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CROSSING DISCIPLINARY BOUNDARIES: COMPARING 19TH CENTURY WATER-BORNE DISEASE TO CONTEMPORARY ENVIRONMENTAL POLICY

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ABSTRACT: *Water-borne diseases like cholera and typhoid fever have traditionally not been included under the category of environmental issues. However, since the contemporary environmental movement has become involved in issues of human health, it will help us to understand current issues better if we look back to the unique case of water-borne, bacterial diseases. In fact, while there are significant differences between the nineteenth-century issue of water-borne disease and contemporary environmental issues, there are also important shared aspects of the two periods. Water-borne, contagious diseases were overcome as satisfactorily as any environmental problem in history. Modern environmental health issues concern chronic diseases of more complex origin. Nevertheless, both policies dealing with water-borne disease, and contemporary environmental policies grew into their emphasis on environmental health, having begun as something else. Also, both modern environmental policy and public health* policies of the 1800s have evolved within governments that favor economic success over environmental protection.

INTRODUCTION

The first major environmental issue in the United States was water-borne, bacterial disease. Diseases such as cholera and typhoid fever have not usually been termed "environmental" issues. They have instead been called "health" issues, but as water-borne hazards they were similar to chemical pollutants which today are the primary focus of environmental policy. Both nineteenth-century health policy and contemporary environmental policy changed dramatically as society around them changed. Public health policy, medicine, and the broader society in the 1800s developed from moralistic fatalism into a scientific approach which helped to overcome most water-borne disease in the United States[1]. Modern environmental policy has evolved from a concern with aesthetics and resource management to a greater emphasis on the science of human health.

In trying to understand the past and present of an interdisciplinary issue as intricate as environmental health, the intellectual "net" should be cast as wide as possible. Disciplinary boundaries (health issues vs. environmental issues) can stifle the broad discourse that is vital to creative ideas and solutions. In this paper, I compare the case of 19th century water-borne disease to contemporary environmental issues in order to broaden the horizons of those who might only look back 30 years when they think of environmental policy. In fact, issues of risk and hazard from the surrounding environment go back much farther. So, this paper compares the problem of and solution for water-borne bacterial disease with contemporary issues, but it is also about breaking down disciplinary barriers that inhibit the creative exchange of ideas.

THE NATURE OF THE HAZARD

Contagious diseases were palpable, almost instantaneous, often deadly phenomena in the pre-antibiotic era. When epidemics struck, fear became a strong motivation for action. The majority of water and sewer improvements implemented in the late 1700s and 1800s followed major epidemics linked to water. The most infamous water-related diseases of the period were cholera, typhoid fever, and yellow fever. Cholera was particularly infamous for striking and killing quickly. These diseases were known to occur most frequently in cities where wastewater collected due to poor drainage. The link between water, particularly standing, dirty water, and disease had been observed as early as Ancient Greece (Hippocrates, 2000). By 1800, little had changed in the concept of disease as it was believed to generate spontaneously from decaying organic waste in unsanitary water, becoming a threat to health. This belief has been termed the theory of "miasmas," or the "filth theory" of disease (Tarr, 1996; Melosi, 2000). A competing idea, the doctrine of contagion, emphasized disease transmission through touch and inhalation. It had been effective in describing the plagues that struck Europe throughout history, but its influence waxed and waned during the 1800s depending on the nature of the most recent outbreak of disease (Evans, 1987). Because these maladies disproportionately affected the urban poor and because their etiology was not well understood they were seen by the politically powerful in the early 1800s as acts of God afflicting the morally weak who were predisposed to disease in the vile, unnatural setting of the city (Rosenberg, 1987; Rosen, 1974).

On the other hand, chronic diseases such as cancers, cardiorespiratory disease, sexual dysfunction, and developmental defects are the primary health risks from contemporary pollution. The results of low-level exposure to synthetic chemicals that can disrupt the endocrine system, such as pesticides, solvents, and combustion by-products, may take years to become manifest. Moreover, the cause and effect relationship between most chemicals and human health has not yet been proven (Miles-Richardson, 2002). Disease in any individual or even in a community may result from workplace exposure, diet, other lifestyle factors, or a synergistic combination of environmental and genetic causes (Heitgerd and Lee, 2003). Epidemiologists typically try to isolate "main effects," risks associated with a particular environmental exposure, rather than confront the complexities of synergy (Cooper, 2003). Thus, as in the search for the causes of 19th century contagions, definitive causes of contemporary diseases remain elusive. However, unlike the instantaneous impact of earlier contagious illnesses, the effects of contemporary disease may take decades to show.

RESPONSES TO THE RISK OF DISEASE

Through the early-to-middle-1800s local governments worked unevenly to eliminate or mitigate hazards, responding only when the threat was greatest. Americans of this period were aware of hazards, particularly contagious diseases, but they lacked the knowledge to effectively combat them. In some cases, local populations rebelled against perceived threats (Meyer, 1995). In other instances, a kind of fatalism led the privileged classes to attribute high death rates from disease to the immorality of the masses. During the middle 1800s, however, this attitude gradually changed, and more knowledge was gained about the conditions of disease. So, as a third epidemic of cholera within 35 years approached New York, the city did form a Metropolitan Board of Health (1866) which mandated a clean up of the city's streets and alleys, minimizing that epidemic's impact (Rosenberg, 1987). During the first half of the nineteenth century, epidemics in major US cities highlighted local governments that were disengaged, and that were slow to respond, or incapable of responding both to threats and to new ideas.

During the past 30 years, environmental policy has evolved from a concern limited to aesthetics and resource management to a broader set of concerns centered around ecosystem health, and, ultimately, human health. Industry, which was still relatively new, and not a major factor in the fight against water-borne disease, is now at center stage as policymakers confront a more complex set of environmental problems, with a dual goal of promoting economic development while limiting hazards to the population.

Removing the Waste and Reaching for the Water

Most permanent settlements in colonial North America and in the early United States dug wells near their dwellings to provide water without the inconvenience of carrying it from a nearby stream or river. Unfortunately, these settlements also dug easily-overflowed cesspools, or permeable privy vaults close by which allowed fecal matter to escape into surface water or groundwater (Tarr, 1996). The result was a growing incidence of diarrhea, cholera, and other water-borne diseases in the late 1700s. Responses to disease took three forms: cleaning the streets of decaying animal or plant waste, reaching out beyond densely-settled neighborhoods for fresh sources of water, and creating sewers to carry sewage away from dense populations to larger bodies of water. The first major response to disease came in Philadelphia during the 1793 yellow fever epidemic, an outbreak that killed 10% of the city's population (USGS, 2000). Yellow fever was mistakenly believed to result directly from unsanitary water, so the city established a Watering Committee to oversee the supply of uncontaminated drinking water. Less severe outbreaks from 1794 until 1798 spurred Philadelphia to establish the first major waterworks in the country, the Centre Square Water Works in 1801, which pumped water from the Delaware River to an elevated cistern for distribution around the city (Philadelphia Print Shop Ltd., 2003).

Other major cities had also begun to collect water in relatively remote locations to pipe into their most densely populated neighborhoods. In 1776, New York constructed a reservoir north of the city's dense settlement which served a limited part of the city until a much larger system was completed in 1799 (DEP, 2002; Skinner and Taylor, 1781). In 1795, Boston began to import water through hollow logs from Jamaica Pond, then southwest of the city (Massachusetts Water Resources Authority, 2003). Other cities built or awarded contracts for water systems through the 1860s, the latest being San Francisco, a city that had not existed fifteen years earlier (Table 1). Typically the systems started small or moderate in size, funded by private capital, and eventually were taken over by municipalities as they grew in size and complexity (Blake, 1956). There is no consistent pattern in the size of cities establishing a water system; they range from Newark, NJ, with a population of 6000 to Brooklyn, an outlier with population of 255,000. Newark's water supply before 1800 was an open pond perceived as unusually accessible to farm animals and other sources of contamination, so a local water company formed when it was still a village (Galishoff, 1988). At the time of establishing its centralized water system, Brooklyn was by far the largest city on the list, which is partly explained by its large area and relatively low population density (Stiles, 1869).

As these cities grew, their need for clean, plentiful water not only for drinking but for fighting fires grew, as well (Pendleton, 1999). Thus, they looked still farther a field for water. Philadelphia built the Fairmount Park Waterworks in 1822, drawing water from the Schyukill River northwest of the city. In the 1840s Boston reached 20 miles west to Cochituate Lake for water, while New York impounded the Croton River, 50 miles north of

Table 1. Top 15 Cities in the US, by population, 1880

	First Water System		First Sewer System		
	Date	Population	Date	Population	Lag Time
New York	1776	61,000	1845	400,000	69
Boston	1796	21,000	1840	320,000	44
Newark	1800	6,000	1852	45,000	52
Philadelphia	1801	41,000	1852	200,000	51
Baltimore	1807	35,000	1911	600,000	104
Washington	1808	7,000	1810	8,000	2
Cincinnati	1819	9,000	1825	16,000	6
Pittsburg	1828	11,000	1889	230,000	61
St. Louis	1832	7,000	1855	135,000	23
New Orleans	1833	60,000	1897	277,000	64
Chicago	1842	9,000	1856	70,000	14
Buffalo	1852	66,000	1883	185,000	31
Cleveland	1856	30,000	1859	40,000	3
Brooklyn	1859	255,000	1862	270,000	3
San Francisco	1862	58,000	1876	195,000	14

Manhattan. With the new water sources available, the cities stopped using their previous, more vulnerable water supplies. Between 1850 and 1880, major cities in the Northeast and Midwest, such as Buffalo, Chicago, and Baltimore, continued to push farther up rivers and farther into large lakes in search of water that was both uncontaminated and plentiful.

The second part of the strategy against water-borne disease was to remove human (and some animal) wastes from densely populated neighborhoods by sewers. Private sewers for non-fecal runoff had been built privately in Boston and New York as early as 1700 (Clarke, 1885). Table 1 shows that the first sewer system was begun in 1810 in Washington, DC. Such early sewers were also meant only for runoff, but might incidentally carry fecal matter after a heavy rain. Ironically, runoff, and thus the need for sewers, was greatly increased by the water systems discussed above, especially with the large-scale introduction of water closets around the time of the Civil War. Most of the sewers built later carried both runoff and sewage from upper-class neighborhoods and commercial districts into nearby water bodies, with moving water the preferred destination. This plan rested on the concept of water as self-purifying, a corollary of the miasmatic theory of disease (Sedgwick, 1918). Still unaware of the dangers of microbes, designers thought that moving water free of putrid smells and discoloration would be safe. In fact, sewers only transported the problem of disease from the micro scale of yards and neighborhoods to the regional scale of rivers and lakes, concentrating a city's fecal waste on the surface of a river flowing toward a downstream city that drew its drinking water from the river. The two cities with the longest delay between their first water system and first sewer system were Baltimore and New Orleans. Despite recurrent epidemics of cholera and typhoid fever, particularly in New Orleans, the cities were both plagued by internal political conflicts which delayed funding their sewers by decades (Boone, 2003; Maygarden et al., 1999). These water and sewer systems alone did not prevent disease because the waterways around major cities could not simultaneously serve as both sewage sink and water source.

A Small Breakthrough

By the 1860s, the voices of researchers who believed that diseases like cholera were somehow "portable" by water and other media were growing in influence, while the idea of disease as divine retribution was fading (Rosenberg, 1987). Insights from miasmists, contagionists, and microbiologists combined with growing support from the economic and political elite to move the discourse on disease in a new direction. The middle- and upper-middle-classes began to fear epidemics they once thought beneath them; Pasteur's experiments refuted the existence of miasmas, and the achromatic microscope was invented, allowing biologists to peer at the microbes causing water-borne disease (Duffy, 1990; Bowditch, 1877). But the most significant work of this period came from the Bavarian scientist, Max von Pettenkofer, a miasmist who hypothesized in 1869 that cholera was not a water-borne disease, but that it was caused by a germ or fungus that could infect people under certain atmospheric and soil conditions. His work was popular both among European and American health officials who shared his disdain for expensive, politically unpopular quarantine (Evans, 1987). It became common for health officials to cling to ideas of miasma even as they began to acknowledge germ theory (Waring, 1877).

Pettenkofer proved to be only a transitional figure because during the 1880s germ theory ascended to dominance under Robert Koch, whose work isolating tubercle bacillus, the cause of tuberculosis, and *vibrio cholerae*, the cause of cholera, paralleled the efforts of the German government to establish itself as a nationalistic world power (Evans, 1987). In the United States, new state health laboratories, notably the Lawrence Laboratory in Massachusetts, tested a range of methods for eliminating harmful microbes (Rosenkrantz, 1972). Two existing technologies, sand filtration and chlorination, emerged as the strongest choices. During the 1890s both sand filters, already in use in some European cities, and chlorine, which had been added to foul-smelling water in limited areas since the 1830s, were effective anti-bacterial measures when applied properly (EPA, 1999). US cities soon began to filter drinking water supplies, and between 1908 and 1915, all major US cities began to chlorinate their water supplies, with a dramatic drop observed in water-borne, disease nationwide (Tarr, 1996).

The identification of bacteria as the cause of a great deal of water-borne disease, and subsequent filtration and chlorination solved perhaps the most serious environmental problem ever encountered. Cities providing the most basic service, bacteria-free water, could now continue to grow to even higher densities without fear of repeated epidemics from 19th century scourges like Cholera and Typhoid Fever. Water supply became another artificial system on which the city depended, along with electricity, commercial agriculture, trash removal, and others.

Sources documenting the history of environmentalism rarely mention drinking water supplies because the movement was new at the time when water-borne disease was being addressed, and it was involved in forest conservation and wilderness preservation at that time. However, a comprehensive view of the environment should not exclude drinking water quality. In fact, it was not the conservation movement embracing health issues; rather, it was public health that expanded to take a broader approach to issues of health and environment in the early 1900s before stepping back to a more limited scope after WWI (Cassedy, 1962). Only recently has environmental policy reconnected with issues of health and well-being.

Most public policy proceeds incrementally, and that is clearly the case here (Anderson, 1985). Once two generations of intellectual transition were negotiated, and the technological questions were answered, the solution to disease in the water supply was uniquely simple. Still, two issues linger. First, any large system like a municipal water supply raises questions of sustainability. It requires the building of additional plants to filter and/or chlorinate water, and ultimately to treat sewage, and it consumes a great deal of energy, as does most modern infrastructure. Second, the difficulties local governments experienced responding to the challenge of disease in the 1800s highlight structural weaknesses that to an extent still exist in American government.

Contemporary Issues

Health has only evolved as a concern of the modern environmental movement since the late 1960s and early 1970s when the Clean Air Act and the Clean Water Act were enacted, and the federal Environmental Protection Agency (EPA) was established. Previously the environmental movement had focused primarily on issues of aesthetics or of natural resource management. And in the debate favoring this new legislation, advocates were more likely to discuss ecosystem health than they were human health (Hays, 1989). Suddenly, in the 1970s ecosystem health, human health, aesthetics, and resource management came together under the umbrellas of water quality and air quality, overseen by a new department with regulatory teeth, and the motto, "Protecting Human Health, Safeguarding the Natural Environment."

Confronting water-borne disease in the 1800s was about local governments, engineers, and researchers developing technologies to protect human populations from their own waste. More recent environmental health issues, however, have involved industry, another layer of actors and interests. Industry has become an important factor in the environmental health equation because the energy input to industry, and its resulting waste production increased dramatically from the early 1900s through the 1970s. For example, both the petrochemical and semiconductor industries developed and matured during this period, creating major air and water pollution streams. So, concern has shifted from bacteria to chemicals, and government action has changed from building infrastructure to legislating against pollution.

In the 1890s Frederick Jackson Turner declared the closing of the American frontier as European-American populations spread through the West. Likewise, the 1970s might be seen as the closing of the "Chemical Frontier" in the United States. For decades prior to the 1970s, polluting industries spewed chemicals onto the land, and into the air and water with relatively few limits (Cutter, 1993). Local opposition might have forced a factory to build a higher smokestack, or dump their waste outside of town instead of into the local river, but there was always some new, overlooked sink where waste could go. Tens of thousands of small hazardous waste sites around the country dating to this period are evidence of this frontier mentality (Colten and Skinner, 1996). In the 1950s and 1960s the federal government began to legislate air and water pollution, providing money for state and local governments to encourage industries to curb their waste streams, to little effect. The only way to deal with the tens of thousands of chemicals used in the United States would be to limit or prevent the most serious at their source.

Fundamental change came in the early 1970s when on the federal level the Clean Air Act (1970) and the Clean Water Act (1972) were amended to include maximum limits on most air and water pollutants. For instance, automobile emissions of nitrogen dioxide, carbon monoxide, volatile organic compounds, and particulates were required to be cut back dramatically, and large-scale chemical streams into water bodies would thereafter need a permit to proceed (US Code, 2002). Failure to abide by these limits would result in civil or even criminal penalties enforced by the newly created EPA. This legislation was followed by complementary laws such as the Resource Conservation and Recovery Act [RCRA–1976], which required "cradle-to-grave" monitoring of hazardous chemical waste, leading to dramatic reductions in dumping and dramatic increases in recycling (McGlinn, 2000). The Comprehensive Environmental Response, Compensation, and Liability Act [Superfund-1980], spurred by the case of Love Canal, has been the mechanism for cleaning up the most dangerous hazardous waste sites, created during the time of the open chemical frontier. If proven responsible, companies must pay for cleaning up their past indiscretions. Otherwise, Superfund has been supported by a chemical feedstock tax paid by wholesale buyers, a tax which has now expired, with any further funds coming from general revenue. To date, 886 sites are considered cleaned up, while 436 sites are underway, and others still wait (EPA, 2003).

Environmental policy in the 1970s broke dramatically from previous efforts to protect the environment. First, it provided enforceable punishment for non-compliant actors. Second, it was national in scope. There should be no more isolated ravines or swamps where waste can be dumped with no consequences. Enforcement of these laws has waxed and waned with the political philosophy of different administrations, and the overall trend has been toward market-based approaches over the past 20 years. But the necessity of dealing with industrial pollution has become a part of American political culture, and over the past 30 years reductions have been noted in the pollution of both air and water (EPA, 1998; American Lung Association, 2000). Nevertheless, as research on environmental health goes on, there remains great scientific uncertainty; just how much of a given chemical, or combination of chemicals, over what period of time can stimulate cancer, lung disease, or genetic changes in a human? The EPA uses molecular-level models of toxicity to estimate relative risk from a wide range of regulated chemicals (Cronin et al., 2003). However, uncertainty remains in predicted results of introducing chemicals to the human body. For Example, the results of high doses of chemicals in small animals may or may not represent the effects of lower doses on humans over longer time periods (Howd, 2002). Also, evidence suggests that childhood exposure to chemicals in the environment may have a greater impact than adult exposure (National Children's Study, 2003). Work continues on verifying such hypotheses, not as a deterministic yes or no, but as a higher degree of certainty. In the foreseeable future there is unlikely to be a perfect resolution of chronic disease. Over the last 30 years, though, we have seen how, often under the threat of penalty for non-compliance, industry can become more efficient. So, near-term progress is likely to come as further reduction of pollution rather than as a simple cure for chronic disease.

DISINCENTIVES TO ENVIRONMENTAL PROTECTION

Nineteenth century sanitarians faced obstacles which seem superficially much different from the obstacles confronting today's environmental policy. However, similarities between the two experiences run deep. For instance, there were no redeeming values to excreta, overflowing cesspools, or leaking privy vaults. Anyone who felt threatened by epidemic disease wanted to see it eliminated. However, the privileged and powerful did not feel threatened by early epidemics. A document published by Boston's city physician during the 1849 Cholera epidemic reads, "For the most part, the temperate, the moral, the well conditioned, escaped; whilst the imprudent, the vicious, and the poorly fed, succumbed to its insidious influence" (quoted in Ward, 1989 p.9). The wealthy often stayed away from public wells and even questionable public water systems, having drinking water from rural springs delivered, or leaving cities in epidemics (Blackmar, 1995). Thus, powerful members of the community often did not have the personal incentive they might have had for a more tangible threat to themselves or to their families.

Compare this view of disease with contemporary land uses such as landfills, power plants, and mining operations. Similarly, the middle- and upper-classes do not generally consider such land uses a threat because they can easily rebuff them through petitions drives, or, if necessary, through the courts. Local and even state governments lack the will and power to site potentially hazardous land uses near established residential communities, so these facilities usually are sited nearer to poor neighborhoods which lack the clout to resist.

Another notable obstacle to protecting water supplies in the late 1800s was the time necessary for politicians and the public to gain trust for expertise. Plumbing contractors and engineers who had built earlier waterworks and sewers, and even physicians who had vainly comforted so many victims of disease during the early and middle 1800s were not as well trained as the new generation of "sanitary engineers," biologists, chemists, and certified engineers who were unraveling the mysteries of disease in state laboratories (Tarr, 1996). Policymakers, who not only made laws but also held research purse strings, were initially skeptical of experts, slowing progress against disease. Ultimately, the value of expertise was recognized, and the role of the expert became uneasily established in the political culture (Rosenkrantz, 1972; Billings, 1885).

Today's experts also have problems of credibility because the role of the expert has become so commodified and politicized that the objectivity they were meant to provide has become meaningless. The conclusion of any individual scientist or panel can be immediately assailed as biased if it does not meet the political litmus test of a given faction or lobby. Industry-funded scientists rarely reach conclusions that are at odds with their employer. And the methodology of research is typically too arcane to be intelligently debated by a layperson. For instance, how can an interested citizen critique the assumptions of a Global Climate Model, particularly as it affects his or her region or city? How accurate is a projection it generates? What are the limits of error? Is there any randomness in the phenomenon which is not accounted for by the model? The questions mount, and trust is in short supply when scientists are polarized according to the agenda of the agency or industry funding them.

The political-economy of environmental protection has dictated a strong role for economic considerations in policy decisions. Concerns over profitability and economic growth mean that environmental regulations have had to and will continue to have to be carefully justified. Sanitarians working against disease in the 19^{th} century had a better defined task at hand, encountering some resistance, but I would argue that the goals of modern environmental policy will take much longer to succeed than the solution to water-borne disease, and they will require more constant vigilance as lawmakers, leaders, and experts come and go.

CONCLUSION

In the history of health-related environmental issues in the United States, none have been as destructive or as satisfactorily resolved as water-borne bacterial disease[2]. The nineteenth-century transformation of the culture of health and science from moral judgment to experimentation and verification helped to eliminate water-borne disease as a significant threat to human populations in the United States. Nevertheless, the circumstances of water-borne disease are unique. It stands out as a clear success in environmental policy, where relative success is usually measured in small increments of having one's view considered or not when policy decisions are made.

Contemporary pollution/health questions are less clear cut and more complicated than the fight against bacterial disease because they involve chronic health problems which can take years to develop. These problems result from a complex environment with many potential hazards where it is difficult to assess causation or blame. The best-case scenario is that we may achieve a healthy balance between pollutants and health, and most agree that we are not there yet (EPA, 2003).

While there are clear differences between health and environmental issues faced in the 1800s and the issues faced today, similarities are even more striking. A fundamental similarity is that the environmental issues of both today and the past can only be dealt with in the context of economic constraint. Programs that solve environmental problems but which require too much tax revenue are unlikely to be enacted. Likewise, there is and was tremendous resistance to strong environmental regulation from industry and their political allies. Health or environmental issues might only become a priority in a time of ecosystem breakdown, and perhaps not even then.

Finally, researchers who seek to understand and inform environmental policy should look beyond labels in their work. The categories of legislation and bureaucracy may change, as they have with human health and the environment, but the core idea remains; that is, to protect human populations from hazards in their surroundings, substances they may come into contact with, inhale, or ingest. Citizens and public officials were trying, within economic and political constraints, to protect themselves 150 years ago, and new generations are still trying to do it today.

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[1] I am aware that as many as two billion people in the world population still do not have consistent access to clean water, and that bacterial disease in developing countries remains a threat (Watts 2003, 1274-75). However, due to space and conceptual considerations I am confining my argument to the United States.

[2] An argument could be made that stratospheric ozone depletion, with a satisfactory substitute for CFCs and near total global agreement, appears to have been resolved, but even if the agreements are successful, residual ozone depletion will remain with us for decades. So, it would be premature to declare success in that case.