

**MANAGEMENT AND TECHNOLOGY TRENDS IN THE  
WASTEWATER TREATMENT INDUSTRY**

by

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B.S. Civil Engineering, Union College  
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Submitted to the Department of Civil and Environmental Engineering  
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**ABSTRACT**

The recent growth and expansion of the wastewater treatment industry can be justified when viewing the industry in the current system of economic, political and social influences. The public need for infrastructure development, including transportation facilities, airports, public schools, environmental remediation, and water and wastewater facilities, far exceeds available federal, state and local resources. Increased concern over public health and the environment has created a need for new high quality wastewater treatment systems and sophisticated pollution prevention strategies. The necessity for innovative financing alternatives has opened the wastewater market to the private sector for providing financing and management and operational services. Ultimately, this growth is occurring as the US environmental industry transitions from a period of regulation-driven, compliance-based business to one which focuses on sustainable, economic-based considerations. One of the implications of this industry climate is that it encourages technology advancement and development. It is the confluence of three principle factors—the increased concern for the quality of the environment, the increased role of privatization, and the focus on alternative treatment processes—that has formed the industry into a ripe market for technological development.

The purpose of this thesis is to identify the factors driving the current growth and expansion of the wastewater treatment industry, and to explain how this growth is encouraging technology advancement and development. This is achieved through a discussion of the various economic, political and social issues relating to the wastewater industry, focusing on the advancement of privatization both as an attractive option for municipalities and as a provider of the necessary incentive for technology development. A framework for charting technology development is presented along with a review of the current state of technological advancement in the industry. The discussion includes a detailed analysis of two technologies—ultraviolet radiation disinfection and infrared sludge drying—whose present development are representative of the types of technological advances being made in the industry. Case studies on the privatization of Indianapolis, Indiana's wastewater treatment facilities and Charlotte, North Carolina's managed competition and public contract award, are also presented. These two events provide examples of the effects of either privatization or the public use of private sector techniques, on treatment facility management and operations. It is argued that, in order to achieve maximum operational efficiencies, this trend of streamlining business operations will support and increasingly value the use of advanced technologies in wastewater treatment systems.

Thesis Supervisor: Fred Moavenzadeh  
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## 1.0 Introduction

### 1.1 Thesis Overview

The history of sewage is not a typical topic of conversation. Nor is it when the toilet is flushed. What sewage, or wastewater, lacks in appeal, however, it certainly makes up in importance. This importance is not for what this waste can provide, but for the potential negative impacts on the environment, and specifically our natural water sources, if wastewater goes untreated. We have been treating wastewater at some level in the United States (US) for over 100 years. It was not until 1948, however, that the first legislation addressing water pollution discharge was enacted. Although the identification of the problem of water pollution—which is essentially all that resulted from this environmental legislation—was a positive step forward, the degradation of streams, rivers, lakes and ponds continued to threaten the country's drinking, irrigation and industrial water supply. In 1972, the US Congress re-focused its water pollution strategy through new legislation which required permits for all wastewater discharges, created new discharge standards, and gave the responsibility of enforcing these requirements to the newly formed Environmental Protection Agency. Congress also began authorizing grants for planning and constructing wastewater treatment plants. Further legislative advances were made, and in 1977 under the Clean Water Act, the country had developed national water pollution objectives which focused on prohibiting the discharge of toxic pollutants, developing the technology to eliminate the discharge of all pollutants, and constructing publicly-owned wastewater treatment facilities. The wastewater treatment industry was born.

The wastewater treatment market accounts for approximately 15 percent of the \$180 billion environmental industry in the US.<sup>1</sup> Sustained capital investment into the wastewater industry by federal and state governments for more than two decades has developed an extensive and complex wastewater infrastructure system. There are currently over 20,000 treatment and collection facilities in operation providing treatment for approximately three-fourths of the nations population. Although increased growth and expansion of wastewater infrastructure will continue, the motivations for the wastewater treatment industry and the environmental industry as a whole are in the process of changing. The philosophy of extensive government regulation to address years of environmental neglect, and to make those contributors to pollution responsible for correcting environmental problems, is giving way to the development of a system of regulatory standards geared towards the economic

sustainability of environmental resources. The initial, heavy-handed regulatory and compliance structure was instrumental in achieving significant improvements in the quality of US waterways. The strategy today, however, is to use our experiences from the first phase, in combination with a better understanding of the role of society in the natural environment, to develop the second phase of the environmental industry; one that is characterized by sustainable, economic-based considerations.

There are a number of factors guiding the wastewater treatment industry through this transition. A mixture of economic, political and social influences, these factors have contributed to the recent expansion and development of the industry, and can be summarized under four main topics: public infrastructure needs, budgetary constraints, the influence of the private sector, and the legislative and regulatory climate. Current new wastewater construction needs in the US are estimated to exceed \$137 billion.<sup>2</sup> This estimate refers to treatment facilities that must be constructed in order to comply with environmental mandates. In addition, however, many of the wastewater treatment plants built in the 1970's under the initial federal Construction Grants program are reaching their design life, creating a widespread need for rehabilitation, repair and upgrades. The costs associated with meeting the needs of deteriorating infrastructure are an additional burden to those municipalities required to upgrade existing plants or construct new treatment systems to meet stricter water quality regulations.

Although the estimated cost to municipalities for wastewater facilities construction is rising, overall federal financial support is in decline. Unfunded environmental mandates are having serious negative impacts on strapped-for-cash municipal budgets. As the share of cost responsibility continues to grow on local towns and cities, household user charges for wastewater treatment services are similarly rising, actually increasing at three times the rate of the Consumer Price Index between 1992 and 1994. Wastewater treatment facilities, however, are not the only line item on a municipality's budget. The recently revised Safe Drinking Water Act places new requirements on drinking water supply, treatment and storage. Capital expenditures for drinking water systems, extensive road and bridge repairs, and the needs of other public services (e.g., police forces) all add to the overall pressure on municipal governments to fund various infrastructure programs with declining federal and state support.

With this combination of wastewater infrastructure needs and the demands on municipal capital budgets, the private sector is playing an increased role in the financing, management

and operation of treatment facilities. There are two potential opportunities for private sector involvement in public wastewater facilities: asset acquisition and ownership, and contract operations and maintenance. While the former is hindered by tax laws and unfavorable grant repayment requirements, the latter has provided the greatest opportunity for private wastewater firms. Local officials may look to private contract operations to solve compliance problems, resolve labor relations problems, or to release financial pressures to provide necessary capital for other needs. The decision of whether to privatize operations, however, is often clouded by politics and unrealistic social concerns. The fear in wastewater treatment privatization is of losing local control of critical personal and environmental services. These concerns, in addition to bureaucratic inertia, create a situation where the outcome of an effort to privatize wastewater infrastructure can depend heavily on having someone in a political leadership position who believes strongly in the benefits of private sector involvement. The case for privatization cannot solely be based on potential cost savings—the relatively few widespread cost impact studies that have been conducted are not enough evidence to support a direct correlation. But with or without guaranteed cost savings through wastewater privatization, municipalities are facing fewer alternatives.

Uncertainty presently surrounds the legislative and regulatory climate of the wastewater treatment industry. At issue in the current debate over reauthorization of the Clean Water Act, is how to structure the legal and regulatory framework in order to minimize the cost implications of advanced pollution control while facilitating the role of the private sector in providing wastewater infrastructure capital and services to municipalities. Recent legislation introduced in Congress provides an indication that the direction of water quality-related regulations may be economically-driven, with a focus on prevention and performance rather than procedure. With regards to privatization, the increased participation of the private sector in public infrastructure has thrust several existing federal laws into the reform spotlight as they present barriers to privatization. For example, grant requirements force municipalities to repay to the federal government any undepreciated portions of federal grants when the public asset is sold. On water quality, certain regulatory requirements impose stricter standards on private facilities than on publicly-owned facilities. Tax rules limit private operational contract terms to five years if the public bonds used to build the facilities are to remain tax-exempt. Related legislative proposals to facilitate the privatization of wastewater infrastructure have been developed over the past several years, however, it is clear that the federal government is approaching the issue with caution.

Of particular concern to today's wastewater engineering and construction community is how the trends in technology development have been affected by the various issues described in the above paragraphs. The development of technologies does not occur in a vacuum, but rather in the dynamic system of economic, political and social influences. In other words, the non-technical climate has a significant influence on the types of technological advancements made in an industry. In general, the need for innovation in a given system of economic, political and social influences dictates to a great extent the acceptance of technological innovation. Wastewater treatment technology innovation is driven by the potential economic benefits of its development in response to this need. The incentive to innovate is based on the degree of assurance that the industry will value benefits such as improved performance, reduced costs or improved services, and that some of these economic benefits will be returned to those responsible for the innovation.

The demand for technological development in today's wastewater industry is not for the creation of entirely new processes. Without the need or a direct incentive for broad-based innovation, the current market conditions support technological advancement in two main forms: the incremental improvement of existing technologies, and the application of technologies from other related industries. The improvement of existing technologies is focusing on alternative processes that may be more effective than existing methods. The efforts of fringe industries to apply certain technologies to wastewater treatment is regarded as innovation through invasion. These efforts exemplify the notion that major technological development does not necessarily involve scientific breakthrough or technologies that were not widely available. Although technologies are continually developed across the various categories of wastewater treatment, the current advancements appear to be particularly focused on advanced treatment technologies, such as ultraviolet radiation disinfection, and in the area of sludge processing, such as sludge drying through infrared heating. This may be due, in part, to the present regulatory climate which is requiring a higher quality discharge and focusing on the recycling and beneficial reuse of sludge solids.

The present state of the wastewater treatment industry has provided a new opportunity for the private sector. With promises of sustained or lower user rates, the release of municipal funds and efficient management methods, wastewater firms are focusing their efforts on those municipalities facing aging infrastructure, shrinking budgets and regulatory compliance-based requirements. To date, there has been only one instance where a US city has sold its wastewater assets to a private firm, and only three other municipalities have

submitted similar plans for federal approval. More common is the shifting of operations and maintenance services from a public to a private entity. The increased activity of private wastewater firms in public facilities has brought about a trend of streamlining operations through implementation of private management techniques to turn wastewater plants into profit-making ventures. The automation of operating systems, improved maintenance programs, and employee training and development, for example, allow the private sector to provide more efficient, cost effective operations.

The threat of privatization has become a great motivator for public utilities to reduce work forces and implement efficient operational systems and management techniques. The re-engineering of public utility business processes to run treatment plants on a more business-like basis has created a niche market for engineering consultants. These consultants are helping the public utilities to develop proposals which can compete with the private sector in a managed competition process. Whether it is through a private operating contract or an equivalent publicly-operated system, management efforts are focused on providing more effective, cost-efficient wastewater treatment services. Within the industry, there are implications of this drive towards operational efficiencies on technology development and advancement. There is a limit to efficiencies that can be achieved through managerial, business-streamlining techniques. Once this limit is reached, further operational improvements and cost savings can only be realized through the use of improved and advanced technologies. Such technologies should be utilized when upgrading or rehabilitating existing treatment systems. Improved technological systems would provide returns on a higher initial capital cost over the extended life of the upgrade through operational efficiencies. Competitive bid processes for privatizing treatment plants provide the opportunity for both the public and private sector—through broad, incentive-based procurement strategies—to develop and utilize improved, more advanced technologies.

It is the economic, political and social influences driving this encouragement of efficient operation and technology development that will help to sustain the current growth and expansion of the wastewater treatment industry.

## **1.2 Purpose and Scope**

The purpose of this thesis is to identify the factors driving the current growth and expansion of the wastewater treatment industry, and to explain how this growth is encouraging

technology advancement and development. This is achieved through a discussion of the various economic, political and social issues relating to the wastewater industry, focusing on the advancement of privatization both as an attractive option for municipalities and as a provider of the necessary incentive for technology development. The discussion includes a detailed analysis of two technologies—ultraviolet radiation disinfection and infrared sludge drying—whose current development are representative of the types of technological advances being made in the industry. Case studies on the privatization of Indianapolis, Indiana's wastewater treatment facilities and Charlotte, North Carolina's managed competition and public contract award, are also presented. These two wastewater privatization events provide examples of the effects of privatization, or the public use of private sector techniques, on treatment facility operations. An outline of the scope of the thesis by section is presented below.

- **Section 1** - Presents an overview and outlines the purpose and scope of the thesis.
- **Section 2** - Provides background information on the history and development of the wastewater treatment industry, and a discussion of the current state of the wastewater market. A brief description of the wastewater treatment process and the methods for financing treatment facilities is included.
- **Section 3** - Provides a description of the factors that are shaping today's wastewater treatment market.
- **Section 4** - Provides an analysis of the development and advancement of wastewater treatment technologies and how the current market conditions are affecting technological development.
- **Section 5** - Provides a discussion of the effects of privatization on the management and operation of wastewater treatment facilities, and the implications of privatization on technology development.
- **Section 6** - Presents the conclusion of the thesis, which includes a discussion of the future expectations for technology development and the wastewater treatment industry in general.

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<sup>1</sup> "US Environment Industry Hits \$180bn in Revenues", *Water & Environment International*, v5 n43, September 1996.

<sup>2</sup> 1992 Needs Survey Report to Congress, USEPA, Office of Water, EPA 430/09-91-008, October 1991.

## **2.0 The Wastewater Treatment Industry**

### **2.1 Introduction**

The purpose of this section is to provide a solid background in the history and development of wastewater treatment in the US. The objective is for the reader to develop an understanding of the industry in the political, economic and social climate of the US, which will be used as the basis for subsequent discussions in the sections which follow. Topics of discussion include the regulatory framework guiding wastewater treatment, the process for treating wastewater, and the current state of the US wastewater treatment industry. In addition, the traditional methods for financing both the construction of new treatment facilities and the rehabilitation of existing ones will be presented.

### **2.2 Regulatory History of Wastewater Treatment**

In 1948, Congress enacted its first ever environmental legislation: the Federal Water Pollution Control Act (WPCA). The WPCA set forth ambient water quality standards, and required states to identify polluted bodies of water and then locate and suppress pollutant discharges. Each state went about trying to meet the WPCA standards in a different manner, and--with little success--most found it nearly impossible to determine who caused what pollution. In the meantime, the degradation of streams, rivers, lakes and ponds continued, threatening the drinking, irrigation and industrial water supply.

With increasing public concern over the decreasing quality of the country's natural water resources, Congress re-focused its strategy in 1972 in the form of the Federal Water Pollution Control Act Amendments. The new approach of these amendments was to require a permit for all pollutant discharges. The use of ambient water quality standards that limited the concentration of pollutants in the given body of water was abandoned. Instead, discharge restrictions relied on the use of effluent<sup>1</sup> standards which relate to the quality of the water being discharged. The newly formed Environmental Protection Agency (EPA), which was created by the National Environmental Policy Act of 1969, was given the responsibility of enforcing the new effluent standards. In addition, Congress began authorizing grants for planning and constructing primary wastewater treatment plants.

Further advancements in Congress were made, and in 1977 the WPCA was amended and renamed the Clean Water Act (CWA). The goal of the CWA is “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” At the time of enactment, six objectives of the CWA were set forth:

1. To prohibit the discharge of toxic pollutants;
2. To develop the technology to eliminate the discharge of all pollutants;
3. The elimination of the discharge of pollutants into navigable water by 1985;
4. To achieve water quality sufficient to protect fish and water recreation by 1983;
5. Construction of publicly-owned wastewater treatment works; and
6. The development of area-wide waste treatment management planning.

In order to achieve these goals and objectives, Congress developed a system of regulations for pollutant discharges, and initiated several programs to facilitate the development of wastewater treatment facilities. For example, the National Pollutant Discharge Elimination System (NPDES) is the permitting process under EPA direction by which all discharges from municipal and industrial treatment facilities must be approved. NPDES requires the states to establish water quality standards for the bodies of water and to administer the permit system within their state. Permits specify limitations on discharge volumes and certain pollutants, as well as monitoring and reporting requirements. Facilities in non-compliance with their NPDES permits face major fines by the EPA.

The 1977 CWA required that municipal wastewater treatment plants upgrade to secondary treatment levels, which subjects the wastewater to biological treatment. The 1972 Act only required passive primary treatment of wastewater which at the time was the state-of-the-art technology. With the increased treatment standards, current federal subsidies were not large enough to help cities and towns build major centralized treatment facilities. The federal Construction Grants Program was substantially increased in 1981 to help defray the costs associated with plant upgrades to secondary treatment and for the construction of new facilities. This program, funded primarily by the federal government and administered by the EPA, established a facilities planning process through which the subsidies were provided to cities and towns, and was the main momentum builder for the centralization of wastewater treatment in the US.

The Water Quality Act of 1987, a reauthorization and set of amendments to the CWA, added a new goal to the CWA to focus on controlling nonpoint source pollution.<sup>2</sup> It

authorized grants to states for developing control strategies and new requirements for controlling specific nonpoint sources of pollution such as storm water runoff from industrial sites and urban areas. The major provision of the 1987 Act, however, was the gradual phasing out of the federal Construction Grants Program. Responsibility for financing the construction of wastewater treatment facilities shifted from the federal government to state and local governments through a revolving loan fund. The State Revolving Fund (SRF) program created a revolving funds system that could be used to make low-interest loans to cities and towns in need of new and upgraded treatment facilities. A more detailed description of the SRF program is provided in Section 2.5.

The CWA has been termed a technology-forcing statute because of the continuous demands placed on those who are regulated by it to achieve higher and higher levels of pollution control. Reauthorization of the CWA last occurred in 1987 and is currently being debated in Congress. A discussion of significant changes made to the CWA since 1987 is included in Section 3.0. A consolidated history of US wastewater treatment legislation is presented in Table 2-1.

Table 2-1: History of Wastewater Treatment Legislation

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<b>Refuse Act of 1899</b> Prevent impediments to navigation.
<b>Water Pollution Control Act of 1948</b> First federal law to deal with conventional forms of water pollution.
<b>Water Pollution Control Act Amendments of 1956 and 1965</b> Established municipal grants program to build sewage treatment plants and establish federal enforcement authority; gave states authority to set and enforce water quality standards.
<b>Federal Water Pollution Control Act of 1972</b> Major revision of law strengthened municipal grants program, shifted issuance of discharge permits to the Environmental Protection Agency.
<b>Clean Water Act of 1977 (Amendments to the 1972 Water Pollution Control Act)</b> Postponed several deadlines set in 1972 law; required treatment plants to upgrade to secondary treatment levels; created the National Pollutant Discharge Elimination System for permitting point source discharges; made clearer distinction between "conventional pollutants" and toxic water pollutants.
<b>Water Quality Act of 1987, also called Clean Water Act</b> Major rewrite of 1997 law further postponed compliance deadlines for technology-based effluent standards; continued high levels of federal aid but shifted responsibility for financing wastewater infrastructure from federal government

(Construction Grants Program) to state and local governments (State Revolving Fund Program); required states to develop control strategies and new requirements for controlling specific nonpoint sources of pollution.

---

### 2.3 State of Wastewater Infrastructure and Future Needs<sup>3</sup>

Although the quality of our nation's natural waters is continuously debated, sustained capital investment by federal and state governments has certainly resulted in significant improvements in US municipal wastewater treatment infrastructure. The number of secondary and advanced treatment facilities has steadily increased since the enactment of the CWA. In 1972, approximately 85 million people were being served by treatment facilities. In 1992, municipalities were operating more than 20,000 treatment and collection facilities, of which 15,613 provided treatment for 181 million people (70 percent of the nation's population in 1992). In addition, approximately 94 percent of those treatment facilities provided at least secondary treatment of municipal wastewater, compared with 89 percent in 1988. Table 2-2 presents a breakdown of the number of facilities meeting the different levels of treatment.

Table 2-2: Treatment Level of Operational Treatment Facilities (1992)

Level of Treatment	Number of Facilities
No discharge	1,981
Less than secondary	868
Secondary	9,086
Greater than secondary	3,678
Total facilities	15,613

The most comprehensive assessment of the status of the wastewater infrastructure is performed biennially by the EPA, as required by the CWA. EPA's Needs Survey Report provides an assessment of the existing infrastructure and documents the capital construction costs necessary to meet municipal wastewater pollution control needs. In 1992, it was estimated that the nation's total unmet wastewater construction needs exceeded \$137 billion, nearly double the \$76 billion estimated by EPA in a 1986 survey. This estimate partially reflects the increasing focus on combined sewer overflows and collection system repair. The capital improvement needs of Association of Metropolitan Sewer Agencies (AMSA)<sup>4</sup> members alone are estimated to exceed \$32 billion for the period

1993 to 1998, a 40 percent increase over the period of 1990 to 1995.<sup>5</sup> Approximately \$23 billion of the costs identified by AMSA members is to comply directly with federal mandates, a hotly-debated issue in today's industry that is discussed in the next section. Table 2-3 presents the treatment facility needs (1992) for each of the various categories of treatment systems.

Table 2-3: Needs for Publicly-Owned Wastewater Treatment Facilities (1992)

Type of Need	Cost (\$ billion)
Advanced treatment	15.5
Combined sewer overflows	41.2
Ground water, estuaries, wetlands	1.2
Infiltration/inflow correction	2.8
New collector sewers	17.9
New interceptor sewers	14.7
Nonpoint source (agriculture and silviculture only)	8.8
Replacement/rehabilitation	3.6
Secondary treatment	31.3
Storm water (institutional source controls only)	0.1
Total Needs	137.1

With a number of treatment plants not yet providing secondary treatment, the increasing concern of nonpoint discharges, and an ultimate goal of zero-discharge from point source treatment facilities, the need for continued infrastructure development is obvious. Arguably, the CWA has been one of the most successful pieces of environmental legislation in terms of the ability to build a system to deal with its targeted segment of the environment. The current challenge, however, is how to meet these increasing capital requirements with decreasing and limited resources. This issue is further addressed in Sections 3.0 and 5.0.

## 2.4 Current Market Conditions

Although regulatory uncertainty currently surrounds the wastewater treatment industry, it is experiencing significant growth. The delay of the CWA reauthorization apparently has had little affect on the \$27.3 billion wastewater treatment works market, which accounts for approximately 15 percent of the \$180 billion US environmental industry.<sup>6</sup> In 1995, as revenues in the environmental industry outpaced the US economy by expanding 4.3 percent,

the wastewater treatment works market grew 6.2 percent to \$27.3 billion, up from \$25.7 billion in revenue in 1994. In 1995, the total US water industry--which includes water utilities, wastewater treatment works, equipment and chemicals, services, consulting and engineering--grew to \$75.2 billion, and is projected to reach \$96 billion by the year 2000.<sup>7</sup> A summary of the US water industry revenues in 1995 is presented in Table 2-4.

Table 2-4: Revenues of the US Water Industry<sup>8</sup>

Business Segment	1995 Revenue (\$ Millions)
<b>Water Equipment/Chemicals</b>	
Biosolids equipment	1,010
Chemicals	3,440
Chemical equipment	360
Delivery equipment	8,070
Destruction equipment	1,430
Separation equipment	2,220
<b>Services, Consulting &amp; Engineering</b>	
Consulting	1,210
Contract operations	540
Design engineering	1,310
Maintenance services	970
Total Solution Companies	1,170
Instruments	540
Analytical Services	410
Water Utilities	25,300
Wastewater Treatment Works	27,300
<b>Total Water Industry</b>	<b>75,280</b>

According to the projections of Environmental Business International, Inc., the trend of increased growth for the wastewater market should continue into the year 2000. Table 2-5 presents a comparison of the annual growth for the wastewater treatment market and the three environmental market segments referenced above.

Although the majority of wastewater infrastructure revenues still fall within the public sector, the privatization of this segment represents the greatest opportunity in the domestic environmental market. Currently only 10 percent of wastewater treatment facilities are managed or owned by the private sector.<sup>9</sup> Contract operations represent the fastest growing area of the industry as more public treatment facilities are being managed by private companies (see Section 5.0).

Table 2-5: Annual Percent Growth for Four Environmental Markets<sup>10</sup>

Industry Segment	Annual . Growth						
	'88-89	'89-90	'90-91	'91-92	'92-93	'93-94	'94-95
Hazardous Waste Mgt.	21%	11%	2.2%	3.0%	-2.1%	-1.4%	-3.1%
Solid Waste Mgt.	13	8.0	3.4	4.4	4.3	5.4	4.8
Remediation/Industrial Services	21	4.0	-7.1	3.8	3.0	1.8	-1.2
Wastewater treatment Works	8.0	8.0	4.5	4.8	7.8	9.8	6.2

Note:

Estimated average annual growth through the year 1999:

Hazardous waste management = -3%

Solid waste management = 4%

Remediation/industrial services = 3%

Wastewater treatment works = 5%

## 2.5 Sources and Methods of Financing Treatment Facilities

The inability to secure the necessary funds for construction of new wastewater treatment facilities, facility upgrades or other wastewater infrastructure rehabilitation projects is typically argued as the main barrier to meeting the nation's wastewater treatment needs. Over the past several years, it has been increasingly difficult for municipalities to undertake wastewater projects that have become more expensive while traditional government funding has decreased. The legislative, regulatory and political processes that surround and control government sources of funds are certainly not uncomplicated. The purpose of this section is to provide a general overview of the various sources of capital available for wastewater treatment infrastructure projects. The use of the private sector as a source of funds is mentioned but is more thoroughly described in Section 5.0.

There are traditionally four sources of capital funding for wastewater treatment infrastructure: 1), federal and state agencies, 2) the US Congress, 3) financial institutions, and 4) the users. In recent years, the private sector has developed into an important fifth source of capital. A description of the type of funds available from each of the five alternatives is presented below.

### Federal and State Agencies

Contrary to public perception, significant federal and state funds remain available, as governments still provide more than \$100 billion of domestic assistance annually through a

variety of funding programs.<sup>11</sup> These funds are available to all although some are more difficult than others to obtain, requiring hard work, determination and a bit of patience.

The most widely known source of government funds for the wastewater industry is the State Revolving Fund (SRF) program. The SRF program was created by the 1987 amendments to the CWA and replaced the long-running (1972-1990) federal Construction Grants program. The Construction Grants program was devoted primarily to building wastewater systems but the SRF takes a broader approach. In addition to traditional municipal wastewater treatment plants, it can finance environmental projects addressing agricultural, rural and urban runoff, contaminated urban stormwater, and combined sewer overflows. The SRF program gives the individual states the responsibility for developing and operating their own programs, as well as the decision-making power over the distribution and use of the capitalization funds.

Under the SRF program, each state (and Puerto Rico) created revolving loan funds to provide the independent and permanent sources of financing. The funds to establish SRF programs are provided through federal government grants and state matching funds, contributed at 83 percent and 17 percent, respectively, of total capitalization. Financial assistance provided by SRFs can include loans and various forms of credit enhancements, but not grants. Loan repayments are used to fund additional loans, with the exception of repayments used to retire SRF program debt. Specific terms of the SRF loan program include:

- Interest rate: 0 percent to market rate;
- Repayment period: Up to 20 years, begins one year after project start-up;
- Adjustable-rate loans, stepped payments, balloon payments (at state discretion);
- Loans cover 100 percent of eligible costs;
- Loans available for all treatment alternatives; and
- Loans can cover excess capacity, collection systems, and advanced treatment upgrades.

In adopting the SRF program, the federal government gave the states greater flexibility to structure the government funding to best meet their needs. States can use capitalization funds for a variety of financial assistance options, including:

- Low interest loans for communities;
- Refinancing, purchasing, or guaranteeing local debt to lower the cost of borrowing for communities;
- Purchasing bond insurance for local debt to increase bond ratings of communities; and
- Issue bonds by leveraging the SRF (i.e., using capitalization funds as security for bonds).

Currently, all fifty states and Puerto Rico are operating successful SRF programs. After eight years of investment by the federal government and the states, over \$16 billion is available for loans for environmental infrastructure projects.<sup>12</sup> In addition to the SRF program, there are a number of other federal and state government funding programs available to the wastewater industry. The following is a list of agencies and their program objectives that fund water and wastewater projects.<sup>13</sup>

1. US Department of Agriculture, Rural Development Administration (RDA): To provide safe and sanitary housing, including water, wastewater, stormwater and solid waste facilities, to rural low and moderate income municipalities.
2. US Department of Housing and Urban Development (HUD) Block Grant Program: To provide affordable housing, including water and wastewater, to low income persons.
3. US Department of Commerce Economic Development Administration (EDA): To create jobs by supporting the development of necessary infrastructure, including wastewater treatment and conveyance facilities.
4. Electric Company Funding: To have higher efficiency electrical systems installed to lower peak power demand by providing financial incentive programs.
5. State Pollution Control Agencies - Various Programs: To administer the EPA's SRF program.
6. US EPA - Various Programs: To provide financial incentives to cities to obtain and maintain compliance with water pollution regulations. A summary of EPA's current funding programs is presented in Table 2-6.

Table 2-6: Current EPA Funding Programs for Wastewater Infrastructure<sup>14</sup>

CWA Reference	Funding Purpose
Sect. 104(b)(3)	Provides \$16 million annually to any agency or individual for 1 to 2 year demonstration type projects
Sect. 106	Provides more than \$81 million annually to state/interstate agencies and Indian tribes for abatement of surface and groundwater pollution
Sect. 303	Provides more than \$1 million annually to any agency or individual for watershed planning priorities
Sect. 314(b)	Expected to provide state agencies and local lake protection groups for technical assistance of watershed management planning projects
Sect. 319(h)	Provides more than \$50 million annually to state-designated Nonpoint Source (NPS) agencies to fund implementation
Sect. 320(g)	Provides more than \$15 million annually to any agency or individual for planning activities in designated estuaries
Sect. 603(d)	Provides states with up to 4% of their State Revolving Fund (SRF) allocation to manage their programs
Sect. 604(b)	Provides states with \$20 million annually to carry out water quality management planning
Sect. (66.419)	Provides more than \$10 million annually to states for the development of State Wetland Conservation Plans
Sect. (66.464)	Provides more than \$5 million annually to any agency or individual for implementation of watershed strategies for coastal areas
Regional Initiatives	The various EPA regions spend more than \$4 million annually on projects that address watershed protection

Note: These funding programs were originally created under the Clean Water Act

Finally, there are state and federal loan programs which sometime provide loans at lower interest rates than available for bond financing. These loan programs typically provide capital at subsidized rates for projects that meet their eligibility criteria, which are often targeted to small and/or rural communities. Arranging these loans may be a quicker means of acquiring capital than issuing bonds, can be acquired without voter approval, and generally do not have statutory limitations.

#### US Congress

Legislatures provide direct funding to correct public policy injustices for a project which would have been eligible for significant grant funds in the past but was delayed beyond the control of the community. The federal authorization and appropriation process has functioned well in providing funding to truly needy projects. In the past four years, the US Congress has provided more than \$2.5 billion in site-specific line item funding to state and local wastewater treatment projects.<sup>15</sup> Table 2-7 provides an example of some of the site specific grants issued by the US Congress since 1992.

Table 2-7: Largest Site-Specific Grants Issued US Congress Since 1992<sup>16</sup>

Location or Project	Amount
Boston, Massachusetts	\$500,000,000
New York City, New York	\$210,000,000
Texas - Colonias	\$200,000,000
San Diego, California	\$131,000,000
Cleveland, Ohio	\$60,000,000
Newark, New Jersey	\$44,300,000
Baltimore, Maryland	\$40,000,000
Lackawanna, Pennsylvania	\$30,000,000
Chicago, Illinois	\$25,000,000
Warren County, New York	\$20,000,000

#### Financial Institutions

In general, financial institutions offer the wastewater industry two sources of financing: loans and bonds. Banks or financial institutions will offer state and local governments commercial loans to finance a variety of wastewater capital projects. The advantage of commercial loans is that the application process is typically faster than for government loan programs. In addition, lenders have no set eligibility criteria or limits on total amount of capital available. The disadvantages are that these types of loans generally have higher interest rates and less favorable payback terms than government-funded loan programs.

A bond is a written promise to repay borrowed money on a definite schedule and usually at a fixed rate of interest for the life of the bond. Bonds can stretch out the costs of a project by making payments over a period of 15 to 30 years. State and local governments repay this debt with taxes, fees or other sources of governmental revenue. Since most government bonds are tax-exempt, the holders of the bond will generally accept a lower rate of return on investment than on a comparable commercial loan. Bond financing, therefore, often provides low-interest capital to state and local governments. The Tax Reform Act of 1986 altered the tax-exempt status of some government-issued bonds by reclassifying bonds into two categories: governmental purpose bonds and private activity bonds. Governmental purpose bonds are automatically tax-exempt but private activity bonds must meet certain criteria to achieve tax-exempt status. A brief description of the different types of bonds available is provided below.

- **Short-term bonds** are usually payable within one year. The two categories are notes (issued in anticipation of grants, bonds or taxes) and tax-exempt commercial paper (unsecured debt backed by a letter/line of credit).
- **Long-term bonds** traditionally match the term of financing with the life expectancy of the project. The two categories are term bonds (loans with entire loan amount and interest payable upon maturity) and serial bonds (payable like home mortgages).
- **General obligation bonds** are long-term bonds backed by the full faith and credit of the state or local government. This means that the government pledges to use all of its taxing and other revenue-raising powers to repay bond holders.
- **Revenue bonds** are long-term bonds guaranteed by the dedication of future project income or system funds, such as user fees.

### Users

Another source of capital for wastewater infrastructure is the users of the infrastructure themselves. These funds are available through a variety of taxes (a charge against income, property or the sale of goods and services) and fees (charges for services rendered) imposed on the user by the state or local government. There are also tax systems which, rather than raising funds, reduces the financial liability of the treatment facility through credits or deductions. A brief description of some of the different types of taxes and fees is provided below.

**Property and sales taxes** are charged as a percentage of property value or gross sales, and are imposed at the state and local levels. Revenue from property and sales taxes can be used to finance public infrastructure or to fund pollution control programs at the local level.

**Tax surcharges** are fees added to established tax rates which are often used for sudden unplanned events. For example, the replacement of a portion of a collection system damaged during a natural disaster could be financed by a tax surcharge on residential sewer bills.

**Tax incentives and disincentives** are set up to encourage or discourage certain behaviors by offering tax reductions or increases. Incentives are usually in the form of state tax credits, deductions or rebates to the treatment facility or utility department. Disincentives

take the form of fees, taxes or price increases and are based on the desire to save money. For example, a tax or fee can discourage the use of an inefficient system or product because of the increased cost of using that system.

**Impact fees** transfer the costs of infrastructure needed for private development directly to developers or property owners. Impact fees are usually collected in one lump sum at the beginning of the project. Several wastewater treatment plants in California have been financed with fees paid by developers based on the projects' anticipated treatment requirements.

**Capacity credits** are a form of financing where private developers purchase future capacity in a public facility, such as a wastewater treatment plant. In such a case, future access to the excess capacity of the particular facility is guaranteed.

**Effluent discharge fees** are imposed on an industrial facility by a local or state government authority. Under such fees, a discharger is required to pay a certain amount for every unit of pollution discharged into surface water. The fee system is usually based on water quality objectives, the costs for financing a pollution abatement plan, or effluent standards. Effluent discharge fees provide incentives to private industry to invest in pollution control technology, however, assigning monetary values to pollution damage may be difficult.

### Private Sector

Currently receiving the most attention in the wastewater treatment industry are the so-called public-private partnerships. These partnerships, defined as private sector involvement in what historically have been public sector activities, can be used to pay for capital and/or operating costs, and help to reduce the burden on public budgets. Capital arrangements can vary from private ownership and operation of the public facility to simply operating one specific portion of the treatment system. Other private sector involvement can be in the form of leases, such as a sale-lease back arrangement. For example, under a tax-exempt lease, a town sells its wastewater treatment plant to a private company in order to finance upgrades, and repays the private investment with lease payments. Private sector involvement in municipal treatment facilities is discussed in greater detail in Section 3 and Section 5.

## 2.6 The Wastewater Treatment Process

The principal objective of wastewater treatment is to produce an effluent that can be discharged without causing negative impacts to the environment. In the US, the quality of effluent discharged from a treatment facility is regulated under the National Pollution Discharge Elimination System, which requires permits for all wastewater discharges. How much pollution allowed to enter a body of water, or water quality standards, is based on the potential uses of the water body. In order to meet and maintain these standards, limitations are placed on industrial and municipal discharges. These limitations often determine the level of treatment which must be achieved and the type of treatment facilities which must be built.

Wastewater treatment systems are composed of a number of unit operations and processes linked together in sequences. The combinations of processes to be used in a particular treatment system are dependent on the characteristics of the raw wastewater being treated, called influent, and the required quality of effluent to be discharged. Because wastewater comes from a variety of sources--residences, businesses, hospitals, industrial facilities, and stormwater runoff--influent contains various types and amounts of constituents, including:

- Suspended and dissolved solid particles;
- Nutrients;
- Pathogens
- Organic chemicals;
- Inorganic metals;
- Oil and grease; and
- Plastics and other floatable material (e.g., garbage, vegetation, old sneakers).

In the wastewater treatment process, these constituents are removed or destroyed by physical, chemical and biological processes. Although these processes and operations are often combined in treatment systems, their fundamental principles for treatment differ. Treatment operations in which change is brought about through the application of physical forces are classified as physical processes. Chemical processes relate to treatment in which the removal or reduction of contaminants is performed by the addition of chemicals or by chemical reactions. Operations which remove contaminants by biological methods are classified as biological processes.

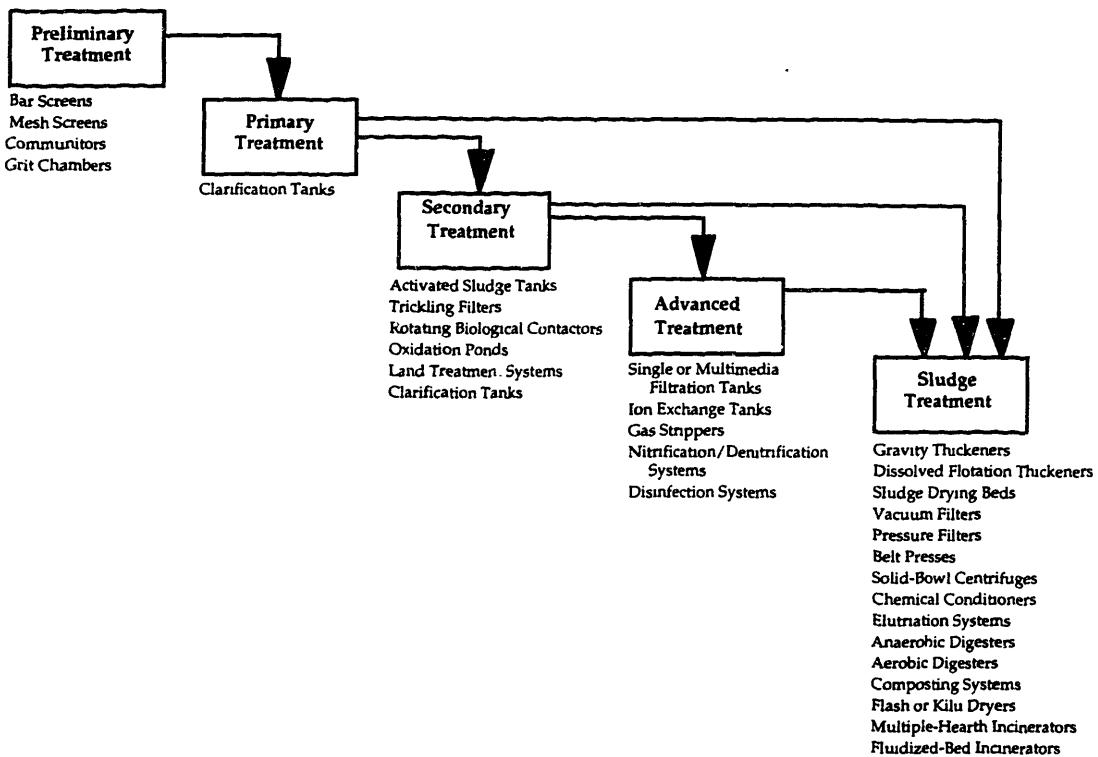
From the portfolio of available treatment processes, a treatment system is designed with the combination of processes best suited to meet the objectives and requirements of a specific treatment facility. Wastewater treatment systems follow a typical sequence of treatment steps to remove the various constituents. This sequence of steps is generally categorized into the following five treatment stages, listed in order in which treatment occurs:

1. Preliminary Treatment;
2. Primary Treatment;
3. Secondary Treatment;
4. Advanced Treatment; and
5. Sludge Processing.

As shown in Figure 2-1, each treatment stage has associated with it a set of operations or systems for performing the specific level of physical, chemical and/or biological treatment. The level of treatment for a wastewater facility is dictated by federal regulation, although the decision to incorporate advanced treatment processes, for example, could be based on a desire to remove a public nuisance or improve public facilities. In general, each treatment level (category) is designed to remove a certain type of pollutant.

Wastewater treatment begins with the preliminary stage which is designed to mechanically remove large floating materials. Wastewater is passed through a screen or bar rack which removes pieces of solid materials. Next, the wastewater flows into a grit chamber where sand, cinders and small stones settle out of the water. Moving to the primary stage, flow is directed to any one of a number of styles of clarification tanks designed to allow suspended solids to settle to the bottom of the tanks. Settled solids on the bottom and scum skimmed from the surface of the tanks are collected as raw primary sludge, which is treated in the sludge processing stage. Primary effluent is directed to secondary treatment systems where biodegradable organic wastes are converted into carbon dioxide and water by microorganisms in an accelerated process. Two common types of secondary treatment systems are the activated sludge and trickling filter processes. In the activated sludge process, aerated wastewater and microorganisms are mixed together in a reactor where treatment occurs. In a trickling filter, the wastewater is passed over a bed of stones or synthetic material which supports the active microorganisms. Sludge solids removed from the wastewater in secondary treatment systems are also treated in the sludge processing stage. By law, all publicly-owned wastewater treatment systems must provide at least secondary treatment.

Figure 2-1: Stages of Wastewater Treatment and Associated Operational Systems



When secondary levels of treatment are not adequate to provide a certain effluent quality, advanced processes must be used. Advanced treatment processes can remove most pollutants remaining after primary and secondary treatment, such as nitrogen, phosphorus, non-biodegradable organic matter and inorganic metals. Most regulatory agencies require that the final step in wastewater treatment be disinfection to kill any pathogenic bacteria and viruses. In addition to disinfection systems, other common advanced treatment processes include filtration to remove inorganics and additional amounts of suspended solids, activated carbon to absorb odor-causing or non-biodegradable organic compounds, and chemical reactions to remove nitrogen. Increased removal efficiencies are achieved at increasing costs. In fact, the elimination of the last 15 percent of major pollutants from wastewater is several times more costly than the removal of the initial 85 percent. Table 2-8 shows the percent of pollutant removed from a wastewater at the primary, secondary and advanced treatment stages.

Table 2-8: Percent of Pollutant Removed by Treatment Level<sup>17</sup>

Pollutant	Primary Treatment	Secondary Treatment	Advanced Treatment
BOD	25-30%	85-95%	90-99%
Nutrients	60-65	85-95	90-99
Suspended solids	minimal	minimal	90-95

Note: BOD = biochemical oxygen demand

Wastewater sludge, solids removed from the wastewater during treatment, requires various degrees of treatment before being disposed. The purpose of sludge processing is to reduce its volume (raw sludge is 90 to 95 percent water) or remove potentially harmful constituents prior to disposal. In addition, sludge is processed such that it can be reused as a beneficial product. Methods used to process sludge include thickening, dewatering, conditioning, stabilization, drying and incineration (complete combustion). These methods are described in detail in Section 4.4.

<sup>1</sup> Effluent is defined as partially or completely treated wastewater flowing out of a treatment plant or process.

<sup>2</sup> Nonpoint sources of pollution are those which are diffuse and do not have a single point of origin such as a discharge pipe. Examples of nonpoint source pollution include construction, mining, stormwater runoff and combined sewer overflows.

<sup>3</sup> Data on wastewater infrastructure needs from 1992 Needs Survey Report to Congress, USEPA Office of Water, EPA 832-R-93-002, September 1993.

<sup>4</sup> The AMSA is a national, Washington D.C.-based trade association representing over 160 of the nation's largest publicly-owned wastewater utilities.

<sup>5</sup> Fox, Richard D., Schellpfeffer, Jon W., and Ridge, Joseph R., "The Rising Cost of Clean: Who Will Pay?", *Engineering News Record*, v237 n13, September 13, 1996.

<sup>6</sup> "US Environment Industry Hits \$180bn in Revenues", *Water & Environment International*, v5 n43, September 1996.

<sup>7</sup> "Rising Tide in the Water Business", *Environmental Business Journal*, v9 n2/3, February / March 1996.

<sup>8</sup> *Ibid.*

<sup>9</sup> "Controlling Interests: US Wastewater Treatment Plants Provoke Public-Private Rivalry", *Engineering News Record*, v237 n13, September 23, 1996.

<sup>10</sup> *Ibid.*

<sup>11</sup> Roecker, Donald F., "Federal and State Wastewater Funding after the 104th Congress: Maximizing Your Potential to Win", presented at WEFTEC '96, Dallas, Texas, October 5-9, 1996.

<sup>12</sup> The Clean Water State Revolving Fund, USEPA Office of Water, EPA 832-R-95-001, January 1995.

<sup>13</sup> Roecker, Donald F., "Federal and State Wastewater Funding after the 104th Congress: Maximizing Your Potential to Win", presented at WEFTEC '96, Dallas, Texas, October 5-9, 1996.

<sup>14</sup> *Ibid.*

<sup>15</sup> *Ibid.*

<sup>16</sup> *Ibid.*

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<sup>17</sup> Working for Clean Water: An Information Program for Advisory Groups, USEPA Office of Water, PB95-156048, 1995.

## **3.0 Expansion of the US Wastewater Treatment Market: The Contributing Factors**

### **3.1 Introduction**

It appears most industry professionals agree that, in the future, the history of the US environmental industry will be looked at as having had two distinct phases. The first phase being characterized by extensive government regulation to address years of neglect and make those who contributed to pollution and waste contamination legally and financially responsible for rectifying environmental problems. The second phase being characterized by the development of a system of regulatory standards geared towards the economic sustainability of environmental resources. Arguably, we are today in transition between the two phases, using our learning experiences from the first phase, in combination with a better understanding of the role of society in the natural environment, as a foundation on which to develop the second phase.

The focus of this section is on those factors which are guiding the wastewater treatment industry from a regulatory, compliance-based business to an industry being propelled by sustainable, economic-based considerations. Today, the quality of US waterways is significantly improved, due mostly to federal and state government-financed water pollution controls. At the same time, costs of providing and treating water are rising dramatically as government funding is becoming less available. With increasing demands on municipal capital budgets and the infrastructure needs of a growing population, the private sector is playing a greater financial and operational role in the traditionally public arena of wastewater treatment. And with the globalization of today's society, the US wastewater market has and will continue to be influenced by the global wastewater treatment industry.

### **3.2 Factors Shaping the US Wastewater Market**

As with any market, the wastewater treatment industry is affected by a variety of economic, political and social issues that combine to influence the direction of the market. Although other factors do exist, the following discussion of these issues will focus on what appears to be the main factors that have contributed to the recent expansion and development of the wastewater treatment market. These factors include:

- Inadequate infrastructure relating to the need for rehabilitation, repair and replacement;
- Municipal budgetary constraints;
- Increasing private sector participation;
- The direction of environmental legislation and regulation; and
- The influence of the global environmental market.

A detailed discussion of each of these market drivers is presented below.

### **3.2.1 Inadequate Infrastructure**

The first real construction boom for wastewater treatment infrastructure came in the 1970's after the passage of the 1972 Clean Water Act. As the federal Construction Grants program grew, hundreds of wastewater plants were built in the 1970's and 1980's. With many of these plants currently reaching their 20-year design life, the need for rehabilitating, repairing and/or upgrading is widespread. As discussed in Section 2.3, the EPA's 1992 Needs Survey for wastewater infrastructure estimates the total unmet wastewater construction needs exceed \$137 billion., an increase of \$35 billion since the 1990 survey. This figure represents the capital construction costs necessary to meet wastewater pollution control needs. What are not reflected, however, are the needs for repairing, upgrading and/or replacing aging treatment facilities. It is estimated that between 1990 and 2010, just wastewater collection and conveyance systems alone require close to \$43 billion worth of repair and upgrading.<sup>1</sup> It is also known that the current annual revenues for municipalities from providing wastewater services do not generate enough capital to meet the rehabilitation and upgrading needs of all wastewater infrastructure.

As a result, not only do municipalities need to be concerned with the cost of regulatory compliance, but they must deal with repairing aging systems. It has become, in some cases, a "catch 22" situation. An aging system no longer operates at optimum efficiency and therefore requires longer treatment times to produce the required quality of effluent to be discharged. Longer treatment times use more energy and materials, which increases facility costs. A treatment plant then operates at a higher cost or chooses to rehabilitate the system, at some cost. Included in the scenario is the effects of an aging, inadequate sewer collection and conveyance system. Deteriorating pipes do not adequately convey the wastewater to the facility and contribute to nonsource point pollution by way of sanitary

and/or combined sewer overflow discharges. When such discharges occur, the untreated flow is directed into natural receiving waters, thereby bypassing the treatment facilities which are designed to protect water quality. The costs for control and/or treatment of these discharges are high relative to point source discharges. In addition, control technologies are less effective than those available for point sources. Therefore, the municipality either repairs the collection and conveyance system or develops a system to manage nonpoint discharges, both at a cost. One can easily understand the economic implications of a deteriorating wastewater infrastructure.

### **3.2.2 Municipal Budget Constraints**

In 1991, the city of Columbus, Ohio, was faced with the task of building, operating and maintaining treatment facilities to comply with federal environmental mandates enacted as of January 1991. The assistant commissioner of public health for Columbus calculated the cost of the required treatment facilities to be \$3,000 per household.<sup>2</sup> Unfortunately, this scenario is not an uncommon occurrence in the US. Unfunded environmental mandates, always a hotly debated public issue, has one of the greatest impacts on strapped-for-cash municipal budgets. The estimated cost of municipal wastewater facilities construction needed to comply with the requirements of the CWA is rising as overall federal financial support declines. It is estimated that the cost of complying with environmental mandates will rise from \$40 billion in 1987 to \$55 billion in 2000. In addition, the EPA estimates that municipalities will pay 87 percent of this cost, rising from 82 percent in 1987.<sup>3</sup> Local towns and cities have had to turn to the users to help meet increasing costs. A 1994 Ernst & Young National Water and Wastewater Rate Survey found that the monthly charge per household for wastewater treatment had risen 18.1 percent since 1992, while during the same two-year period, the Consumer Price Index increased by only 6.1 percent.(#)

Improvements in the way federal regulatory agencies issue new rules from a cost-benefit approach have been attempted. Recently, there was an effort in the US Congress to require the EPA to use "comparative risk assessment" when determining environmental quality standards. This comparative process would balance the costs and benefits of proposed regulations and then choose standards with the greatest environmental benefits and lowest cost. The effort, along with similar proposals, has failed to gain adequate support in Congress. However, although it is difficult from both a scientific and social standpoint to put a price on a clean environment, it is well understood that changes need to be made to help state and local governments meet the costs of environmental compliance.

The same municipalities that must meet increased wastewater treatment requirements and develop stormwater and nonpoint source pollution control program are also faced with significant capital expenditures for their drinking water systems. The Safe Drinking Water Act places new requirements on drinking water supply, treatment and storage. Include in the budget equation other infrastructure needs, such as road and bridge repairs, and as well as public services (e.g., police forces, public works departments), that municipalities must address. All of these needs add to the overall pressure on municipal governments to fund various infrastructure programs with declining federal and state support.

It is well established that federal financial assistance for municipal wastewater programs is necessary. Given the extraordinary amount of capital needs, however, it seems essential that the legislative branch of the federal government allow for flexibility in various financing alternatives for municipalities. The flexibility would come in a regulatory structure which supports the use of financial partnerships to leverage limited municipal budgets and facilitate the development and maintenance of adequate wastewater treatment infrastructure. Financial partnerships with the private sector, whether or not the disadvantages outweigh the advantages from a political and social standpoint, appears to be necessary economically. Section 3.2.3 provides a detailed discussion of the various issues relating to public/private partnerships.

### **3.2.3 Private Sector Participation**

The business of the private sector providing wastewater treatment operation and maintenance services is not a new one--private firms have been operating public wastewater facilities for nearly 20 years. There are, however, two distinct businesses for private sector involvement in public wastewater treatment facilities, each guided by different regulations, different capital and service requirements, and different potential returns on investments: 1) acquisition and ownership, and 2) contract operations and maintenance. Due to certain restrictions and legal barriers the current focus of private sector participation is on contract operations and maintenance. Given the economic pressures and infrastructure needs facing today's municipal governments, private sector participation in public facilities is looking increasingly attractive to elected officials.

Private contract services range from part-time staffing assistance to comprehensive management services and financing, as well as operations and maintenance. Traditionally,

municipalities may look to private contract operations for their wastewater systems for several reasons, such as:

- To solve compliance problems or deal with increasing regulations;
- To resolve labor relations problems;
- To deal with financial pressures; and
- To address various issues and problems such as new facility start-ups, recurring odor complaints, and difficulty in keeping or attracting qualified plant operators and managers.

There are a number of techniques available to facilitate private sector participation in the design, financing, construction, ownership, operation and/or maintenance of a public wastewater treatment system. The type of public/private arrangement to be used depends on the specific objectives and needs of the state or local government. The following is a list and brief explanation of the various public/private arrangements available for procuring private sector services.

1. **Private Sector Operation:** A private firm is contracted to manage, operate and maintain (or provide only one or two of these services) the publicly-owned facility.
2. **Turnkey Services:** Used for construction of a new facility. The public agency will contract a private developer to construct the facility, often using fast-track techniques such as design-build which protects the procurement process from public sector procurement regulations. This can enable the private partner to complete construction in less time and for less cost than traditional construction delivery techniques.
3. **Build-Operate-Transfer (BOT):** Used for construction, operation and ownership of a new facility. Under BOT, the private partner constructs a facility (most likely under a turnkey arrangement), operates the facility for a period of time specified in the contract, and then transfers ownership of the facility to the public agency at the end of the operational period. In most cases, the private partner will provide the capital to finance construction of the facility, therefore the length of the operational period must be sufficient to allow recuperation of the initial capital outlays.

4. **Lease-Purchase/Operating Lease:** Used for construction of a new facility. Under this arrangement, the private sector constructs a facility which it then leases to the public agency. At the end of the lease term the property can be bought by the public agency at fair market value. This allows a public agency to obtain a new treatment facility without providing the capital investment.
5. **Lease-Develop-Operate:** Used to purchase or renovate an existing facility. The private partner either buys or leases the facility from the public agency, renovates and/or expands the facility, and then operates the plant under contract with the public agency. The public agency again avoids having to provide capital for facility repair/upgrading.
6. **Sale/Leaseback:** This is a financial arrangement in which the owner of the facility sells it to another entity and then leases it back from the new owner. Both the public and private sector can enter into sale/leaseback arrangements. An example of the benefits of this is where a public agency sells a treatment facility to a private partner in order to finance construction or upgrades, and then repays the private investment with lease payments.
7. **Tax-Exempt Lease:** Under this arrangement, a public entity finances public facilities by borrowing funds from a private investor. The portion of the lease payment that is used to pay interest on the capital investment is tax-exempt under state and federal laws. Since the lease arrangements do not count against local debt limitations, they can be very useful for communities nearing their debt capacity.

Considering the economic benefits of private sector participation in public wastewater treatment infrastructure, it is unfortunate that the evaluation of public versus private can be hampered by local politics. Local elected officials often fear the loss of control of a major public service, and a high comfort level must be established so that public officials do not come under public scrutiny. Typically, the issues of greatest concern to government officials are those which affect the outward appearance of the project: implementation schedule, price, revenue and overall facility appearances. The driving force of privatization is the need to achieve economic efficiency, yet it brings with it somewhat uncertain political, organizational, and social consequences. Often, economic concerns that are the primary

focus at the beginning of the process end up taking a backseat to politics. The main political issues seem to be accountability or control of services and public acceptance. Because of the public uncertainty of the adequacy of privatization, we have experienced that the successful outcome of an effort to privatize wastewater infrastructure can depend heavily on having someone in a political leadership position (e.g., a mayor, as was the case in Indianapolis, Indiana—see Section 5.3), who believes strongly in the need for private sector involvement. Such individuals need to be willing to overcome current legal constraints and bureaucratic inertia surrounding private sector participation.

Widespread perception is that private sector ownership and/or operation of treatment facilities brings with it cost savings. However, there is little empirical evidence to support this, as little has been done in the way of widespread cost impact studies. Currently, the answer is to the cost savings question is in some cases yes, in others, no. A recent report by the Reason Foundation challenged the assumption that municipalities pass on to consumers the benefits of access to cheaper capital. The report found that investor-owned water companies provide comparable water services at virtually the same price as government water companies even though government companies get tax subsidies and have higher costs.<sup>4</sup> Whether or not there is guaranteed cost savings in privatizing wastewater infrastructure, municipalities are facing fewer alternatives with their budgetary constraints. As discussed in Section 3.2.1, wastewater treatment systems are only one piece of a town's whole infrastructure system. If privatization allows the release of capital for use for another important infrastructure need, then logically it should be considered as an alternative.

A discussion of the legal and regulatory issues relating to private sector participation in the wastewater treatment market is included in Section 3.2.4.2 below.

### **3.2.4 Legislative/Regulatory Climate**

The legislative and regulatory climate surrounding the wastewater treatment industry today is one of change and uncertainty. Reauthorization of the Clean Water Act, which has not been reauthorized in almost 10 years, has been under debate now for several years. Most parties associated with the industry, including those in Congress, agree that some of the provisions of the CWA need to be modernized or reoriented to address the problems of today. Providing the legal and regulatory framework to allow state and local governments, and the private sector, to address water quality needs in a scientifically appropriate and cost-effective manner is not the issue. What is debated is how to structure that framework

in order to minimize the cost implications of advanced pollution control while facilitating the role of the private sector in providing wastewater treatment infrastructure and services. A discussion of the direction of federal legislation and regulation with regards to both water quality and private sector involvement in the industry is presented below.

### **3.2.4.1 Water Quality**

Local governments are subject to extensive requirements specified by the CWA with regards to the planning, design and construction of sophisticated treatment facilities. As discussed in Section 2.2, the 1977 CWA required that municipalities meet technology-based secondary treatment levels, comply with some water quality limits more restrictive than secondary treatment, and develop and implement industrial pretreatment programs to protect both water quality and wastewater treatment plant processes. Significant new requirement were added by the 1987 amendments and subsequent regulations. These requirements include: 1) controls on chemical-specific toxic substances, 2) controls on combined sewer overflows, and 3) compliance with NPDES stormwater permits.

Comprehensive reauthorization of the CWA will not occur in 1996, due in part to the fall elections, however the House of Representatives did pass its comprehensive reauthorization bill. Introduced in February 1995 and passed in May 1995, HR 961--entitled the Clean Water Act Amendments of 1995--provides an indication of the future direction of the CWA, but the Senate lags far behind. The following is a summary of some of the major provisions of HR 961.

- Biosolids - makes the beneficial use of biosolids a goal of the CWA;
- Coastal Discharge - allows an exemption from secondary treatment for coastal cities meeting certain requirements;
- Cost-Benefit - prohibits the EPA from issuing regulations imposing costs greater than \$25 million unless EPA certifies that the regulation maximizes net benefits to society. It also makes cost the overriding factor when there is a conflict with other criteria;
- National Policy - sets new national policies of encouraging water reclamation and reuse, water conservation, beneficial use of biosolids, and basing water quality programs on maximizing net benefit to the environment;
- Nonpoint Source Pollution - requires state nonpoint source management programs to include management practices and measures to reduce nonpoint

source pollution. It also authorizes \$1 billion for nonpoint source programs and cost sharing, but postpones requirements if full funding is not authorized;

- Pollution Prevention - allows the EPA or states to modify permit requirements if dischargers implement pollution prevention measures which will result in a net decrease of releases to the environment;
- Small Community Assistance - authorizes grants for technical assistance and training to small communities and systems and \$50 million per year through fiscal year (FY) 2000 for grants to small communities for constructing treatment facilities and alternative systems. It also authorizes communities of 10,000 people or less to use alternative treatment technologies that are equivalent to secondary treatment or provide an adequate level of protection. It requires the EPA to develop simplified SRF procedures for small communities;
- Wastewater Construction Funds - authorizes \$2.25 billion for the SRF loan program in FY 1996, and \$2.3 billion per year in FY 1997-2000. Eligible uses for SRF funds are expanded and clarifies that land acquisition is an eligible use. It also sets up procedures for privatizing publicly-owned wastewater treatment facilities.

Based on the above, it appears the direction of wastewater-related regulations is economically-driven with a focus on prevention and performance rather than procedure. With regards to the Senate, only one hearing on CWA authorization has been held in the Senate Environment and Public Works Committee. Although there is obvious effort with HR 961, the debate over CWA authorization continues.

### **3.2.4.2 Public/Private Partnerships**

Considering the continued need for wastewater treatment facilities, the need for existing wastewater infrastructure repairs and upgrading, and the strain on municipal budgets, it is evident that the industry could benefit from an influx of capital. It enters the private sector. Actually, the business of the private sector providing wastewater treatment operation and maintenance services is not a new one--private firms have been operating public wastewater facilities for many years. The recent focus by municipalities on considering the use of private firms to free needed capital, however, has propelled this opportunity onto center stage. Certain regulatory restrictions in arranging private ownership of public wastewater facilities appear to be the main focus of proposed federal legislation in this area. A

discussion of the existing regulatory barriers to these public/private partnerships and the recent developments to facilitate this process is provided below.

#### Existing Regulatory Barriers

Federal laws and regulations governing everything from taxation of capital-raising bonds to repayment of federal construction grants make it difficult for local governments to tap private-sector capital. A 1996 US Congress Joint Economic Committee (JEC) report identified three federal barriers that keep state and local governments from privatizing wastewater treatment facilities.<sup>5</sup> These three barriers are discussed below.

- 1. Grant requirements that force municipalities to repay the federal government any undepreciated portions of federal grants.*

Executive Order No. 12803 outlines the process by which the proceeds from the sale of state and local infrastructure assets must be distributed. After the state and local governments have recouped their respective portions of the initial project costs, the federal government must be repaid the full amount of the federal grant that was originally awarded to construct the facility, minus the amount of asset depreciation. According to the JEC report, this requirement may inhibit privatization because the undepreciated portion of the asset (the facility) will sometimes exceed the current market value of the asset. Consequently, the sale of the asset would not cover the amount of the original grant owed to the federal government. In other situations, the sale of the asset may allow full repayment of federal grants but leave only marginal proceeds for the state and local governments, creating little incentive to privatize.

- 2. Regulatory requirements which impose stricter standards on private facilities than on publicly owned facilities.*

Under the Resource Conservation and Recovery Act (RCRA), which governs solid and hazardous waste management, EPA regulations allow industrial users of publicly owned treatment works (POTWs) to discharge their waste to a POTW without a RCRA permit. However, industrial discharges to privately owned facilities are subject to RCRA regulations. The CWA also applies different standards to publicly versus privately owned facilities by imposing stricter effluent discharge limits on privately owned facilities.

3. *Tax policies which provide certain benefits to publicly owned facilities but deny similar benefits to private parties.*

State and local governments receive a subsidy from the federal government to build and own their infrastructure. Interest on state or local government debt incurred to build infrastructure is tax-exempt to the debt providers. The interest on private debt incurred to construct an identical facility, however, is taxable.

The Internal Revenue Service (IRS) imposes a cap as to the amount of tax-exempt private-activity bonds that a state may issue. Wastewater treatment infrastructure therefore competes with other state and local needs for the limited amount of tax-exempt financing available under the cap.

The IRS also severely limits the sale of public assets with outstanding tax-exempt bonds. If such a sale occurs, the IRS will most often deny the tax-exempt status of the bonds and will regard the debt on the assets sold to the private party as taxable, retroactive from the date the bonds were issued. This creates a substantial hurdle for privatization, as the private investors would need to raise enough funds to purchase the facility and pay off its bond-financed debt simultaneously.

Many private firms have or are willing to assume responsibility for operation and management of POTWs. Current IRS rules, however, limit contract periods to five years if the bonds used to build public facilities are to remain tax-exempt.

In addition to the above issues, it is required that the sale of POTWs which are federally financed be approved by the federal government, specifically the EPA. This is not necessarily a barrier to privatization--the requirement is needed to allow the federal government to perform its duty of public protection--rather it creates a time-consuming process which is not a process favored by private investors.

#### Regulations Facilitating the Process

A key component of the 1972 CWA called for the repayment of federal construction grants in uninflated dollars in the event the asset was transferred out of municipal hands. In April 1992, President Bush signed Executive Order No. 12803 which amended the repayment obligations to allow repayment in depreciated dollars based upon a 15-year useful life. One

of the fundamental principles of the executive order was that..."Federal financing of infrastructure assets should not act as a barrier to the achievement of economic efficiencies through additional private market financing or competitive practices, or both."<sup>6</sup> The purpose of the order was to encourage private sector financing of infrastructure assets and to promote private sector modernization and expansion of wastewater infrastructure. Consequently, municipalities were positioned to be able to cash in on the value of their wastewater treatment plants. As evident from the discussion of the JEC report, this executive order contains some prohibiting provisions, however, it was a positive first step towards developing public/private partnerships.

In January of 1994, President Clinton also approved of the role of private participation in infrastructure developments with Executive Order No. 12893. The order directs executive agencies to seek private sector participation in infrastructure investment and management, and to minimize the legal and regulatory barriers to private sector participation in providing infrastructure facilities and services.

Legislative proposals to facilitate the privatization of wastewater infrastructure have been developed over the past several years. A brief description of three legislative proposals currently under discussion is provided below.

- "Federal-aid Facility Privatization Act of 1995" - provides that no state or local government is required to repay the federal government any grant money used for construction of a facility that is being privatized;
- "Municipal Wastewater Treatment Facility Private Investment Act of 1995" - would treat privately owned wastewater treatment plants the same as POTWs in terms of the effluent discharge limits under the CWA;
- IRS tax policy reform - would expand the maximum contract period permitted for the private operation/management of a treatment facility to 15 years (up from the current 5-year limit).

Two organizations are focusing professional efforts for influencing the legislature on these issues. In the summer of 1995, the US Conference of Mayors formed the Urban Water Institute to help cities cope with the cost of meeting federal water and wastewater mandates. The institute is seeking tax and regulatory changes that will make it easier for municipalities to hire private firms to operate their water and wastewater treatment plants, or to sell their treatment facilities to private firms. The Water Environment Federation

(WEF), an organization committed to preserving and enhancing the global water environment, has taken the position that private sector involvement should be an option available to local governments based on the specific local needs and concerns. In their December 13, 1995 statement to the Senate Committee on Environment and Public Works regarding Clean Water Act reauthorization issues, the WEF recommended that Congress do the following:<sup>7</sup>

- Remove legal barriers which deny POTWs access to private funds, giving local governments the flexibility to recycle funds and access needed capital for water pollution control requirements;
- Clarify that the sale of existing wastewater treatment assets--constructed with federal grants--to the private sector for continued operation will not require a return of grant money to the federal government. This would apply as long as the proceeds of the sale are used for further wastewater facility construction or rehabilitation; and
- Revise the definition of "publicly owned" facilities to include those owned and/or operated by private parties which are subject to contracts or service agreements with the municipality. This would apply for agreements which stipulate municipal oversight of plant performance and provide a service equivalent to that which was or would have been proved by a POTW.

It is clear that the federal government is approaching the privatization issue with caution--it is an issue of both public and environmental safety, and there is still widespread skepticism of using the private sector to provide traditionally public-run services. It is also clear that, with the proposals currently being debated in Congress and the positions taken by highly-regarded professional organizations like the WEF for a move towards a clearer and more effective public/private process, the light has undoubtedly changed from red to yellow. What shade of green it will end up on remains to be seen.

### **3.2.5 Global Market Influence**

Whether it is the uninhibited reach of the Internet or the opening of the first McDonald's in Bangalore, India, today's is unarguably a global society. No other issue has had as great effect on reducing the size of the globe than the environmental movement and the push towards sustainability. However, the global environmental business has certainly not been reduced. The \$408 billion global environmental market will experience a 4 to 5 percent

growth in developed nations over the next several years, and growth averaging over 10 percent in the rest of the world. Although only one of a number of different industry segments, water treatment works is a significant part of the global environmental market, commanding 39.4 percent of the total market.<sup>8</sup> As shown in Table 3-1, five of the top 15 environmental companies in the world focus on water/wastewater equipment and services. Also indicated by this table is that none of the five companies are US firms, however, joint ventures and ownership arrangements have allowed these companies a substantial presence in the US.

Table 3-1: Top Worldwide Environmental Companies by Revenue<sup>9</sup>

Company	Country	Industry Focus	1994 Revenues (\$ millions)
WMX Technologies	USA	Solid waste/diversified	10,097
Generale des Eaux	France	Water/solid waste/diversified	7,889
Asea Brown Boveri Corp.	Switzerland	Diversified/equipment	5,321
Browning Ferris Industries	USA	Solid waste	4,679
Lyonnaise des Eaux	France	Water/diversified	3,980
RWE Entsorgung	Germany	Solid waste	2,800
Mitsubishi Heavy Industries	Japan	Incineration/APC/water equipment	2,100
Ebara Corp.	Japan	Water/incineration equipment	1,940
Laidlaw Inc.	Canada	Solid/hazardous waste	1,829
Thames Water	UK	Water/wastewater equipment	1,740
Severn Trent	UK	Water/wastewater/consulting & engineering	1,587
Noell GmbH	Germany	APC/engineering & construction	1,500
Phillip Holzmann	Germany	Solid waste/engineering & construction	1,446
North West Water	UK	Water/wastewater equipment	1,323
Deutsche Babcock	Germany	Diversified/equipment	1,148

For example, Compagnie Generale des Eaux (CGE), Paris, France, is a giant worldwide water business provider, with revenues now approaching \$10 billion. CGE's presence in the US is extensive, with holdings which include:

- Air & Water Technologies, which umbrellas Professional Services Group, Metcalf & Eddy and Research-Cottrell (consulting, engineering, operating and analytical services);
- Kruger (wastewater plant construction);
- OTVD (biosolids composting);
- Birwelco (dissolved air flotation);
- PICA (activated carbon for water and wastewater treatment);
- Emery/Trailigaz (ozone systems); and
- Major shareholdings of Philadelphia Suburban Corp. and Consumers Water Co. (privately owned water utilities).

The financial strength and size of the French and British firms, relative to US competitors, has produced increased competition in the private financing of wastewater facilities in the US. The size of these companies, in terms of services offered and their seemingly endless supply of capital dwarfs most US firms. In the international arena, this poses a major challenge, but domestically the US firms have a political and social homefield advantage. There are also valuable lessons to be learned from the overseas wastewater industry, particularly in the United Kingdom (UK) which has had an entirely privatized water and wastewater industry since 1989. The driving forces behind the 1989 move of water services from the public to the private sector were: 1) to provide the industry with the stable financial structure needed to implement major capital works projects, and 2) the desire to improve efficiency and productivity by introducing a privatized management structure and operational economy of scale. Changes that have resulted from the privatization have included lower manpower requirements, increased purchasing efficiency, technology improvements and vertical expansion of water service companies.<sup>10</sup>

Globalization of the wastewater market has become very apparent in the last several years. Although water quality remains a local and personal issue to the public, it is no longer correct to think of water/wastewater services as an internal US-only industry, let alone strictly a publicly operated industry. International competition for private sector involvement in US wastewater infrastructure is influencing the way services are marketed and provided. Clearly, the privatization experience in the UK has dramatically changed the

water industry worldwide, and provides valuable lessons that should be used in the US as a learning experience.

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<sup>1</sup> Crawford, Roger, "Municipal Sewage and Water Systems Are In a State of Crisis", *Environmental Science & Engineering*, v9 n4, September 1996.

<sup>2</sup> Luberoff, David, "The Risky Business of Cleaner Water", *Governing*, March 1996.

<sup>3</sup> Ibid.

<sup>4</sup> "Rising Tide in the Water Business", *Environmental Business Journal*, v9 n2/3, February/March 1996.

<sup>5</sup> DeMasi, Deborah A., Reid & Priest LLP, Washington D.C., "Wastewater Infrastructure Financing: Dispelling the Myths and Realities of Public vs. Private Financing", May 30, 1996.

<sup>6</sup> Ibid.

<sup>7</sup> Statement of the Water Environment Federation to the Senate Committee on Environment and Public Works, Clean Water Act Reauthorization Issues, December 13, 1995.

<sup>8</sup> "The Global Environmental Market", *Environmental Business Journal*, v8 n8, August 1995.

<sup>9</sup> Ibid.

<sup>10</sup> Walsh, Michael J., "Privatization in the UK Water Industry: The Five Year Report Card", WEFTEC '96, Dallas, Texas, October 5-9, 1996.1

## **4.0 Technology Trends in Wastewater Treatment: Incremental Improvements and the Development of Alternative Processes**

### **4.1 Introduction**

The development of technologies does not occur in a vacuum, but rather in a dynamic system of economic, political and social influences. At any given time, the motivations for and consequences of technological development are a function of the specific characteristics of that system. Simply stated, the non-technical climate has a significant influence on the technological climate of an industry. As evident from the discussions in the previous two sections, technology development in the wastewater treatment industry is no different. Economic influences are present in the industry in both traditional forms, such as the forces of supply and demand, and the less traditional, as in the implications of unfunded mandates. Political influences also exist, the most obvious example being the current bout between public versus private treatment facility ownership and/or operation. Social influences, such as the increased emphasis on recycling and reuse due to a growing, global concern for the quality of the environment, are also influencing the direction of the industry.

The focus of this section is on the development and advancement of wastewater treatment technologies and how the current trends in technological development have been affected by the system of influences described above. With the wastewater treatment industry a mature one—we have been treating wastewater at some level for over 100 years—the demand for technological development is not for the creation of entirely new processes. Instead, the current focus appears to be on the improvement of existing technologies as well as the development of alternatives to existing technologies.

A discussion of the basis for technology development and the important drivers of technological innovation in the industry today is presented below. The current trends in technology development are also discussed, providing descriptions of some of the recent advances in wastewater treatment technology. A matrix evaluation framework provides the basis for comparing the technologies in terms of their evolution and stage of development. The majority of the section is then devoted to a detailed discussion of two specific technologies that represent the trend of incremental technological improvement. These two technologies—ultraviolet radiation for disinfection and infrared sludge drying—are at very

different stages in terms of their development, providing an interesting comparison of the various motivational influences that may play a role in technology development.

## **4.2 Technological Innovation and Development<sup>1</sup>**

An industry's receptiveness to technological advancement is a function of the industry structure. A traditional conclusion is that innovative technological advancements, in both products and processes, which improve performance and quality or cost effectiveness will be readily accepted. However, the need for innovation in the current system of economic, political and social influences dictate to a great extent the acceptance of technological innovation. The wastewater treatment industry provides a structure which requires continuous development and refinement of age-old processes and encourages new developments in technology. The industry's structure also plays a major role in creating new "fringe" industries by allowing technological change to be a principle driver of competition.

Science and technological development often teach us the principles behind a process. Although the process is understood, the development of an associated technology does not begin until the identification of an appropriate application for that process. At the same time, a major technological development does not necessarily involve scientific breakthroughs or technologies that were not widely available. This point is exemplified by the current effort to apply certain technologies that are used extensively in other industries to the wastewater treatment process.

The following discussion provides a general description of the process by which technology evolves and matures. A framework is established for comparing and evaluating technologies in terms of the stages of development. The current state of technological advancement in the wastewater treatment industry is discussed, providing examples of specific technologies under development or recently introduced into the market.

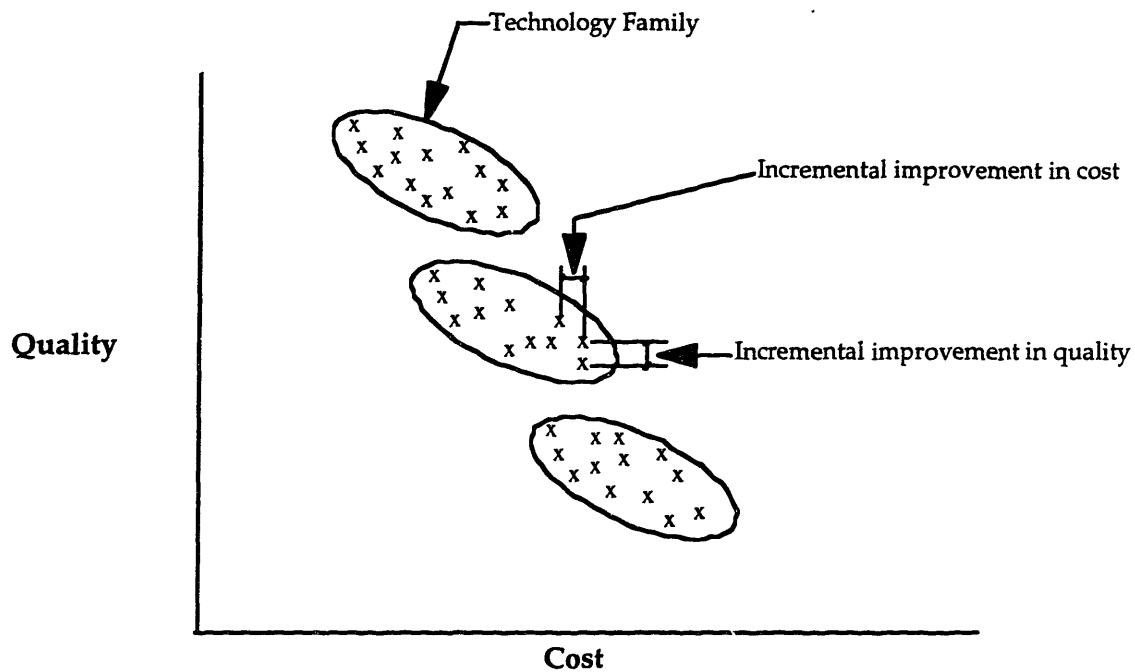
### **4.2.1 Industry Framework for Technology Development**

As described in Section 2.6, each category of wastewater treatment--preliminary treatment, primary treatment, secondary treatment, advanced treatment and sludge processing--has anywhere from a few to many different processes and technologies available to perform the treatment. Therefore, it is advantageous to consider technology development in the industry

within a set of groups or families of technologies. An analysis of technological advancement in the wastewater industry based on families of technologies is an effective approach because of the broad array of physical, chemical and biological methods that are combined in various ways to perform specific levels of treatment. A family is created from the incremental improvement and development of a technology. The technology family collectively represents the methods, products, or operations that evolved from a technology and which perform a procedure or produce a desired outcome, although with varying degrees of effectiveness. For example, under the category of sludge processing there is the method of sludge stabilization. Anaerobic digestion is one of several available types of sludge stabilizing processes. Its associated family of technologies, each of which can perform the process, include low-rate digesters, high-rate digesters, two-stage digesters and egg-shaped digesters. The only necessary connection between technologies in a family is that they share a common end-goal (e.g., stabilize sludge).

The incremental improvement of technologies within a family can be measured by the relationship between quality and cost, and how this relationship changes with the advancement of the technology. When a new technology is first developed, it will typically offer a low quality at a high cost. Inefficiency is a direct incentive for technological advancement. Incremental improvements on the original technology are then made from the lessons offered by bench-scale and pilot-scale testing, full-scale applications, and market and user responses. As the technology improves, less resources (labor, materials, energy, capital) are required to produce the same or a better product or process. The relationship between quality and cost is then affected by these incremental improvements, where a decrease in cost occurs as the quality increases. Due to the desire to continually develop cheaper, more effective processes, while one family of technologies is advancing, the development of other technologies create new products or processes that threaten to substitute for the original family. The pattern of technological evolution is shaped by whether these substitutes are threatening based on improved cost or product differentiation. Families of technologies may reach limits to the value added by further improvement, which can also force the evolution of technology substitution. Figure 4-1 presents a graphical representation of the relationship between quality and cost relating to the evolution and development of technological families.

Figure 4-1: Technology Family Development as a Function of Quality and Cost<sup>2</sup>



The development of technologies associated with disinfecting water and wastewater provides an example of technological evolution and advancement. One of the first technologies used for the disinfection of drinking water was ozonation. Although ozone is a powerful oxidant, and therefore a very effective disinfectant, the capital and operating costs of ozonation are high. Improvements on original methods and equipment used for producing ozone created a family of technologies which evolved ozonation as a disinfection process. A substitute process, chlorination, is then introduced which rivals ozonation based on cost. Chlorination is also an effective disinfectant, but at a lesser cost than ozonation. Internal incremental improvements help to develop the original chlorination technology into a family which achieved a very desirable quality/cost relationship. Chlorination may have reached its technological limits in terms of its ability to realize further improvement. In the meantime, developments in ultraviolet radiation allow this process to become another technological family available for disinfection. Ultraviolet radiation disinfection is effective and economical compared to chlorination and ozonation, and has developed as a substitution for these other families of technologies.

Wastewater technology innovation is driven by the potential economic benefits of its development. Innovation comes about through both demand pull and technology push

forces. Demand pull forces are those where changes in a market create new needs which can be satisfied with innovative or advanced technology. For example, in the automobile industry, the demand for reduced pollutant emissions from car exhaust led to the development and widespread use of the catalytic converter. Technology push forces are created by manufacturers and suppliers of new technology who actively market new products and processes. In the computer industry, continued development and improvement of the microchip has created an industry that rapidly develops and brings to market new products, which then become obsolete within a few years as the technology advances.

Whether by demand need or the ability to create a new product, there must exist an adequate incentive for technological development. The incentive to innovate is based on the degree of assurance that the economic benefits of the innovation will be valued by the user. These benefits could include improved performance, reduced costs or improved services. In addition, the potential that some of those economic benefits will flow back to the party responsible for the innovation must be adequate to compensate for the investment cost. Incentive to innovate may also be favorably influenced as perceived costs associated with the innovation decreases. In the end, the realization of economic benefits is not a function of whether the innovation is characterized by high or low technology but of the structure of the industry and its ability to provide value for improvement.

Technologies can be introduced into the market at any stage of their development, depending on industry need and other opportunities, such as available investment capital. A rationale for comparing new technologies in the wastewater treatment industry can be based on these different stages of development. The following matrix framework provides a mechanism for charting the origin, treatment application, and stage of development of treatment technologies.

Figure 4-2: Matrix Framework for Technology Comparison

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology						
Technology from other industry						

In the above framework, the origin of a technology relates to whether that technology emerged as a new process, is the further development of an existing technology, or is one used in some other industry which is being applied to wastewater treatment. Application refers to the phase in the wastewater treatment process in which the technology is utilized (i.e., preliminary, primary, secondary, advanced or sludge processing). There are essentially five stages of technology development. The scientific basis for a technology usually comes about through some level of laboratory research. The pilot-scale stage is where a technology is tested to determine its effectiveness and to identify and correct any operational difficulties. At the bench-scale level, the technology is applied to an actual treatment scenario for cost analysis and performance evaluation. A technology is in the stage of full-scale development once it is utilized in a treatment facility. The final stage of development is reached when a technology is used extensively in the industry. For purposes of comparison, this matrix framework will be applied to each of the wastewater treatment technologies discussed in this section.

#### **4.2.2 State of Current Technological Advancement**

The wastewater treatment industry is a mature one with well developed, accepted and proven processes. There are hundreds of engineering companies with significant design experience and expertise who have grown with the wastewater treatment industry. Similarly, there are many construction companies who are well experienced in building treatment facilities. Consequently, the industry appears to have a minimal need, and provides little incentive, for the pioneering development of entirely new treatment processes. An evaluation of the current market conditions, however, indicates that technological advancement is occurring in two main forms: 1) incremental improvement of existing technologies, and 2) the application of technologies from other related industries. The advancement of existing technologies is focusing on alternative processes that may be more effective than existing processes for dealing with increased hydraulic and organic loading, or for meeting stricter water quality requirements. The efforts of other fringe industries to apply technologies to wastewater treatment is regarded as innovation through invasion.

In addition to a weak need for broad technological innovation, there also appears to be a lack of funding for the development of entirely new processes. Scientific research is necessary to ensure the development of processes that can adequately address environmental regulatory decisions, but to who's cost should this research be conducted is unclear. The EPA's innovative and alternative treatment assistance program for

wastewater treatment was phased out along with the Construction Grants program in 1990. Since then, federal investment in the development of improved wastewater treatment technologies has been significantly reduced. Local governments have only afforded limited investments in research and demonstration studies, almost entirely through the efforts of individual municipal facilities. The current SRF program for funding municipal treatment facilities provides less incentive for the use of innovative and alternative technologies than did the Construction Grants program.<sup>3</sup> One of the requirements of the Clean Water Act is the consideration of innovative and alternative treatment technologies during the planning phase of a wastewater treatment project. Few states, however, offer any direct incentive for innovation. In addition, because the SRF is a loan program, municipalities assume a greater financial risk. The added risk and uncertainty associated with innovative technologies may therefore discourage their use.

Innovation in the wastewater industry is also being influenced by both demand pull and technology push forces. As regulations on nonpoint source pollution are developed, there is a demand for technologies and processes to control this pollution. There is also a push from related industries that are trying to apply specific technologies to the wastewater treatment process. An example of this "push" is liquid-liquid extraction, a technique commonly used in the pharmaceutical, petroleum and petrochemical industries which separates components in a liquid using liquid solvents.

Without the need or a direct incentive for broad-based innovation, the trends in wastewater treatment technology appear to be limited to that of incremental advancement. Clearly, we are seeing the incremental development and improvement of specific technologies within technological families relating to certain treatment processes. Although technologies are continually developed across all categories of wastewater treatment, the current advancements appear to be particularly focused on advanced treatment and sludge processing. This is due in part to today's regulatory climate, which is requiring a higher quality effluent discharge and focusing on the recycling and beneficial reuse of biosolids. In addition, families of technologies may have reached limits beyond which further improvement is difficult or does not add any additional value, which may explain the dormancy of innovation in a particular treatment category, such as in primary treatment. The opportunity created by the need for technological advancement in the advanced treatment and sludge processing categories is also demonstrated by the increased efforts of fringe industries to apply related technologies to these treatment processes. The current focus on advanced treatment and sludge processing technologies is discussed in detail in

Section 4.3 and Section 4.4, respectively. These sections present detailed analyses of the advanced treatment process of ultraviolet radiation disinfection and sludge drying through infrared heating. The following is a brief listing and description of some recent technological developments and advancements in wastewater treatment. Each technology is charted in the matrix framework for comparing their origin, application and current stage of development.

#### Attached-Growth Fixed-Film Media<sup>4</sup>

The addition of different types of biomass-forming media, such as plastic cylinders, sponge foam material and loop cord, into biological treatment units help to improve organic reduction and nitrogen from wastewater. Several different systems exist which allow easy upgrading of existing activated sludge tanks and are also flexible in design to be able to utilize existing tanks at the treatment plant. Benefits include the ability to treat increased flow volumes as well as increased loading without increasing plant size.

Technology: Attached-Growth Fixed-Film Media

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology	Secondary Treatment				X	
Technology from other industry						

#### Advanced Oxidation Process Using Fenton's Reagent<sup>5</sup>

Fenton's Reagent is a dilute solution of cheap ferrous sulfate and commercial strength hydrogen peroxide. The reaction between hydrogen peroxide and iron sulfate was invented in 1894 by Dr. H.J. Fenton in England. The reaction produces extremely reactive hydroxyl radicals and destroys organics in wastewater, leaving only carbon dioxide and water. Batch reactors are typically used for Fenton wastewater systems because waste compositions vary greatly and batch systems allow control over processing time (useful to ensure achievement of desired effluent quality).

### Technology: Advanced Oxidation Process Using Fenton's Reagent

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology						
Technology from other industry	Advanced Treatment				X	

### Liquid-Liquid Extraction<sup>6</sup>

A liquid-liquid extraction process used in the pharmaceutical, petroleum, petrochemical and nuclear industries has the potential to be applied to the treatment of wastewater. The technique involves separating components in a liquid using liquid solvents, similar to the processes used to recover antibiotics from fermentation broths. The greatest potential for the process in wastewater treatment is the removal of organic contaminants from wastewater. The extraction technique also offers the potential to recycle materials.

### Technology: Liquid-Liquid Extraction

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology						
Technology from other industry	Advanced Treatment			X		

### Peat-Based Sorbent Granules<sup>7</sup>

A new peat-based granule, developed after three years of research by the Natural Resources Research Institute at the University of Minnesota, sorbs a wide variety of organic compounds and heavy metals from wastewater. Peat is partially fossilized material created in oxygen-deficient, plant-abundant wetlands. It is one of the few natural materials that behaves both like activated carbon in sorbing organic compounds and like ion-exchange resins in sorbing heavy metals. The granular material is designed to be used in tank columns similar to those used for activated carbon units.

### Technology: Peat-Based Sorbent Granules

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology	Advanced Treatment		X			
Existing technology						
Technology from other industry						

### Advanced Fluidized Composting<sup>8</sup>

Advanced fluidized composting (AFC) is a new biological treatment technology which combines the best features of aerobic and anaerobic biological treatment. AFC is a proprietary combination of autothermal biological treatment with an additional step to provide rapid destruction of high-strength waste while minimizing biomass production. Operating at much higher temperatures (45-75 degrees Celsius) than conventional aerobic treatment systems (18-20 degrees Celsius), the system sustains higher kinetic rates, allowing for more efficient treatment of high-strength waste per unit volume of the reactor. In addition, the process produces less sludge per pound of organics removed than traditional processes.

### Technology: Advanced Fluidized Composting

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology	Secondary Treatment				X	
Technology from other industry						

### Macro Porous Polymer Extraction for Hydrocarbon/Water Separation<sup>9</sup>

The Macro Porous Polymer Extraction (MPPE, developed by Akzo Nobel, Arnhem, The Netherlands) technology removes dissolved hydrocarbons in ground water and process water by combining liquid-liquid extraction and steam stripping with an innovative polymer particle. The extraction liquid (insoluble in water) contained in the pores of the polymer extract the hydrocarbons from the water, which is passed through a column packed with the polymer particles. Hydrocarbons having a greater affinity for the extraction liquid than for water will be captured, including aliphatic hydrocarbons, aromatics such as benzene,

toluene and xylene, and chlorinated hydrocarbons (including polychlorinated biphenyls). Volatile hydrocarbons are then released from the extraction liquid with low-pressure steam. The concentrated hydrocarbon product is then available for recycle or reuse.

Technology: Macro Porous Polymer Extraction for Hydrocarbon/Water Separation

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology	Advanced Treatment		X			
Existing technology						
Technology from other industry						

Ultrafiltration Membranes for Advanced Treatment<sup>10</sup>

This technology, which has been in operation at industrial applications for the last decade, is receiving considerable attention from the municipal treatment industry. A cost-effective application of the microfilter membrane technology, which directly immerses the microfilter into a biological reactor, has been developed for the treatment of high-flow wastewater, such as municipal sewage.

Technology: Ultrafiltration Membranes for Advanced Treatment

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology						
Technology from other industry	Advanced Treatment				X	

Continuously Self-Cleaning Fixed-Film Bioreactors<sup>11</sup>

Continuously self-cleaning fixed-film (CSCF) bioreactors are simple, compact devices which maximize the inherent advantages of attached-growth processes for aerobic biological oxygen demand reduction. The bioreactor was developed in Japan, where its compact design is a key advantage due to high land costs. Depending on the application, CSCF bioreactors may be used alone or as a cost-effective pretreatment stage to upgrade existing treatment systems. Research is currently underway to adapt this technology for use with

specially developed microbial populations for such treatment purposes as nitrogen and phosphorus removal.

#### Technology: Continuously Self-Cleaning Fixed-Film Bioreactors

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology	Secondary Treatment	X (new uses)			X	
Technology from other industry						

#### Circulating Floating Bed Reactor<sup>12</sup>

The circulating floating bed reactor is a novel three-phase reactor which combines the main advantages of fluidized bed reactors--high removal efficiency, high nitrification rate, no clogging problems, better mass transfer, reduced sludge production--with a simple design and operation.

#### Technology: Circulating Floating Bed Reactor

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology	Secondary Treatment				X	
Technology from other industry						

#### Organoclays<sup>13</sup>

Organoclay is a bentonite modified with quaternary amines that removes oils or chlorinated hydrocarbons from water up to about 60 parts per million and at seven times the rate of activated carbon. Removal is performed by two processes: 1) the quaternary amine chains dissolve into the oil droplets, thereby fixating them through coulombic forces, and 2) chlorinated hydrocarbons are removed by anion exchange. Presently, organoclays are used primarily to clean up groundwater, landfill leachate, stormwater runoff, and several industrial wastewater treatment processes.

### Technology: Organoclays

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology	Advanced Treatment				X	
Existing technology						
Technology from other industry						

### Supercritical Water Oxidation for Treating Sludge<sup>14</sup>

Supercritical water oxidation (SCWO) is a high pressure, high temperature process that takes advantage of the characteristics of water above its critical point to destroy liquid wastes. SCWO can convert aqueous wastes to clean water, carbon dioxide, and stabilized inorganic oxides, all of which can be refined and recycled. The technology has been under development since the early 1980's. Typically used to destroy aqueous organic wastes at any concentrations, the technology is also suitable for treating wastewater sludge containing toxic organic substances. The SCWO process is being developed as an alternative to typical sludge disposal methods such as landfilling, land application and incineration.

### Technology: Supercritical Water Oxidation for Treating Sludge

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology						
Technology from other industry	Sludge Processing			X		

### 4.3 Wastewater Disinfection by Ultraviolet Radiation

Disinfection is the process of destroying pathogenic (disease-causing) microorganisms. In the US, water and wastewater disinfection is accomplished almost solely by some form of chlorination. Although an effective disinfectant, concerns have risen about the safety, toxicity and byproducts of using chlorine (and related compounds) for water and wastewater disinfection. The EPA has recently been looking at the use of chlorine as a disinfectant to determine if it should be banned or its use be restricted. Consequently, with

growing concern in the US about health problems related to water quality, and environmental concern about chlorine disinfectant by-products, ultraviolet (UV) radiation for disinfecting wastewater is emerging as an effective treatment alternative.

Currently, only 5 percent of US wastewater is treated using UV systems. Over the next five years in the US, however, it is estimated that the number of UV disinfection systems will increase from 1,000 to 3,000, and the US market for UV disinfection equipment and systems will increase from \$20 million in 1995 to \$100 million in 2000.<sup>15</sup> The driving forces for this increase in the use of UV radiation for disinfection appear to be both the regulatory and safety concerns over chemical disinfection, and the recent developments and advances in UV radiation technology. This section will discuss the disinfection process and the various methods available to remove harmful microorganisms from wastewater. The development of UV radiation technology and the current trend to use this technology in place of traditional chlorination, or to replace chlorine disinfection in existing plants, will be discussed by focusing on Trojan Technologies, Inc., one of the market leaders for UV systems.

#### Technology: Ultraviolet Radiation Disinfection

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology						
Existing technology	Advanced Treatment					X
Technology from other industry						

#### 4.3.1 Purpose and Methods of Wastewater Disinfection

The purpose of disinfection is to reduce the concentrations of pathogenic microorganisms in water and wastewater to levels which minimize the potential negative effects on humans who come into contact with the water. An individual could receive an infective dose of pathogenic microorganisms from consuming reasonable volumes of infected water/wastewater by, for example, swallowing river or lake water while swimming, breathing mist from reclaimed water irrigation sprays, or by eating produce which was irrigated with reclaimed water. The term disinfection refers to the inactivation and/or destruction of disease-causing organisms. In contrast to sterilization, which is the

destruction of all organisms, disinfection does not completely eliminate the organisms present. In the US, the main categories of organisms that have the greatest effects in causing disease in humans are bacteria, viruses, amoebic cysts and protozoan cysts. The concentrations of organisms in raw wastewater varies considerably. The degree of disinfection required also depends on what level of treatment the wastewater has undergone prior to disinfection. As an example, Table 4-1 details the expected effluent fecal coliform concentrations through a typical wastewater treatment plant.

Table 4-1: Estimated Fecal Coliform Concentrations in Effluent<sup>16</sup>

Effluent Type	Expected Fecal Coliform Concentration (coliforms/100ml)
Primary	$10^6$ to $10^7$
Secondary	$10^4$ to $10^5$
Tertiary	$10^3$ to $10^5$

The ability to adequately disinfect a water from these pathogens is dependent upon several factors, including<sup>17</sup>:

- The physico-chemistry of the disinfectant;
- The cyto-chemical nature and physical state of the pathogens;
- The interaction of these two factors; and
- The quantitative effects of factors in the reaction medium, such as temperature, pH, electrolytes, interfering organic substances and reaction time.

Temperature affects disinfecting action because a more rapid kill of the microorganisms can be achieved with increased temperatures. The presence of organic matter reduces the effective concentration of the disinfectant, because chemical disinfecting reagents may react with the organic substances. Particularly in chlorination, pH is important because it influences the relative distribution of disinfecting agents which have varying degrees of effectiveness. Although chlorination is the traditional method used for disinfection, there are other processes available, the most prominent being:

- UV radiation;
- Chlorine dioxide;

- Ozonation; and
- High-pH treatment.

In addition to chlorine, two other halogens are available for chemical disinfection, namely bromine and iodine. These halogens are good disinfectants, but cost and difficulty of application have prevented their widespread use. UV radiation is recently being recognized as the most effective alternative to chemicals for disinfecting water/wastewater, and is discussed in detail in the following two sections. Brief descriptions of the chlorination, chlorine dioxide, ozonation and high-pH treatment disinfection processes are presented below.

### Chlorination

Chlorine is the most widely used disinfectant because it is effective at low concentrations, is inexpensive, and forms a residual concentration if applied in sufficient dosage to prevent reinfection of disinfected water. The disinfecting ability of chlorine is due to its powerful oxidizing properties which oxidize those enzymes of microbial cells that are essential to the cells' metabolic processes.<sup>18</sup> When chlorine gas is added to water, two reactions occur--hydrolysis, which forms hypochlorous acid (HOCl), and then ionization, which yields the chlorite ion (OCl). Hypochlorous acid and the chlorite ion are both excellent disinfecting agents.

Chlorine is most commonly applied as a gas but can also be added in the form of a hypochlorite. Chlorine gas is dissolved in water using one of a variety of chlorinators to produce a concentrated solution. This solution is then piped into the water stream to be disinfected. Hypochlorites are added using solution-type feeders. In water and wastewater treatment, chlorination can be applied either before or after treatment, or both. Prechlorination is the use of chlorine prior to any treatments, and is used to control undesirable growth and resulting odors that might occur in collection and conveyance equipment. Postchlorination is the application of chlorine after all treatments, and is used for terminal disinfection.

The toxic effects of chlorinated effluents on receiving waters has received significant attention, and the removal of chlorine residuals prior to discharge is becoming a common requirement. The use of chlorine can result in the production of carcinogenic compounds such as trihalomethanes and chloroform which can have negative impacts on receiving waters and the people who use them. The process of removing chlorine residuals is called

dechlorination, which can be accomplished by the application of sulfur dioxide, sodium sulfite, sodium bisulfite, sodium thiosulfate, hydrogen peroxide and ammonia. Sulfur dioxide is the most widely used dechlorination chemical in wastewater treatment.

### Chlorine Dioxide

The use of chlorine dioxide was originally for taste and odor control at water treatment plants. Applications of chlorine dioxide in wastewater treatment have been limited to phenolic waste treatment and to the control of sulfide in wastewater collection systems. Chlorine dioxide is a more powerful oxidant than chlorine and, unlike chlorine, does not produce measurable amounts of trihalomethanes or organic halogens. The major disadvantage of its use in wastewater disinfection is the high expense of both the equipment and sodium chlorite (used in producing chlorine dioxide). Recent technological advances in generation equipment and sodium chlorite production may reduce the cost of using chlorine dioxide in the future.<sup>19</sup>

### Ozonation

Ozone, an allotrope of oxygen, is also a powerful oxidant. Its use as a disinfectant has several advantages compared to chlorination. Because ozone rapidly degrades to oxygen, toxic residuals are not present in the effluent following disinfection. In addition, ozone disinfection does not result in increased total dissolved solids in the effluent. Ozonation systems, however, have higher capital and operating costs than chlorination, and do not leave a residual concentration to prevent reinfection of disinfected water. Ozone must be produced on-site at the treatment facility because it cannot be stored like chlorine. It is produced by passing air between oppositely charged plates or through tubes in which a core and the tube walls serve as the oppositely charged surfaces. In aqueous solution ozone is relatively unstable.

Ozone is never used as a terminal disinfection treatment because it has been shown that organisms, under certain conditions, reproduce in distribution systems, causing various problems. As a result, ozone is used in some countries as the primary disinfectant, using the residual action of chlorine in low doses as a secondary disinfectant to prevent reinfection. Extensive effort has been made to develop ozonation for wastewater disinfection. There are still uncertainties about the reaction of ozone with organic materials in wastewater. Its reaction with pesticides may produce a more toxic material which may have significant consequences to human health and the environment, influencing the use of ozone for wastewater treatment.

### High-pH Treatment

High pH in water or wastewater is typically accomplished by the addition of lime. The theory behind the treatment is the higher the pH, the greater the bacterial reduction. The use of lime in treating the contents of outhouses, dead animals and battlefield mortalities to mitigate nuisance conditions has been practiced for many years. Its effectiveness in the water treatment industry at destroying bacteria has also been known for many years, but is not relied upon as the sole disinfectant. Similar to ozone, after the neutralization of the high pH there is no residual to protect the water, requiring the use of an additional residual disinfectant, such as chlorine. High-pH treatment of wastewater sludges, called lime stabilization, is a common practice.

## 4.3.2 Ultraviolet Radiation Disinfection

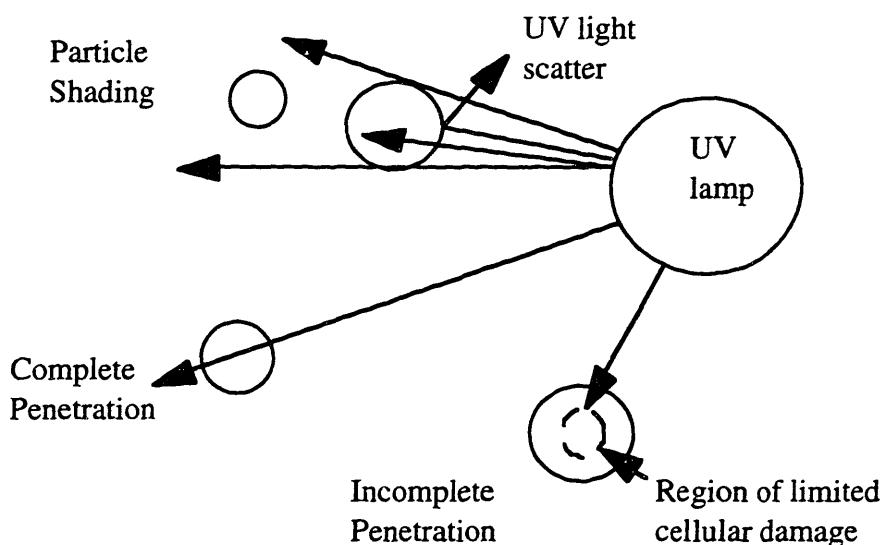
### 4.3.2.1 Theoretical Basis of Ultraviolet Light for Pathogen Inactivation

UV disinfection is a physical, as opposed to chemical, form of disinfection. UV light is defined as light between the wavelengths of 40 nanometers (nm) and 400 nm, which is longer wavelengths than x-rays and shorter wavelengths than the light visible to the human eye. UV light has germicidal properties between the wavelengths of approximately 200 nm and 300 nm, with radiation near 260 nm being the most germicidal. This radiation is referred to as germicidal because of its ability to inactivate viruses and bacteria that can be harmful to human health. The nucleic acids in microorganisms are the most important absorbers of the radiation, specifically in the wavelength range of 240 nm to 280 nm. Nucleic acids are common to all life forms, and damage to the nucleic acids inhibits access to the genetic information needed for growth and cell division. The genetic material within the nucleic acids of the cells (DNA and RNA) absorbs the UV light and is damaged so that the cells can no longer replicate themselves. Without access to this information, the organism becomes inactivated. If replication does occur, mutant daughter cells will be produced that cannot replicate.

The performance of UV disinfection depends on the characteristics of the wastewater, including transmittance, as well as suspended solid concentration and the presence of constituents that can precipitate. Transmittance is the amount of UV light that will pass through the wastewater. Certain inorganic and organic compounds in the form of

suspended solid particles absorb or scatter UV light, thereby reducing transmittance. Figure 4-3 provides a graphical representation of the effect of suspended solid particles on UV disinfection. The lower the transmittance, the lower the average intensity of light in the reactor, and the longer the retention time required to deliver a specified dose. The transmittance of UV light therefore improves with increasing levels of treatment--domestic effluents typically have a higher UV transmittance than industrial effluents.

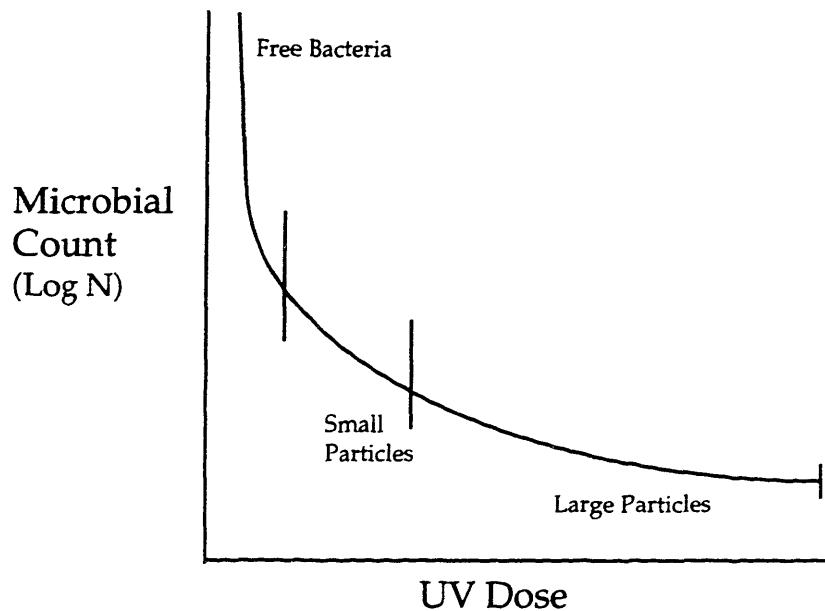
Figure 4-3: Effect of Particles on UV Disinfection<sup>20</sup>



Disinfection of wastewater must be performed to meet specific regulatory criteria which dictates the allowable concentration of organisms in the effluent discharge. Disinfection criteria differ by state, but many states utilize a fecal coliform limit of 200 organisms per 100 milliliters (ml) of water. A 4-logarithm ( $10^4$ ) reduction in fecal coliform is sufficient in most wastewater applications to meet a fecal coliform concentration of 200 organisms/100 ml. According to Trojan Technologies, Inc., the UV dose required for a 4-logarithm reduction in fecal coliform is approximately 30,000 microwatts-second per square centimeter ( $\mu\text{W}\cdot\text{s}/\text{cm}^2$ ). UV dose is typically expressed in  $\mu\text{W}\cdot\text{s}/\text{cm}^2$ , and is equal to the mathematical product of the average UV intensity in the lamp ( $\mu\text{W}/\text{cm}^2$ ) and the retention time of the flow passing through the lamp array (seconds). The cumulative dose which each element of water receives as it moves through the system determines, in part, the performance of the UV disinfection system.

The major factor in achieving good microorganism kill is the ability of the radiation to pass through the water and get to the target organism. Hence, the ability to disinfect wastewater is dependent on the number of particles in the wastewater and the particle size distribution. Figure 4-4 shows a typical relationship between the UV dose applied and the logarithm of the surviving microbial. The dose-response in wastewater relating to organisms inactivated is linear at first, but as dosage increases, the dose-response curve tails off before eventually assuming a slope of zero. This is a result of the presence of particles and microbes within the interior of a particle being shielded from some of the UV light by the outer layers of the particle (depicted in Figure 4-3). Consequently, large numbers of larger particles will make an effluent less disinfectable than small numbers of larger particles.

Figure 4-4: UV Dose-Response Curve<sup>21</sup>



The larger particles are the greatest challenge to UV disinfection, and, actually, any form of disinfection. Intuitively, any pretreatment prior to disinfection (e.g., clarification) which removes particles, especially the larger particles, will have a beneficial effect. Table 4-2 presents the effect of UV disinfection on various wastewater qualities.

Table 4-2: Ultraviolet Disinfectibility of Various Wastewater Qualities<sup>22</sup>

Effluent Type	Suspended Solids (mg/l)	Percent Fecal Coliform Reduction
CSO with pretreatment	78-236	>99.90
Raw sewage	100	99.99
Primary effluent	96	99.99
Physico-chemical primary effluent	14	99.96
Secondary effluent	13	99.99
Tertiary effluent	<5	>99.99

#### 4.3.2.2 Ultraviolet Treatment Systems

UV disinfection systems are currently available in two configurations, enclosed systems and open-channel systems. The earliest systems were enclosed, but open-channel systems are the predominant systems in wastewater treatment. Open channels are able to maximize the use of the entire space around the lamps, since flow enters and leaves the lamp cluster without changing direction. Typical UV treatment systems are composed of a number of UV radiation-producing lamps clustered together to form a lamp array. UV radiation lamps are shaped similarly to fluorescent lamps, and typically range in size from 36 to 58 inches long and 0.6 inches in diameter. In open-channel systems, the lamps are mounted horizontally in a channel and parallel to the flow. The water depth over the top row of lamps must be limited to prevent discharge of wastewater that is not adequately exposed to the UV light. There are three types of controls used to regulate the water level in open-channel systems: automated control valves, self-adjusting counterbalanced gates, and weirs.

In designing UV systems, the number of lamps required to disinfect the peak design flow is determined using the relationship between flow per lamp and UV dose delivered. The number of lamps required increases exponentially as the wastewater's transmittance decreases: an effluent with a UV transmittance of 50 percent can require twice as many lamps as an effluent with a transmittance of 65 percent. An extremely low transmittance can make UV disinfection too expensive or impractical. Although several different lamps are commercially available, typical UV systems use either the conventional low pressure mercury arc lamp or the higher intensity medium pressure mercury arc lamp. Approximately 85 percent of the low-pressure mercury arc lamp's output is monochromatic UV at the 253.7 nm wavelength (within the germicidal wavelength range of 200-300 nm).

Medium pressure lamps are polychromatic with emissions at all wavelengths (concentrated in select peaks, the strongest at 265 nm and then 254 nm) throughout the germicidal wavelength region. The output of medium pressure lamps is roughly 50 to 80 times higher than the output of low pressure lamps. Increased lamp UV intensity output is one factor that may allow the design of smaller treatment systems, either in terms of smaller lamp size (more compact and less complicated cleaning mechanism) or a reduction in number of lamps required. This is particularly useful for very large wastewater treatment plants which would require thousands of low intensity lamps. In addition, with medium lamp technology, the application of UV light disinfection can be extended from secondary and tertiary effluent treatment to poorer quality effluents such as primary effluents and combined sewer overflows.<sup>23</sup>

The disinfection properties of UV lamps are a function of intensity and exposure time. UV intensity dissipates with distance from a lamp, therefore, a main objective of UV system design is to have close contact between the lamps and the effluent being treated. Because it is not practical to design lamps for direct contact with the effluent, most manufacturers enclose the lamps in clear quartz sleeves. Quartz sleeves are used because they transmit approximately 90 percent of the UV radiation, and they protect the lamps from fouling by the wastewater. The sleeves themselves eventually become fouled and require periodic cleaning. Fouling is the accumulation of opaque substances, such as oil, grease, suspended solids, debris, mineral salts or biofilm, on UV lamp sleeves. These substances adsorb or block the UV light available for disinfection. Removal of some of these substances occurs by the shear forces of water flow which increase at higher flow rates. Detergents, citric acid, and phosphoric acid have been used successfully clean lamp sleeves. In smaller plants, the easiest cleaning method is wiping each lamp sleeve with a cleaning solution by hand.

#### **4.3.2.3 Ultraviolet Radiation Versus Chlorination**

Wastewater disinfection has traditionally been accomplished using some form of chlorination, mainly because it is effective at low concentrations, is inexpensive, and forms a residual. Although an effective disinfectant, concerns have risen about the safety, toxicity and byproducts of using chlorine (and related compounds) for water and wastewater disinfection, propelling increased efforts in the advancement of alternative disinfection methods, particularly UV radiation. In many European countries, chlorination of wastewater is not practiced because of the possible formation of chlorinated hydrocarbons.<sup>24</sup> In the US, the EPA is looking at the use of chlorine to determine if it should

be banned or its use be restricted. In addition to its byproducts, chlorination has recently been attacked as being ineffective in destroying certain viruses and protecting water distribution systems from biofilm growth. Attempts to overcome the limitations of chlorine disinfection by using higher chlorine doses result in the additional production of carcinogenic compounds (trihalomethanes, chloroform, etc.). Dechlorination to remove toxic residuals adds about 30 percent to the cost of chlorination.<sup>25</sup>

New regulations relating to storage and handling, specifically the Uniform Fire Code (UFC) has also added to the cost of chemical disinfection. These regulations have no impact on UV disinfection. Because the risk of leaks and spills is always present with liquid and gaseous chemicals, detailed safety procedures are required at treatment plants using chemical disinfection. The use of UV disinfection, however, eliminates the transport, storage and handling of chemicals, and does not require extensive safety equipment, special chlorine handling training, or evacuation plans. Other factors contributing to the increasing popularity of UV radiation for the disinfection of wastewater include:<sup>26</sup>

- The combined cost-effective and user-friendly nature of UV compared with chemical disinfection alternatives;
- Advances in UV technology which have overcome some of the earlier limitations of UV disinfection; and
- An increased understanding of the UV disinfection process.

Recognizing that chlorination and UV radiation represent the two most feasible disinfection alternatives for wastewater, in 1995, the Water Environment Research Foundation (WERF) released the results of a two-year study comparing UV radiation to chlorination.<sup>27</sup> The objectives of the research project were:

- To compare the efficiencies of UV radiation and chlorination using secondary effluents of varying quality;
- To assess the efficiency of UV inactivation of total and fecal coliforms;
- To investigate the effect of various water quality parameters (suspended solids, particle size, UV absorbence) on UV disinfection of secondary wastewater effluent;
- To evaluate and refine existing UV disinfection models for predicting performance and aiding in design of full-scale UV systems; and

- To compare the economic feasibility of UV radiation to chlorination/dechlorination.

One of the outcomes of the WERF report was a broad-based discussion of the advantages and disadvantages of the use of chlorine and UV radiation for disinfection. A summary of some of the advantages and disadvantages of both treatment methods is presented in Table 4-3.

Table 4-3: Advantages and Disadvantages of Chlorine and UV Disinfection<sup>28</sup>

<b>Chlorine Disinfection</b>	
Advantages	<ul style="list-style-type: none"> <li>• Well-established technology</li> <li>• Effective disinfectant</li> <li>• Chlorine residual can be maintained</li> <li>• Combined chlorine residual can also be provided by adding ammonia</li> <li>• Germicidal chlorine residual can be maintained in long distribution lines</li> <li>• Traditionally inexpensive (requirements of UFC increase costs significantly)</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>• Residual toxicity of treated effluent must be reduced through dechlorination</li> <li>• Formation of trihalomethanes and other chlorinated hydrocarbons</li> <li>• Stringent safety regulations, including the new UFCs</li> <li>• Total dissolved solids level of treated effluent increases</li> <li>• Chloride content of the wastewater increases</li> <li>• Release of volatile organic compounds from chlorine contact basins</li> <li>• Chemical scrubbing facilities may be required to meet UFC regulations</li> <li>• Acid generation--pH of the effluent can be reduced if alkalinity is insufficient</li> </ul>
<b>Ultraviolet Radiation Disinfection</b>	
Advantages	<ul style="list-style-type: none"> <li>• Effective disinfectant</li> <li>• No residual toxicity</li> <li>• In some cases, more effective than chlorine in inactivating most viruses and spores</li> <li>• Fewer safety concerns</li> <li>• Usually requires less space than chlorine disinfection</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>• No immediate measure of whether disinfection was successful</li> <li>• No residual effect</li> <li>• Relatively expensive (cost is decreasing with improved technology)</li> </ul>

As existing chlorine disinfection facilities reach their useful life, the option of replacing them with UV systems is becoming a likely alternative. However, because the quality of wastewater and the level types of treatment processes differ at every treatment facility, each situation must be evaluated separately.

### **4.3.3 Case Study: Trojan Technologies, Inc.<sup>29</sup>**

#### **4.3.3.1 Company Background**

One company that has been a major contributor to the growth and development of UV disinfection technology is Trojan Technologies, Inc. (Trojan). Founded in 1976 in London, Ontario, Canada, Trojan's core business is the design, manufacture, and sale of UV-based technologies to global wastewater and clean water markets. In fiscal year 1996, combined wastewater product sales accounted for 90 percent of Trojan's total sales, with clean water products contributing the remaining 10 percent. The company introduced the first open-channel horizontal lamp UV system in 1982, and has since grown to provide UV disinfection equipment and systems in Australia, Canada, Europe, the Far East, Latin America, the Middle East, New Zealand, and the US.

Trojan is a full-service UV technology company, conducting research into commercial applications for UV technology, designing products that use this technology, and manufacturing and distributing UV disinfection equipment and systems. The company markets its products in most, if not all, of the water/wastewater market segments, including:

- Wastewater disinfection;
- Industrial process water disinfection;
- Drinking water disinfection;
- Residential disinfection;
- Recreational waters disinfection; and
- Specialized applications.

UV disinfection equipment and systems are sold primarily through indirect distribution channels, with a network of over 90 manufacturers representatives. Currently, over 1,400 Trojan municipal wastewater UV disinfection systems are in operation worldwide, with sizes ranging from 25,000 gallons per day to 212 mgd. The company went public on the Toronto Stock Exchange in October 1993.

#### **4.3.3.2 History of Technology and Product Development**

Trojan's research and product development strategy for its UV disinfection technologies has been to follow two distinct but related paths. The first has been to develop and improve upon the efficiency, reliability and cost of conventional UV systems (those using low intensity technology). The second has been to continuously improve upon its understanding of the wastewater quality parameters which impact the UV disinfectability of different effluent types and do not allow the use of conventional UV systems, and then to develop unique treatment systems which address these parameters.

In 1980, Trojan pioneered and subsequently patented the Trojan System UV2000™ which is a completely modular system for open channel applications. The UV2000™ system, introduced into market in 1982, is an open channel disinfection system which uses low intensity UV lamps with primary energy discharges at the germicidal wavelength of 253.7 nm. The lamp array is installed below the water line while hot cathode instant start lamps inside a mechanically sealed housing isolates each individual lamp in the array. As its first product developed for water and wastewater, Trojan's UV2000™ system became widely used within the UV disinfection industry.

During the 1980's, Trojan continued to develop and refine the concept of open channel UV disinfection systems. Building on the modular system concept, Trojan introduced the UV3000™ system in 1991 after three years of research and development. The UV3000™ system employs the same lamp orientation and modular design, but began a new generation of solid state, computer controlled UV systems. Some of the advances made in the UV3000™ system over the UV2000™ system include:

- Electronic ballasts (as opposed to electromagnetic ballasts) for increased power efficiency;
- Integrated solid-state circuitry to allow for greater monitoring capability;
- Programmable controls to simplify operation and enhance performance;
- A compact weatherproof system control system; and
- No large ballast panels and interconnecting cables to the UV modules.

The UV3000™ was Trojan's first system to incorporate an electronic ballast as opposed to an electromagnetic ballast. Electronic ballasts had existed for many years but had not been modified to power the slim UV lamps used in wastewater disinfection. The basic difference

between the two is that the electronic ballast operates at a very high frequency of 17,000 kilo-hertz (kHz) versus 60 Hz for electromagnetic ballasts. Using this high frequency requires a much smaller coil, reducing the weight of the ballast and the amount of heat generated (60 percent less heat). Since the ballast does not require air cooling, the large ballast cabinets accompanying the UV2000™ system were eliminated. Mounting the ballasts on the UV modules also eliminated the lengthy electrical cables connecting the ballasts in the cabinets to the lamps in the water, reducing the number of connections from an average of ten per lamp to three per lamp. In addition, the electronic ballasts incorporate the use of electronic controls, which provide features such as remote monitoring, individual lamp status and identification, classification of alarms into major and minor, and records of past alarms. Trojan made available the UV3000™ system to all sizes of treatment plants by developing the UV3000™ PTP system, a packaged UV treatment plant for small scale treatment applications (for flows up to approximately 10 mgd, depending on effluent quality and discharge limits).

In the spring of 1994, Trojan introduced System UV4000™, the latest in its series of open channel UV disinfection systems. This system was developed specifically for the treatment of low quality wastewater addressing the operational limitations of conventional low-intensity UV systems, particularly in treating such low-quality wastewater as primary effluent, combined sewer overflows and stormwater, and wastewater reclamation and reuse. The challenges of treating low quality wastewater with UV technology include much higher levels of suspended solids, a reduced UV transmittance (requires more UV equipment), and an increased rate of dirt accumulation on the quartz sleeves which protect the UV lamps (requires more frequent cleanings). In order to address these issues, the System UV4000™ includes high intensity output UV lamps which provide for shorter water retention times. The use of high intensity lamps reduces the total number of lamps required, resulting in reduced space requirements and decreased installation costs. In addition, the system includes an in situ automatic cleaning system which can be activated manually or automatically to clean the quartz sleeves containing the UV lamps. This cleaning is accomplished by a combination of mechanical and chemical processes that remove the deposits which build up on the sleeves. The complete cleaning process takes place while the UV equipment is in its normal operating position so that the disinfection process does not need to be interrupted.

Trojan's research and development group was instrumental in the development of an electronic ballast for high intensity UV lamps (the electronic ballasts used in the UV3000™

systems are with low intensity lamps). The first commercial version was introduced into the System UV4000™ product line in 1996. The electronic ballast for high intensity lamps provides significant advantages over the conventional electromagnetic ballast, such as control over lamp intensity which can be adjusted to match the changing UV demand and flow rates of the particular wastewater.

Together, the Trojan UV3000™ and UV4000™ systems provide UV disinfection for a broad range of wastewater qualities. In an effort to provide UV disinfection equipment to all areas of water and wastewater treatment, Trojan developed a number of UV systems using similar UV technologies. Table 4-4 provides a list and description of the additional UV disinfection systems manufactured by Trojan.

Table 4-4: Specialized UV Disinfection Systems Manufactured by Trojan Technologies, Inc.

Disinfection System	Application
UV6000™ UV7000™	Low intensity UV lamps for disinfection of drinking water and industrial process water
UV8000™	High intensity UV lamps for disinfection of drinking water and industrial process water
Aqua UV 700™ Series	Residential water disinfection for treated or untreated water sources
Trojan Beachcomber	Disinfection of recreational waters

Trojan is currently developing Advanced Oxidation (AO) processes and technologies for the treatment of toxic wastes from liquid waste streams. This process is in the pilot-scale stage with collaborative research being conducted with several universities. The first commercial installation of the AO process is expected during 1997.

#### 4.3.3.3 Market Performance<sup>30</sup>

As stated in a 1995 UV industry market survey report published by Future Technology Surveys, Inc., the current marketshare leaders in the UV disinfection industry are Trojan, Fisher-Porter/Elsag Bailey (Toronto, Ontario, Canada) and Infilco-Degremont, Inc. (Richmond, Virginia, US).<sup>31</sup> The recent success of Trojan's UV systems and technologies, and evidence of the increased acceptance of UV technology as an effective disinfection process in general, is demonstrated in the pages of Trojan's most recent annual report, dated August 31, 1996. The annual report states record revenues for the company of \$26.5 million--60 percent growth over the previous year, and a net income of \$2.4 million which is

a 240 percent growth over the previous year. Total System UV4000™ sales increased to \$13.8 million from \$2.5 million for the previous year. Total export sales beyond the North American market exceeded \$5.6 million compared with \$2.1 million for fiscal 1995. First-time municipal UV system sales were negotiated in four new countries. Today, more than 70,000 Trojan UV systems are in operation around the world. Trojan is in the process of expanding its main facilities (London, Ontario, Canada) to handle expected future growth. The addition will almost double the existing total floor space, and includes tripling the size of the manufacturing area dedicated to production of the UV4000™ product line. This is understandable when realizing that the UV4000™ system accounted for 52 percent of the total revenues for Trojan in fiscal year 1996.

UV disinfection technology for wastewater treatment has come a long way over the past several decades, particularly in this decade, and the market leaders in the industry have been instrumental in the advancement of this technology. At the present time, there are approximately a dozen wastewater plants in North America that use medium pressure lamp technology for disinfection. By the end of 1996, this number will more than triple.(#) With demand for UV disinfection systems increasing, there is significant competition amongst the major market leaders, however, strong barriers exist to the entrance of new competitors into the UV equipment market. Through their widespread operations and technological knowledge base, Trojan and the other market leaders can provide economies of scale to their customers--a large hurdle to overcome when entering the UV disinfection market. In addition, the high capital costs associated with developing, manufacturing and servicing UV disinfection systems strengthens the entry barriers to the market. In fact, the number of manufacturers in North America for UV disinfection equipment and systems is expected to increase from 10 to only 15 over the next five years.<sup>32</sup> Although the number of participants in the UV disinfection market may not substantially increase, with the concern over the effects of chlorination and new safety regulations for building codes, as well as major advancements in UV technology, the market for UV disinfection systems should continue to experience significant growth.

#### **4.4 Sludge Processing by Infrared Drying**

One of the major objectives of wastewater treatment is the removal of solids from the wastewater. These solids are generally referred to as sludge (also called biosolids), and

require various degrees of treatment before being disposed. Due to extensive regulations and restrictions in the US regarding sludge handling and disposal, sludge processing can account for 25 to 50 percent of the total capital cost of a wastewater treatment plant, and about 50 percent of the operating cost. Sludge processing is one of the most difficult aspects of wastewater management because: 1) the sludge contains much of the material that was offensive in the raw wastewater; 2) wastewater sludge is organic and biological and will decay, and 3) only a small percentage of sludge is solid matter--raw sludge has a solids content of only two to six percent. What is sometimes overlooked is that water and wastewater treatment does not actually treat water in terms of destroying undesirable constituents, rather it merely removes these constituents from the water and concentrates them into another media which needs treatment--sludge.

With increasing regulatory standards for effluent quality, increasing quantities of sludge are being generated. In addition to being considered a potential threat to the environment, however, sludge is also a potential resource that can be utilized. Current efforts in sludge processing are focusing on the volume reduction and beneficial reuse of sludge to reduce the cost of disposal and to meet stricter regulations. One emerging technology in the area of sludge processing is sludge drying through the use of infrared radiation. Infrared drying is expected to reduce treatment plant operating costs by reducing the volume of sludge that must be disposed of, but it also produces a dried material which can be used as a soil amendment or fuel supplement. This section provides a detailed analysis of the infrared sludge drying process currently being developed by Infrared Drying Technologies, LLC. A description of the different processes for treating sludge, and the treatment systems available to perform each process is presented as a basis for the analysis.

#### Technology: Infrared Sludge Drying

Origin	Application	Stage of Development				
		Lab Research	Pilot Scale	Bench Scale	Full Scale	Extensive Use
New technology	Sludge Processing			X	X	
Existing technology						
Technology from other industry						

#### 4.4.1 Purpose and Methods of Sludge Processing

In wastewater treatment plants, sludges are produced that eventually require disposal. In conventional wastewater treatment plants, the sludges are mostly organic in nature, such as primary settlement sludge or waste activated sludge. In advanced wastewater treatment, however, the sludges are mainly of a chemical nature because they often result from coagulation or precipitation. The quantity of sludge that must be processed and ultimately disposed of depends on the characteristics of the raw wastewater, the required effluent quality, and the treatment methods that are used in treating the wastewater. These factors also influence the type of sludge produced from treatment of the wastewater. Table 4-5 summarizes the types and characteristics of typical sludges encountered in wastewater treatment.

Table 4-5: Common Wastewater Sludges<sup>33</sup>

Sludge Type	Percent Solids	Characteristics	Source(s)
Primary	2.5-5.0	Very strong odor, does not drain well, can be dewatered mechanically	Primary settling
Secondary	0.5-1.5	Little odor, fluffy, difficult to dewater, very active biologically	Secondary settling
Mixed Primary and Secondary (digested)	6-8	Musty, produces gas, some difficulty in dewatering	Aerobic and anaerobic digesters
Chemical	0.5-1.5	Odorless, very difficult to dewater, biologically inactive	Advanced treatment of secondary effluent

The degree of sludge processing can range from very simple methods such as dewatering for reducing the volume of sludge, to highly complex methods such as the total destruction of all organic matter by incineration. Treatment facilities have the option of using different sludge processing and disposal methods and combinations thereof, depending on their specific treatment objectives. In general, the larger the treatment plant, the more complex the sludge processing system. The operations and treatment systems available for sludge processing can be classified under the following categories:

- Thickening;
- Dewatering;

- Conditioning;
- Stabilization;
- Heat drying;
- Incineration; and
- Land treatment.

Ultimate disposal of solids produced from sludge dewatering or the ash from incineration is usually in regulated sanitary landfills. Digested stabilized sludge may be spread on agricultural land serving as both a fertilizer and a soil conditioner. Heat-dried sludge is commonly sold as a fertilizer. A description of the various technical operations and processes associated with each of the above categories of sludge treatment is presented below.

#### **4.4.1.1 Thickening**

Thickening consists of increasing the solids content of a sludge, thereby reducing the volume of sludge to be processed by subsequent units. Thickening achieves considerable sludge volume reduction. For example, if a sludge having 1 percent solids is thickened to 2 percent solids, the volume is reduced by 50 percent. Thickening is the concentration of solids to less than 15 percent, whereas dewatering concentrates sludge solids to greater than 15 percent. The following systems are the two most common methods of sludge thickening.

##### **Gravity Thickening**

Gravity thickening is the most common thickening method. A gravity thickener takes advantage of the difference in specific gravity between the sludge solids and water, and is very similar in design to circular clarifiers except that the floor has a much greater slope. The feed sludge entering in the middle of the unit is distributed radially, and the sludge solids are collected as underflow in a sludge sump where they are removed. Agitation caused by scrapers at the bottom of the unit releases entrained water from within the sludge.

##### **Dissolved Air Flotation**

Thickening using dissolved air flotation may be used whenever the specific gravity of the solids is near that of water (1.0). Flotation uses the formation of air bubbles on the solid particles to buoy them to the surface, where they are skimmed from the flotation tank. The air is introduced under pressure to recycled effluent, which is then mixed with the incoming

sludge and pumped into the flotation tank. The release in pressure forces the excess air gases to come out of solution in the form of bubbles, which attach to the sludge solids and bring them to the surface. Flotation aids, such as polymers, are frequently used to increase performance.

#### **4.4.1.2 Dewatering**

Dewatering consists of removing as much water from a sludge as possible so that the dewatered sludge volume to be processed or disposed is minimized. Dewatered sludge behaves as a solid. Common dewatering methods include sludge drying beds, vacuum filters, pressure filters, belt presses and centrifuges.

##### **Sludge Drying Beds**

Sludge drying beds are used to dewater sludge by both drainage from the sludge mass and evaporation of water to the atmosphere. The drying bed is constructed with a bottom-sloped drainage layer, consisting of a layer of sand over gravel. Underdrain piping beneath the drainage layer collects the sludge drainage, which is returned to the treatment system. Sludge is placed on top of the beds, usually in an 8- to 12-inch layer, and may dewater sufficiently for removal after about 2 to 4 weeks in dry weather. Only digested sludges may be dewatered on drying beds because fresh sludges will decompose anaerobically and create severe odor problems.

##### **Vacuum Filters**

Vacuum filters are used to dewater sludges so that the sludge has the proper physical characteristics for subsequent processing. Vacuum filtration is performed with rotary vacuum filters. The rotary vacuum filter consists of a cylindrical drum covered with a filter medium, such as cloth or fine wire mesh. The drum rotates partially submerged in a vat of the sludge, and a vacuum within the drum draws liquid from the sludge, forming a cake on the filter of partially dewatered sludge. As the drum rotates, the cake emerges from the liquid sludge pool while suction is still maintained to promote further dewatering. A scraper mechanism located at the bottom end of the rotation removes the caked sludge from the drum.

##### **Pressure Filters**

Pressure filtration is a batch process which produces a sludge cake of low moisture content. The pressure filter consists of numerous vertical filter plates mounted on a horizontal shaft.

The plates have recesses covered with filter cloth and drain holes for the discharge of fluid. Sludge is pumped under pressure into the space between the plates and the plates are then pressed together with either a mechanical screw-type ram or a hydraulic ram. The filtrate passes through the filter cloth into the drain holes while the solids are retained and form a cake on the surface of the cloth. The press is then opened, allowing the cake to fall from the press onto a conveyor or into a trailer. The filter press is one of the most successful dewatering methods used to dewater waste activated sludges.

### Belt Presses

Belt presses consist of two converging belts mounted on rollers. The lower belt is made of fine wire mesh which is very porous. The upper belt is an impermeable press belt that runs at the same speed and in the same direction as the lower belt. As the liquid sludge moves onto the belt, some of the water drains through the lower belt in a gravity drain zone. As the two belts converge, the pressure provided by the belts and rollers causes dewatering. A shear zone follows where the belts travel in an S-shaped curve to facilitate further dewatering. The dewatered sludge cake is then removed by a scraper mechanism. The belt press has low energy requirements and does not require a vacuum or pressure pump.

### Centrifugation

Dewatering by centrifuges can be defined as a sedimentation process that uses centrifugal forces greater than the ordinary forces of gravity. The main type of centrifuge that has been successfully used in dewatering wastewater sludges is the solid bowl centrifuge. The solid bowl centrifuge consists of a bowl and a scroll conveyor joined through a gear system which is designed to rotate the bowl and the conveyor at slightly different speeds. Liquid sludge enters the system through the hollow shaft of the rotating bowl and is slung outward from the shaft and, as a result of the centrifugal force, solids collect on the inner wall of the bowl. The scroll conveyor, spinning at a slightly slower speed than the bowl, moves the collected solids down to the end of the bowl where the sludge cake is discharged.

#### **4.4.1.3 Conditioning**

The purpose of sludge conditioning is usually to increase the efficiency of dewatering or thickening. Three methods of sludge conditioning are chemical treatment, elutriation and heat treatment.

### Chemical Treatment

The addition of chemical conditioners to a sludge causes coagulation and aggregation of the sludge solids, which releases the entrained water. Both organic polymers (polyelectrolytes) and inorganic coagulants have been used for conditioning, however, organic polymers are used more often because of their effectiveness. The coagulation of the sludge particles occurs mainly as a result of the reaction between the polymer and the sludge particles.

### Elutriation

Elutriation is the washing of a sludge with water to remove specific constituents that would interfere with subsequent dewatering operations. It is commonly used following anaerobic digestion. The potential problem with elutriation is that a large amount of fine solids may be returned with the wash water, and the solids could build up in the treatment plant, causing operational problems. The process also tends to remove nitrogen from the sludge, making it less valuable as a fertilizer.

### Heat Treatment

Heat applied to sludge aids in the separation of solids and liquids, and is often used to condition waste activated sludges. The sludge solids are mainly microbial cells that contain significant amounts of water. The heat, usually applied through steam injection, causes the cells to rupture, releasing the water bound in the cell. A problem with heat treatment is the concentrated effluent produced from the operation which can result in additional biological load on the treatment plant.

#### **4.4.1.4 Stabilization**

Stabilization consists of treating the sludge so that future decomposition by biological action does not occur. It results in a sludge that will not undergo bacterial decomposition, has good dewatering characteristics, and has very little odor. With municipal sludges, it also results in a low pathogen content. Anaerobic and aerobic sludge digestion are the main processes for sludge stabilization and are used for stabilizing high-strength wastewater. Composting, chemical (lime) treatment, and lagoons are additional methods to stabilize sludge.

### Anaerobic Digestion

Anaerobic digestion, the most common sludge treatment, is the biological oxidation of degradable organic sludges by microbes under anaerobic conditions. Anaerobic digestion

utilizes microbes that thrive in an environment free of oxygen and where there is a substantial amount of organic matter. The microbes convert the organic material into oxidized materials, new cells, energy for oxidation, and gaseous products such as methane and carbon dioxide. One benefit of anaerobic digestion is the production of methane gas which is a usable by-product. A brief description of four types of anaerobic digesters is presented below.

1. *Low-rate Digesters:* Low-rate or conventional digesters are circular concrete or steel tank structures with a conical shaped bottom and either floating or fixed covers. These digesters have intermittent mixing, intermittent sludge feeding, and intermittent sludge withdrawal. When mixing is not being performed, the contents are stratified in the following layers (from top to bottom): gas, scum, supernatant (the liquid released during digestion), digesting sludge, and digested sludge.
2. *High-rate Digesters:* High-rate digesters usually have fixed covers, employ continuous mixing, and continuous or intermittent sludge feeding and withdrawal. The digester structure is the same as conventional digesters. The contents of these digesters are in a homogenous state, therefore the entire digester volume is available for digesting sludge. This allows the digester to operate at organic loadings much greater than for conventional digesters, and the detention times are much shorter. Sludge mixing within the digester may be provided by recycling gas or by mechanical mixing.
3. *Two-stage Digesters:* A two-stage digester utilizes two separate vessels, where the first tank is used for digestion and the second tank is used for supernatant separation, gas storage, and digested sludge storage. The first stage is usually a high-rate digester with a fixed cover, whereas the second stage is usually a conventional digester with a floating cover.
4. *Egg-shaped Digesters:* Egg-shaped digesters are high-rate digesters with a shape that resembles an egg standing vertically on its end. These digesters use an external recycle pump or other means for mixing the contents. The advantages over cylindrical tanks include:
  - Better mixing;
  - Better control of scum at the top of the digester;

- Virtually no grit accumulation due to the steeply-sloped sides; and
- Smaller land requirements.

The disadvantages of these digesters compared to cylindrical ones are that they are more expensive and their height restricts their usage.

### Aerobic Digestion

Aerobic digestion is the biological oxidation of organic sludges under aerobic conditions, and it closely resembles the activated sludge process. Major objectives of aerobic digestion include odor reduction, reduction of biodegradable solids and improved sludge dewatering. Aerobic bacteria stabilize the sludge more rapidly than anaerobic bacteria, although the breakdown of cells is usually less complete. The tanks or basins used for aerobic digestion are similar to those used for the activated sludge process, and both diffused compressed air and mechanical aeration are used. Aerobic digesters usually require a thickener either upstream or downstream from the digester. One advantage of aerobic over anaerobic digestion is that it is not as sensitive to environmental factors (pH, temperature, toxic substances, nutrient concentrations) as anaerobic digestion, and therefore has fewer operational problems.

### Composting

The composting of thickened and dewatered undigested sludges has been applied to a limited extent in the United States. The sludge is usually mixed with organic solid wastes, such as sawdust, straw, peat, tree and lawn trimmings, with the stabilization essentially being an aerobic process. Continuous agitation of the sludge must be performed to provide sufficient aeration for the aerobic process. Compost material can be used as a low-grade fertilizer and soil conditioner for agricultural applications. The lack of use is primarily due to the lack of demand for the compost product.

### Chemical Stabilization

Lime has been used to stabilize primary and secondary sludges, temporarily preventing odors. The addition of lime in quantities to maintain a high pH stabilizes sludge for land application and provides high bacterial reduction, however it produces essentially no organic destruction. It has been found that lime-stabilized sludges disposed in lagoons have a gradual pH reduction and a gradual increase in biological action. Therefore, lime treatment is often considered a temporary sludge stabilization method.

### Lagoons

The use of lagoons for the digestion and stabilization of sludges has been limited. Stabilization lagoons are essentially ponds filled with sludge with a typical depth of three to five feet. Sludge solids settle to the bottom, where it undergoes anaerobic digestion. The top portion of the water depth remains aerobic, which prevents odors. If organic loadings are too great, anaerobic conditions will occur throughout the water depth, producing odors. Sludge lagoons are limited to warm climates that have high sunlight intensities and inexpensive available land.

#### **4.4.1.5 Heat Drying**

Sludge heat drying produces a dry product and is used when fresh sludge is to be processed to produce a fertilizer. The cost of drying sludge is rather high. Fuel must be employed in all the drying methods, which adds considerably to operational costs. Traditionally, heat drying is accomplished by flash drying, kiln drying or multiple-hearth furnaces. In flash drying, the fresh sludge is mixed with some previously dried sludge, and then the mixture is dried by a stream of hot combustion gases from a fuel-fired furnace. In the kiln dryer, the fresh sludge moves through a rotating kiln against a current of hot combustion gases that dry the material. In the multiple-hearth furnace, the sludge is dried as it passes downward through the hearths at about 700 to 900 degrees Fahrenheit. Infrared sludge drying, which is discussed in detail in subsequent section, is an emerging technology which dries the sludge using infrared radiation instead of hot combustion gases.

#### **4.4.1.6 Incineration**

Incineration consists of the complete combustion of a sludge to produce an inert ash, which is usually disposed of in a landfill. Incineration is often preceded by dewatering so that the sludge will sustain combustion during incineration. The two types of incinerators used for sludge processing are the multiple-hearth incinerator and the fluidized-bed incinerator.

#### Multiple-Hearth Incinerator

This incinerator consists of a furnace with several hearths of varying temperatures. The sludge moves downward through hearths which vaporize the water, and then ignite and burn the sludge solids to produce the ash at the bottom of the incinerator.

### Fluidized-Bed Incinerator

This incinerator consists of a combustion reactor containing a bed of sand above a grid. Fluidizing air is passed upward through the bed to suspend the sand and heat it to sufficient temperatures (around 1500 degrees Fahrenheit). Sludge is fed into the incinerator where the water is vaporized and the sludge solids are burned in the fluidized sand bed.

#### **4.4.1.7 Land Treatment**

Depending on its quality, wastewater sludge can be a beneficial resource. Sludge applied to land receives treatment by several mechanisms. Organisms in the soil use biodegradable material in the sludge as a food and energy source. Natural drying, exposure to ultraviolet radiation in sunlight, adsorption in the soil, and nutrient use by vegetation are other ways in which the sludge is treated. The most common form of land treatment is the agricultural use of sludge as a fertilizer and soil amendment. Application of sludge to unproductive or disturbed land assists in reclamation of vegetation. Factors to consider when evaluating the use of land treatment include the chemical, biological and physical characteristics of the sludge; federal, state and local regulations; and the estimation of land area required.

#### **4.4.2 Infrared Sludge Drying<sup>34</sup>**

As discussed earlier, sludge drying is performed to produce a dry product which can be subsequently used as a fertilizer and soil conditioner. An emerging technology, infrared sludge drying differs from typical heat drying methods (flash drying, kiln drying, multiple-hearth furnace) in that it uses radiation heating which does not require the presence of a medium (solid, liquid or gas) to transmit energy to the sludge. This eliminates the heat losses associated with other heating methods and results in faster and more efficient heating. The infrared sludge dryer produced by Infrared Drying Technologies, LLC (IDT) has been proven to process dewatered sludge to meet the Class A requirements of Part 503 of the US Code of Federal Regulations for pathogen and vector attraction reduction, which allows for the beneficial reuse of the sludge. This section provides the theoretical basis of infrared radiation heating, and a detailed analysis of IDT's recent efforts for developing and marketing its infrared sludge drying system.

#### 4.4.2.1 Theory of Infrared Radiation and Radiant Heat Transfer

Radiation is the process by which energy is transmitted through space in the form of electromagnetic waves. Heat is the result of the absorption of this radiant energy by the receiving object. The electromagnetic spectrum is the term used to denote the whole range of known radiations, including gamma rays, x-rays, ultraviolet, visible, infrared, microwaves and radio waves. All radiation, regardless of its wavelength, travels through space at the speed of light (182,000 miles per second). The infrared portion of the spectrum includes those wavelengths which will produce heat upon being absorbed by an object. In fact, infrared radiation was discovered due to its thermal effect, and was therefore originally called "heat radiation"--although any radiation, if absorbed by matter, exhibits a thermal effect. Although it is located beyond the visible spectrum, infrared radiation is essentially identical to visible light in terms of its characteristics--it travels in straight lines, is reflectable and refractable, exhibits interference, and can travel through a vacuum.

The elementary sources of infrared radiation are the atoms and the movements (vibrations) of the molecules of the substance which is producing the radiation. All materials are made up of atoms in motion. Atoms contain positively and negatively charged particles which create an electrical field, and the movement of these charged particles generates a magnetic field. As charged particles within an atom move and cause the atom to vibrate, the electric and magnetic fields created by the charged particles are disturbed. This disturbance in the electric and magnetic fields is called an electromagnetic wave. Because they contain atoms in rapid vibrational motion, hot objects radiate electromagnetic waves which, when absorbed by an object, cause that object to heat up. This is the principle of radiant heating--that energy is transferred from a hot object to an object of lower temperature in the form of electromagnetic waves. Based on the characteristics of electromagnetic waves, the energy (heat) transfer is accomplished without physical contact and without a medium in between the source and the receiving object.

Theoretically, every body with a temperature exceeding zero degrees Kelvin (absolute zero--where there is no vibrational motion of atoms) is a thermal source of radiation. For technological applications, infrared radiation can be produced by two types of sources: heat sources and luminescent sources, the former being applicable to sludge drying. With heat sources, such as the heating elements used in electric ovens, infrared radiation is emitted due to the increased temperature of the source.

#### **4.4.2.2 Heating Through Infrared Radiation Versus Convection**

Heat can be transferred from a warmer object to a cooler object in three different ways: conduction, convection or radiation. Although an integral part of heat transfer theory, conduction, in which the source of radiation is in direct contact with the object being heated, is not applicable to sludge heat drying. With convection, thermal energy is not transferred directly from the source but through a gas or liquid medium. This constitutes a double heat transfer: thermal energy is transferred from the source to the heating medium, and then from the medium to the object being heated. With radiation heat transfer, thermal energy from the source is converted into electromagnetic radiation which travels through the medium and is absorbed by the object, where it is then transformed back into thermal energy. Radiant heat transfer can take place even if the source and the heat receiving object are separated by a vacuum. The advantages of heating by infrared radiation over convection heating include:

- The efficiency of energy transfer by radiation compared with the transfer by convection increases rapidly for large differences in temperature between the source and the object being heated.
- With radiation heating, the temperature of the object being heated increases rapidly as soon as the source of radiation is activated. Convection heating, however, requires a certain amount of time to heat the transfer medium (liquid or gas) between the source and object being heated. Other objects in the system, such as furnace walls, also absorb heat energy which adds to convection heating time. The larger the volume of the transfer medium, the longer it will take to heat the medium.
- With radiation heating, it is possible to concentrate the radiation on the object being heated through the use of mirrors and other reflective surfaces. This results in almost no energy loss to heating the environment around the object.

Sludge heating through convection of heated air has the disadvantage of requiring a significant air flow rate with some amount of heat loss. In addition, heating large volumes of sludge through convection with high air flow rates requires air emission treatment systems capable of handling large exhaust air volumes. Radiation heating only requires an air flow rate to remove volatile vapors and moisture, reducing both the size of the air emission system and the amount of energy lost in the exhaust air. By eliminating the heat transfer

medium, radiant heating also eliminates the heat and energy losses associated with the other heating methods. Radiant heating, therefore, is the most efficient heating process.

#### **4.4.3 Case Study: Infrared Drying Technologies, LLC<sup>35</sup>**

##### **4.4.3.1 Company Background**

Infrared Drying Technologies LLC (IDT), founded in 1990 under the name of Sludge Drying Systems, Inc., has applied the theories of infrared radiant heat to the sludge processing industry with its patented Series "IR" Infrared Sludge Dryers. The development of the company and its infrared sludge drying technology was based on research work that one of the IDT founders was working on regarding the comparison of continuous run versus batch drying processes using microwaves. As mentioned earlier, microwaves are part of the electromagnetic spectrum and follow the infrared band in terms of increasing radiation wavelengths. Based on the application of microwave and infrared technology for material heating purposes, IDT then developed its sludge dryer mainly in response to the ongoing development and eventual release in 1993 of EPA's comprehensive sewage sludge regulations. The evolution of IDT's infrared sludge drying system correlated with the anticipation of a new or growing market for sludge processing technologies and equipment for treating sludge to meet these new regulations. IDT actively markets its infrared sludge dryer as being able to meet these regulatory requirements to facilitate the beneficial reuse of the sludge material.

The US EPA's Standards for the Use and Disposal of Sewage Sludge is contained in Part 503 of Section 40 of the US Code of Federal Regulations (40 CFR 503). The Part 503 regulations include standards on allowable pollutant concentration limits for 10 pollutants in sludge, and pathogen destruction and vector attraction reduction requirements. Vector attraction is the characteristic of sludge that attracts rodents, flies, mosquitoes, or other organisms capable of transporting infectious agents. Part 503 creates incentives for municipalities to produce high quality sludges by drastically reducing the management practice requirements for utilization of those sludges. High quality sludge must meet both the pollutant concentration limits and Part 503's Class A pathogen and vector attraction

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Infrared Drying Technologies LLC (IDT), founded in 1990 under the name of Sludge Drying Systems, Inc., has applied the theories of infrared radiant heat to the sludge processing industry with its patented Series "IR" Infrared Sludge Dryers. The development of the company and its infrared sludge drying technology was based on research work that one of the IDT founders was working on regarding the comparison of continuous run versus batch drying processes using microwaves. As mentioned earlier, microwaves are part of the electromagnetic spectrum and follow the infrared band in terms of increasing radiation wavelengths. Based on the application of microwave and infrared technology for material heating purposes, IDT then developed its sludge dryer mainly in response to the ongoing development and eventual release in 1993 of EPA's comprehensive sewage sludge regulations. The evolution of IDT's infrared sludge drying system correlated with the anticipation of a new or growing market for sludge processing technologies and equipment for treating sludge to meet these new regulations. IDT actively markets its infrared sludge dryer as being able to meet these regulatory requirements to facilitate the beneficial reuse of the sludge material.

The US EPA's Standards for the Use and Disposal of Sewage Sludge is contained in Part 503 of Section 40 of the US Code of Federal Regulations (40 CFR 503). The Part 503 regulations include standards on allowable pollutant concentration limits for 10 pollutants in sludge, and pathogen destruction and vector attraction reduction requirements. Vector attraction is the characteristic of sludge that attracts rodents, flies, mosquitoes, or other organisms capable of transporting infectious agents. Part 503 creates incentives for municipalities to produce high quality sludges by drastically reducing the management practice requirements for utilization of those sludges. High quality sludge must meet both the pollutant concentration limits and Part 503's Class A pathogen and vector attraction

requirements. There are two classes of pathogen requirements—A and B. Class A sludge can unrestrictively be applied to the land or a surface disposal site, whereas the use of Class B sludge contains site restrictions depending on the potential exposure of the public to the land. IDT's infrared sludge drying process produces a sludge which meets the Class A requirements and can be reused as a soil amendment or fuel supplement. In addition, the infrared dryer does not require the addition of lime, ash or other bulking materials often required with traditional drying methods, and reduces the sludge volume by up to 80 percent—greatly reducing transportation and disposal costs.

#### **4.4.3.2 Description of the Series "IR" Infrared Sludge Dryer**

The Series "IR" Infrared Sludge Dryer (the dryer) consists of a primary drying zone and a secondary drying zone. The primary drying zone is located above the secondary drying zone, with both zone enclosures being constructed of carbon steel. Both drying zones contain a varying number of 12-inch diameter augers used to agitate and convey the sludge through each drying zone. Dewatered sludge is conveyed from dewatering equipment (used prior to drying) to the dryer on a conveyor belt. A hopper device on top of the dryer drops the dewatered sludge into the augers located in the primary drying zone. Positioned above the entire length of the augers are infrared heating elements which produce the infrared radiation that heats and dries the sludge. These infrared heating elements are mounted on element racks equipped with stainless steel infrared element reflectors. Specially designed variably angled auger blades agitate the sludge to maximize the exposure of the sludge to the infrared radiation. In addition, infrared radiation is absorbed by the auger troughs and blades thereby creating additional heat which is transferred to the sludge through conduction. Having conveyed the length of the primary drying zone, the sludge then drops through a chute and enters the secondary drying zone—identical to the primary zone in terms of equipment and process.

The vapor generated in the dryer from the sludge drying is removed from the dryer from eight different exhaust extraction points. The vapor is processed through an air emission and odor control system consisting of an EnviroCare VenturiPak wet scrubber system with chemical feed options. The scrubber removes over 99 percent of particulate and condensable pollutants, and several odorous compounds. Additional odor control can be achieved by chemical addition. Following scrubbing and chemical treatment (as necessary), the exhaust air passes through a woven stainless steel mist eliminator before discharge.

The drier includes two features that are designed to allow for operational flexibility to facilitate drying of the sludge to the percent solids desired: 1) variable speed controlled conveyance augers, which allows for the adjustment of sludge retention time in the dryer; and 2) the dryer is divided into at least eight separate heating zones which are controlled by an automated Dryer Loop Control (DLC™—patent pending). Other dryers can control the amount of energy and heat going into the dryer, but cannot control that energy and heat within the dryer. The automated controls gives the system the ability to control the amount of energy used in each heating zone, thereby controlling the temperature of the sludge as it dries and reducing the potential for combustion of the sludge. Although IDT's dryers can be designed to operate on either natural gas or electricity, the latter energy source is the one recommended by the company, as gas systems require additional valves and pumps. In addition, the dryers incorporate a modular design whereby each dryer module can treat up to 500 pounds of wet sludge per hour. The ability to stack the modules together allows each dryer system to be custom designed to meet the size requirements at each specific installation.

#### **4.4.3.3 Current Installations and Future Outlook**

As both a young company and technological process, IDT has a limited number of installations of its Series "IR" Infrared Sludge Dryer. A complete list of IDT's full-scale installations and pilot plant testing units is presented below in Table 4-6.

A pilot study using IDT's model IR-1000 infrared sludge dryer was conducted in St. Johns County, Florida, in March of 1994.<sup>36</sup> The objective of the pilot study was to determine if infrared drying of the County's sludge was a viable option in an effort to eliminate the landfilling of the County's sludge and reduce the ultimate cost of sludge disposal. The pilot study was performed in a series of five tests over two days at the County's Anastasia wastewater treatment plant, with sludge feed concentrations ranging from 15.3 to 18.0 percent solids. The test results indicated that the infrared drying unit was consistently capable of drying the sludge to 90 percent dry solids. An economic analysis was performed to determine the total estimated cost of constructing and operating an infrared sludge drying unit at the Anastasia facility. Results of the analysis indicated a cost per dry ton of sludge treated of approximately \$540, compared to a cost of \$775 per dry ton for landfill disposal. The pilot study at St. Johns County showed that infrared drying can be a cost

effective method of sludge treatment. Table 4-7 presents some of the advantages and disadvantages of infrared sludge drying as concluded from the pilot study.

Table 4-6: IDT Infrared Sludge Dryer Installation List

<b>Full-Scale Permanent Installations</b>
University of Florida, Gainesville, Florida
Fulton County, Georgia (not yet operational; startup mid-1997)
<b>Pilot Plant Testing Installations</b>
Baton Rouge, Louisiana (Central Wastewater Treatment Plant)
Bradenton, Florida (Manatee County Southwest Wastewater Treatment Plant)
Calhoun, Georgia (Wastewater Treatment Plant)
City of Avalon, California (Santa Catalina Island)
Clear Lake, Texas (Clear Lake City Water Authority)
Fulton County, Georgia (Camp Creek Water and Pollution Control Division)
Gwinnett County, Georgia (Beaver Ruin Wastewater Treatment Plant)
Jefferson County, Alabama (Valley Creek Wastewater Treatment Plant)
Kimberly Clark (Beech Island--Pulp and Paper)
Lafayette Parish, Louisiana (Ambassador Caffery Wastewater Treatment Plant)
Lenoir, South Carolina
Ore-Ida Food, Inc., Boise, Idaho
Orlando, Florida (Iron Bridge Plant)
Rock Hill, South Carolina (Rock Hill Wastewater Treatment)
San Antonio, Texas (San Antonio Water System)
St. Augustine, Florida (St. Johns County)
St. Petersburg, Florida (Pinellas County Northwest Wastewater Treatment Plant)

Table 4-7: Advantages and Disadvantages of Infrared Sludge Drying<sup>37</sup>

<b>Advantages</b>
<ul style="list-style-type: none"> <li>Reduces the volume of sludge to be handled up to 85 percent.</li> <li>Can produce a 40 CFR 503 Class A sludge with respect to pathogens and vector attraction reduction.</li> <li>No sidestream is produced from the drying unit.</li> </ul>
<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>High electric energy costs could make the process cost prohibitive.</li> <li>System requires a higher degree of operator training and attention than traditional technologies.</li> <li>Potential for odor problems exists, therefore, the system may need odor controls.</li> <li>Better suited for long operating periods instead of start and stop operation due to warm-up period.</li> </ul>

IDT's first full-scale commercial unit was put into operation approximately two years ago at the University of Florida's three mgd wastewater treatment plant in Gainesville, Florida. A three-day demonstration test that was conducted on the installation as part of the

performance specifications indicated that the dried sludge meets the Class A sludge requirements of Part 503 for pathogen and vector attraction reduction. As with any first-time installation, however, much of the two years was spent troubleshooting small problems and modifying the system so that it operates at maximum efficiency. Used as a learning process, the problems encountered with the University of Florida installation have prompted a few changes and modifications to IDT's sludge drying system. Some of the design modifications that were made based on the operating experience at Gainesville include the following:

- *Problem:* Excessive heat generation in the unit resulted in the combustion of sludge solids, which caused deflection in the auger shaft; *Design Correction:* Zone temperature control based on the auger trough metal temperature.
- *Problem:* Varying solids content in the feed sludge produced excessive heat generation and combustion of the sludge solids; *Design Correction:* Procedures to ensure dewatering unit (prior to dryer) provides a uniform solids content, and improved zone temperature controls.
- *Problem:* Differential thermal expansion of the dryer unit and its structural bracing resulted in the shearing of the tie-down bolts and broke the end plates between the upper and lower dryer units; *Design Correction:* Expansion sleeves were installed on the end plates, and a structural/metallurgical analysis and certification of the dryer unit was performed for high temperature operation.
- *Problem:* Uneven sludge feed distribution produced a drying which was not uniform; *Design Correction:* A sludge feed header manifold was added to the unit.

The above design changes have also been incorporated in the new infrared sludge drying unit currently being installed in Fulton County, Georgia.

With the deregulation of the energy industry, IDT anticipates a reduction in electricity costs which would have a significant impact on the costs associated with its infrared drying systems. IDT's infrared sludge drying technology is being studied by the Electric Power Research Institute (EPRI) as an emerging technology for electric heat sources, and one that is expected to reduce the energy use associated with sludge processing. According to EPRI,

IDT's infrared sludge drying system is compact, easy to install and operate, and can be a competitive alternative where the cost of electricity is low (generally \$0.03 to \$0.05 per kilowatt-hour). Although EPRI does not endorse specific products or processes, it does expect future municipal and industrial applications for infrared sludge dryers.

The future of IDT's infrared sludge drying system appears to be hinged on the EPA's sludge use and disposal regulations. IDT believes that the marketplace for alternative sludge processing systems is still young, due in part to the fact that the new sludge regulations have been in place for only a few years. Currently, the EPA does not have the financial resources to enforce Part 503, and it is up to the individual states to do so if a state's sludge regulations are less stringent than Part 503. The sludge processing industry is consequently in a state of flux. Those facilities that already meet the Part 503 standards based on existing operations need only to bring their monitoring and record-keeping procedures up to standards. Other facilities that do not meet the new standards must upgrade existing sludge processing systems or construct new facilities. Engineering feasibility studies are being performed to determine the cost implications of various potential alternatives for complying with Part 503. In addition, the industry is beginning to emphasize the need to reduce the volume of sludge for ultimate disposal, which is being driven by increasing landfill disposal costs as many sanitary landfills are nearing capacity. What this means for companies like IDT is that the market for alternative sludge processing technologies and systems is still maturing but should strengthen in the next several years. IDT's strategy for technological innovation is to develop an advantage through the opportunity of timing. By developing its infrared sludge drying system with introduction of new regulations, IDT hopes to show its presence early on, and advance its technology as the sludge processing industry looks to alternative, cost-effective treatment methods.

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<sup>1</sup> Portions of technology development theory in Section 4.2 are based on concepts discussed in Porter, Michael E., Competitive Advantage: Creating and Sustaining Superior Performance, The Free Press, New York, NY, 1985; and Porter, Michael E., Competitive Strategy: Techniques for Analyzing Industries and Competitors, The Free Press, New York, NY, 1980.

<sup>2</sup> Professor Fred Moavenzadeh, George Macomber Professor of Construction, Massachusetts Institute of Technology.

<sup>3</sup> State Revolving Fund Final Report to Congress, USEPA Office of Water, EPA 430/09-91-008, October 1991.

<sup>4</sup> Source: Biomatrix Technologies Inc., Providence, RI; Lotepro Corporation, Valhalla, NY; Purac Engineering Inc., Wilmington, DE.

<sup>5</sup> Source: Technotreat Corporation, Tulsa, OK.

<sup>6</sup> Source: Glitsch Process Systems, Parsippany, NJ.

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<sup>7</sup> Source: Peat Technologies Corporation, Cook, MN.

<sup>8</sup> Source: Colvin, Richard J. and Rozich, Alan F., "The Best of Both Worlds", *Environmental Protection*, v7 n9, September 1996.

<sup>9</sup> Source: Akzo Nobel MPP Systems, Louisville, KY.

<sup>10</sup> Source: Marshall H. and Mourato D., "Membrane Technology: Are Membranes the Future for Wastewater Treatment?", *Environmental Science & Engineering*, v9 n4, September 1996.

<sup>11</sup> Source: Dickeson D. (Lantec Products, Inc.) and Yoshimura T. (Able Company Ltd.), "Compact Biofilm Reactor For Aerobic Wastewater Treatment".

<sup>12</sup> Source: Lazarova V., Duval L., Bellahcen D., and Manem J., "An Innovative Process for High Rate Nitrification", Centre of International Research for Water and Environment (CIRSEE), Lyonnaise des Eaux.

<sup>13</sup> Source: Alther G., "Wastewater Solutions: Organoclays Lead the Way to Zero Discharge", *Environmental Solutions*, v9 n8, September 1996.

<sup>14</sup> Source: Dr. Michael Modell, Senior Lecturer, Massachusetts Institute of Technology; Modell M., Mayr S., and Kemna A., Modell Environmental Corporation, "Supercritical Water Oxidation of Aqueous Wastes", The 56th Annual International Water Conference, Pittsburgh, PA, October 31, 1995.

<sup>15</sup> Miller, Richard K., Little, Laura A. and Moore, Kyra L., "UV Disinfection in Municipal Water and Wastewater", Future Technology Surveys, Inc., Market Survey Report #280, 1995.

<sup>16</sup> Cramer, James A. and Mann, Melanie A., "Disinfecting With Ultraviolet Radiation", *Water Environment & Technology*, December 1992.

<sup>17</sup> Unit Operations and Processes in Environmental Engineering, Second Edition, Reynolds, Tom D. and Richards, Paul A., PWS Publishing Company, Boston, MA, 1996.

<sup>18</sup> Ibid.

<sup>19</sup> Ibid.

<sup>20</sup> Comparison of UV Irradiation to Chlorination: Guidance for Achieving Optimal UV Performance, Executive Summary, Water Environment Research Foundation, Project 91-WWD-1, 1995.

<sup>21</sup> Cairns, William L., Sakamoto, Gail and Nowicki, Mark, "UV Technology Options for Disinfection of Wastewaters With Different Characteristics", WEF Specialty Conference: New and Emerging Environmental Technologies and Products, Toronto, Ontario, Canada, June 4-7, 1995.

<sup>22</sup> Cairns, William L., "UV Widens Range for Effluent Disinfection", *Water Management International*, 1995.

<sup>23</sup> Cairns, William L. and McKee, Jim, "New Advances in Ultraviolet Light Disinfection Technology", 1996 WEAO Technical Symposium and OPCEA Tradeshow, Toronto, Ontario, Canada, March 24-26, 1996.

<sup>24</sup> Tchobanoglous, George and Schroeder, Edward D., Water Quality: Characteristics, Modeling, Modification, Wesley Publishing Company, Reading, MA, 1985.

<sup>25</sup> Cairns, William L., "Ultraviolet Disinfection: An Alternative to Chemical Disinfection", Trojan Technologies, Inc., London, Ontario, Canada, revised September 1992.

<sup>26</sup> Cairns, William L., "UV Widens Range for Effluent Disinfection", *Water Management International*, 1995.

<sup>27</sup> Comparison of UV Irradiation to Chlorination: Guidance for Achieving Optimal UV Performance, Executive Summary, Water Environment Research Foundation, Project 91-WWD-1, 1995.

<sup>28</sup> Comparison of UV Irradiation to Chlorination: Guidance for Achieving Optimal UV Performance, Executive Summary, Water Environment Research Foundation, Project 91-WWD-1, 1995.

<sup>29</sup> Information for case study on Trojan Technologies, Inc. obtained from company literature, publications and conversations with Linda Schneider, Manager of Corporate Communications, Trojan Technologies, Inc., London, Ontario, Canada.

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<sup>30</sup> All specified dollar amounts regarding the performance of Trojan Technologies, Inc. are in US dollars, converted from original Canadian Dollar figures using an exchange rate of US\$0.7502 per Canadian Dollar as published in The Wall Street Journal, November 13, 1996.

<sup>31</sup> Miller, Richard K., Little, Laura A. and Moore, Kyra L., "UV Disinfection in Municipal Water and Wastewater", Future Technology Surveys, Inc., Market Survey Report #280, 1995.

<sup>32</sup> Ibid.

<sup>33</sup> Vesilind, P. Aarne, Treatment and Disposal of Wastewater Sludges, Ann Arbor Science Publishers Inc., Ann Arbor, MI, 1974; and Reynolds, Tom D. and Richards, Paul A., Unit Operations and Processes in Environmental Engineering, Second Edition, PWS Publishing Company, Boston, MA, 1996.

<sup>34</sup> Sources: Vasko, Antonin, Infrared Radiation, CRC Press, Cleveland, OH, 1963; and Infrared Drying Technologies, LLC, Lafayette, LA.

<sup>35</sup> Information for case study on Infrared Drying Technologies, LLC obtained from company literature, publications and conversations with James A. Martin, Vice President of Engineering, Infrared Drying Technologies, LLC, Lafayette, LA.

<sup>36</sup> Domingue, Hille and Graham, Brian J., "Pilot Testing of Infrared Drying Technology to Achieve EPA Class A Biosolids".

<sup>37</sup> Ibid.

## 5.0 Wastewater Treatment Privatization: Perceived or Real as a Driver of Industry Efficiency

### 5.1 Introduction

Privatization is the shift from government ownership to investor, or private, ownership. In the wastewater treatment industry, privatization by this definition has not widely occurred. In 1995, Franklin, Ohio became the first US city to totally sell its wastewater treatment plant to a private firm. Since then, only three more municipalities have submitted similar privatization plans to the EPA for approval. More common in the industry is the shifting of management, operation and maintenance services from a public to a private entity--the type of privatization that is the focus of this section. Local governments are realizing that their infrastructure is deficient and require modernization at costs beyond their resources. Given the economic pressures facing municipalities, privatization of public services is an attractive option, however, only ten percent of all wastewater treatment facilities in the US today are managed by the private sector.<sup>1</sup> It appears that, in addition to federal grant repayment requirements and specific tax laws, a major hurdle for privatization is that it is often driven more by political issues rather than economic considerations. One of the big social questions with regards to privatization is whether a profit-making entity (the private sector) can protect the public's interest--an issue which is characteristic of all public-service industries. The fear in wastewater treatment privatization is of losing local control of critical personal and environmental services.

Based on the recent successes and failures of privatization in the wastewater treatment industry, a successful outcome may depend heavily on having someone in a leadership position, such as a city manager or mayor, who believes strongly in the need to privatize under the expectation of cost savings. The privatization of two major wastewater treatment facilities in Indianapolis, Indiana provides an excellent example of the savings and operational efficiencies that can be realized with a city government committed to securing private services while maintaining public control. Recently, cities are also opening up wastewater privatization races to public utility contenders in so-called "managed competitions." Such competitions are pushing public wastewater utilities to redevelop their management and operational processes to run their treatment plants more like a business and allow them to compete with the private sector. The managed competition process conducted for the Irwin Creek wastewater treatment plant in Charlotte, North Carolina

demonstrates how the public sector can compete successfully with private firms and provide effective services for the lowest costs.

This section presents detailed case studies of the privatization competitions that were conducted for the Indianapolis and Charlotte wastewater treatment facilities. The section then concludes with a general discussion of the implications of privatization on technology development and the use of advanced technologies. It is believed that, whether a facility is operated by the private sector or a public utility—that is, whether efficiencies are realized through real privatization or the threat of private sector control—the industry will subsequently provide incentive for technological advancement.

## **5.2 Influence of the Private Sector on Facility Management and Operations**

The newest opportunity for the private sector in the wastewater treatment industry is with public utilities. With promises of sustained or lower user rates, the release of municipal funds and efficient management methods, wastewater firms are focusing their services on those municipalities facing aging infrastructure, shrinking budgets and increased water regulations. The increased activity of private wastewater firms in public facilities has brought about a trend of streamlining facility operations to turn wastewater treatment plants into profit-making ventures.

The private sector strives for more efficient operations by implementing methods for improving employee productivity, reducing electrical and chemical costs, reducing maintenance costs and using proven management techniques. The automation of operating systems, cross-training of employees, and use of newer, more efficient technological processes are other typical changes which add to the cost savings. Private firms often rely on attrition to trim existing staff, as opposed to the common misconception that there occurs an immediate firing of public employees. Most public entities operate under restrictive civil service and union rules regarding job classes, duties, salary and promotion. They also typically use cumbersome purchasing and accounting procedures. It is in these areas that private companies make modifications which streamline all facets of treatment facility operations—from treatment process to bill collection.

The threat of privatization has become a great motivator for public utilities to reduce work forces and implement efficient operational systems and management techniques. Although

labor unions are slow to embrace change, some wastewater operator unionists are beginning to realize that technology, budget pressures and private service firms are forcing a new era of competition. Engineering consultants are expanding into a niche market in the re-engineering of public utility business processes, which emphasizes streamlining, automation and other efficiencies to run treatment plants on a more businesslike basis—something the private firms have been perfecting over the past decade. These consultants are allowing the public utilities to develop proposals which can compete with the private sector in a managed competition process. Because they do not have to include profit, administrative costs and other private-firm overhead costs, public utility bids can be, and have been, lower than the competition's. Some private service firms indicate that they avoid cities with managed competitions, expressing fears that the "playing field" for such procurements may not be level and that in-house bidders may not have to provide the same guarantees as outside private firms.

Even for municipalities that ultimately do not go private, the success of recent privatization efforts is being used as a wake-up call to public utilities. These utilities are being forced to introduce more efficient management and operational systems in order to compete with the private sector. The biggest hurdle for public utilities is the cultural change required to develop a private-industry mind set, a change which is inherently difficult due to bureaucratic structure. A progressive political environment is a key requirement if any form of wastewater privatization, either actual private operation or an equivalent publicly-operated system, is to take place. The following two case studies—the privatization of Indianapolis, Indiana's wastewater treatment facilities, and the managed competition and public contract award in Charlotte, North Carolina—provide examples of the effects of privatization or the public use of private sector techniques on improving treatment facility operations.

### **5.3 Indianapolis, Indiana, Department of Public Works Advanced Wastewater Treatment Facilities**

In 1991, Indianapolis' Mayor Stephen Goldsmith ran on a platform of eliminating monopolies and focusing on competition. His objective was essentially to do more in government with less money. In the last five years, Indianapolis has banked or accrued into the future \$230 million in savings from over 70 privatization projects, including the high-profile privatization of its wastewater treatment facilities.<sup>2</sup> The private operation and

maintenance contract is projected to save the city \$65 million over the five-year term of the agreement while maintaining or improving wastewater effluent quality. This section presents a discussion of the changes and efficiencies that have been realized as a result of privatizing the management and operation of Indianapolis' wastewater facilities.

### **5.3.1 Facility Background and Description<sup>3</sup>**

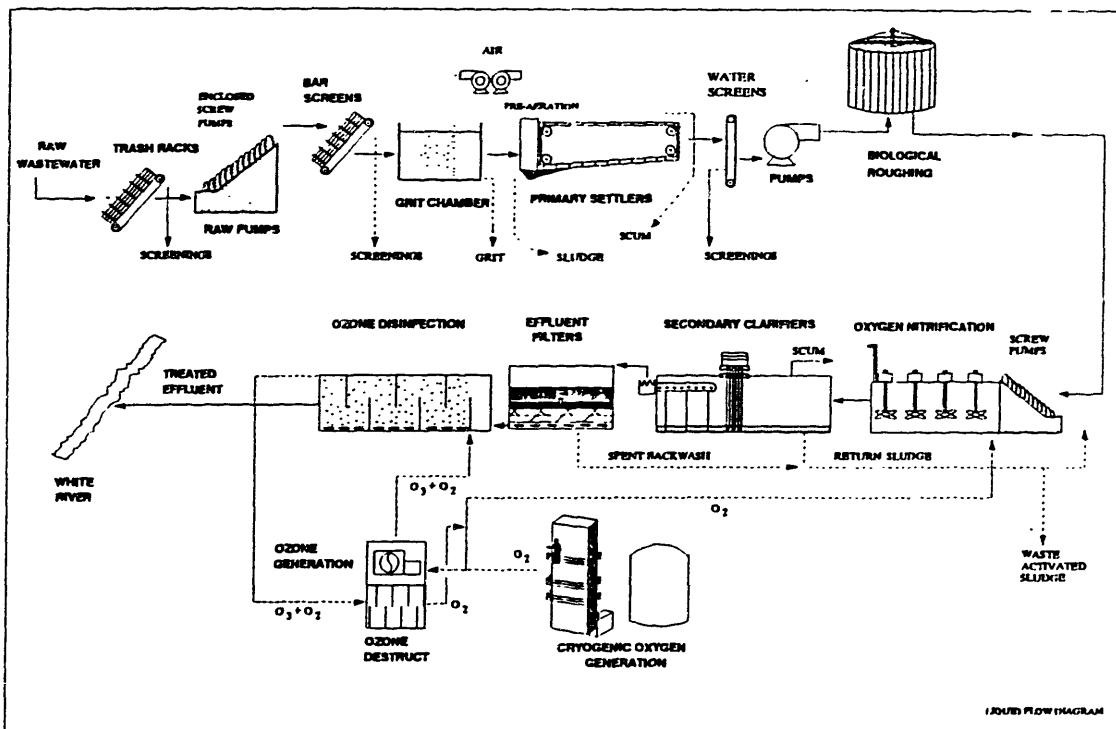
The City of Indianapolis, the twelfth largest city in the US, provides wastewater treatment for Indiana's Marion County. The City's Department of Public Works (DPW), under its Sewer and Water Division, is in charge of the Advanced Wastewater Treatment (AWT) Facilities, a system of treatment works which includes two wastewater treatment plants, a solids handling facility, and an analytical laboratory. The Belmont and Southport wastewater plants, located within seven miles of each other, utilize advanced treatment processes which treat a total average capacity of 245 mgd. The resulting effluent from both treatment plants is discharged into the White River. The first wastewater treatment facility in Indianapolis was constructed and put into service in 1924 at the present site of the Belmont facility. Treatment facilities were expanded and upgraded continually at this location through the years. In the mid-1960's, the decision was made to build a new treatment plant at the Southport location. Upgrading of both treatment facilities for the removal of suspended solids, biochemical oxygen demand and ammonia began in the 1970's. The upgraded Southport and Belmont AWT facilities were then placed in service in 1982 and 1983, respectively. The sludge handling facility was originally constructed in 1955 at the Belmont site, underwent remodeling in 1969 and 1970, and then a complete rehabilitation in 1988 through 1990. Both Belmont and Southport AWT processes include preliminary treatment, primary clarification, secondary biological treatment and clarification, air nitrification (Southport only) or oxygen nitrification, filtration and ozone disinfection. The sludge handling facility incorporates the use of thickening, dewatering and incineration. A brief description of the process operations at the Belmont, Southport and sludge handling facilities is presented below.

#### **Belmont**

The Belmont treatment facility is designed to handle an average flow of 150 mgd and a primary peak flow of 300 mgd. Preliminary treatment at the Belmont facility consists of trash removal, screening, and grit removal. Trash racks remove large debris from the influent before it flows through a series of bar screens. Grit is removed from the influent by aerated grit chambers and is subsequently disposed of at a landfill or incinerated at Indianapolis'

Resource Recovery Facility. Primary treatment is performed using four units of open-channel rectangular settling tanks. Each unit consists of four channels 265 feet long, 16 feet wide and 15 feet deep. Sludge is collected at the bottom and floatable material is skimmed off the surface with a flight and drag solids removal system. Effluent is then directed through a series of traveling water screens to remove additional solids. Secondary treatment is accomplished using four biological roughing towers (trickling filters) designed to handle a peak flow of approximately 37.5 mgd per tower. Flow from is then directed to an oxygen nitrification system, consisting of six reactors with eight stages each, for the removal of biochemical oxygen demand and ammonia-nitrogen. Each stage is equipped with a mechanical aerator for mixing and oxygen transfer to the wastewater. Twelve secondary clarifiers remove additional solids through settling, which are collected by a floating-bridge siphon mechanism. Surface scum is removed from each clarifier by automatic skimmers. Clarified effluent is then directed to the filter building equipped with 12 multi-media filters. Spent washwater from filter backwashing is returned to the treatment system. Chlorination equipment is available for disinfection of the tertiary utility water, backwash water and the filter effluent, if necessary. Primary disinfection is provided by ozone gas disinfection. The filter building effluent flows through four ozonation contactors. Oxygen from the Cryogenic Oxygen Generation Facility, an air distillation-type oxygen plant, flows to four ozone generators. The ozone/oxygen mixture produced by the generators is diffused into the wastewater flowing through the ozonation contactors. Any remaining ozone is destructed in catalytic ozone destructors and excess oxygen is released to the atmosphere. A process-flow chart showing the complete treatment process at the Belmont AWT facility is presented in Figure 5-1.

Figure 5-1: Belmont Facility Wastewater Treatment Process-Flow Chart<sup>4</sup>

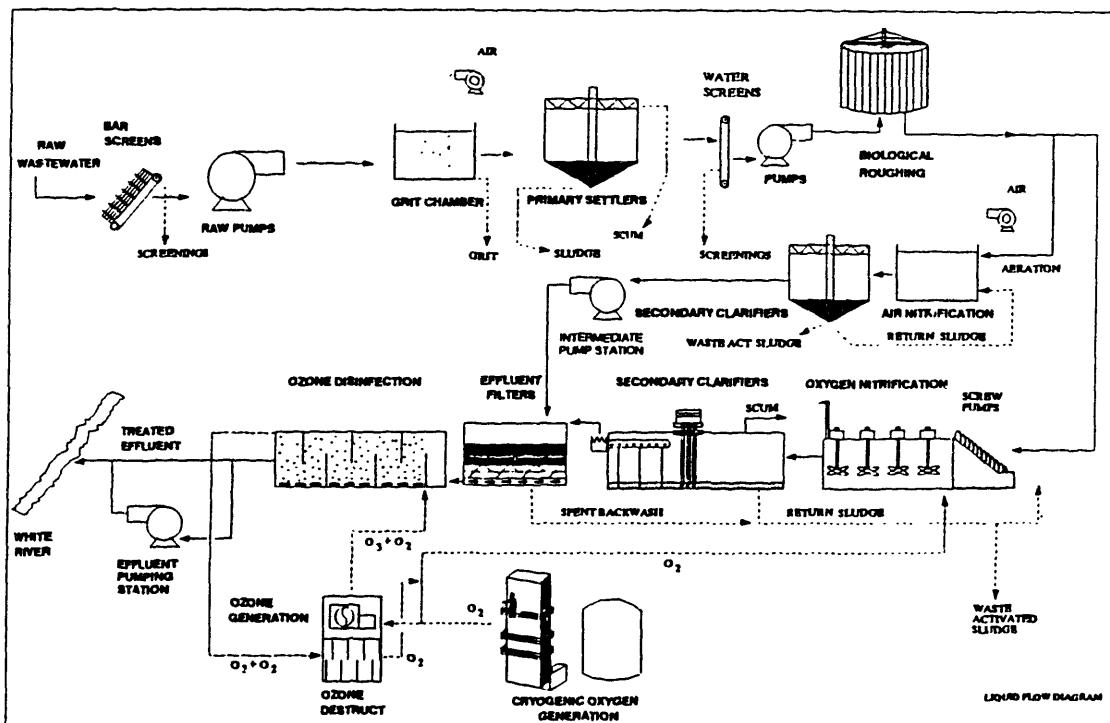


### Southport

The Southport treatment facility is designed to handle an average flow of 125 mgd and a peak flow of 150 mgd. Preliminary treatment at the Southport facility consists of mechanically cleaned bar screens followed by aerated grit removal chambers. Grit removed from the influent is also disposed of at either a landfill or incinerated at the City's Resource Recovery Facility. The primary treatment system consists of two sets of four circular center-feed clarifiers, each 95 feet in diameter with a sidewall depth of eight feet. Solids accumulated in the hoppers located in the center of each tank are transferred to the sludge handling facility. Modifications to the primary sludge pumping, piping and valving were made in 1989 to allow for equalization and aeration of primary sludge before being transferred to the sludge handling facility at the Belmont plant. Grease accumulation on the surface of the primary clarifiers is removed by a scum skimmer and transported to a landfill or incinerated. Primary effluent is directed through traveling water screens to four biological roughing towers for secondary treatment. At the Southport plant, the discharge from the bioroughing towers is conveyed to a diversion structure for distribution to the oxygen nitrification system, an identical system to the one at the Belmont plant, or to an air nitrification system. The air nitrification system consists of two sets of four rectangular aeration reactors. Each reactor contains four channels that are 188 feet long, 25 feet wide

and 15 feet deep. Air is supplied to the reactors by 14 blowers through diffusers located in the center of the tanks near the bottom. Secondary clarification is provided by two sets of four circular center-feed clarification tanks, each 100 feet in diameter with a sidewall depth of nine to ten feet. Advanced treatment processes at Southport are identical to the Belmont facility. Both AWT plants are monitored and controlled by a distributed main control computer system. A process-flow chart showing the complete treatment process at the Southport AWT facility is presented in Figure 5-2.

Figure 5-2: Southport Facility Wastewater Treatment Process-Flow Chart<sup>5</sup>



Effluent from both the Belmont and Southport treatment plants is ultimately discharged into the White River. The quality of the effluent discharged is regulated by the EPA through specific discharge permits issued under the National Pollution Discharge Elimination System (NPDES) for each treatment plant. Table 5-1 presents the NPDES effluent discharge limitations for certain parameters at Indianapolis' AWT facilities.

Table 5-1: NPDES Effluent Limitations for Indianapolis' AWT Facilities<sup>6</sup>

Parameter	Belmont AWT		Southport AWT	
	Monthly Avg. (mg/l)	Daily Max. (mg/l)	Monthly Avg. (mg/l)	Daily Max. (mg/l)
Flow (mgd)	monitor only	--	monitor only	--
Total BOD <sub>5</sub> <sup>a</sup>				
Summer	10	--	10	--
Winter	20	--	30	--
Total suspended solids				
Summer	10	--	10	--
Winter	20	--	30	--
Ammonia-Nitrogen				
Summer	3.4	--	4.0	--
Winter	7.0	--	7.0	--
Cadmium	--	0.02	--	0.02
Chromium	--	0.25	--	0.25
Copper	0.04	0.1	--	0.1
Cyanide	--	0.027	--	0.027
Lead	--	0.06	--	0.06
Mercury	--	0.0005	--	0.0005
Nickel	--	0.5	--	0.5
Zinc	--	1.0	--	1.0
Dissolved oxygen				
Summer	--	≥8.0	--	≥8.0
Winter	--	≥6.0	--	≥4.0
Fecal coliform	200/100ml	--	200/100ml	--
Total residual chlorine	≤1.0	--	≤1.0	--
pH	--	≥6 & ≤9	--	≥6 & ≤9

notes:

1. a = BOD<sub>5</sub> is the five-day biochemical oxygen demand.
2. -- = does not apply.
3. mg/l = milligrams per liter.
4. Fecal coliform limit is organisms per 100 milliliters.

Sludge Handling

The sludge handling facility located at the Belmont site processes sludge from both wastewater treatment plants. Waste activated sludge from the Southport plant is transferred to the sludge handling facility through a pair of six-mile long sludge lines, where it is then sent to dissolved air flotation (DAF) thickeners. The Belmont plant's waste activated sludge is pumped directly to the DAF thickeners. The sludge will pass through equalization/mixing tanks prior to thickening in any number of ten flotation thickener tanks, each approximately 93 feet long and 20 feet wide. Sludge pumped into the DAF thickeners is combined with air-entrained water to thicken and float the sludge. Primary sludge from the Belmont and Southport primary clarifiers are thickened using gravity thickener systems.

The gravity-thickened and flotation-thickened sludge is then dewatered using belt filter presses. The final sludge treatment process consists of the complete combustion of the sludge using multiple-hearth incinerators.

The original cost of Indianapolis' AWT facilities totaled approximately \$250 million. Seventy-five percent of the funds for construction of these facilities was provided by the EPA through the Construction Grants Program. Additional funds were contributed by the EPA for the use of innovative and alternative technology in the treatment systems. The Indiana State Board of Health provided close to ten percent of the costs, and the City contributed the remaining funds from the issuance of general obligation bonds.

### **5.3.2 Competition for AWT Facility Contract Operations and Maintenance**

With the general goals of reducing government spending, limiting increased taxes, freeing capital resources, and creating a more efficient and less bureaucratic government, the City of Indianapolis choose to evaluate the option of privatizing its wastewater treatment facilities. In 1993, the City received the results of a financial management and operations assessment study of its AWT facilities, performed by an outside consultant.<sup>7</sup> The purpose of this assessment was to perform an analysis of the existing wastewater treatment operations, develop a 20-year projection for the expenditures and revenues of the facilities, and evaluate various alternatives to improve upon operations and generate increased revenue for wastewater capital improvement projects. The study concluded that the AWT facilities were, in general, operated effectively, however several key findings and recommendations were stated in the final report, including:

- Funding for the City's capital improvement program for the AWT facilities had not kept pace with the infrastructure needs during recent years prior to the study;
- The user charges and debt service funded from property tax revenues at that time were insufficient to fund both the operations and raise the capital required for improving the AWT facilities' collection system;
- In 1993, the user charges had not been increased in several years; and
- It appeared that a private contractor under contract operations could operate the AWT facilities for an estimated five percent less in personnel cost than the City.

Among other recommendations, the consultant report recommended that the City competitively bid the operation and maintenance of the AWT facilities to outside companies. With these recommendations in mind, Indianapolis' DPW issued a Request for Statement of Qualifications (RFQ) in May 1993 relating to the operation and maintenance of the City's AWT facilities. The RFQ was used as an initial screening process to provide the City with the necessary information for evaluating and selecting the most qualified contractors that would be asked to submit full proposals. Information to be highlighted in each contractor's statement of qualifications (SOQs) mostly related to previous experience with wastewater contract operations and maintenance projects, and innovative approaches to treatment facility operation for improving efficiency. Based on a review of the SOQs, five qualifying groups were selected to the next bidding round, including:

- American Water Works Company/Anglican Water, PLC;
- AWT Management Group (the City employees);
- Professional Services Group;
- White River Environmental Partnership; and
- Yorkshire Water PLC/Heritage Environmental Services.

In mid-July 1993, Indianapolis's DPW issued a Request For Proposals (RFP) to these five qualified private contracting firms for the full management, operation and maintenance of the City's AWT facilities. In the RFP, the City outlined its objectives of achieving additional efficiencies in the operation of its AWT facilities while producing cost savings to the City and its ratepayers. The City believed that, through private operation by a firm with several years experience on a variety of wastewater treatment systems, savings could be realized by the economies of scale brought by an experienced company. Prolonging equipment life, improved training of facility employees, and innovative solutions to the problems and challenges of managing, operating and maintaining treatment facilities could provide an adequate return on investment for the private firm while allowing the City to utilize the capital budgeted for the AWT facilities for other infrastructure needs. Through the RFP, the City requested general information from the private firms regarding their experience with complex treatment systems, examples of previous operating success stories in terms of the savings provided, and safety history. In addition, due to the presence of labor unions, the RFP requested details of the manner in which the private contractors have dealt with existing unions and how labor problems were eventually resolved. Some of the main objectives and requirements outlined in the RFP are presented below in Table 5-2.

Table 5-2: Main RFP Specifications for Indianapolis' AWT Facilities<sup>8</sup>

Topic	Requirements/Specifications
Compensation	Detailed estimate of fixed and variable costs for operation and maintenance. Costs to include personnel, utilities, travel, training, equipment, subcontracts, materials and supplies. Encouraged to propose innovative compensation arrangements.
Employees	How existing employees will be treated as new employees of the contractor.
Investment Objective	Contractor to remain current with new technology and inform the City of capital investment opportunities for new equipment which would lead to more efficient operation.
Maintenance Objective	Perform predictive, preventive and corrective maintenance, upgrading and replacement to preserve the City's original capital investment.
Operating Objective	Provide uninterrupted operation in accordance with all applicable federal, state and local laws and regulations. To maintain the facilities at a level that meets or exceeds the current practice.
Scope of Services	Responsible for daily management, operation and maintenance of the AWT facilities. Provide all personnel, material, services, wages, salaries and benefits. Responsible for monthly reports of operation and payment of any fines resulting from inadequate operation. Prepare annual expenditure estimates and report actual amounts to the City. Evaluate all plant equipment and structures annually and provide notification of capital expenditure needs. Attend monthly meetings to review operations, reports and costs. Provide indemnification to the City from any loss or liability for damage or claims due to contractor negligence.
Training Objective	To provide continuous training of AWT management and staff to keep current on state-of-the-art operation and maintenance.
Miscellaneous	All land, buildings, equipment and improvements to the AWT facilities remain the property of the City. An annual contract performance review will be conducted. The City can terminate the contract if it determines that contract performance has not been in full compliance.

Following a review of the proposals submitted by the five contracting companies, the City awarded a five-year management, operations and maintenance contract to the White River Environmental Partnership (WREP). WREP is a joint venture led by IWC Resources Corp., the holding company of the Indianapolis Water Company and a 52 percent owner of the WREP joint venture. WREP also includes JMM Operational Services, Inc. (JMM), a Denver-based water/wastewater management company, and Lyonnaise des Eaux-Dumez, a French water-utilities firm. The WREP joint venture, headquartered in Indianapolis as an Indiana

partnership, was formed specifically to pursue the private contract for the operation of Indianapolis' AWT facilities. Some of the specific terms of the contract operations agreement between Indianapolis and WREP (the contractor) are briefly described below.<sup>9</sup>

- *Community Relations* - the contractor is required to institute programs for the education of the citizens of Indianapolis regarding the operation of the wastewater treatment facilities, and to create a national training center in Indianapolis for cooperative studies on advanced wastewater treatment. WREP must also contribute annually at least five percent of its pre-tax profits to civic or other community organizations to further support economic development initiatives.
- *Compensation and Adjustments* - the City will pay the contractor an annual fee for its services over the five-year contract as shown below:

Year 1 = \$15,155,400

Year 2 = \$14,650,000

Year 3 = \$14,600,000

Year 4 = \$14,000,000

Year 5 = \$13,831,075

The fee is to be adjusted for inflation annually after the first year. If utility costs fall below an established baseline, the City can request a reduction in the annual fee in an amount equal to one-half the reduction in utility costs. Actual annual hydraulic and organic loadings that fall below or exceed established average loading baselines can also result in the adjustment of the annual fee. Other adjustments may be allowed as a result of changes in federal or state legislation or regulations relating to the operation of the treatment facilities.

- *Environmental Compliance* - in addition to the general compliance with all federal, state and local environmental and other laws, the contractor is responsible for the preparation of all permits relating to changes in the wastewater treatment process. The City is responsible for routine permit renewals.
- *Facility Expansion and Modification* - provides a mechanism for either the contractor or City to propose and negotiate an expansion or modification of the

facilities due to a need for increased treatment capacity, changes/advances in technology and/or changes in environmental regulation.

- *Facility Maintenance* - the contractor is responsible for performing routine, predictive, preventive, and corrective maintenance of the AWT facilities. In addition, within 90 days of the start of the contract, the contractor was required to conduct a full review of the existing AWT facilities' maintenance management program and then make recommendations regarding any changes or modifications that will provide a more efficient maintenance management program.
- *Personnel* - the contractor must make an effort to employ all interested and qualified employees that originally worked for the City. The contractor is also required to provide current City employees a total package of compensation and benefits equivalent to or better than that provided by the City. The terms of employment for unionized employees will be determined through a negotiated agreement with the union's collective bargaining representatives. The City will attempt to place any employees displaced by the contractor in other jobs with the City. The contractor will also pay \$300,000 to fund a "Worker Assistance Program to provide training programs, assistance with job search skills, an outplacement allowance and career counseling programs.
- *Other Privatization Opportunities* - the partners and parent companies of the contracting group are encouraged to pursue other wastewater privatization projects that may arise in Indiana, Ohio, Kentucky, Illinois and Michigan.
- *Repair and Replacement Fund* - the City will annually provide a \$1,500,000 Repair and Replacement Fund for major repair and maintenance activities associated with the AWT facilities.
- *Termination of Agreement* - the City has the right to terminate the contract agreement with substantiated cause at anytime throughout the contract period, and can terminate the agreement without cause after three years of service by the contractor. The contractor can terminate the agreement only after an event of default by the City.

- *Waiver of Provisions* - the City may waive a provision of the agreement or negotiate to amend a provision if it is concluded that the provision may cause the operation of the AWT facilities to be treated as a private business under the Internal Revenue Code of 1986.

In summary, the City of Indianapolis pays WREP approximately \$14 million per year to run the AWT wastewater treatment facilities. WREP is responsible for covering the cost of operations, preventive maintenance, labor and management while the City is responsible for the costs of all long-term capital improvements or corrective maintenance, and remains as owner of the treatment facilities.

### **5.3.3 Performance Summary for the White River Environmental Partnership**

On January 31, 1994, WREP assumed responsibility for the management and operation of Indianapolis' AWT facilities. The Compliance Section of Indianapolis' DPW maintains oversight of the AWT contract with four employees, one of which is stationed at the Belmont treatment facility. The compliance personnel have regular interaction with WREP to monitor compliance with the contract provisions. A review of the operation of the treatment plants by independent industry and environmental experts is conducted through monthly meetings of the AWT Advisory Group. This group also advises the City on long-term needs of the facilities. Monthly operating reports are submitted by WREP to the state, and regulatory personnel visit the facilities on a regular basis to ensure continued environmental compliance. In addition, monthly reports are prepared by WREP for the City which include information on both operation and maintenance issues and the progress of the various AWT capital projects supervised by WREP in its project management role.

As of the completion of two full contract years (1994 and 1995), the AWT contract has been very successful for the City, especially in terms of effluent quality, asset maintenance, the issue of City employee job placement, and cost savings. A brief discussion of the impacts that WREP's management and operations have had on each of these issues is presented below.<sup>10</sup>

#### **Effluent Quality**

One of the major goals of the privatization initiative was to provide an equal or better effluent quality. Based on the effluent discharge during the first two years of operation, WREP has successfully achieved this goal, discharging cleaner water into the White River.

As shown in Table 5-3, the concentrations of the specific wastewater parameters of ammonia-nitrate (NH<sub>3</sub>), biochemical oxygen demand (BOD), fecal coliform and total suspended solids (TSS) have been equal to or less than those during prior operation by the City.

Table 5-3: Average Effluent Concentrations in AWT Facility Discharge<sup>11</sup>

Parameter	1993	1994	1995
BOD	6	7	7
Fecal coliform	86	51	36
NH <sub>3</sub>	1.1	1.1	1
TSS	6	4	5

Notes:

1. BOD, NH<sub>3</sub> and TSS given in mg/l.
2. Fecal coliform given in counts per 100 ml.
3. 1993 = City operations; 1994-95 = WREP operation.

During wet weather events, wastewater treatment plants are often required to operate at maximum capacity which can cause raw and partially treated wastewater to be discharged into the receiving waters, a situation that occurs at most treatment facilities. WREP improved the AWT facilities' wet weather operations by increasing the plants' ability to process a greater flow during rain events. This significantly reduced the number and duration of raw and partially treated overflow discharges into the White River: the total number of hours per year in which raw overflows occurred during 1993 (City operation) was 415 hours compared to 150 hours during 1994 (WREP operation). Maximizing a treatment plant's flow during wet weather can result in increased NPDES permit exceedences. Compared to a City average of seven NPDES permit exceedences per year, WREP operation incurred only one exceedence in 1994 and five in 1995.

Asset Maintenance

By strictly following manufacturers' guidelines and servicing equipment regularly, WREP's preventive maintenance program has decreased the City's corrective maintenance costs by 50 percent in the first year of the contract. Increased preventive and predictive maintenance efforts have reduced equipment vibrations problems by 80 percent since the contract began, and have added to the reduction of corrective maintenance costs. A 1995 audit of WREP's maintenance management program revealed that 70 percent of the equipment surveyed in the audit received scheduled maintenance at the same interval as during City operations, while the remaining 30 percent received scheduled maintenance at a more frequent interval.

A new computerized maintenance manager system was installed in 1995 to improve the tracking of inventory and work orders.

### Employees

One of the ways in which WREP reduced operating costs was through an evaluation and reduction of the AWT facilities' workforce. Originally staffed with 328 city workers, by the third year of contract operations, the workforce had been reduced to 168. All but eight of those employees were former city workers who transitioned to WREP's operations at the start of the contract. WREP recognized the Association of Federal, State, County and Municipal Employees (AFSCME) as the official employee bargaining unit, representing approximately 35 percent of the plant employees. Through negotiations, a signed bargaining agreement was ratified by an overwhelming 20-1 margin. This agreement is one of the first in the US between AFSCME and a private company. Grievances filed by AWT workers have decreased from 38 in 1993 under City management to one in 1994 and zero in 1995. The existing workforce received higher salaries, increased benefits and more training than under previous city management. Those workers displaced by the transition to private management and operation were assisted in finding comparable jobs by both WREP and the City. Within an eight month period, 100 percent of these workers were placed as detailed in Table 5-4 below.

Table 5-4: Placement of Displaced AWT Facility Workers<sup>12</sup>

Placement Option	No. of Hires
City (other municipal positions)	67
JMM Operation Services	1
Outplacement Assistance Program	43
Outside Employment	10
Retirement	5

### Savings and Efficiencies

Cost savings on the operations and maintenance side have exceeded initial projections and total \$21.6 million over the first two years of the contract (1994 and 1995). Table 5-5 presents a summary of the operations and maintenance savings for the first two contract years in relation to the original AWT budget and the projected costs and savings. Consolidation and reduction efforts in fleet services, inventory and warehousing produced decreased costs of more than 50 percent in each category. Monthly fleet costs were reduced by 54 percent through the use of an outside contractor. Inventory decreased from \$6.7 million to less than \$2 million, and on-site warehouses were reduced from 37 to two.

Although reduced payroll provided the biggest savings (overall payroll expenses were cut 46 percent), WREP was also able to reduce the treatment plants' electricity usage by 30 percent through a more efficient operation of equipment. Increased savings were also produced through improved accounting and invoice processing, as vendors provide cost discounts for prompt payment within ten days of billing. The short turnaround time for accounts payable creates pricing advantages from vendors who do not have to account for interest mark-ups, and has permitted additional smaller vendors to provide services for WREP.

Table 5-5: Summary of AWT Facility Operations and Maintenance Savings<sup>13</sup>

	1994	1995	1996	1997	1998
AWT budget	\$27,618,175	\$30,615,388	\$30,615,388	\$30,615,388	\$30,615,388
Projected costs	17,769,966	18,935,565	19,564,991	19,564,991	18,644,125
Projected savings	9,848,209	11,679,732	11,050,397	11,050,397	11,971,263
Cumulative projected savings	9,848,209	21,527,941	32,578,338	43,628,735	55,599,998
Actual costs	16,913,124	19,696,563	--	--	--
Actual savings	10,705,051	10,918,825	--	--	--
Cumulative actual savings	10,705,051	21,623,876	--	--	--

### Conclusion

Based on the performance to date, it is apparent that Indianapolis' partnership with WREP has been a major success, providing the City with a more effective and cost efficient operation of the AWT facilities. Since 1991, Indianapolis has been able to put \$530 million in capital improvements for the city without raising taxes, which is partially attributable to the success of the wastewater treatment privatization.<sup>14</sup> Over 2000 people have toured the AWT facilities in the first two years of the private contract, and WREP, City and AFSCME officials have been invited to participate in more than 25 state, national and international forums on competitive government. Furthermore, in conjunction with Lyonnaise des Eaux, WREP established the Indianapolis International Centre for Development and Training at the Belmont site to provide information and training courses on the latest technology and management techniques in the wastewater treatment industry. Both the success of the public-private partnership and the new development and training centre should keep the attention on Indianapolis as more municipalities consider the possibility of joining forces with the private sector in wastewater treatment.

## **5.4 Charlotte, North Carolina's Irwin Creek Wastewater Treatment Plant**

Over the past several years, the City of Charlotte, North Carolina, has focused its attention on providing more efficient and effective public works services. In pursuit of this objective, Charlotte has accepted and encouraged the use of competitive bidding with outside private firms for providing traditionally public services. One example of the outsourcing of public services in Charlotte is the recent contract awarded to a private firm for operating a significant portion of the city's solid waste collection services. Another example is with Charlotte's water and wastewater services. Urged by inquiries from the private sector and unsolicited proposals to purchase system components, the Charlotte-Mecklenburg Utility Department (CMUD) developed a managed competition process to allow private firms to compete with city staff for the operation and maintenance of one residuals management facility, one water treatment plant and one wastewater treatment plant. This section focuses on the managed competition process that was conducted for the operations and maintenance contract at Charlotte's Irwin Creek Wastewater Treatment Plant, which was ultimately awarded to the city's employees. This case provides an example of how a public entity can provide effective and efficient wastewater treatment services by forcing itself to function like a private company.

### **5.4.1 Facility Background and Description<sup>15</sup>**

The Charlotte-Mecklenburg Utility Department (CMUD) administers, operates and maintains a unified water and wastewater system for a service area which includes the City of Charlotte, Mecklenburg County, and a number of smaller municipalities and areas in the region. The wastewater system serves a population of 550,000 and consists of five wastewater treatment facilities having a total plant processing capacity of approximately 92 mgd. The Irwin Creek Wastewater Treatment Plant, one of the five facilities, is designed to treat an average flow of 15 mgd. The Irwin Creek plant was originally constructed in 1927 and subsequently upgraded and expanded in 1953, 1971, 1979 and 1987. Designed to provide secondary treatment, the facility was recently upgraded to tertiary (advanced) treatment with the addition of a single media effluent filter.

Preliminary treatment at the Irwin Creek facility consists of influent screening using mechanical bar screens and grit removal via mechanical and aerated grit chambers. Screenings and grit removed from the influent are disposed of at a sanitary landfill. Primary treatment is performed using three circular primary clarification tanks. Sludge solids are

collected at the bottom of the clarifiers for further processing. Secondary treatment consists of a series of trickling filters (bioroughing), aeration basins and secondary clarifiers. The four high-rate biological trickling filters use rock media to sustain biological growth in the reactors. Tank bottom diffusers provide necessary oxygen in the two, rectangular plug-flow aeration basins, while the three circular secondary clarifying tanks provide final clarification of the wastewater. A portion of the settled sludge from the secondary clarifiers is returned to the waste stream leaving the trickling filters while the remaining waste activated sludge is stored for further processing. Flow is then directed to single-media filters to provide advanced filtration of the effluent. Spent washwater from filter backwashing is returned to the treatment system. Disinfection of the effluent is performed through chlorination in a chlorine contact tank. Dechlorination occurs in a final post-aeration system which uses a cascade-type flow basin. The treated effluent is discharged directly to the nearby Irwin Creek which is part of Charlotte's Catawba River Basin. The quality of the effluent discharges is regulated by the EPA through a NPDES discharge permit. Table 5-6 presents the NPDES effluent discharge limitations for certain parameters at the Irwin Creek facility.

Table 5-6: NPDES Effluent Limitations for Charlotte's Irwin Creek Facility<sup>16</sup>

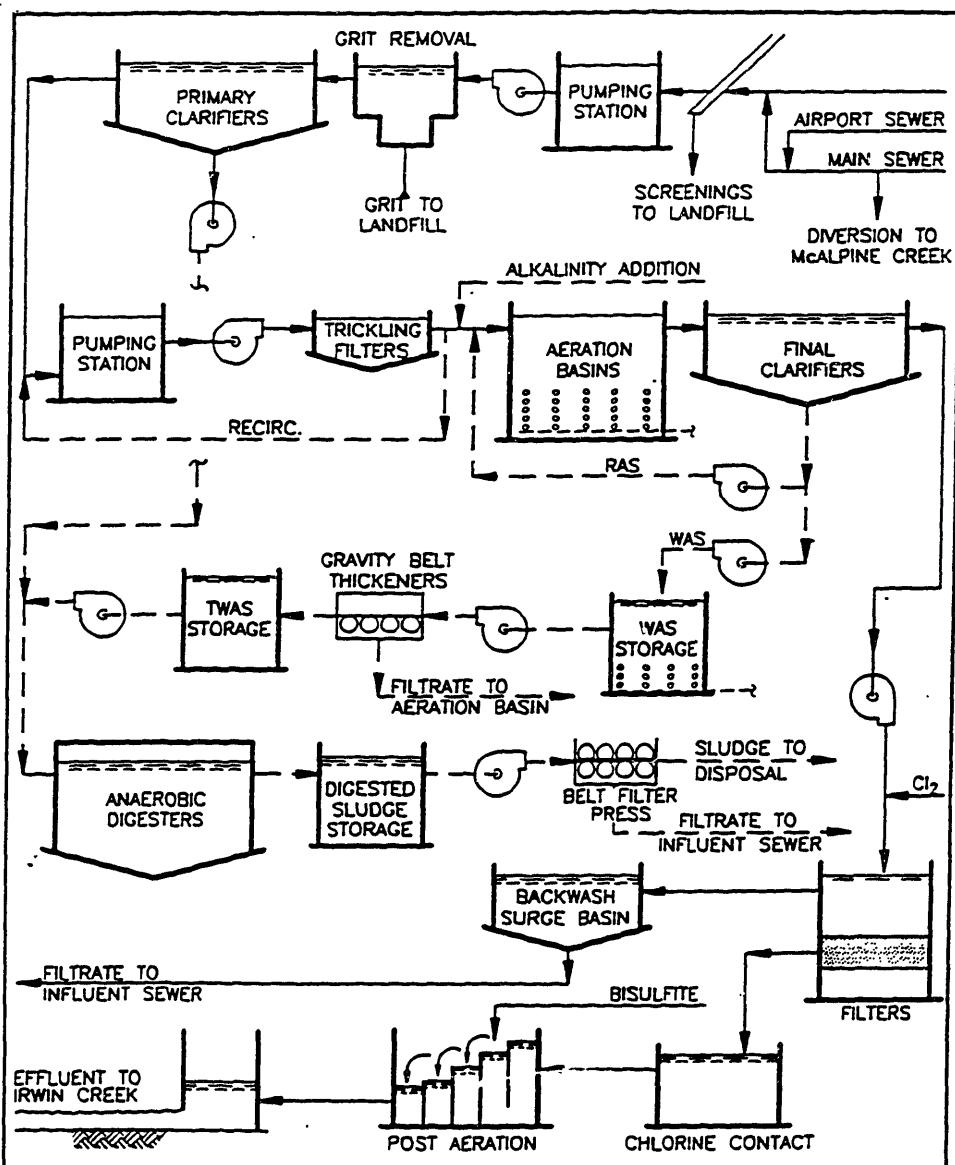
Parameter	Monthly Avg. (mg/l)	Daily Max. (mg/l)
Flow (mgd)	15	--
Total BOD <sub>5</sub> <sup>a</sup>		
Summer	5	--
Winter	10	--
Total suspended solids		
Summer	15	--
Winter	30	--
Ammonia-Nitrogen		
Summer	1	--
Winter	2	--
Cadmium	--	0.0061
Chromium	--	0.224
Cyanide	--	0.021
Lead	--	0.041
Nickel	--	0.428
Dissolved oxygen	--	≥6
Fecal coliform	200/100ml	--
Total residual chlorine	.021	--
pH	--	≥6 & ≤9

notes:

1. a = BOD<sub>5</sub> is the five-day biochemical oxygen demand.
2. -- = does not apply.
3. mg/l = milligrams per liter.
4. Fecal coliform limit is organisms per 100 milliliters.

Sludge processing at the Irwin Creek treatment plant consists of anaerobic digestion and dewatering to produce a Class B sludge based on the 40 CFR Part 503 federal sludge regulations. Primary sludge and waste activated sludge is stabilized in any number of the six, two-stage anaerobic digester tanks. Digested sludge is stored in sludge storage tanks prior to dewatering using a belt filter press. Filtrate from the dewatering process is returned to the treatment system while processed sludge is transported off-site for final disposal. A process-flow chart showing the complete treatment process at the Irwin Creek treatment plant is presented in Figure 5-3.

Figure 5-3: Irwin Creek Facility Wastewater Treatment Process-Flow Chart<sup>17</sup>



#### **5.4.2 Managed Competition for Contract Operations and Maintenance**

In early 1995, the City of Charlotte was approached by a private company proposing to acquire the largest and newest treatment facility under CMUD's water/wastewater system. Although the City eventually declined the offer, other offers were made by private companies for providing contract operation and maintenance services. Advised that contract operations and maintenance could potentially provide significant savings, Charlotte decided to conduct a managed competition that would be open to both public and private bidders. Managed competitions have the potential to provide an unfair advantage to the public bidding group, however, the City was committed to creating a level playing field for what was called an "arms length" competition among outside contractors and CMUD employees.

With the objective of obtaining the most advantageous approach for providing effective, efficient operation and maintenance of the Irwin Creek treatment plant while ensuring a fair and equitable competition, the City instituted specific procedures in its competition process. Prior to the competition, two independent teams were established within CMUD. One team was responsible for preparing the City's proposal while the other was responsible for assisting with the procurement process. The two teams were strictly prohibited from exchanging information or communicating in any way on issues relating to the competition to prevent the CMUD bid team from gaining inside knowledge. Another procedure instituted to ensure an unbiased competition related to the evaluation of proposals submitted by interested parties. The proposal evaluation team consisted of two citizen members of City advisory committees, two non-CMUD City staff members, and two City Department Management staff members. Finally, an independent consulting team made up of Camp Dresser & McKee and its subconsultant Raftelis Environmental Consulting Group, Inc. was retained by Charlotte to manage the overall process and assist in the evaluation of submittals.

A traditional two-step procurement process was utilized by the City for the selection and award of the Irwin Creek operation and maintenance contract. The first step involves a review of the submittals responding to an RFQ, performed in order to select a limited number of groups deemed by the City to be the most qualified. The second step involves the evaluation of detailed proposals submitted in response to an RFP given to those groups passing the qualifications stage. Materials submitted in both steps were evaluated by the independent evaluation team and the City's consultant team.

In August 1995, Charlotte issued the RFQ requesting the submission of SOQs from companies interested and experienced in providing wastewater treatment services. The RFQ outlined the scope of services to be provided to CMUD consisting of the full operation and maintenance of the Irwin Creek wastewater treatment plant, and specified the term of the contract to be three years with two annual renewal options, subject to annual appropriation. Information to be highlighted in each company's SOQ mostly related to previous experience with wastewater contract operations and maintenance projects, and innovative strategies to be implemented to provide maximum operational efficiencies. In addition, the RFQ outlined the selection criteria to be used by the City in evaluating the SOQs for selecting those companies which would advance to the proposal stage. The selection criteria included:

- Management and organization arrangements of the proposed company;
- Relevant and quality of experience in providing similar services;
- Experience and qualifications of key staff;
- Technical and financial resources of the proposed company;
- Performance history; and
- Quality and usefulness of any contracting suggestions.

Based on a review of the SOQs, seven qualifying groups were selected to the next bidding round, including:

- CMUD-Contract Operations (the City employees);
- Duke Power Services Group;
- J.A. Jones Management Services/JMM Operational Services;
- OMI Inc.;
- Professional Services Group;
- U.S. Water; and
- Wheelabrator EOS.

CMUD-Contract Operations (CM-ConOp), a separate accounting entity established within CMUD for the purpose of the contract bidding, was prequalified based upon the years of operating experience at the Irwin Creek facility and demonstrated knowledge of the City's overall treatment system. At the end of January 1996, the City of Charlotte issued an RFP to these seven qualified contracting firms for the full management, operation and

maintenance of the Irwin Creek wastewater treatment facility. The RFP outlined the scope of services to be provided under contract with the City and the requirements of the base proposals to be submitted by each of the above contracting groups. The RFP also allowed the development of alternate proposals that could be submitted in addition to the required base proposal. One alternate proposal per company could be provided through which the company could vary the technical approach or the contractual terms and conditions reflected in the base proposals. The purpose of the alternate proposal was to provide a mechanism for demonstrating innovative or creative approaches for the cost-effective operation and maintenance of the Irwin Creek plant which would be beneficial to the City. Some of the main objectives and requirements outlined in the RFP are presented below in Table 5-7.

Following a review of the proposals submitted by the seven contracting groups, the City of Charlotte awarded a five-year management, operations and maintenance contract to CM-ConOp, the accounting entity made up of City employees. CM-ConOp's bid proposal received the highest technical rating and was also the lowest bid submitted. The group's bid prices were the result of a ten-month optimization process designed to help the public employees think and perform operations and maintenance duties like a private company. The city employees consulted with HDR Inc., a private engineering consulting firm, to help formulate CM-ConOp's proposal and rearrange its organization to more closely resemble private firms. In fact, in addition to its objective of the most efficient operation of the Irwin Creek wastewater treatment plant, CM-ConOp had a broader goal of demonstrating that public sector services can be improved through the use of private sector incentives and technical innovations. CM-ConOp took two major steps in order to achieve private sector benefits. The first was to identify and eliminate the barriers to efficiency, such as outdated work rules and compensation programs. The second was to adopt private sector use of staffing programs including cross training, teamwork strategies and flexible shift planning.<sup>18</sup>

Table 5-7: Main RFP Specifications for the Irwin Creek Wastewater Treatment Plant<sup>19</sup>

Topic	Requirements/Specifications
Coordination with City	Responsible for coordination with CMUD staff, regulatory agencies and other contractors regarding: water treatment plant sludge deliveries; dewatered sludge disposal; capital improvement project oversight; industrial pretreatment sampling program; hauled waste deliveries; regulatory agency inspection; and diversion of excess flow to the McAlpine Creek wastewater treatment plant.
Maintenance Objective	Perform routine, predictive, preventive and corrective maintenance, upgrading and replacement to preserve the City's original capital investment.
Operating Requirements	Provide uninterrupted operation in accordance with all applicable federal, state and local laws and regulations. To operate the sludge processing system to produce a Class B sludge product in accordance with the 40 CFR Part 503 regulations. Operate and maintain the existing trucked waste facility located at the Irwin Creek facility.
Pricing Structure	Present detailed information on proposed annual fee and potential adjustments to the fee. Cost estimates to be based on baseline flow and loading conditions for the facility. Annual fee to incorporate an assumed level of inflation.
Scope of Services	Responsible for daily management, operation and maintenance of the Irwin Creek plant. Provide all personnel, material, services, wages, salaries and benefits. Responsible for monthly reports of operation and preparation and submittal of required regulatory agency reports. Evaluate all plant equipment and structures annually and provide notification of capital expenditure needs. Attend monthly meetings to review operations, reports and costs.
Technical Approach	Provide a detailed description of the contractor's management plan, staffing plan, operations plan, and maintenance management plan.
Training	Provide employee training to maintain necessary certification and other qualifications.
Miscellaneous	Indicate how the City's Minority and Women's Business Development Program requirements will be met. Proposers are encouraged to offer innovative solutions and approaches to operating and maintaining the facilities beyond the base level of services required.

A review of CM-ConOp's proposal shows that the group anticipates providing savings to the City of Charlotte in excess of \$4 million over the life of the five-year contract. Based on the proposal, the City will pay CM-ConOp an annual fee for its services over the five-year contract as shown below.

Year 1 = \$1,051,227  
Year 2 = \$1,084,459  
Year 3 = \$1,106,773  
Year 4 = \$1,131,010  
Year 5 = \$1,195,847

While CM-ConOp was not required under city procurement laws to enter into a service agreement, the group volunteered to sign a Memorandum of Understanding (MOU) with the City for the contract services. The purpose of the MOU, a document containing essentially the same language as a service agreement, is a demonstration of good faith by the CM-ConOp employees as a public entity to honor their bid proposal and fee structure.

CM-ConOp's proposal strategy focused on controlling/reducing costs associated with four primary cost drivers at the Irwin Creek plant: chemicals, energy, labor and solids handling. Oxidation/reduction potential technology would be installed to control chemical dosing rates for chlorination/dechlorination processes. The operation of sludge digester mixing and dewatering systems only during off-peak periods was one of several energy consumption strategies. Plant staffing would be reduced from 17 to 9 positions while empowering operators with increased operational and decision responsibility. Raw primary sludge and secondary sludges would be separated to maximize sludge thickening and minimize volume. In addition, the proposal discusses the use of additional technology in the areas of facility automation, staff reductions, and planned maintenance to provide additional cost savings. These are examples of some of the many changes proposed by CM-ConOp which helped it to win the contract over six private wastewater service firms.

#### **5.4.3 Performance Summary for the CM-ConOp Group<sup>20</sup>**

On July 1, 1996, CM-ConOp assumed responsibility for the management, operation and maintenance of the Irwin Creek wastewater treatment plant. Having been under contract for less than six months at the time of this case study, performance data exists for only one operational quarter (July-August-September). In its first quarterly progress summary, CM-ConOp has already reported a cost savings to the city while providing gain-sharing cash bonuses to its employees. A monitoring plan developed between Charlotte and CM-ConOp outlines the details for oversight of contract duties and monitoring compliance. Four main monitoring areas help facilitate the City's oversight of the Irwin Creek operations. These areas include:

- *Quarterly Reporting* - submitted to the Privatization and Competition Advisory Committee and the CMUD Advisory Committee;
- *Performance Criteria* - operations in accordance with the criteria outlined in the Request for Proposals and the Memorandum of Understanding between Charlotte and CM-ConOp;
- *Cost Review* - performed internally by the contract compliance officer and externally through a business support services audit; and
- *Operations and Maintenance* - monitoring internally by the contract compliance officer, and externally by state and federal regulatory agencies and through a business support services audit.

A review of the Irwin Creek facility performance summary indicates that CM-ConOp has met the requirements specified in the RFP for sludge processing, sludge dewatering, routine/predictive/preventive/corrective maintenance, and facility staffing. In terms of the quality of effluent discharged into Irwin Creek, with the exception of slightly elevated ammonia-nitrogen levels, the contract operations has continued to produce an effluent which meets the facility's NPDES permit requirements, as shown in Table 5-8.

Table 5-8: Average Monthly Effluent Concentrations at Irwin Creek  
Under CM-ConOp<sup>21</sup>

Parameter	Permit	July '96	Aug. '96	Sept. '96
Flow (mgd)	15	7.765	8.136	7.609
BOD (mg/l)	5	2.9	3.8	4.8
NH <sub>3</sub> (mg/l)	1	0.6	1.3	1.5
TSS (mg/l)	30	4	6	13
Sludge Processing	Part 503 Class B	met	met	met

Although cost savings to the City based on the annual fee paid to CM-ConOp can not yet be determined, first quarter operating expenditures were below those which were projected in the bid proposal. The first quarter expenditures totaled \$205,697 (personnel - \$68,122; operating - \$116,367; overhead - \$21,208), which is 19.38 percent of the annual bid of \$1,060,446 for the first contract year (as opposed to 25 percent for one-fourth of one year completed). As shown in Table 5-9, the savings achieved in the first three months of

operation have already provided gainsharing bonuses--based on permit compliance, safety and budget control--to the employees.

Table 5-9: First-Quarter Results of CM-ConOp Operation<sup>22</sup>

Item	Amount
Bid Projection	\$225,796
Expenditures	205,697
Savings	20,099
Employee Gainsharing	5,551
-treatment plant (50%)	2775.50
-employee reserve (25%)	1,387.75
-employees (25%)	1,387.75
-bonus per employee	155
Total Plant Savings	17,323.50

It is difficult to assess the full impact of Charlotte's managed competition process and contract award to a public contracting entity after only three months of operations. All indications to date, outside of a few discharge permit exceedances, are that CM-ConOp will provide effective and efficient operation and maintenance services. The result of the Irwin Creek Facility competition is an example of what can happen when the pressure to streamline robust government services is combined with the belief that private sector techniques and philosophies provide the direction to achieve significant savings.

## 5.5 Implications of Privatization on Technology Development

There are essentially two ways in which to improve operations at a wastewater treatment facility: 1) managerial techniques for organizational and operational productivity, and 2) technological advancement of treatment processes. The two case studies above provide examples of how private sector techniques can be used to streamline operations and management structure to provide cost savings and improved services. Competitive bid processes for privatizing treatment plants also provide the opportunity for a public utility to encourage, through broad RFPs, the development of creative technological solutions to a public facility's treatment problems. The opportunity to operate a treatment plant under an annual contract/fee arrangement with a city provides strong incentive to optimize operations at the plant. But in addition to plant automation, process optimization, and energy and chemical conservation, upgrading treatment systems using advanced

technologies will improve operation and add to cost savings beyond those business streamlining techniques.

Within the current tax laws, private firms are not rewarded for technological innovation. The Internal Revenue Service limits the length of time a private operator can contract with a public facility to one, three-year contract with two, one-year renewals. The problem this creates is that private firms cannot easily obtain financing for the higher upfront capital costs of new technologies with only a five year contract. With a longer contract, the private companies would be willing to operate and invest in new technologies that lead to greater efficiencies. Long-term privatization, therefore, may facilitate the development and implementation of new or advanced wastewater treatment technologies. The complete asset sale of a plant to the private sector, a full privatization event that has occurred only once in the US to date, could also lead to technology development. The private sector views a treatment plant as a potential profit center where improved efficiencies go straight to the bottom line. Basic economics dictate that the best use of capital is to match a contract term to the economic life of the plant's assets.<sup>23</sup> The sale of a plant to a private firm for a 20 or 30-year term would then encourage and allow the firm to pay for major capital upgrades and additions using more efficient, technologically advanced systems.

Advanced, more effective technologies should be utilized when upgrading or rehabilitating existing treatment systems whether a facility is operated by the private or public sector. Public utilities must be willing to invest in the higher upfront capital costs associated with advanced technologies. Over the life of the capital upgrade, improved technological systems would return the higher cost of the upgrade by providing operational efficiencies and increased cost savings. The problem is that, in addition to the lack of available capital, the political structure of municipalities often prevents public utility employees from introducing more efficient systems and technologies. Once these bureaucratic constraints are removed, publicly operated plants may more easily move to adopt advanced technologies.

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<sup>1</sup> Sherman, David R. and Stayton, Michael B., "Better Than Expected", *Infrastructure Finance*, October/November 1995.

<sup>2</sup> McGoldrick, Beth, "Income Streams", *Infrastructure Finance*, June 1996.

<sup>3</sup> Source: Advanced Wastewater Treatment Facilities Annual Report, City of Indianapolis Department of Public Works, 1992.

<sup>4</sup> Ibid.

<sup>5</sup> Ibid.

<sup>6</sup> Ibid.

<sup>7</sup> City of Indianapolis Department of Public Works, Financial Management and Operations Assessment Study for Advanced Wastewater Treatment Facilities, 1993.

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<sup>8</sup> Request for Proposals for the City of Indianapolis, Indiana Advanced Wastewater Treatment Facilities, July 15, 1993.

<sup>9</sup> Agreement for the Operation and Maintenance of The City of Indianapolis, Indiana Advanced Wastewater Treatment Facilities, December 30, 1993.

<sup>10</sup> Sources for entire section: Indianapolis Advanced Wastewater Treatment Facilities, White River Environmental Partnership One Year Summary, March 20, 1995; Indianapolis Advanced Wastewater Treatment Facilities, White River Environmental Partnership Second Year Summary of Activities, 1996; and Initiative Management Review: Advanced Wastewater Treatment Initiative, Enterprise Development, August 16, 1996.

<sup>11</sup> Indianapolis Advanced Wastewater Treatment Facilities, White River Environmental Partnership One Year Summary, March 20, 1995; and Initiative Management Review: Advanced Wastewater Treatment Initiative, Enterprise Development, August 16, 1996.

<sup>12</sup> Indianapolis Advanced Wastewater Treatment Facilities, White River Environmental Partnership One Year Summary, March 20, 1995.

<sup>13</sup> Initiative Management Review: Advanced Wastewater Treatment Initiative, Enterprise Development, August 16, 1996.

<sup>14</sup> "Controlling Interests: US Wastewater Treatment Plants Provoke Public-Private Rivalry", *Engineering News Record*, v237 n13, September 23, 1996.

<sup>15</sup> Sources: Request for Qualifications, Operations and Maintenance Services for the Irwin Creek Wastewater Treatment Plant, The City of Charlotte, North Carolina, 1995; and Request for Proposals, Operations and Maintenance Services for the Irwin Creek Wastewater Treatment Plant, The City of Charlotte, North Carolina, January 31, 1996.

<sup>16</sup> National Pollution Discharge Elimination System Permit No. NC0024945 for the Irwin Creek Wastewater Treatment Plant, State of North Carolina, Department of Environment, Health and Natural Resources, Division of Environmental Management.

<sup>17</sup> Source: Request for Qualifications, Operations and Maintenance Services for the Irwin Creek Wastewater Treatment Plant, The City of Charlotte, North Carolina, 1995.

<sup>18</sup> CMUD Contract Operations Proposal for Irwin Creek WWTP O&M Services, April 11, 1996.

<sup>19</sup> Source: Request for Proposals, Operations and Maintenance Services for the Irwin Creek Wastewater Treatment Plant, The City of Charlotte, North Carolina, January 31, 1996.

<sup>20</sup> Source for entire section: Quarterly Progress Report, CM-ConOp Operations and Maintenance, Vest WTP and Irwin Creek WWTP, July-August-September 1996.

<sup>21</sup> Ibid.

<sup>22</sup> Ibid.

<sup>23</sup> Maldonado, Monica, "Public Water in Private Hands", *Civil Engineering*, v67 n1, January 1997.

## 6.0 Conclusion

The recent growth and expansion of the wastewater treatment industry can be justified when viewing the industry in the current system of economic, political and social influences. The public need for infrastructure development, including transportation facilities, airports, public schools, environmental remediation, and water and wastewater facilities, far exceeds available federal, state and local resources. Increased concern over public health and the environment has created a need for new high quality treatment systems and sophisticated pollution prevention strategies. The necessity for innovative financing alternatives has opened the wastewater market to the private sector for providing financial, management and operational services. Ultimately, this growth is occurring as the US environmental industry transitions from a period of regulation-driven, compliance-based business to one which focuses on sustainable, economic-based considerations.

One of the major implications of this industry climate on wastewater treatment technologies is that it encourages technology advancement and development. It is the confluence of three principle factors that has formed the industry into a ripe market for technological development. These three factors are summarized below.

- 1. Increased concern for the quality of the environment.*

As overall concern for the quality of the environment has risen, so has the desire and necessity to reduce capital, operating and maintenance costs associated with wastewater treatment. These concerns have created a need for innovative technologies able to produce high-quality effluents to meet more stringent discharge requirements at lower costs. The increasing regulatory focus on preventing and controlling nonpoint source discharges contributes to the need for technological development.

- 2. Increased role of privatization.*

Increased private-sector involvement in wastewater facility management/operation is helping to release the financial burden on some municipalities. When assuming wastewater contract responsibilities, private firms realize that limits exist on the rates that can be charged to the users. Consequently, cost savings and, therefore, profits must result from improved facility operations. Once the limit to operational efficiencies via managerial and operational streamlining techniques is reached, additional cost savings

(profit) can only be achieved through the use of advanced technological systems. With public utilities feeling the pressure from the private sector, the trend in streamlining public wastewater facilities to more resemble a business will add to the number of facilities eventually requiring technological innovation to improve operations. This eventual stage will become one of the main drivers of technological development.

3. *Focus on alternative treatment processes.*

The arguments for using advanced technologies are that they reduce long-term operating costs, increase available treatment capacity, extend the life of the plant, result in more efficient use of natural resources (energy, chemicals), and improve the quality of effluent discharge. Because these benefits are valued in the current industry structure, the incentive exists to develop advanced, innovative technological alternatives to, or improvements on, existing treatment processes. Related industries possessing technical solutions to wastewater process objectives have provided opportunities in wastewater technology development through the application of fringe-industry innovation.

As a result of the current market conditions, we can expect some of the business segments which support the wastewater treatment industry to take advantage of opportunities provided by industry expansion. Some areas of opportunity that are likely to produce considerable activity in the near future include:

1. *Increased public-private partnerships.*

The ability of wastewater firms to provide efficient operational services and much-needed capital will continue public-private partnering in the industry. It is estimated that by the year 2020, municipalities will have outsourced approximately 50 percent of their water and wastewater operations.<sup>1</sup> With current private participation only at 10 percent, significant barriers to privatization will be softened in the future. The lowering of regulatory hurdles might come in the form of the 1995 Federal-Aid Facility Privatization Act. This bill attempts to alleviate those problems faced by municipalities when they are required to repay the depreciated value of federal grants. The passage of this bill would also make it easier for mayors and private firms to draw up long-term (e.g., 20-year) leases. With long-term contracts, private firms are willing to spend money on capital-intensive advanced technologies and facility upgrades because the length of the concession is such that a return on investment can be realized.

*2. Full-service, turnkey construction*

With current infrastructure needs, lack of available public funds, and privatization an accepted and valued alternative, there will be a market opportunity for wastewater construction and engineering firms to provide the full range of services to municipalities looking to construct new or upgrade existing facilities. These full range of services could include requirement studies and conceptualization, securing financing, engineering design, treatment plant construction, and facility operation. The use of established project delivery systems such as design-build-operate (DBO), build-operate-transfer (BOT), and design-build-operate-transfer (DBOT) provides the mechanism to take advantages of this opportunity.

*3. Venture capital investment*

The operational efficiencies achievable through advanced technological systems will have private wastewater firms focused on the development of wastewater technologies. With all indications pointing towards increased innovation and technological development, venture capitalists may find adequate investment opportunities in supporting basic technological research and pilot-scale testing for new wastewater treatment technologies. In addition, investment opportunities exist for contributing capital which is required for the types of infrastructure development projects described above.

As we look to the future of the wastewater treatment industry, it appears that the current system of market influences has sparked an expansion of the wastewater industry; one which will continue to grow as a result of technological development efforts and a refined, more productive partnership mentality between the public and private sector.

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<sup>1</sup> Maldonado, Monica, "Public Water in Private Hands", *Civil Engineering*, v67 n1, January 1997.

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