16. A Proactive Microbial Control In Philadelphia

Presenter

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A PROACTIVE MICROBIAL CONTROL IN PHILADELPHIA

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INTRODUCTION

Some time ago, the Philadelphia Water Department (PWD) Public Affairs manager confided in her colleagues that the first time she heard of *Cryptosporidium* was while dining at a restaurant. She was alerted by a TV reporter seeking PWD's comment about a boil water emergency in Milwaukee resulting from protozoa in the drinking water. This happened in 1993 when the general public and even many water utility managers had little knowledge about *Cryptosporidium* during the 1980s. *Cryptosporidium* had only recently been identified by JN Rose and a few others in the 1980s, but is an emerging pathogen that has greatly affected the United States of America (USA) water industry.

There were also concerns related to *Giardia,* but they were generally relegated to unfiltered systems. Much of the attention and research were focused on identifying or treating chemicals in the drinking water such as pesticides, herbicides, heavy metals, and trihalomethanes, which are known as disinfection byproducts (DBPs). In the recent past, drinking water regulations were simple and well understood and the level of public interest and involvement in drinking water quality was generally low. That was then, but since 1990 the water industry has undergone rapid changes due to the occurrence of waterborne outbreaks of previously unknown "bugs" such as *Cryptosporidium,* as well as increasingly complex regulations. The 1990s can be characterized as the decade of the microbials as many utilities were confronted with outbreaks caused by *Cryptosporidium.* With advanced analytical techniques and research, scientists have also detected and found previously less known organic chemicals and DBPs such as haloacetic acids that might have adverse health effects on humans.

In this report, the USA water industry's perspectives on waterborne microbes and a local utility's efforts to meet the challenges to provide microbiologically safe drinking water will be presented.

Key Words: Microbial concerns, Safe Drinking Water Act Regulations,
Best Management Practices, Partnership

SAFE DRINKING WATER ACT REGULATIONS ON MICROBIALS

Drinking water quality in USA is regulated by the US Environmental Protection Agency (USEPA) under the statutory authority of the Safe Drinking Water Act (SDWA). While SDWA regulations greatly affect the water industry, as water utilities have to prepare and comply with requirements specified in SDWA regulations, the act has been a driving force in protecting the public from waterborne microbes. It has provided opportunities for the water industry to improve its research and treatment techniques related to microbials and DBPs.

In 1989, EPA issued two important National Primary Drinking Water Regulations (NPDW): The Total Coliform Rule (40 CFR 141.21) and the Surface Water Treatment Rule (SWTR) (40 CFR 141 Subpart H).

In the Coliform Rule, the EPA set a maximum contaminant level goal (MCLG) of zero and an MCL for total coliforms. If more than 5.0 % of the samples taken within a month contain coliforms within a month, a water system must report this violation to the state and the public.

The SWTR sets MCLGs for Legionella, *Giardia lamblia*, and viruses at zero since any exposure to these contaminants presents some level of health risk. Specifically, the rule requires that surface water has sufficient treatment, known as treatment technique (TT), to reduce the source water concentration of *Giardia lamblia* and viruses by at least 99.9 % (3 log) and 99.99 % (4 log), respectively. The rule does not account for systems with high pathogen concentrations and it does not specifically control for the protozoan *Cryptosporidium*. There are a number of well-documented waterborne outbreaks of Cryptosporidiosis that occurred during the 1990s, including an outbreak in Milwaukee in 1993 that killed over 50 persons and affected over 400,000 persons. Some of the water utilities where such outbreaks occurred were meeting federal and state standards for acceptable quality of drinking water.

In consideration of the above mentioned concerns and in the height of *Cryptospridium* outbreaks that occurred in the earlier 1990s, the USEPA promulgated the Interim Enhanced Surface Water Treatment Rule (IESWTR) in 1998. This built on the SWTR by adding protection from *Cryptosporidium* through strengthened filter effluent turbidity performance standards (June 2001, IESWTR Implementation Guidance, EPA).

The rule lowers the combined filter effluent turbidity to 0.3 NTU in 95% of samples collected in a month, with no combined effluent having a turbidity of 1 NTU (see Supplementary Information). USEPA also promulgated the Stage 1 Disinfectants/Disinfection Byproducts Rule (DBPR) concurrently with the IESWTR to address risks associated with disinfectants and DBPs.

MICROBIAL CONTROL IN USA

Crytptosporidium is one of the most important pathogens in the USA and other countries (Public Health Handbook, 1997: *Cryptosporidium* and Water). It is ubiquitous in surface (JN Rose, 1991) and source waters (LeChevallier, 1991). Ordinary disinfection methods cannot kill *Cryptosporidium* oocysts, and even the best filtration units may allow a few organisms to pass through in treated water. Once infected, a healthy person will recover from illness within two weeks, however an immuno-compromised individual may not be able to recover and could possibly suffer chronic and debilitating symptoms. In addition to concern mounted over the difficulty in controlling *Cyrptosporidium*, the water industry has been facing increasingly complex regulations, scientific uncertainties, aging infrastructure, and competition for limited resources.

While there were no simple answers and no magic solutions, the water industry believed that the best measure of efficiency for removing of microbes was by assessing plant performance for turbidity and particle removal and disinfection. During the earlier part of 1990s a well-coordinated effort was made between water utilities, USEPA, American Water Works Association and health authorities to brainstorm and to come up with an action plan that has the same voice and the same approach. Many utilities across the nation formulated programs to assess their systems through an evaluation of treatment as well as source water and distribution systems. Then, they prioritized deficiencies and limiting factors that had been identified and optimized their process by making the following corrections:

1. Identify Constraints
    - Regulatory
    - Water Quality
    - Operational
    - Management and Human Resources
    - Design & Engineering
    - Financial
2. Rank the Constraints on a Priority Basis
3. Develop Goals
    - Water Quality
    - Operational
    - Other
4. Estimate Costs and Reflect the Costs in Budgets
5. Assess the Possibility of Rate Increase
6. Correct or/and Optimize based on the Ranking
7 Identify Treatment Alternatives to address Future Regulations

With the exception of some small systems, many medium and large utilities have been able to upgrade their systems and improve treatment performance so that their treatment capability not only meet the SDWA regulations, but also operates at optimum efficiency for microbial removal and disinfection.

PWD is one of those utilities that has adopted best management practices and set stringent water quality goals beyond those of the existing regulations to better prepare for the future, especially for microbial concerns.

CASE STUDY: OPTIMIZATION

In many ways, PWD symbolizes larger utilities in the USA faced with numerous challenges that are in the process of meeting the challenges through optimization and long-term planning. Optimization usually means improving a process using existing resources. It applies not only in treatment areas, but also in the distribution system, communication and other administrative areas. Below is Philadelphia's experience to serve as an example of how many water utilities are improving water quality by source water protection, treatment optimization, and infrastructure integrity.

PWD's plants and distribution system are one of the oldest in the country. The plants were built almost 100 years ago and many of the mains and pumping facilities were constructed during the 19th century or early part of the 20th century. Some of the treatment facilities were renovated during the 1970s and 1980s, however, the existing systems could be regarded as outdated by today's standards.

In the early part of 1990s PWD began to look at microbial issues, especially the occurrence of *Cryptosporidium* and *Giardia.* All three treatment plants and their finished waters were meeting SWTR requirements and SDWA regulations. However, PWD was concerned with its source waters, which were suspected to contain protozoa, in light of the treatment plants' outdated systems especially for filter performance. In 1995, national and international experts teamed up with PWD personnel and examined the treatment facilities and identified various deficiencies at the plants. Their findings and recommendations helped establish short and long-term goals, as all parties concurred that PWD plants were vulnerable to microbial risks. Following this, PWD joined the Partnership for Safe Water, a joint program of USEPA/AWWA and the water industry, and began a composite correction program (CCP), from which it has greatly benefited. The self-assessment helped PWD identify deficiencies and factors that limited the plants' performance. The limiting factors identified through this self-assessment have since been prioritized and corrections and optimizations have been made. The findings were reflected in operational and 5-year capital budgets. In 1993, PWD began a research program, which involved monitoring PWD's drinking water sources and its finished water for *Giardia* and *Cryptosporidium.* PWD has also recruited personnel with strong academic credential to foster its research areas in microbes and DBPs.

Below are some examples of how the quality of finished water and plant management have been significantly improved. Over the past seven years each plant has upgraded all the processes enabling them to operate the system with turbidity levels at <0.06 NTU more than 99% of the time and the maximum allowable turbidity spike during the backwash at 0.3 NTU. Each filter has an online turbidity analyzer and is classified based on its physical integrity and performance. Each of the filter effluents has an online particle counter to measure particles of protozoan sizes that pass through the filter. The flocculation tanks have been renovated with improved baffling to achieve better mixing known as T_{10} values. Chlorine is applied at multiple locations to avoid any failure in achieving a minimum C*T value (C, residual disinfectant concentration x T, contact time). The SWTR prescribes C*T levels for disinfectants, which will achieve different levels of inactivation under various conditions. For many water utilities disinfection is a priority and they achieve more credit for disinfection, as determined by their C*T values. For instance, PWD's daily average C*T values as an example range from 400 to 900%, which is much more than it is required.

If the plant fails to maintain any of the prescribed goals, the manager must notify his superior and PWD's water quality division, though performance typically exceeds USEPA requirements.

Pilot plants were installed in 1998 and they have provided critical information in calibrating and optimizing existing processes such as finding the optimum pH for coagulation and DBP formation control. Also, they have provided the basis for evaluating the feasibility of applying alternatives such as ozone, UV, dissolved air floatation (DAF) and plate settling. Through a plant-scale study, PWD is using potassium permanganate as a pre-oxidant for replacing chlorine dioxide and free chlorine. It was found that pH 6.5 for ferric chloride and pH 5.5 for alum were ideal levels for optimizing the coagulation wherein particles and NOM would be removed most effectively. However, algae blooms in the watersheds (i.e., diatoms) can threaten the optimum performance of coagulation and filtration. In such cases, polyelectrolytes (known as polymers) can be used as coagulant aids. A variety of cationic, an ionic and ampholyctic (has both positive and negative) products that have been approved for use in drinking water treatment by water utilities are now in use. More than half of the water plants in the U.S. use one or more polymers to improve treatment efficiency (1998 Chemistry of Water Treatment, Faust et al).

As noted, water utilities in the USA choose treatment chemicals that are economically feasible and work for their own processes. National Sanitary Foundation (NSF) provides information about commercial chemicals and substances that can be used in treatment and distribution systems. PWD reviews the products listed in NSF and tests them to assure that the quality of the products are maintained.

In addition to treatment improvement, PWD considers that protecting its watersheds and the distribution system to be equally important for providing safe water to customers. The source waters for the plants have long been of concern because they contain various contaminants such as protozoa and coliforms that may originate from creeks outside of the utility's boundary and from other sources such as storm water and combined sewer overflow in the city. In 1998, PWD created a new unit to focus on watershed management to address these concerns.

Under the PWD's distribution water quality policy, new pipes must have caps on the pipe ends and newly installed pipes must be disinfected and tested. Existing pipes that require repairs or that are taken out of service must also be disinfected and tested. A cross connection control policy stipulates that all buildings and facilities, except small homes must install cross connection control devices (backflow preventers) on their service lines and PWD will shut off a building's water service if it has no backflow preventer. A cross connection is an improper connection between a drinking water and a non-drinkable system. The USEPA and the water industry recognize that cross connections have been the leading causes of outbreaks and other major water quality problems in the USA.

PWD has a Water Quality Committee to better communicate with the public on water issues and to help the executive staff make decisions when a serious microbial problem occurs. The committee has developed a microbial communication plan with Health Department physicians to address waterborne microbial events and assist the Mayor or Water Commissioner in making decisions concerning events. For instance, if E.coli or other microbes are detected or there is an indication of treatment defect the Health

Department will track the number of cases of Giardiasis, Cryptosporidiosis and acute diarrheas so that the committee can assess the situation.

PARTNERSHIP

PWD has actively participated in USEPA's regulatory process and supported AWWA, which represents the water industry. PWD helps USEPA by providing research reports and data and comments on proposed regulations.

At the same time USEPA and AWWA have greatly helped PWD and other water utilities on plant optimization and other improvements by offering "Partnership for Safe Water Program" and training and guidance (i.e., Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, EPA/625/4-89/023). Since the early 1990s AWWA has offered satellite conferences on treatment, DBPs, distribution and other water quality issues which recognized as a highly effective and instrumental for the water industry.

PWD is member of the Waterworks Management Workshop Group. It consists of 17 major water utilities, which meet twice a year to exchange specific information on their operations and experiences including treatment techniques and process control, distribution infrastructure management, water quality, and laboratory issues. Before the meeting, they solicit and answer related questions electronically.

ALTERNATIVE AND ADVANCED MIROBIAL CONTROL

While PWD has been able to meet the new regulations (i.e., IESWTR, Stage 1 DBPR), ozonation and ultraviolet (UV) radiation are also being studied as alternate treatment techniques to balance microbial and DBP issues and address future regulations and uncertain water quality concerns. UV radiation has been receiving increased attention since UV systems are proved to reliably achieve high levels of disinfection at moderate UV doses with no DBPs and relatively low costs (2000 PWD's Water Treatment Plant Optimization and Advanced Treatment Pilot Studies). Costs for constructing the above mentioned systems have also been greatly reduced in recent years.

DISCUSSION

The water industry's environment has been changing rapidly with increased awareness and expectations from customers on water quality. The public water utilities, which traditionally had little competition for their products, are in the era of the Consumer Confident Report. Under the Right to Know Rule, water utilities are required to annually publish and distribute their water quality results to customers. This is analogous to a school report card so that well-informed customers can see whether their water supplier did well or poorly compared to the quality of drinking water treated elsewhere.

In general, water quality regulations may be a baseline for setting performance and water quality goals. In fact, EPA recommends that all parameters be at least one half of the maximum contaminant levels (MCLs). However, many utilities across the nation including PWD have gone beyond the regulations and set higher performance and water quality standards. There are still a variety of water quality concerns that are not addressed by the drinking water regulations such as public perception, emerging issues that may require future regulations, and uncertainty about health effects.

Providing drinking water is a public trust and creates a unique responsibility for the water industry in the USA. Water utilities must balance their efforts to make the drinking water microbiologically safe while minimizing the production of DBPs.

PWD must continue to meet these challenges, but we can not do it alone nor without specific goals.

A PROACTIVE APPROACH TO MICROBIAL CONTROL IN PHILADELPHIA

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OVERVIEW

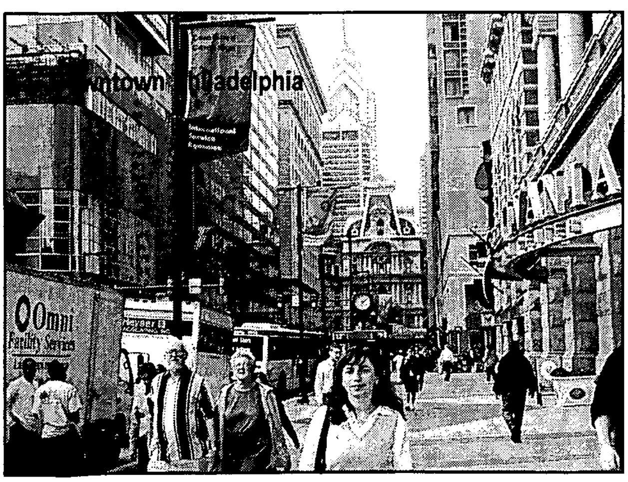
- Introduction
- Microbial Concerns
- Microbial Controls

INTRODUCTION

- City of Philadelphia
- Philadelphia Water Department

PHILADELPHIA

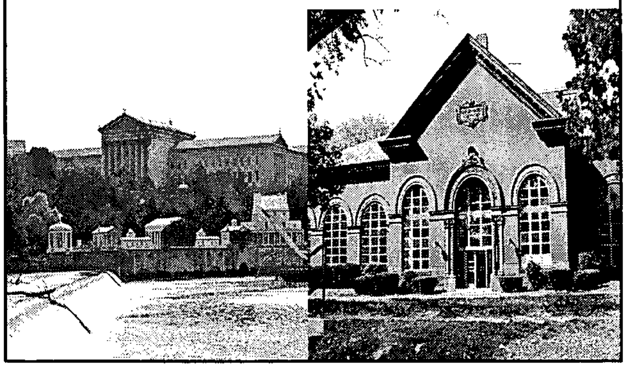
- First Capital in US
- 2nd Largest City on the East Cost with 1.5 Million Population
- Population has decreased over the last 30 Years



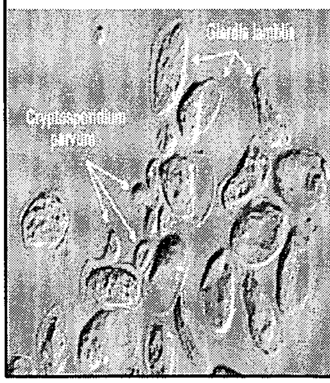
PHILADELPHIA WATER DEPARTMENT

- Founded in 1799
- Pumping River Water with Steam-powered Engine began in 1801
- Filtration began in 1901 and Chlorination began in 1913
- Three Treatment Plants with 3,300 Miles of Piping

Pumping Stations on the Schuylkill River Constructed in 1801 (Left) and 1870 (Right)



US WATER UTILITY CONCERNS ON MICROBES

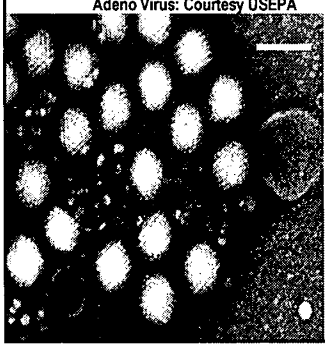


- Watershed Challenge: Where & What are the Source? How and Who will Control?
- Treatment Challenge: What Level to meet the Current & Future Regulations? Process Control and Reliability

Courtesy: USEPA

US WATER UTILITY CONCERNS ON MICROBES

Adeno Virus: Courtesy USEPA



- Microbial vs. Disinfection Control
- Analytical Challenge: Sampling, Testing, Recovery
- Early Warning Issues, Viability Issues
- Public Health Challenge: Can We Correlate Disease Occurrence to Density and Endemic Rate

US WATER UTILITY APPROACH ON MICROBES

- Priority: Turbidity/Particle Removal & Disinfection
- Action:
  - Self assessment
  - Optimization
  - Research: Occurrence, Removal, Alternate treatment
- Education and Communication

CASE STUDY - PHILADELPHIA EXPERIENCE

PROBLEMS IDENTIFIED IN 1990 - 1993

- Source Water Concerns
- Treatment Deficiencies
- Distribution Issues

PROBLEMS IDENTIFIED IN 1990 - 1993

- Source Water Concerns:
  - Protozoa found in Source Waters
  - Some Sewer Pipes interconnected with Storm Water Pipes
  - Contaminants Discharged from Neighboring Communities Upstream of City

PROBLEMS IDENTIFIED IN 1993-1994

- TREATMENT DEFICIENCIES
  - Process Control and Reliability Concern
  - *Cryptosporidium* resistant to PWD's Conventional Chlorine Treatment
  - Complacency: No Outbreaks, No Problem Meeting SDWA, No Competition

PROBLEMS IDENTIFIED IN 1990 - 1992

- DISTRIBUTION ISSUES
  - Aging Infrastructure
  - Reservoir Structures/Hydraulic Operations
  - Cross Connections and Backflow
  - Main Replacement Practices

BEST MANAGEMENT PRACTICES:

- " Multiple Barrier " from Watershed to Tap
- Emphasis on Research
- Emphasis on Communication and Education
- BMP Initiated by Technical Staff

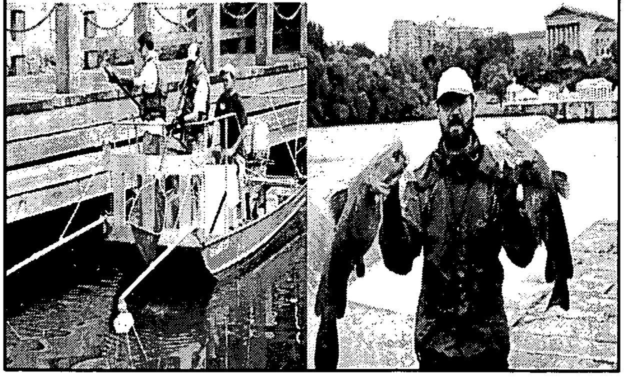
PHILADELPHIA'S ACTION: 1993 - PRESENT

- Allocate, Recruit Technical Resources
- Research: Monitoring, Pilot Plants
- Conduct Expert Workshop
- Join "Partnership for Safe Water"
- Perform Self-Assessment: Composite Correction Program
- Optimize: Treatment, Watershed, Distribution, Management

SOURCE WATER PROTECTION

- Form Office of Watersheds to Specialize in Watershed Protection
- Watershed Monitoring and Surveillance Partnership with Community Groups and State of Pennsylvania
- Identify and Correct Illegal Connection to Storm Water System

Watershed Surveillance

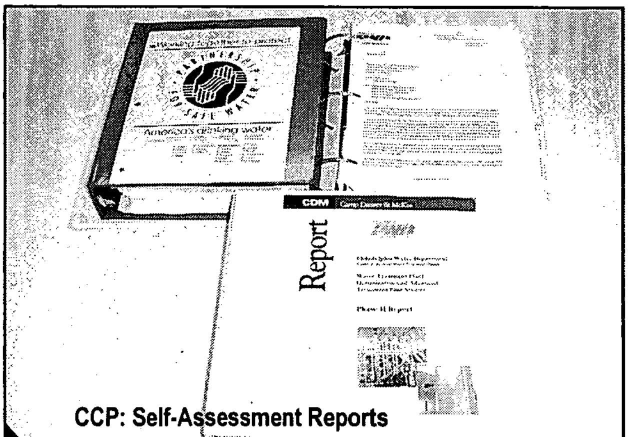


TREATMENT OPTIMIZATION

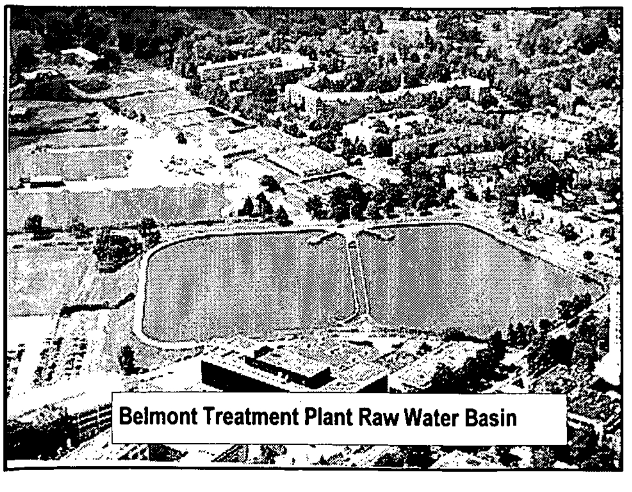
- Conduct Expert Workshop
- Join "Partnership for Safe Water"
- Perform Self-Assessment by Composite Correction Program
- Optimize Treatment Processes

TREATMENT OPTIMIZATION

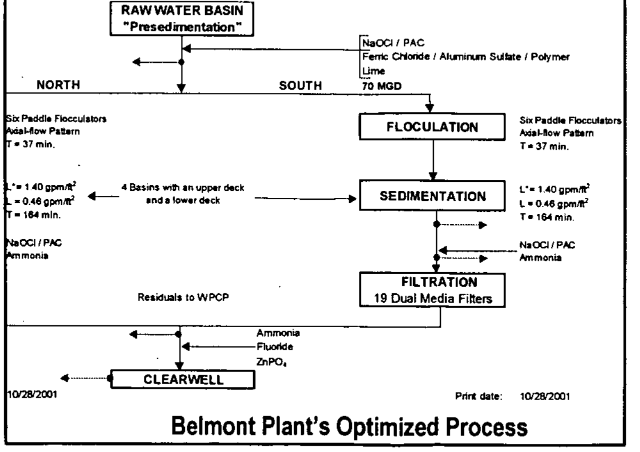
- CCP: Identify Limiting Factors
- Prioritize the Limiting Factors
- Set Performance and Water Quality Goals
- Obtain Finance and Management Support
- Optimize Based on Ranking: i.e., Filter Classification, C*T Increase
- Enhance Monitoring for Process Control



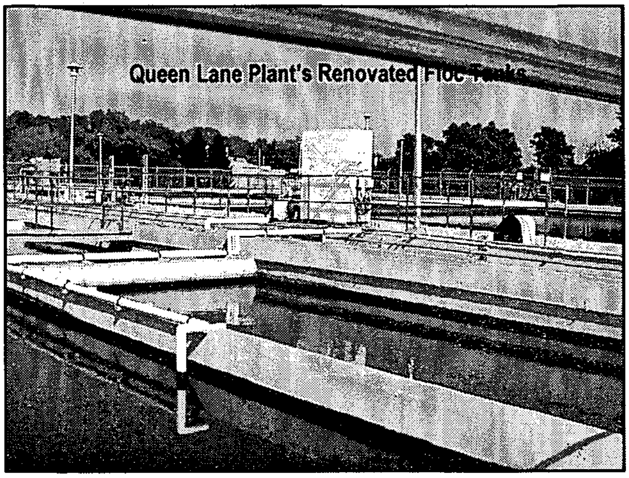
CCP: Self-Assessment Reports

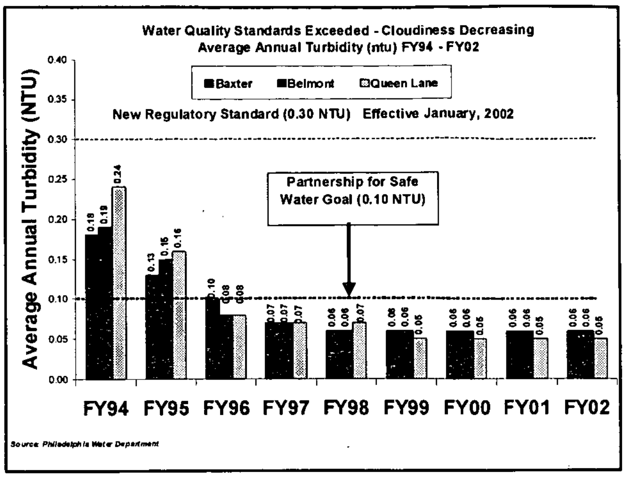


Belmont Treatment Plant Raw Water Basin



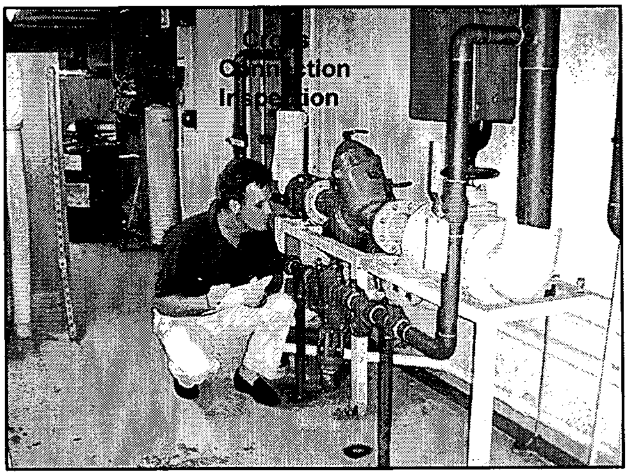
Belmont Plant's Optimized Process



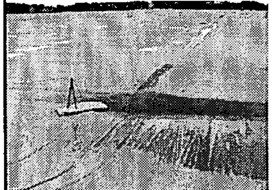


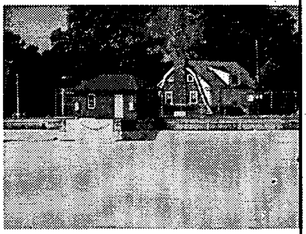
DISTRIBUTION WATER QUALITY CONTROL

- Enhance Water Quality Monitoring
- Rehabilitate Reservoirs
- Train and Enforce Sanitary Practices for Main Repair and Replacement
- Issue Cross Connection Control Regulation and Enforce the Regulation



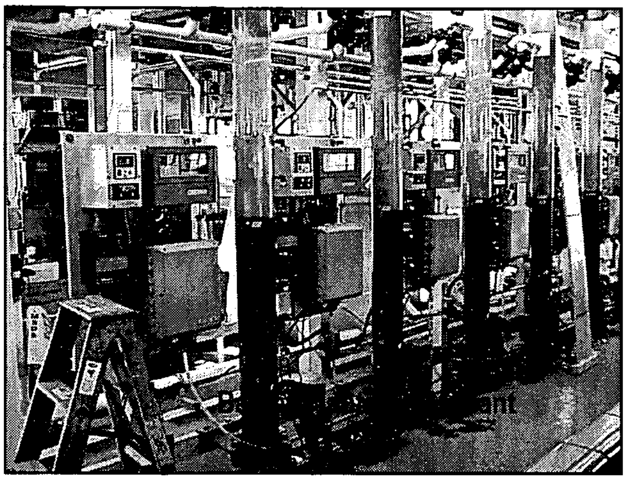
Oak Lane Reservoir Rehabilitation: 1996





EMPHASIS ON RESEARCH

- Treatment Optimization and Process Adjustment through Pilot Plant Studies
- Research on Turbidity & Particle Count Removal
- Research on Protozoa Detection, Occurrence and Removal



EMPHASIS ON COMMUNICATION AND EDUCATION

- Microbial Response with City Health Department
  - Offer Media Workshop with Health Department Disease Control Experts
  - Implement a Microbial Communication Plan with Health Department

MICROBIAL COMMUNICATION RESPONSE

- **If Major Water Quality Problem Occurs**
  - ✓ **Review Operation Performance and Water Quality Data**
  - ✓ **Increase Monitoring including Protozoa Testing**
  - ✓ **Review Gastrointestinal, Diarrhea Reports**
  - ✓ **Take Corrective Action and Notify the State of Pennsylvania and the Public**