver being incorporated into clothing in order to reduce odors may damage aquatic microorganisms as the clothing is washed and the washwater discharged to the environment [47]? Do they know that if their baby's skin is broken they should refrain from applying the sunscreen that may contain nanoparticles that could enter the bloodstream? Do they know that formaldehyde could be coming from their hair straightener [48]?

That the consumer right to know about toxic ingredients is not well-established is first and foremost a question of rights and values, and secondarily a matter for technical estimations of the level of impact or whether the costs are more or less than the benefits. A technical assessment may reveal that the risk is very low, and the cost of removing it very high. But it is hard to imagine that the average person would elect not to know

about it, and to allow another to impose risk without his or her knowledge or consent. That the chemical industry in many locations poses serious risks to the health of highly-impacted communities near large plants [49], is a continuing source of toxic wastes and significant related management costs as well as contaminated sites not cleaned up (1337 sites still on the national priority list) [50], and incorporates toxics ingredients into products without sufficient notice to those who use them concerning the risks, is often cast as a technical issue, but it is an ethical or moral problem [51]. These issues are not properly resolved using only the tools of risk assessment or cost-benefit analysis. They must also be addressed using the lens of relative rights and universal values.

An ethical or moral chemical industry would actively seek to prevent harm to the extent a reasonable person would consider sufficient. The principle that a reasonable person would act to forestall foreseeable harm is a bedrock principle of the common law, and it has been well-settled that at least to some extent, what is right is in the eye of the beholder, and not simply determined by the intent of the actor. As Oliver Wendell Holmes Jr. wrote in his landmark summary of legal principles, *The Common Law*, even if a defendant "considered carefully what would be the conduct of a prudent man under the circumstances, and, having formed the best judgment he could, acted accordingly… it is very clear that the court would say (to the jury), Gentlemen, the question is not whether the defendant thought his conduct was that of a prudent man, but whether you think it was…" [52].

An ethical chemical industry would welcome the spur of potential liability, because it would accept that there is a responsibility to work seriously to avoid injury that one's profit-making activities may cause. An ethical chemical industry would recognize the value of strong governance and participate as a co-equal, not a dominant party, in the development of effective regulatory programs that satisfy the concerns of the public. A more ethical chemical industry would respect those concerns and seek to reduce them through product design and engineering, and through support for systems that ensure that producers are responsible. Many in the chemical industry are demonstrating that they know the value of making more environmentally friendly products. But have we yet seen the exemplars of ethical participation in democracy, who can rebuild a relationship of trust with fellow citizens?

References

Papers of particular interest, published within the period of review, have been highlighted as:

- •• of outstanding interest

1. Morrison A: *Man in a chemical world, Scribner and Sons*. 1937. Introduction. Issued to celebrate the 300th anniversary of the "birth of chemical industry in the United States".

2. •• Mehlich J, Moser F, Van Tiggelen B, Campanella L, Hopf H: **The ethical and social dimensions of chemistry: reflections, considerations, and clarifications**. *Chem Eur J* 2017, **23**: 1210–1218. https://doi.org/10.1002/chem.201605259.
The academic Humboldtian ideal of scientific conduct being free and independent from any kind of political, economic, and social management/control/regulation is no longer tenable. The Gemeinnütziger Wissenschaftler (the scientist for the common good) that emerged also at the turn of the 19th century, is more appropriate than ever.

3. B. Commoner: *The closing circle*. 1st ed. New York: Knopf; 1971: 131–133.

4. MIT's Mission: *Addressing species extinctions and reductions in biodiversity*. 2015. http://web.mit.edu/12.000/www/m2015/2015/solutions_for_industrial_pollution.html.

5. The President's Cancer Panel report of 2008-2009, Reducing environmental cancer risk, https://deainfo.nci.nih.gov/advisory/pcp/annualReports/pcp08-09rpt/PCP_Report_08-09_508.pdf.

6. •• World Health Organization: *Public health impact of chemicals: knowns and unknowns*. 2016. http://www.who.int/ipcs/publications/chemicals-public-health-impact/en/.
Available data on chemical exposures is scant, but "people are exposed to many more chemicals every day." The major part of unintentional poisonings are preventable. Lead exposure alone causes "9.8% of intellectual disability, 4% of ischemic heart disease and 4.6% of stroke in the population, yet many countries do not regulate lead paint."

7. Planes A: *Why is Monsanto the most hated company in the world?*. The Motley Fool; June 8, 2013. https://www.fool.com/investing/general/2013/06/08/why-is-monsanto-the-most-hated-company-in-the-worl.aspx.
The threat of tainted food – whether by chemicals or through genetic manipulation – is a cause that arouses outrage at a pitch few other causes will ever muster. The threat of a shadowy corporation with its fingers buried in the heart of our food supply only heightens this outrage, and Monsanto's heavy-handed efforts at control have done nothing to soften its public image.

8. a) Markowitz G, Rosner D: *Deceit and denial, the deadly politics of industrial pollution*. Milbank Books; 2013;
b) Rabin R: **The lead industry and lead water pipes: "a modest campaign"**. *Am J Public Health* September, 2008, **98**(9);
c) Kitman JL: **The secret history of lead**. *The Nation* 2000. https://www.thenation.com/article/secret-history-lead/.
(From the latter): "for more than four decades, all scientific research regarding the health implications of leaded gasoline was underwritten and controlled by the original lead cabal–Du Pont, GM and Standard Oil; such research invariably favored the industry's pro-lead views, but was from the outset fatally flawed; independent scientists who would finally catch up with the earlier work's infirmities and debunk them were–and continue to be–threatened and defamed by the lead interests and their hired hands."

9. •• J. Reyes, Presentation to the Boston Office of Fair Housing and Equity, October 22, 2014. https://www.cityofboston.gov/images_documents/Jessica%20Reyes.%20Social%20Cost%20of%20Lead_tcm3–48540.pdf.

10. Cecil KM, *et al.*: **Decreased brain volume in adults with childhood lead exposure**. *PLoS Med* May 2008, **5**(5). https://doi.org/10.1371/journal.pmed.0050112.
Whole brain MRI scans showed reductions in adult gray matter affecting the prefrontal cortex, the area of the brain responsible for making decisions and mood regulation.

11. Seo J, *et al.*: **Altered executive function in the lead-exposed brain: a functional magnetic resonance imaging study**. See comment in PubMed Commons below *Neurotoxicology* 2015 Sep, **50**:1–9. https://doi.org/10.1016/j.neuro.2015.07.002. Epub 2015 Jul 14.
Using fMRI to examine the direct neural correlates of executive function in participants with past lead exposure, the study found the "neural activation of left dorsolateral prefrontal cortex was greater in healthy controls than in participants with lead exposure". It suggests that "that lead-induced neurotoxicity may be persistent rather than transient."

12. Environmental Working Group, Chemical industry spending surges, crediting work by the Center for Responsive Politics, http://www.ewg.org/enviroblog/2014/05/chemical-industry-political-giving-surges.

13. Kristof N: **Are your sperm in trouble?** *Sunday Rev Sect N Y Times* March 12, 2017.

14. Union of Concerned Scientists, Bad chemistry: how the chemical industry's trade association undermines the policies that protect us, http://www.ucsusa.org/center-science-and-democracy/fighting-misinformation/american-chemistry-council-report#.WMlox4WcEdU.

15. Hakim D: **Herbicide is facing new doubt on safety**. *N Y Times Bus Sect* March 15, 2017.

16. Rich N: **The lawyer who became Dupont's worst nightmare**. *N Y Times Mag* January 6, 2016.

17. Ashford N, Heaton G, Priest WC: **Environmental, health, and safety regulation and technological innovation, A framework for viewing the effect of regulation on technological change**. In *Technological innovation for a dynamic economy*. Edited by Hill CT, Utterback JM, Pergamon Press; 1979.

18. Lanoie P, *et al.*: *The porter hypothesis at 20: can environmental regulation enhance innovation and Competitiveness? Resources for the future discussion paper*. 2011.

19. •• GAO Report 14-519: *EPA should improve adherence to guidance for selected elements of regulatory impact analyses*. July, 2014. http://www.gao.gov/assets/670/664872.pdf.

20. The National Pollution Prevention Roundtable. An ounce of prevention is worth 167 billion pounds of cure, http://www.csu.edu/cerc/researchreports/documents/AnOunceOfPollutionPreventionIsWorth2003.pdf.

21. a) Abt Associates: *Program evaluation, for the toxics use reduction institute*. 1997;
b) Massey R: **Program assessment at the 20 year mark: experiences of Massachusetts companies and communities with the toxics use reduction act (TURA) program**. *J Clean Prod* 2011, **19**:508–516.

22. Case Studies of the Office of Technical Assistance, http://www.mass.gov/eea/grants-and-tech-assistance/guidance-technical-assistance/agencies-and-divisions/ota/ota-publications/ota-case-studies/.

23. Annual Massachusetts Department of Environmental Protection Toxics Use Reduction Data and Results, http://www.mass.gov/eea/agencies/massdep/toxics/reports/tura-data-and-results.html.

24. Ashford N: **Implementing the precautionary principle, incorporating science, technology, fairness, and accountability in environmental, health, and safety decisions**. *Int J Risk Assess Manag* 2005, **5**(2/3/4):112–124.

25. Maine Attorney General's Office: *Consumer rights when buying a home*. March 2004. http://www.maine.gov/ag/consumer/law_guide_article.shtml?id=27941.

26. •• The Lowell Center for Sustainable Production, http://www.chemicalspolicy.com/chemicalspolicy.us.state.php. See the updated database at: http://theic2.org/chemical-policy.

27. •• The Attorneys General of MA, CA, HI, IA, ME, MD, NH, NY, OR, RI, VT, WA, January 19, 2016 to James Inhofe, Frederick Upton, Barbara Boxer and Frank Pallone.

28. Office of Chemical Safety and Pollution Prevention, U.S. EPA, Initial Report to Congress on the EPA's Capacity to Implement Certain Provisions of the Frank R. Lautenberg Chemical Safety for the 21st Century Act, Prepared for the Committees on Energy and Commerce, and Appropriations of the U.S. House of Representatives, and the Committees on Environment and Public Works, and Appropriations of the U.S. Senate.

29. Toxic Substances Control Act, Section 2625 (b), also referred to as TSCA 26(b).

30. Supreme Court of California, 26 Cal.3d 588, March 20, 1980.

31. Cranor C, Nutting K: **Scientific and legal standards of statistical evidence in toxic tort and discrimination suits**. *Law Philos* 1990, **9**:115. https://doi.org/10.1007/BF00142831.

32. Cranor C: *Legally poisoned*. Harvard University Press; 2011:238.

33. U.S. Supreme Court, Indus. Union Dept. v. Amer. Petroleum Inst, 448 U.S. 607 (1980).

34. Applegate J: **Synthesizing TSCA and REACH: practical principles for chemical regulation reform**. *Ecol Law Q* September 2008, **35**(4).

35. California Office of Environmental Health Hazard Assessment: *Cumulative impacts: building a scientific foundation*. 2010:2.

36. Guth J: **Cumulative impacts: death-knell for cost-benefit analysis**. *Barry Law Rev* Fall 2008, **11**:23. http://www.sehn.org/pdf/CostBenefitinEnvironmentalDecisions.pdf.

37. US EPA: *Framework for cumulative risk assessment*. 2003. https://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf.
Foreword cites the National Research Council's 1994 Science and Judgment in Risk Assessment and the 1997 report by the Presidential/Congressional Commission on Risk Assessment and Risk Management, Risk Assessment and Risk Management in Regulatory Decision-Making for the need to "move beyond single chemical assessments" and to take account of the cumulative effects of chemical exposures occurring simultaneously.

38. Baram M: **Cost-benefit analysis: an inadequate basis for health, safety and environmental decision-making**. *Ecol Law Q* 1980, **8**:473. originally prepared for the Administrative Conference of the U.S.

39. Ackerman F, Heinzerling L: *Priceless: on knowing the price of everything and the value of nothing*. The New Press; 2004.
Publishers Weekly wrote: "What sounds like a purely technical process has enormous political implications, thanks to the pervasive use of cost-benefit analysis in government decision making." http://www.ase.tufts.edu/gdae/publications/other_books/priceless.htm.

40. •• Heinzerling L: **The rights of statistical people**. *Harv Environ Law Rev* 2000, **24**:189–207.

41. Kelleher P: **Energy policy and the social discount rate**. *Ethics Policy Environ* March 2012, **15**(1).

42. Centers for Disease Control: *Third National Report on exposure to environmental chemicals*. 2005. The report identified 148 chemicals in blood and urine. The Fourth National Report in 2009 identified 212.

43. Environmental Working Group: *The body burden in newborns*. 2005. http://www.ewg.org/research/body-burden-pollution-newborns.

44. Barnett S: *Huff Post* October 6, 2011. http://www.huffingtonpost.com/sloan-barnett/body-burden_b_995154.html.
The author of *Green Goes with Everything* reported on the analysis performed by Harvard's School of Public Health that found flame retardants, non-stick coatings, and other chemicals in her blood, and noting the lack of information on the health risks of 75% of the 42 billion pounds produced in or imported into this country.

45. Massachusetts Office of Technical Assistance: *Safe spraying and intelligent insulation: workshop presentations*. 2011. http://www.mass.gov/eea/grants-and-tech-assistance/guidance-technical-assistance/agencies-and-divisions/ota/safe-spray.html.

46. Tavernise S: **F.D.A. Bans sale of many antibacterial soaps, saying risks outweigh benefits**. *N Y Times* September 2, 2016. https://www.nytimes.com/2016/09/03/science/fda-bans-sale-of-many-antibacterial-soaps-saying-risks-outweigh-benefits.html?_r=0.

47. Burke M: **Nanosilver in consumer goods under the spotlight**. *Chem World* July 16, 2012. https://www.chemistryworld.com/news/nanosilver-in-consumer-goods-under-the-spotlight/5222.article.

48. OSHA Hazard Alert Update: *Hair smoothing products that could release formaldehyde*. September, 2011. https://www.osha.gov/SLTC/formaldehyde/hazard_alert.html.

49. a) Allen B: *Uneasy alchemy, citizens and experts in Lousiana's chemical corridor disputes*. MIT Press; 2003;
b) Eckerman I: *Chemical industry and public health, Bhopal as an example*. Göteborg, Sweden: Nordic School of Public Health; 2001. MPH 2001:24;
c) Orum P: *Chemical security 101: what you don't have can't leak, or be blown up by terrorists*. Center for American Progress; 2008. https://www.americanprogress.org/wp-content/uploads/issues/2008/11/pdf/chemical_security.pdf.d) Bohme S: *Toxic injustice, A*

transnational? History of exposure and struggle. U Cal. Press; 2015.
** On the continued use of dibromochloropropane long after it was known it causes male sterility.

50. US EPA, Superfund, National Priority Lists State by State, https://www.epa.gov/superfund/national-priorities-list-npl-sites-state.

51. •• Walzer M: **Does betrayal still matter?** *N Y Rev Books* May 11, 2017.
Discusses the distinction by philosopher Avishai Margalit between ethical and moral violations, the former being a betrayal of one's social group, and the latter a betrayal of responsibility to humanity in general.

52. Holmes OW: *Lecture III, Torts*: *The common law*. 1881. https://h2o.law.harvard.edu/text_blocks/951.