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Expert Disagreement and the Clean Water Act: The Difficult Necessity of Providing Interdisciplinary Advice for Environmental Policy

Abstract
The development of the U.S. Clean Water Act provides excellent examples of both the necessity of and the deep difficulties inherent in working across disciplinary boundaries in science. Students of the development of scientific disciplines recognize that one of the things that individuates disciplines is their differing assumptive frameworks. The history of the U.S. federal policy for water pollution effectively highlights a key tension:

1. Making successful environmental policy *requires* crossing disciplinary boundaries. Failure to question the assumptive frameworks of individual disciplines fails to serve the public interest.
2. Crossing these boundaries is, however, fraught with difficulty because of deep methodological differences in the functioning of different disciplines. Individual disciplines have their own languages, experimental procedures, problem solving strategies and standards.

The history of the Clean Water Act provides examples of both the importance of crossing disciplinary boundaries and the difficulties of doing so. What is particularly valuable about this case study is that it provides both negative and positive examples. The passage of water pollution legislation in the United States owes something to the work of scientists who's willingness to cross disciplinary boundaries in their research helped achieve political consensus. I will argue, however, that key difficulties in implementing the Clean Water Act can be traced to the differing assumptive frameworks of scientists who served as advisors to the policy-making process and their failure to effectively integrate their expert advice.

Introduction
The development of the U.S. federal water pollution law provides unusually clear examples of both the necessity of and the difficulties inherent in working across disciplinary boundaries in science. Since the second world war, the role of scientists as key advisors to makers of public policy has become increasingly important. The history of the U.S. federal policy for water pollution effectively highlights the key tension:

3. I will argue that making successful environmental policy *requires* scientists to cross their disciplinary boundaries. Failure to question the assumptive frameworks of individual disciplines fails to serve the public interest.

4. Crossing these boundaries is, however, fraught with difficulty because of deep methodological differences in the functioning of different disciplines. Individual disciplines have their own languages, experimental procedures, problem solving strategies and standards.

The history of the Clean Water Act provides examples of both the importance of crossing disciplinary boundaries and the difficulties of doing so. What is particularly valuable about this case study is that it provides both negative and positive examples. The passage of water pollution legislation in the United States owes something to the work of scientists whose willingness to cross disciplinary boundaries in their research helped achieve political consensus. I will argue, however, that key difficulties in implementing the Clean Water Act can be traced to the differing assumptive frameworks of scientists who served as advisors to the policy-making process, and the failure to effectively integrate their solutions to the problems of environmental policy. These scientists were asked for advice on three kinds of issues:

- Problems of causal analysis - identifying the effects of a large diverse group of substances found in US water sources
- Problems of standard setting - judging what doses of each substance constitute a significant health threat in a variety of situations (if the water was used for the purpose of drinking, swimming, or agriculture, for example)
- Problems of remediation - proposing methods of ridding water sources of substances so as to meet the standards set.

Attempts to address all of these issues were made by ecologists, sanitary engineers[1], natural resource managers, economists and geographers. Successful integration of several disciplines, as in the case of the Report of the Select Committee on National Water Resources to the Senate in 1961, helped establish the political consensus necessary to pass early water pollution legislation. But the failure of this research and that of later scientific advice to effectively incorporate other

[1] [1]The term sanitary engineering is not in common use today. Sanitary engineering was renamed environmental engineering, just as sanitary chemistry became environmental chemistry, in the early 1970s. Sewage engineering, a term I will also make use of, is the main subdiscipline of sanitary engineering and is often used as an equivalent term. I refer to the scientists consulted on the CWA and its predecessors as sanitary engineers because that is what established members of the field in the late 1960s and early 1970s would have called themselves.

disciplines (ecology in particular) produced legislation that has both serious ethical problems and encounters unnecessary regulatory difficulties.

In addressing both the necessity and difficulties of producing interdisciplinary science advice for public policy the key legal documents I will consider are: the 1972 Federal Water Pollution Control Act Amendments (better known as the Clean Water Act) and two of its predecessors, the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966. My project will draw heavily on Paul Milazzo's 2001 dissertation "Legislating the Solution to Pollution: Congress and the development of water pollution control policy, 1945-1972" and his shortened book version of this research, *Unlikely Environmentalists: Congress and Clean Water 1945-1972*. Milazzo has traced the internal workings of water pollution policy-making in great detail, a historical labor which greatly simplifies my philosophical task of analyzing the relevant scientific advice. This work provides access to a usually hidden process – the efforts of the congressional subcommittee and the experts they consult in the crafting of legislation. He introduces all the key players in the writing of the Clean Water Act and what disciplines they come from. The philosophical issues I wish to address are deeply imbedded within the historical context he has provided.

3. Defining Disciplinary Boundaries and the Interdisciplinary Goal

In the previous section I suggested that producing effective policy advice requires integration of input from experts working in many different disciplines. To do so, however, it will be necessary to consider what it is that divides kinds of technical expertise in the first place. What defines a discipline like ecology and what divides it from the profession of sanitary engineering? Perhaps the most famous definition of a discipline is Thomas Kuhn's: a scientific community which is bound together by a shared paradigm. In the 1969 Postscript to *The Structure of Scientific Revolutions* Kuhn attempted to clarify what constitutes a shared paradigm, and introduced the concept of a “disciplinary matrix.” A discipline’s matrix, on this account, has four components: symbolic generalizations (or theories), metaphysical presumptions (or models), values, and exemplars (which help introduce the concept of tacit knowledge.) There can be cumulative progress within the discipline only when there is agreement about the elements of the disciplinary matrix.

Kuhn’s concern in *Structure* was to explore what happens within an individual discipline when the paradigm changes – i.e. when members of the discipline question previously accepted elements of their matrix. He argues that failure to agree on the contents of a disciplinary matrix makes it terribly difficult for scientists to communicate, indeed, that scientists working in different paradigms live in “different worlds.” Kuhn’s description of paradigm shifts within a discipline (better known as scientific revolutions) one of the most discussed topics in the history and philosophy of science. Much less space has been devoted however, to considering the implications of the difficulty of communicating *between disciplines*. If a discipline is defined by its paradigm, and communicating across paradigms is terribly difficult, then interdisciplinary research should be all but impossible. Working across disciplines means working without agreement on about the elements of the disciplinary matrix, which should greatly hinder, if not entirely halt cumulative progress.

While Kuhn offers an important starting point for defining a discipline, it has been argued that Kuhn’s disciplinary matrix, while it describes the physical sciences with some accuracy, does not capture the essence of the life sciences particularly well. Neither is it intended to encompass expertise in engineering or resource management, which are perhaps better described as professions than disciplines. If, as Galison observed, it takes considerable time and effort to create a pidgin language for communication among physical scientists, how much more difficult will it be to reconcile the differences of assumption and methodology that exist between scientists and engineers?

If I am recommend "interdisciplinary research," it will also be necessary to define it. The term has become very popular, but its meaning is hardly precise. The European philosophy and sociology of science community has done considerably more to further this discussion than the American community. A Dutch environmental science textbook attempts to clarify interdisciplinary research as follows.

> "1. If several disciplines orient their activities to the same environmental problem, without there being a clear interaction between the contributions of the respective disciplines, then the research is called *multidisciplinary*.
> 2. If the researchers in the different disciplines not only work on the same problem, but in addition work jointly on the same research-goal, e.g. a certain environmental plan, then the research may be called *interdisciplinary*.
> 3. A further step would be that also the concepts, theories and methods of the separate disciplines are integrated. In this case, we might rightly speak of an interdisciplinary science, with its own concepts and methods, rather than just an interdisciplinary research project using the concepts and methods of the separate disciplines relevant to the project." (Zandvoort, 48 italics mine)

While much of the European Mode II debate focuses on the final option, I wish to emphasize the problems raised by multidisciplinary research (definition one) as exemplified in the Clean Water Act. Ed Muskie and his staff, the primary authors of the original CWA proposal, rightly felt that the inclusion of advice from diverse sources of scientific expertise would improve the legislation. The language of the CWA of 1972 thus reflected advice from a number of very different disciplines including ecology, sanitary engineering, and natural resource management. Because experts from these disciplines worked "without there being a clear interaction between the contributions of the respective disciplines" however, they failed to integrate their policy advice. The CWA actually set *three different* goals for the nation's water quality:

- employing the Best Available Technology in addressing municipal effluents by 1977 and industrial effluents by 1983 - suggested by natural resource managers and the Army Corps of Engineers and requiring enforcement by sanitary engineers
- achieving fishable and swimmable waters by 1983 – an ambient strategy inspired by the environmental movement that put heavy burdens on ecological expertise

- achieving zero-rates of discharge by 1985 – an effluent strategy advised by the ecologists but requiring huge technological advances by both sanitary engineers and resource managers

Meeting all three at once could only be a regulator's nightmare.

I have suggested that to make successful environmental policy it is necessary to include input from multiple scientific disciplines. There are at least two reasons for this. The more obvious reason is that problems like water pollution involve multiple areas of expertise – freshwater ecologists have expertise in how organisms react to changes in their environment; sanitary engineers have experience in water purification techniques; natural resource managers specialize in quantitative data about sources and volumes of water. I argue that there is a second, more philosophically interesting reason for seeking advice from scientists of multiple disciplines. In Helen Longino's account of *Science as Social Knowledge* she argues that background assumptions are woven into theory and practice of scientific disciplines. These assumptions can affect the description, presentation and interpretation of data. Longino's main concern is with gender stereotypes in science and her solution to the problem of background assumptions involves a more socially diverse and responsive community of science. I will argue that in the case of water pollution the background assumptions of individual disciplines significantly affect the data gathering and interpretation. Questioning of these background assumptions comes about not by feminist critique but instead by the interaction of experts from a more diverse group of disciplines. I will argue that successful water pollution policy is made when advice is gathered from experts in a number of disciplines who question each other's background assumptions. By contrasting the different methodological assumptions of other scientific practices, the blind spots of individual disciplines can exposed.

To clarify this point, I will briefly trace one path of the interactions between experts of several disciplines, and their struggles to produce both accurate and viable advice for policy. This will require, first, some background on the history of U.S. water pollution policy.

The Necessity and Difficulties of Crossing Disciplinary Boundaries

Water policies in the United States before 1950 generally addressed two, quite distinct, concerns. The arid regions west of the Mississippi River to the Pacific were constantly concerned with the *quantity* of water available for development – particularly for irrigation. The more heavily populated eastern states, on the other hand, were primarily concerned with the degradation of water *quality*. In the 1950s, however, eastern and western congressmen began to draw the connection between water *quality* and water *quantity*. Paul Milazzo has shown that in the 1950s and 60s it became politically expedient for western senators concerned with ensuring that large quantities of water were available for development to ally themselves with eastern politicians whose districts were more concerned with the quality of waters fouled by municipal sewage and industrial wastes.

In 1959 the senate commissioned experts from the Public Health Service (PHS) and Legislative Reference Service to "provide quantitative assessments of current water supplies, current uses, projections of future demand, and the means to meet that demand." (Milazzo 2006, 46) Experts involved in the preparation of this report included Theodore Schad, Melvin Scheidt, Abel Wolman and George Reid, all civil engineers with expertise in sanitation and water resources; Nathaniel Wollman, an economist; and Gilbert White, a natural resource manager. The civil engineers combined their expertise in water *quality* with Wollman's expertise in the amount of water necessary for economic growth and White's knowledge of the amount of freshwater actually available. . The Report of the Select Committee on National Water

Resources to the Senate in 1961 suggested that in order to ensure economic growth, the United States required enormous amounts of fresh water, much more water than was actually available in our lakes and rivers. Therefore all water used would have to be used more than once, which required that any one use must not degrade the quality of the water beyond its capacity for reuse downstream. This application of water *quality* arguments (derived from English common law) from the polluted eastern states to the development-based water *quantity* concerns of the arid west created a common cause between eastern and western senators. Thus an interdisciplinary coordination of expertise helped create the political consensus that resulted in the passage of the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966.

However, these experts' task of preparing, on a one year time scale, an assessment of water quality and quantity demands for the economic development of the United States required enormous oversimplification in mathematical modeling and underdetermination of the theory of underlying such models by available evidence. To estimate the water demand of the whole nation it was necessary to consider estimates of population growth, levels of economic activity, common uses of water, how to maintain water quality, and natural variation in water supply – for every region and river basin system in the United States. To simplify this enormously complex task

> "Wollman and Schad decided to designate an arbitrary level of 4 parts per million of dissolved oxygen as the average [desired] water quality for any given region…on average, that much dissolved oxygen could sustain aquatic life and recreation and would also enable repeated reuse for other functions as the water flowed downstream. (Milazzo 2006, 50)

The basic methodological assumptions involved were that 1) water would self-purify given sufficient time to mix with a sufficient quantity of diluting water and 2) that dissolved oxygen was the key indicator of water quality. Dissolved oxygen was selected by this group of experts because of their specific areas of expertise. It was, and remains, the standard method of measuring the amount of decaying organic matter in a watercourse – precisely the measurement that sewage engineers (who are most concerned with the disposal of human and animal wastes) are commonly concerned with. Unfortunately, this method of pollution estimation neglects thermal pollution – a kind of water pollution particularly endemic to large power plants, an issue of growing concern in the 1960s. Thermal pollution from nuclear power plants would a major issue in the Water Quality Improvement Act of 1970, but this study, from only a decade before, leaves thermal pollution entirely outside its methodology. On the subject of nuclear power, dissolved oxygen regulation also tells us nothing about pollution of water courses by radioactive substances, a particularly serious problem in the cold war years of large scale production and above-ground testing of nuclear weapons. Finally, dissolved oxygen content tells us nothing about inorganic pollutants – toxic metals and other inorganic chemicals primarily released into the environment by industry.

A key ethical problem thus arises: the use of dissolved oxygen as a measurement of pollution places the most of the responsibility for relevant pollution production on cites, towns, and farms. It shifts the responsibility away from 1) privately operated traditional power plants and industries and 2) government operated nuclear power plants, weapons production and testing. This makes the pollution by local citizen groups and the agricultural sector far more significant that pollution by the federal government or industry. A scientific critique of the dissolved oxygen standard came from a discipline that in the 1960s and 70s began to emerge as a source of policy advice – ecology. Ecologists stressed the necessity of understanding how the whole ecological system functioned and how the effects of many kinds of pollutants – including thermal, inorganic and radioactive as well as organic matter – all impacted the health of an ecosystem. This concern with the functioning of a total system lead ecologists to suggest to policy makers a national goal of a “zero-rate of discharge” of pollutants to be achieved by 1985. This zero-discharge limit was incorporated into the CWA of 1972. It has become a cliché - scientists and engineers love to hold up the “zero-rate of discharge” standard as an example of Congress people’s limited grasp on scientific reality. But as Milazzo’s work makes clear, the zero-discharge goal was actually a direct response to scientific advice from ecologists. It represents a condemnation of a basic assumption of sanitary engineers: “that aquatic systems had a natural capacity to absorb pollutants that could be calculated mathematically and factored into sewage treatment requirements… [Ecologist] Walter Westman insisted that streams could not function as waste sinks, since matter and energy moved in cyclical, not linear pathways.” (Milazzo 2006, 218) The basic methodology of sanitary engineering rests on the assumption that streams are capable of absorbing pollution, that running water is inherently “self-purifying” given sufficient volume of flow and sufficient time. Ecologists rejected the dissolved oxygen standard and the assumption that water was self-purifying. Instead they argued that it was necessary to understand how the ecological *system* could be affected by *all* kinds of pollution, many of which could not, unlike organic wastes, “self-purify” away.

Thus the ecologists revealed a problematic background assumption of sanitary engineering. But they had significant difficulties of their own. Defining ecosystem integrity is a challenge in itself. But still more difficult is constructing a regulatory system to achieve it. Achievement of a zero-discharge of pollution is improbable at best. The difference between controlling pollution and many other desirable moral goals of public policy, such as ending racial discrimination or child labor, is that pollution is a necessary evil. We can get all the children out of factories; we cannot cease producing waste products. Mark Sagoff argues that pollution control is subject to the law of diminishing returns –the higher we set our standards for how “clean is clean enough” the more difficult and expensive pollution clean up and prevention becomes. He argues that polluters have a duty to *limit* waste product disposal, but cannot be expected to *eliminate* it. He suggests that “if we are serious about encouraging improvements, we must recognize some as supererogatory, that is, as better than good enough, at least temporarily, and acknowledge them as such…we need to recognize plateaus or resting points to reward and thereby encourage further progress.” (Sagoff, 208)

A more viable pollution control strategy was suggested by a group of natural resource managers who had trained under Gilbert White. Their practical expertise in environmental regulation helped expose the difficulties of implementing the ecologist’s advice. This strategy requires that municipal and industrial wastewater be processed using the “Best Available Technology,” or BAT. It utilizes the sanitary engineers’ expertise in measuring what concentrations of what materials come out of pipes, without the need spend a lot of political capital setting effluent standards. The least polluting method currently available simply sets the standard until a technological improvement is developed. Checking that specific technologies are in place is relatively simple. This approach however, has several problems of its own. First, technology based standards don’t do a particularly good job of addressing non-point source pollution like urban and agricultural run-off. Moreover, the best available technology might fall far short of achieving a water quality in the public interest and yet give no power to regulators to control polluters who despite having the “best available” were still causing significant public harm.

Suggestions for Improving Disciplinary Advice

If using a single source of advice fails, and so does a multidisciplinary approach, then in order to make effective environmental policy there is a need to overcome the disciplinary boundaries identified in the previous section. My suggest that we need to create an institutional space in which interdisciplinary experts can communicate with each other, questioning the background assumptions of their own discipline and devising coherent, integrated technical advice to those who write policy. The science advisory boards studied by such authors as Bruce L. R. Smith and Sheila Jasanoff do not serve this role – they mostly give advice to regulators in the agencies charged with enforcing policy that is already written. The Office of Science and Technology Policy does not serve either – its role is to advise the President, and the executive branch is not the primary source of legislation in the American democratic system. I will argue that it is the legislative branch of government that especially requires an organization whose primary purpose is to provide responses to effective, truly interdisciplinary expertise for specific policy purposes. A possible analogue to such an organization existed between 1972 and 1994 – the Office of Technology Assessment. It is my hope that with further work my research will serve as an argument for the reestablishment of an organization of this type.

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