# One Hundred Years of Environmental Law and Policy: Water

## *The Role of Science and Engineering in Water Regulation Over the Past 100 Years*

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## Abstract

Scientific and engineering principles are inexorably linked to the regulation of water. Scientists and engineers first discovered the link between disease and water sources in the mid-19th century. Over the years, scientists and engineers have led the way to identifying water quality problems and their causes. These discoveries have directly contributed to the scope of water regulation in the United States and elsewhere. In addition, changes in water quality regulation have dictated the need for increasingly sophisticated water treatment technologies and engineers have been at the forefront of the development of these water control technologies. This session will discuss the historical roots, and the development over the century, of scientific principles and engineering technology in identifying and combating water pollution. It will also provide a solid foundation for understanding current efforts underway to solve current and future water quality issues.

## Introduction

Scientists and Engineers have played a central role in shaping water regulation over the last 100 years. Prior to about 100 ago, human waste was commonly discarded into open ditches, sinks and gutters. This, of course, diminished the quality of life, particularly in urban centers, and helped to spread disease.

Thus, cities (and their planners and engineers) began to design sewer and other sanitary systems to transport human waste for discharge into nearby water bodies, often used for drinking. This led to further spread of disease, including typhoid due to discharge of raw sewage into these sources of drinking water.

Scientific advancements and the discovery of germ theory changed this practice. This led in turn to discharge of raw sewage into surface waters, including ocean waters, estuaries, lakes, rivers and streams not directly used for drinking. This once again led to concerns about the spread of disease from urban centers elsewhere, including those from scientists that human waste from New York City caused or contributed to the spread of disease in New Jersey, or that Chicago's wastes caused sickness and death in St. Louis and elsewhere.[1]

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[1] New York v. New Jersey, 256 U.S. 296 (1921); Missouri v. Illinois, 200 U.S. 496 (1906).

Over the last 100 years, scientists and engineers have played a central role in shaping water quality goals. Engineers are largely employed to design technological systems to control pollution so as achieve water quality goals. Scientists are largely enlisted to inform discussions about the level of pollutant stressors that receiving waters can withstand and still be sufficiently safe for aquatic and human use.

During the evolution of America's regulation of water pollution, law, from the first permit systems at the beginning of the twentieth century, to the modern day Clean Water Act, the sciences and engineering have played an integral role. The large-scale management of water requires large-scale infrastructure. Nowhere have the sciences and engineering been more instrumental in protecting water than in the area of water treatment and delivery systems. However, the sciences and engineering have done more than simply design our piping and filter our drinking water. Scientists and engineers are an integral element in the regulatory process. When disagreements over water regulation spill into the courts, scientists and engineers also provide expert testimony and help settle disputes. Water regulation would be impotent without the sciences and engineering.

This paper discusses the evolution of engineering and the sciences in regulating water pollution during the last 100 years. First, it first traces the role of science and engineering in shaping water quality laws over the last century, culminating with the Clean Water Act, the nation's premier water pollution control law. Second, it examines the pivotal role engineers have played in developing the Clean Water Act's principal means of achieving water quality goals: technology based standards. Third, it discusses the role scientists play in developing and achieving water quality standards under the Clean Water Act. Fourth, it briefly accounts for how technology based standards and water quality standards are implemented under the Clean Water Act's permitting system. Fifth, it touches on the emerging role engineers and scientist play in addressing water rights – as opposed to water pollution – issues. Last, it describes the role of science and engineering in addressing ongoing water quality challenges. Essentially, law, science and engineering work in tandem to protect the strong public interest in clean water, and to track and control pollution so as to keep waters sufficiently safe and healthy for intended purposes.

## Three's Company: Science, Engineering, Congress and the Clean Water Act

Clean, safe, fresh water is important to the nation's environment, economy, and security. If all of the water in the world were represented as 100 gallons, 97 would be undrinkable saltwater. Two gallons would be trapped in glaciers and icecaps. Two quarts would be groundwater. Less than one-half pint (the carton size of elementary school milk) would be freshwater. Of that one-half pint, roughly one teaspoon exists within a two hour drive from the locus of this conference, which consists of almost 60 million people, and draws an additional 50 million visitors who make 250 million trips annually, and spend $20 billion on services, $5 billion on tourism, $75 billion on food and fiber, and enjoy 3 billion pounds of fish and shellfish. Manufacturers and cattle and crop farmers need clean water too. The ones in this region alone use more than 15 billion gallons of water a year, producing products worth more than $25 billion.

The nation's great commercial and social traditions depend on ready access to clean, dependable water. A century ago, DuPont depended on the fast, clean-flowing Brandywine River to fuel his first powder mills and usher in the petrochemical revolution. Today, clean water is no less important than it was then. It goes without saying that clean water is important for fish and wildlife and their habitat. What we often forget is that clean water is essential to the nation's great petrochemical, pharmaceutical, agricultural and animal farming, mining, automotive, port, fishing, crabbing, housing, shopping, motel, restaurant and tourism industries. The nation's manufacturing sector depends on clean water to run efficiently. By maintaining property values, clean water is good for homeowners and developers. It helps keep health care, taxes and insurance costs down. In short, clean water is essential to the success of the nation's economy, sustains our values and quality of life, and is good for business. Following the Great Depression and World War Two, Congress sought to apply broach federal regulatory programs to address national challenges, from commerce to clean water. During this time, federal approaches to water pollution evolved away from focusing on local water conditions to one establishing national, technology based standards based upon feasible an engineering practices.

It took a while to submit to a technology based approach. Sixty years ago Congress enacted the Water Pollution Control Act of 1948[2], which established a kind of quasi state and federal cooperative to provide means for resolving disputes about interstate water quality. The Federal Water Pollution Control Act of 1956[3] continued this approach. Neither law did much if anything to improve water quality.

With the Water Quality Act of 1965[4] Congress had states set water quality standards, for example, maintaining 5 parts per million of oxygen in interstate freshwater used for trout fishing. The federal role was minimal, however, largely consigned to helping to resolve interstate disputes. Again, the 1965 Act resulted in little activity, and water quality continued to decline dramatically.

Indeed, at this time the majority of people in the country lived near water too polluted to use. One could not fish, swim or even boat in large parts of the Delaware and Schuylkill Rivers, suppressing commerce, home values and health. The Anacostia River was dying. Baltimore Harbor and the Port of Wilmington closed to all but tanker traffic, and major rivers like the Delaware and the Susquehenna were open sewers, dashing hopes of urban revitalization.

Congress considered how to improve water throughout the late 1960's and early 1970's. At core were two schools of thought about how to make the nation's waters "fishable and swimmable." The first, largely based in the Senate, would dispatch with water quality standards-based approaches in favor of a command and control, technology based approach led by the newly established EPA. The second, largely from the House of Representatives, would use a more muscular ambient based approach than contained in the 1965 Act. It had EPA set water quality criteria for certain "designated" uses, such as swimming, fishing, drinking or recreation. It then had the states – as had the 1965 Act – develop and implement water quality standards to meet designated uses. The compromise legislation largely embraced the Senate's technology-based approach, with consideration of local water quality conditions in

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[2] *See* 33 U.S.C. § 1251 – 1376 (2008).

[3] *Id*.

[4] *Id*.

those instances where installation of innovative technologies alone was not sufficient to achieve water quality standards.

The Clean Water Act of 1972[5] reflects a hybrid of the competing technology and ambient-based approaches. It is largely a response to earlier failed approaches rooted in common law that linked compliance responses to the ability of the water body to withstand the polluting activity. Congress determined that there is not sufficient scientific certainty to measure the "tolerable effects" of discharges.[6] Thus Congress opted for an innovative approach based on national, uniform technology based standards for categories and classes of point sources.

The Clean Water Act requires EPA to set technology-based standards for categories and classes of point source dischargers, such as pulp and paper mills, breweries and steam-electric fossil-fuel burning steam electric generating stations (power plants). When calculating these standards, regulators "aim to set effluent limits at feasible levels while still encouraging innovation."[7] It also allows EPA and states to set more stringent requirements wherever technology based standards alone are not sufficient to protect water quality for a particular water body. Engineers and scientists are involved every step of the way.

## The Role of Engineers and Scientists in Shaping Regulation of Water Regulation

### A. Role of Engineers in Shaping Water Quality

More than anything else, engineers help design, apply and implement technological means of controlling pollutant discharges as a means of protecting water quality. The following sections discuss some of the legal concepts that engineers and scientists apply in water regulation. For a listing of some selected scientific concepts and engineering responses to achieve water quality and protect drinking water systems, please see the appendix that appears at the end of this paper.

### 1. **The Use of Technology Based Standards**

Most federal environmental laws contain provisions that require EPA to set national technology-based standards on the regulated community, rejecting quasi-common law regulatory approaches that link the regulatory response to local conditions. For example, the first such statute to do so in 1970 – The Clean Air Act – requires EPA to develop and implement technology based standards for "stationary" and "mobile" of air pollution.[8] Since 1972, the Clean Water Act has required EPA to set and implement technology based standards for "point sources" of water pollution.[9] The Safe Drinking Water Act requires EPA to set technology based standards drinking water from "public drinking water systems."[10] Safe

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[5] 33 U.S.C. § 1251 – 1376.

[6] EPA v. Cal. State Water Res. Control Bd., 426 U.S. 200, 202 (1976).

[7] *Id*. at 38.

[8] Clean Air Act of 1970, Pub. L. No. 91-604, 84 Stat. 1676 (codified as amended at 42 U.S.C. § 7401-7671g (1994)).

[9] Clean Water Act of 1972, Pub. L. No. 92-500, 86 Stat. 816 (codified as amended at 33 U.S.C. §§ 1251-1385 (1994)).

[10] Safe Drinking Water Act, 33 U.S.C. § 300g-1(b)(4) (2008).

Drinking Water Act, 33 U.S.C. § 300g-1(b)(4). The Resource Conservation and Recovery Act requires EPA to set technology based standards for facilities that dispose hazardous wastes.[11]

Congress has turned to technology-based standards because they are fair, predictable, efficient, adaptable, and enforceable. First, they are even-handed. Rather than allowing inefficiently disparate, site-specific standards, national technology based standards level the playing field by treating those who engage in regulated activity to meet a certain threshold standard. Second, they are predictable. Rather than being subjected to agency decision-making on an ad hoc basis, national technology based standards allow the regulated community to forecast regulatory requirements. Third, they are socially efficient. Regulatory rulemaking – even that taking many years as in the case at hand – is still generally a more efficient regulatory mechanism than case-by-case determinations. Fourth, they are adaptable. Technology based standards can be adjusted to fit innovation and feedback. Last, they are readily enforceable. Technology based standards are usually embodied by a particular technological requirement or a performance standard, either which are readily discernible by governmental enforcement agencies and by courts.[12]

### 2) **Water Pollution Control is Primarily Technology (Engineering) Based**

Technology-based standards are the central regulatory tool adopted in the Clean Water Act for achieving the “national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and ... for recreation in and on the water.”[13] Under this approach, Congress instructed industry to reduce environmental harms as much as technology allows. In so doing, Congress made a sharp break with the failed regulatory approach that had governed until 1972, which sought to meet water quality standards by trying to determine how much pollution the water could assimilate and still be clean enough for human and aquatic uses. Congress found this pre-1972 approach to be “inadequate in every vital respect.”[14] Instead, technology based standards “facilitate enforcement by making it unnecessary to work backward from an overpolluted body of water to determine which point sources are responsible and which must be abated.”[15]

Technology based standards apply to existing and new point sources. The level of performance for existing facilities is a function of pollutant, and becomes more stringent over time. Initially, existing point sources were to meet “best practicable control technology currently available” (BPT) for all regulated pollutants.[16] Thereafter, they were to meet more stringent technology based standards, as a function of whether the regulated pollutant is “conventional”

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[11] Resource Conservation and Recovery Act, Pub. L. No. 94-580, 90 Stat. 2795 (codified as amended at 42 U.S.C. §§ 6901-6992K); *see* e.g., Patricia McCubbin, *The Risk in Technology Based Standards*, 16 Duke Envtl. L. & Pol'y F. 1, 7-8 (2005).

[12] Wendy Wagner, *The Triumph of Technology Based Standards*, 2000 U. Ill. L. Rev. 83, 87-105 (2000).

[13] 33 U.S.C. § 1311 (2008).

[14] *See* Milwaukee v. Illinois, 451 U.S. 304, 310 (1980), quoting S. Rep. No. 92-414, 7 (1971), 2 Legislative History of the Water Pollution Control Act Amendments of 1972, 1425 (Committee Print compiled for the Senate Committee on Public Works by the Library of Congress), Ser. No. 93-1 (1973).

[15] EPA v. Cal. ex rel. State Water Res. Control Bd., 126 U.S. 200, 204 (1976).

[16] 33 U.S.C. § 301(b)(1)(A) (2008).

(such as oil & grease, pH, nitrogen, phosphorus and dissolved oxygen) or non-conventional (such as toxics and metals). Conventional pollutants discharges were to comply with "best conventional pollutant control technology," (BCT).[17] Non-conventional pollutant discharges were to comply with "best available control technology economically achievable … which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants," (BAT).[18] New sources were to meet "best available demonstrated control technology" (BADT). EPA, or a state with delegated permitting authority, would then implement the applicable technology based standards when issuing National Pollutant Discharge Elimination System (NPDES) permits. The CWA prohibits the discharge of a "pollutant" from a point source in the absence of a permit.[19] EPA must set technology based standards for point source discharges of pollutants[20], including for discharges of "heat."[21]

### 3.) **Examples of Technology Based Standards Under the Clean Water Act**

#### a.) Best Practicable Technology

The Clean Water Act has a broad range of technology-based standards. Best Practicable Technology (BPT) is the least restrictive technology-based standard. Instead of setting forth a standard not widely available in an industry, BPT surveys existing technologies and selects those operating at the most efficient levels.[22] Facilities may adopt the specific technology used by the top-performing facilities, or develop an alternative that performs at the same level.[23] Compliance may therefore take the form of further innovation. As companies seek to lower the costs of modifying their facilities to meet the BPT standard, engineers and other scientific professionals assume a very important role.

With water regulation, these technology-based standards describe the desirable characteristics of water when it is released from some municipal or commercial facility. This type of regulation is called "effluent limitations," because the concern is the integrity of the water as it enters the nation's streams, lakes, and rivers. A selected few "effluent limitations" will be discussed to highlight how regulators create and enforce technology-based standards.

Water regulation touches many subjects, and in 1976 the EPA codified effluent limitations on the photography process.[24] This regulation is a Best Practicable Technology standard. These regulations describe a permissible daily discharge of certain contaminants (silver and carbon nitrate, as well as parameters for pH levels) that are used in the photography process. The regulation places an additional limitation on the average daily discharge for a 30 day period. These limitations are:[25]

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[17] *Id*. § 301(b)(2)(E).

[18] *Id*. § 301(b)(2)(A)

[19] 33 U.S.C. § 1311 (2008).

[20] 33 U.S.C. § 1311 (existing sources) & 1316 (new sources).

[21] 33 U.S.C. § 1362(6) (2008).

[22] JOEL M. GROSS & LYNN DODGE, CLEAN WATER ACT 39-40 (American Bar Association 2005).

[23] LYNN M. GALLAGHER, CLEAN WATER HANDBOOK 44-45 (Government Institutes 2003).44-45.

[24] 40 C.F.R § 459 (2008).

[25] *Id*. § 459.12(a).

**Table 1** BPT – 40 C.F.R § 459.12(a): Effluent Limitations on the Photography Process

| **Effluent characteristic** | **Effluent limitations** | |
|---|---|---|
| | **Maximum for any 1 day** | **Average of daily values for 30 consecutive days shall not exceed—** |
| | Metric units (kilograms per 1,000 $m^2$of product) | |
| Ag | 0.14 | 0.07 |
| CN | 0.18 | 0.09 |
| pH | 6.0-9.0 | 6.0-9.0 |

The regulation educates on how these numbers were calculated. Because of a lack of industry-wide information regarding photography and its manufacturing process, a Best Practicable Technology standard was advisable [26] Regulators were also unable to effectively sub-categorize the manufacturing process because of this lack of information. It is thus more advisable to use a less stringent standard (BPT) and to allow more discretion in the permit process when comprehensive data is unattainable. To mandate stricter requirements without an understanding on its economic impact would offend the overarching purpose of technology-based standards, which seeks to balance the interests of the environment with the economic interests of the regulated industry.

### b.) Best Available Technology

Best Available Technology Economically Achievable (BAT) mandates "the maximum feasible pollution reduction for an industry."[27] A more stringent standard than BPT, this approach designs regulation on "the optimally operating plant," seeking to maximize pollution reduction without causing large-scale facility closures, even if the technology is not widely used in the industry.[28] The role for innovation is even more relevant in this circumstance. While this standard only requires what is theoretically achievable by the industry, there is always pressure to find a more cost-efficient means of compliance. Scientists and engineers undoubtedly play a major part in the research and development of these cleaner technologies. Similarly, when determining BAT, regulators must consult with those developing technology in a specific industry and determine the outer limits of pollution reduction.

As stated above, Best Available Technology Economically Achievable (BAT) is most applicable in a circumstance where the regulated contaminants are especially harmful, or when the costs of a "heightened" technology can be reasonably borne by the industry. In

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[26] *Id*. § 459.12(b).

[27] *Id*. at 45.

[28] GROSS, *supra* note 22, at 41 (internal quotations omitted).

1976, EPA codified regulations regarding the manufacturing process of oil-based paints.[29] These regulations apply a BAT standard by simply declaring that "there shall be no discharge of process waste water pollutants to navigable waters."[30] Regulators determined that the state of technology permitted a wholesale ban on the release of oil-based paint into the nation's water. Correlatively, such an approach reflects the danger that oil-based paint poses to the nation's water supply. Also, from the perspective of a layperson, it follows logic to place the most restrictive regulation on something like paint. In other words, it would be unsettling to think that manufacturers could lawfully release paint into our water supply.

### B. The Role of Scientists in Protecting Water Quality

Congress enacted the CWA to "restore and maintain the chemical, physical and biological integrity of the nation's waters."[31] The goal of the CWA is to eliminate "the discharge of pollutants into the navigable waters," and in the interim, to attain "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water."[32] The passage of the CWA "marked the ascendancy of water-quality control to the status of a major national priority."[33]

Scientists – biologists, botanists, lymnologists, arborists, zoologists – play a key role in protecting waters for which technology based standards alone are not sufficient to protect water quality and ensure that otherwise allowable pollutant loadings do not exceed the assimilative capacity of the water receiving the discharge. In modern times, this is largely accomplished by developing and implementing "water quality standards" under the Clean Water Act. The Clean Water Act is intended to ensure protection of our nation's waters by requiring states to take certain measures to ensure both that safe and healthy waters would not become more polluted and that impaired waters would be restored. To meet these objectives, the CWA requires EPA to set water quality "criteria" to protect uses, such as fishing, swimming, drinking and recreation. The CWA then has states identify impaired waters, establish pollutant load limitations for such impaired waters to ensure that they meet water quality standards, and develop an implementation plan to see to it that such standards are met for all waters in a state.

To achieve these ends, section 303 of the CWA requires the establishment and implementation of water quality standards.[34] States are required to establish water quality standards subject to review and approval by EPA.[35] The Supreme Court has described the achievement of water quality standards as one of the CWA's "central objectives."[36]

The linchpin to achieving water quality standards is the "Total Maximum Daily Load" ("TMDL") program of Section 303(d) of the Clean Water Act.[37] This provision establishes a

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[29] 40 C.F.R § 446 (2008).
[30] *Id*. § 446.13.
[31] 33 U.S.C. § 1251(a) (2008).
[32] *Id*. § 1251(a)(1) and (2).
[33] Monongahela Power Co. v. Marsh, 809 F.2d 41, 45-46 (D.C. Cir. 1987).
[34] 33 U.S.C. § 1313 (2008).
[35] *Id*. § 1313(a).
[36] Arkansas v. Oklahoma, 503 U.S. 91, 105 (1992).
[37] 33 U.S.C. § 1313(d).

detailed interrelated process. First, section 303(d)(1) of the CWA requires every state in the mid-Atlantic to identify every segment of the waters within its boundaries that do not meet or are not expected to meet applicable water standards even after the imposition of best-practicable technology-based effluent limitations, secondary treatment standards for publicly owned treatment works, and controls on thermal discharges.[38] EPA refers to these impaired waters as "Water Quality Limited Segments" ("WQLSs").[39]

Following its identification of impaired waters, states must determine the maximum tolerable pollution so that pollutant loading in an impaired water body does not, taking into account seasonal variations and allowing an ample margin of safety, exceed the standards established for the water body. Section 303(d)(1)(C) requires states to develop the limits or load.[40] In its simplest term, a total maximum daily load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the point and nonpoint sources of that pollutant.

Once states complete the above steps, they are to submit the list of standards and allowable loadings to the United States Environmental Protection Agency ("EPA") for review. Section 303(d)(2) states: "Each State shall submit to the Administrator … for his approval the waters identified and the loads established under paragraphs (1)(A), (1)(B), (1)(C), and (1)(D) of this subsection."[41] EPA either must approve or disapprove the list of impaired waters and allowable loadings. If EPA disapproves, EPA must promulgate a new list of standards or allowable loadings within 30 days.[42]

Thus, the CWA establishes a dual approach to achieving water quality goals, with national technology based standards as the primary tool, and local, ambient-based standards as a safety net for waters for which technology based standards alone are not sufficient to achieve water quality standards.[43] Scientists in turn play an important role at every stage of this process. They help develop criteria, set standards, identify impaired waters, develop assimilative loading capacities, and determine allowable discharges. They also help to design and enforce permits that incorporate technology based and water quality based standards.

**Bringing it All Together: Science, Engineering and Permitting**

Permits serve "to transform generally applicable effluent limitations and other standards—including those based on water quality—into the obligations (including a timetable for compliance) of the individual discharger."[44] A century ago, Congress sought to hinder the **"**[d]eposit of refuse in navigable waters"[45] by enacting The 1899 Rivers and Harbors Act, a

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[38] *Id.* § 1313(d)(1)(A) and (B).

[39] 40 C.F.R. § 130.7(b)(1) and (2) (2008).

[40] 33 U.S.C. § 1313(b)(1)(C).

[41] 33 U.S.C. § 1313(d)(2).

[42] *Id*.

[43] *See* James R. May, *The Rise and Repose of Assimilation-Based Water Quality, Part I: TMDL Litigation*, 34 Envt'l L. Rep. 10247 (Env. L. Inst. 2004).

[44] EPA v. California ex rel. State Water Resources Control Board, 126 U.S. 200, 204-205 (1976).

[45] 33 U.S.C.A. § 407 (2008).

"rudimentary permitting system" that was the precursor to the modern-day Clean Water Act.[46] In subsequent legislation, the federal government attempted to devolve water regulatory efforts to state governments, with federal authorities taking more of an oversight role.[47]

Under the Clean Water Act the federal government established nationwide system of limiting water pollution. This permit process, known as the National Pollutant Discharge Elimination System (NPDES), is primarily enforced by state governments, although regional Environmental Protection Agency offices administer the process when state agencies lack the relevant authorization.[48] While water pollution occurs in a variety of forms, the NPDES system focuses primarily on industrial and municipal facilities that release pollutants into surface waters.[49]

At any point in the evolution of permitting systems, government relied on scientists and engineers to set effective standards that simultaneously protected water resources and enabled industry to operate without unreasonable barriers. Many questions arise during the process. Are some pollutants more destructive than others? Can some pollutants exist in water without effecting the health and safety of the public? Where should regulators draw the line? These questions fall well outside the realm of common knowledge. In determining the criteria for a meaningful permit process, government relies on the scientific and engineering communities.

Similarly, when industrial and municipal facilities apply for permits, scientists and engineers play a central role in gathering the relevant information and communicating with their counterparts in government. For example, NPDES applications require extensive quantitative data about the structure of a facility and the contents of its discharges.[50] This information is so esoteric that companies sometimes hold "'signing ceremonies'" where corporate officers have an opportunity to question those responsible for the content of the application.[51] Even when a facility receives a permit, technical assistance is still required to decipher the permit's terms, conditions, and methods of calculation.[52] Without this assistance, a company or municipality will not be able effectively to suggest revisions or otherwise comment on the permit process. Furthermore, NPDES permits require a facility to records its own discharge levels and submit reports to the relevant government authority.[53] Clearly, each step in the process calls for technical assistance.

## Scientists, Engineers and Water Rights

For centuries, people have fought over access and control of water. Whether in 18th century England or the modern day American West, water rights are broad and easily

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[46] JOEL M. GROSS & LYNN DODGE, *supra* note 21 , at 5

[47] *Id*. at 6.

[48] Environmental Protection Agency, National Pollutant Discharge Elimination System (NPDES), *available at* http://cfpub.epa.gov/npdes/.

[49] *Id*.

[50] LYNN M. GALLAGHER, *supra* note 22, at 23-24.

[51] *Id*. at 25.

[52] *Id*. at 27.

[53] GROSS, *supra* note 21, at 33-34.

offended.[54] When adjudicating disputes over water rights, the importance of expert testimony is unquestioned. Often, litigation involves private parties seeking to use water, a public resource, for private purposes.[55] Water appearing on Earth's surface is an overwhelmingly small percentage of our potable water.[56] In other words, most of the water consumed by humans (and subject to potential litigation) exists underground. Engineers, geologists, and other scientists are therefore essential in pinpointing water sources and explaining their potential use. Without this technical knowledge, settlement of disputes in water cases would extremely difficult and potentially very costly, both in terms of dollars and water misuse.

## Epilogue and Conclusion

Engineers and scientists will continue to play a featured role in water regulation for the next 100 years. While water quality has improved, according to EPA, approximately 60 percent of assessed waters nationally are safe enough for fishing and swimming. Wetland losses have slowed to one-quarter the rate of 30 years ago. These efforts have helped clean up pollutant discharges throughout the nation, from waters of the Delaware Basin and the Inland Bays, to the Baltimore Harbor and the Chesapeake Bay, to the Susquehenna and the Three Rivers system, to Lake Erie, to the Potomac and the Anacostia, to the Blackwater, to name a few.

Notwithstanding what's been done, to borrow from David Frost, it seems we still have far to go before we sleep. Pollutant discharges from factories are on the upswing for the first time in 30 years. Polluted runoff from farm fields, city streets and parking lots is virtually uncontrolled, choking half the nation's waters. Wetlands continue to be destroyed at an alarming rate, nearly 250,000 acres (one-half size of Delaware) each year. Thousands of lakes, streams, and miles of rivers used by 3 in 4 in the mid-Atlantic fail to meet some basic water quality standard.

From 1998 to 2000, the percentage of polluted rivers rose from 35 to 40 percent, shorelines from 12 to 15 percent, and polluted estuaries – the best measure of ecosystem health -- from 44 to 51. The latest statistics reveal there were more than 400 beach closings because of health advisories, 2,500 waters with fish consumption advisories or bans, 37 "water outbreaks" in 17 states assessed by the CDC, including red tide and algae outbreaks in Delaware, Physteria in Maryland and Delaware, and shellfish contamination in the Chesapeake.

These statistics obscure that the vast majority of the nation's waters are not even assessed. The Bush Administration has refused to issue a report to Congress on the state of the nation's waters. The National Academy of Sciences recently concluded there is too little data to know much of anything about water quality, and less being developed recently. States are doing less, amid political and economic shortfalls. The Heinz Fund picked up the slack by releasing its Environmental Indicators Project about five years ago. It suggests water quality is

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[54] Raphael J. Moses, *The Expert Engineer: The Water Lawyer's Best Friend*, available in WATER LAW: TRENDS, POLICIES AND PRACTICE 11 (Kathleen Marion Carr & James D. Crammond ed.) (American Bar Association 1995).

[55] *Id*. at 12-13.

[56] U.S. Geological Survey, Where is the Earth's water located?, *available at* http://ga.water.usgs.gov/edu/earthwherewater.html

worse now than 30 years ago, but due to the lack of data, concluded that no trends could be forecasted.

Looking forward, the regulation of water requires collaboration between the law, science and engineering. Healthy communication between government and science and engineering is critical to safeguard the public's overwhelming interest in safe, clean and accessible water.

## Appendix

# I. SCIENCE, ENGINEERING AND WATER POLLUTION SOURCES, TYPES AND CONTROL TECHNOLOGIES

**Background**: Driving Forces of Treatment Technology Development

(a) government standards
(b) chemical/physical nature of pollution
(c) cost effectiveness
(d) potential consideration

A. **Types and Sources**

1. *Water Quality Parameters of General Interest*

Fecal coliform
TSS
Color
Hardness
Taste & order
Hardness
Alkalinity
TDS
Iron & Manganese
Phosphorous
Nitrogen

2. *Typical Parameters*

BODs
COD
O&G
TSS
pH
Nutrients
Metals
toxics

3. *Important Terms*:

a. Completely soluble or miscible $H_2O$ & Alcohol
b. Suspension & sediment
c. Emulsion (oil & $H_2O$)

B. **Technologies**

1. *Coagulation & Sediment*

a. Usually preceded by precipitation hydroxide or chromium hydroxide, ferric iron.
b. Opposite method is dissolved air floatation (DAF)

2. *Biological Treatment*

a. Aerobic
b. Anerobic

3. *Chemical Oxidation*

   a. Example: Chlorine treatment for disinfection ozonation (like aeration chemical).

4. *Membrane Processes*

   a. Gatekeepers - only allow certain molecules to pass.
   b. Generally made from organic polymers - reverse osmosis; ultrafiltration, electrodialysis.
   c. Typically used with desalination plants.

5. *Ion Exchange*

   a. Water softener.
   b. Fills up "exchange sites in $H_2O$ that would otherwise be filled by calcium/magnesium in hard $H_2O$ .

6. *Sorption Processes*

   a. Example: fish tank.
   b. Activated Carbon for removal of organic compounds, or for polishing and toxics.

7. *Vapor Phase Systems*

   a. Frowned upon - Wastewater problem = air pollution.

8. *Polishing Systems*

   a. For solids
   b. Filtration
   c. Settling
   d. Marshes (natural/manmade)

9. *Subsurface considerations* (bioremediation)

   a. Pumping
   b. In site treatment (proprietary bacteria)

C. **Wastewater Technologies**

1. *Primary*
   a. Protect equipment in the treatment process
   b. Screening – rags, large material
   c. Pretreatment – typically to reduce odor by adding chemicals to wastewater
   d. More obnoxious materials removed
   e. 1 – 2% of the pollutants removed

    - f. Costs – 5 – 10% of plant costs
    - g. $100,000 – $200,000/million gallons of capacity
    - h. Significant source of odor release

2. *Removes*
    - a. 40 – 50% of solids
    - b. 20 – 30% of organics
    - c. Small reduction in toxics unless chemicals added (chemically enchanced primary – CAP)

3. *Physical Processes*
    - a. Settling – larger, heavier materials settle to bottom of basin and removed. (Primary Sludge)
    - b. Lightest material float to top of the basins and are scrapped off. (Scum)

4. *Settling Basins*
    - a. May be circular or rectangular and may be stacked on congested sites

5. *Costs*
    - a. $1.0 – 1.5 million per million gallons of capacity
    - b. Significant odor release possible; may require covering of basins and treatment of removed gases.

6. *CAPS* (chemicals added to):
    - a. Improve settling – up to 80% removal
    - b. Remove nutrients
    - c. Improve toxics removal
    - d. Significantly increases volume of primary sludge
    - e. Cannot meet secondary treatment standards but may be adequate technology

7. *Secondary Treatment*
    - a. Typically follows primary treatment
    - b. Designed to remove:
        - 1) Solids that didn't settle
        - 2) Floatables that don't float
        - 3) Organic material dissolved in the water
        - 4) 85 – 90% removal of solids
        - 5) 85 – 90% removal of organics
        - 6) 50 – 90% removal of most toxics

8. *Biological Process*
    - a. Soil bacteria are grown in large quantities (called activated sludge or biological films) the bacteria consume remaining pollutants, the bacteria are then removed by secondary settling.

9. *Settled Bacteria*
    - a. Some returned to aeration to consume more waste.
    - b. Some thrown away (Secondary Sludge)

10. *Various technologies*
    - a. Activated sludge
    - b. Biological towers
    - c. Pure oxygen
    - d. Because the process is biological, it's more difficult to control.
    - e. Costs – $2.0 – 3.0 million per million gallons of capacity including primary treatment.

11. *Air emissions*
    - a. Can release odors but usually reduced because secondary uses aerobic process.
    - b. Can release substantial quantities of VOC's and may release air toxics
    - c. Some reduced efficiency in cold climates.

12. *Advanced Treatment*
    - a. Treatment added to primary and secondary to get even higher levels of removal
    - b. 95 – 98% removal of solids, organic matter
    - c. 80 – 95% removal of toxics

13. *Other technologies*
    - a. Filters – to improve solids/organics

    - b. Chemical addition
        - 1) Lime, ferric chloride, alum, polymers to remove
        - 2) Phosphorus or improve toxic removal

    - c. Biological – grow bacteria that convert ammonia to nitrogen gas, hence removing nitrogen.

    - d. Polishing
        - 1) Membranes
            - a) Very high quality removal by technology (including only certain chemicals to pass through a membrane – Reverse Osmosis).
            - b) Used for highest quality water, or removal of toxics or desalination.
            - c) Has been limited to smaller plants because of costs.
            - d) Technological improvements are making it more attractive for larger plants.

    - e. Electrodialysis Reversal
        - 1) Electrical charges are used to remove undesirable materials or to separate materials.
        - 2) Use heavily in desalination.
        - 3) Costs – $3.0 – 7.0 million per million gallons of capacity including the costs of primary and secondary operating costs.
        - 4) Operating costs are 2 – 3 times those of secondary

f. Air Emission
    1) Generally not of concern if preceded by secondary facilities.

g. Disinfection (usually drinking water technologies)
    1) Follows other treatment units
    2) Designed to kill harmful bacteria and inactivate viruses
    3) Chlorine
        a) Extensively used until recently
        b) Chlorine by-products have been found to be carcinogenic
        c) If chlorine used, dechlorination may be used to remove by-products. (Add another chemical – sulfur dioxide)

    4) Ozone
        a) Used instead of chlorine where effluent quality is high.
        b) Avoids by-products

    5) Ultra-violet
        a) Used on high quality effluent.
        b) Becoming more affordable.
        c) Efficiency affected by solids

14. *Management of Residuals*
    a. Wastewater's "forgotten sister"
        1) Became a major national issue when secondary treatment was imposed because of larger quantity solids.

    b. Broadly not treated as a solid waste.

    c. Screenings (very obnoxious)
        1) Almost universally buried in landfills, sometimes burned

    d. Grit (similar to screenings)

    e. Scum
        1) Can be dewatered and landfilled.
        2) Can be burned because has high energy value.
        3) Can be digested with primary/secondary sludge.

    f. Primary/Secondary Sludge
        1) Contains large quantities of water
        2) Contains large percentage of putrescible solids
        3) Major odor source
        4) Primary/Secondary Sludge Technology
            a) <u>Stabilization</u> – to reduce the putrescible nature
            b) <u>Dewatering</u> – to reduce the amount of water
            c) Disposal by:
                i. Beneficial reuse

ii. Incineration
iii. Landfilling
iv. Disposal at sea is no longer permitted in the U.S.

g. Stabilization
1) Chemical addition, usually lime, doesn't destroy putrescible solids; merely controls their decomposition
2) Aerobic or anaerobic digestion (with or without air) bacteria are used to reduce putrescible solids by 60 – 70%
3) Anaerobic digestion produces useable methane gas

h. Dewatering
1) Design to convert sludge that is 92 – 97% water to sludge that is 60 – 75% water.
2) May use chemicals to aid dewatering.
3) Technology to remove water.
  a) Centrifuges
  b) Belt presses
  c) Filter presses

i. Disposal
1) Sludge has beneficial value as a soil conditioner/fertilizer if properly prepared.
2) Reuse technologies include:

a) <u>Agricultural application</u> – sludge is applied to agricultural land in liquid or dewatered state.

b) <u>Composting</u> – various equipment is used to further stabilize and dry sludge until it reaches a humus like consistency. It then can be applied to agricultural land and used in landscaping.

c) <u>Pelletizing</u> – dewatered sludge is thoroughly dried and broken into small, fertilizer like pellets for reuse on agricultural land and landscaping.

d) <u>Incineration</u> – dewatered sludge is burned at high temperatures. If the sludge is dry enough, incineration occurs without adding fuel. Heat/steam are often recovered from the incineration. The high temperatures substantially reduce but do not eliminate air emissions concerns.

e) <u>Landfilling</u> – dewatered sludge is burned in an approved landfill. The sludge is stabilized by digestion or by chemical addition prior to landfilling.

f) <u>Costs</u>
i. Landfilling – generally the least expensive but very difficult to cite – $80 – 200 per ton

            ii. Agricultural Application – $100 – 300/ton.

            iii. Composting, Incineration Drying – $200 – 800/ton

            Note: In colder climates, beneficial reuse options may require storage for several months each year.

- j. Technological Advancement
  - 1) Basic Technology – settling and biological treatment have changed very little in the last 100 years
    - a) Improvements:
      - i. Equipment – more energy efficient
      - ii. Controls – more intelligent systems with expanded computer use
      - iii. Chemicals – more variety, especially polymers
      - iv. Success – still achieved by the men and women who operate and maintain every hour of every day

## II. TECHNOLOGY, SCIENCE AND DRINKING WATER

### A. **Contamination**

- 1. Physical
  - a. Solids
  - b. Color

- 2. Biological
  - a. Bacterial
  - b. Viral
  - c. Giardia

- 3. Chemical
  - a. Toxic Metals
  - b. Organics
  - c. Special Concerns – Lead

### B. **Standards – Basis – Risk Profile**

- 1. *Management versus Control*
  - a. watershed protection
  - b. Aquifer management
  - c. Corrosion control

- 2. *Control (Treatment)*
  - a. Pretreatment
  - b. Chemical addition
  - c. Chlorine
  - d. Ozone
  - e. Coagulation/Settling

f. Filtration
g. Disinfection
h. Ammonia Control
i. Storage (Covered)