2007

Evaluation of compliance with the Long Term 1 Enhanced Surface Water Treatment Rule

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EVALUATION OF COMPLIANCE WITH THE LONG TERM 1 ENHANCED SURFACE WATER TREATMENT RULE

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Environmental Studies

by
Racquel Rena Douglas
B.S., Louisiana State University, 2005
B.GS., Louisiana State University, 2005
December 2007

ACKNOWLEDGEMENTS

I would like to thank my parents, Cynthia Brown and Lloyd Douglas, my sisters, Kendra and Natasha, my niece, Taylor, and the rest of my family and friends for their love, support, and encouragement. To my friend, Charisma Edwards, thank you for listening when I needed to reconceptualize my entire thesis and for assisting me after my move to Dallas, Texas. A special thanks to Wally Dows and the Environmental Department at Marathon Petroleum Company, the LSU Department of Environmental Studies, and the LSU Graduate School.

I want to thank my major professor, Dr. Margaret Reams, for agreeing to serve as the head of my committee. Thank you for your guidance. I would also like to thank Dr. Ronald Malone and Michael Wascom, JD for serving on my committee. Without your input and advice, this final product would not be what it is today. I especially want to thank Dr. Malone for being my academic and professional advisor since my undergraduate studies at LSU. You taught me to be a better environmental engineer and not to lose my green. Thank you!

Finally, I want to thank God for giving me the strength, wisdom, and courage to complete my thesis and many other tasks in my life. I am truly blessed to be surrounded by people who love and support me in all that I do. A million thanks will never be enough!

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ABSTRACT

Cryptosporidium is a common protozoan parasite that causes cryptosporidiosis, a severe gastrointestinal disease. Currently, there is no antibiotic available to treat the disease. Cryptosporidium has been responsible for several waterborne disease outbreaks in the United States. The largest cryptosporidiosis outbreak in United States history occurred in Milwaukee, Wisconsin in spring 1993. The vulnerability of the United State drinking water supply to waterborne disease outbreak is still prevalent nearly 15 years after the Milwaukee outbreak.

In order to effectively control Cryptosporidium, the EPA has strengthened the regulations on turbidity control for filtration performance by implementing the Long Term 1 Enhanced Surface Water Treatment Rule. The Long Term 1 Enhanced Surface Water Treatment Rule applies to all public water systems that serve fewer than 10,000 people and use surface water or ground water under the direct influence of surface water. The turbidity level of combined filter effluent water samples must be less than or equal to 0.3 NTU in at least 95% of the measurements taken each month, with no samples exceeding 1 NTU. Systems meeting these filter performance requirements are presumed to achieve at least a 2-log removal (99%) of Cryptosporidium.

The purpose of this research is to evaluate compliance with the Long Term 1 Enhanced Surface Water Treatment Rule for a potable water treatment system operated by an oil refinery in southeast Louisiana that has been experiencing turbidity spikes since February 2006. The turbidity and disinfection data obtained from this facility will be examined.

This study found that, despite meeting compliance requirements of the Long Term 1 Enhanced Surface Water Treatment Rule, there were still several areas of concern within the treatment process. Additional information is needed to determine the effectiveness of the turbidity data management tool. The regression analysis showed that raw water turbidity could not accurately predict daily average turbidity. Recommendations were made regarding comprehensive system evaluation, monitoring, improvements in treatment technique, and best practices. Although this study concluded in September 2006, significant improvements were made to the gravity sand filters. In April 2007, an ultrafiltration system replaced the gravity sand filters in the potable water treatment system.

CHAPTER 1 INTRODUCTION

Cryptosporidium is a common protozoan parasite that causes cryptosporidiosis, a severe gastrointestinal disease with symptoms consisting of diarrhea, stomach cramps, nausea, loss of appetite, and a mild fever (Finch and Belosevic, 2002; Hsu and Yeh, 2003; USEPA, 2002; USEPA, 2003; USEPA, 2003; USEPA, 2004). There is currently no antibiotic available to treat the disease. Cryptosporidium has been responsible for several waterborne disease outbreaks in the United States. Human and animal waste, sewage, and combined sewer outfalls are the primary sources of Cryptosporidium found in surface and ground water supplies (Neumann, 2005; Okun et al., 1996).

The largest cryptosporidiosis outbreak in United States history occurred in Milwaukee, Wisconsin during the spring of 1993. When the filtration process at one of the two municipal drinking water treatment plants failed, the inadequate removal of Cryptosporidium oocysts resulted in contaminated water being distributed to the residents of the community (Corso et al., 2003). The result of this break was the infection of more than 400,000 people, the deaths of over 100 residents, and the permanent incapacitation of residents (Corso et al., 2003; Okun et al., 1996). The total cost associated with the outbreak was estimated to be $96.2 million (Corso et al., 2003). MacKenzie et al. (1994) documents the health impacts of the outbreak stemming from the contaminated public water supply.

The vulnerability of the United State drinking water supply to waterborne disease outbreak is still prevalent nearly fifteen years after the Milwaukee outbreak. The National Academy of Engineering named the mass production of drinking water as the fourth greatest engineering achievement of the 20^{th} century (Neumann, 2005), so how could widespread contamination be possible? Since 1974, Congress has taken an active role in protecting public health by regulating the national drinking water supply (USEPA, 2004). The Safe Drinking Water Act of 1974, along with the 1986 and 1996 amendments, requires several actions to protect drinking water and its sources. The Act also authorizes the United States Environmental Protection Agency, or EPA, to develop national drinking water standards based on sound science in order to protect the public from health risks while considering available technology and costs.

The group of regulations set by the EPA to provide protection from microbial pathogens and decrease health risks from disinfection byproducts are known as the Microbial and Disinfection Byproduct Rules (USEPA, 2001). In particular, the Long Term 1 Enhanced Surface Water Treatment Rule, finalized January 2002, aims to improve control of microbial contaminants, mainly Cryptosporidium, for small systems. Previous regulations only addressed large public water systems serving populations greater than 10,000 people.

The purpose of this research is to evaluate compliance with the Long Term 1 Enhanced Surface Water Treatment Rule. A potable water treatment plant operated by an oil refinery in southeast Louisiana had been experiencing turbidity spikes since February 2006. The turbidity and disinfection data obtained from this facility will be examined in this study. The objectives of this thesis are to:

1. calculate monthly compliance and probability distributions using various statistical analysis techniques,
2. develop and evaluate a turbidity data management tool, and

3. determine whether there is a relationship between raw water turbidity and daily average turbidity.

Additionally, recommendations will be made that will benefit other public water systems required to comply with the Long Term 1 Enhanced Surface Water Treatment Rule and future drinking water regulations.

CHAPTER 2 LITERATURE REVIEW

2.1 Regulatory Compliance

Under the Safe Drinking Water Act, the EPA has promulgated fourteen major rules between 1976 and 2002 that regulate 90 contaminants (USEPA, 2003). There are two categories of risk that each regulation addresses:

1. Chemical & radiological contaminants: inorganic chemicals, volatile organic chemicals, synthetic organic chemicals, disinfectants, disinfection byproducts
2. Microbial contaminants: turbidity, total coliform bacteria, fecal coliform, E. Coli, viruses, protozoa, bacterial pathogens

When establishing monitoring and reporting requirements, a corresponding Maximum Contaminant Level (MCL) or treatment technique also must be established. An MCL is the greatest concentration of a contaminant in drinking water allowed by law. The MCL is set to minimize possible health risks while taking costs into account. A treatment technique is a required process intended to reduce the level of a contaminant in drinking water.

2.1.1 Effects of Regulations on Drinking Water Systems

Every regulation has its own set of requirements that impacts each drinking water system the same basic way (USEPA, 2003). The requirements are as follows:

1. Monitoring: monitor contaminants and report to the State
2. Decision-making: make compliance decisions base on monitoring results and State reviews
3. Action: take action to reduce health risks identified through monitoring

4. Communication: provide the public with information about water quality and public health risks
5. Deadline: compliance required within three years after a rule has been promulgated, unless compliance requires major capital expenditures

2.1.2 Microbial Contaminants of Concern

This research will focus primarily on Cryptosporidium, a protozoa. Protozoa are disease-causing organisms that originate from the intestines of warm-blooded animals. They may present in water contaminated with fecal pollution. Turbidity, a measure of cloudiness in water, is used as a water quality indicator and a measurement of how effectively a treatment process removes pathogens like Cryptosporidium from source water. Although turbidity is not a microbe and has no health effects, it can interfere with the disinfection process and provide a medium for microbial growth. Turbidity may indicate the presence of disease-causing organisms. These organisms like bacteria, viruses, and parasites can cause symptoms such as nausea, cramps, diarrhea and headaches.

2.1.3 The Multiple Barrier Approach

Efforts to reduce microbial risks in drinking water and concerns about source water quality have prompted the multiple barrier approach to protecting consumers from risk of contamination and waterborne disease (Hsu and Yeh, 2002; Finch and Belosevic, 2002; USEPA, 2003). From raw, untreated source water to the delivery of treated finished water, the multiple barrier approach, as outlined in Figure 2.1, is a series of technical and managerial barriers designed to ensure a safe drinking water supply at each step of the treatment process.

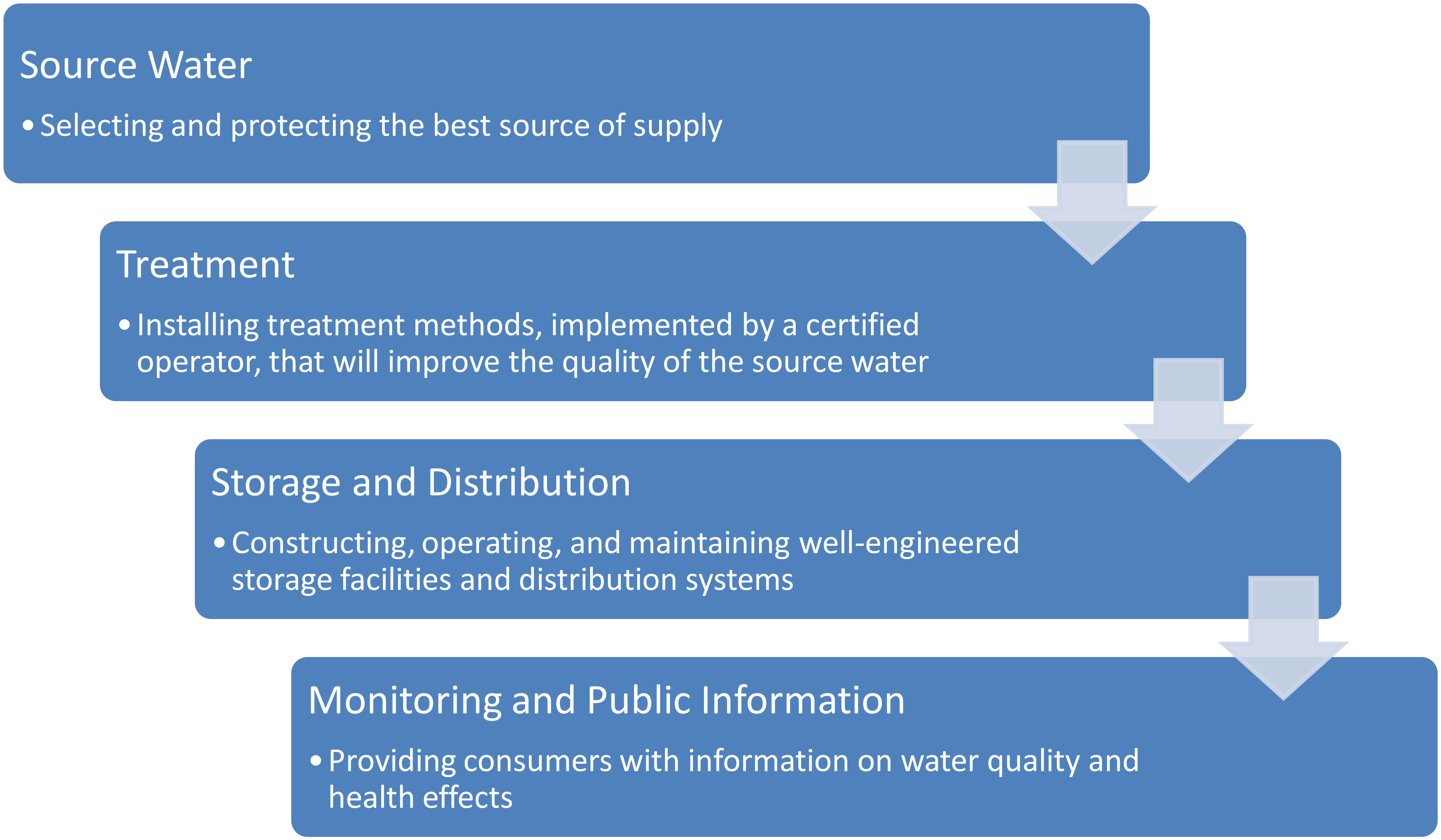


Figure 2.1 The multiple barrier approach to ensuring safe drinking water

Current drinking water regulations implemented under the Safe Drinking Water Act (Figure 2.2) use the multiple barrier approach by erecting barriers that require a certain treatment technique, emphasize monitoring, or require public notifications (USEPA, 2003b).

2.2 Cryptosporidium

2.2.1 Overview

Figure 2.3 illustrates the life cycle of Cryptosporidium (Fayer and Ungar, 1986). The cycle begins when the host ingests the Cryptosporidium oocysts by drinking contaminated drinking water. Finch and Belsovic (2002) summarize the life cycle of Cryptosporidium by six events: (1) excystation of the oocysts in the intestine of the host, (2) replication within the host, (3) gamete formation, (4) fertilization, (5) oocysts wall formation, and (6) sporazoite formation. An infected individual may excrete up to 10^9 oocysts/day in the stool.

2.2.2 Renewed Awareness

The history of public concern regarding drinking water treatment quality can be traced back to 1842 by Okun (1996). Today, clean and safe drinking water is often taken for granted. Our dependence on water treatment and sanitation technology has resulted in a complacent attitude (Neumann, 2005). In the past few years, Cryptosporidium has emerged as a concern for public health (Neumann, 2005; Hsu & Yeh, 2002). Gregory (1998) and Okun (1996) are primarily concerned with recent waterborne cryptosporidiosis outbreaks in systems that meet current drinking water regulatory standards.

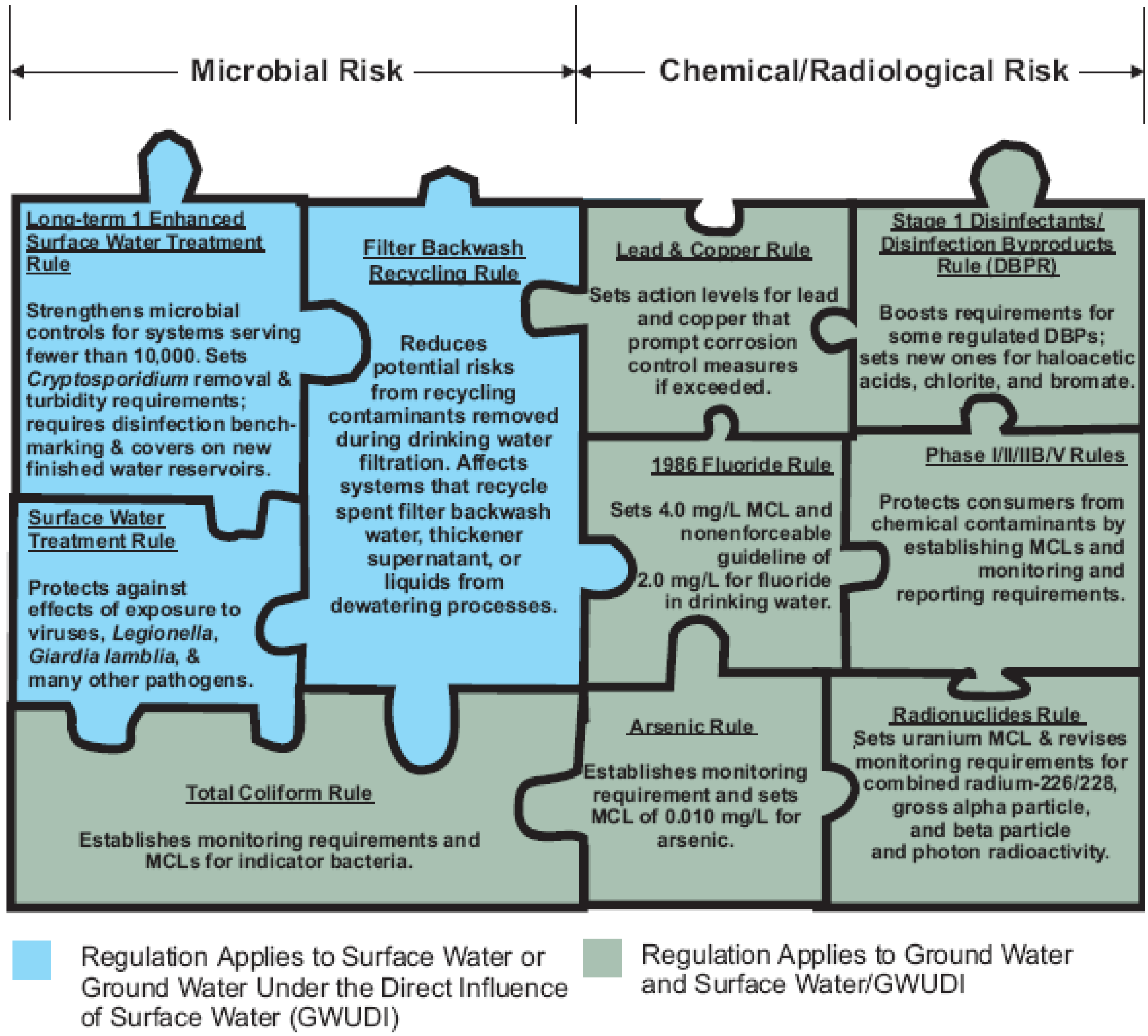


Figure 2.2 Current EPA regulations using the multiple barrier approach

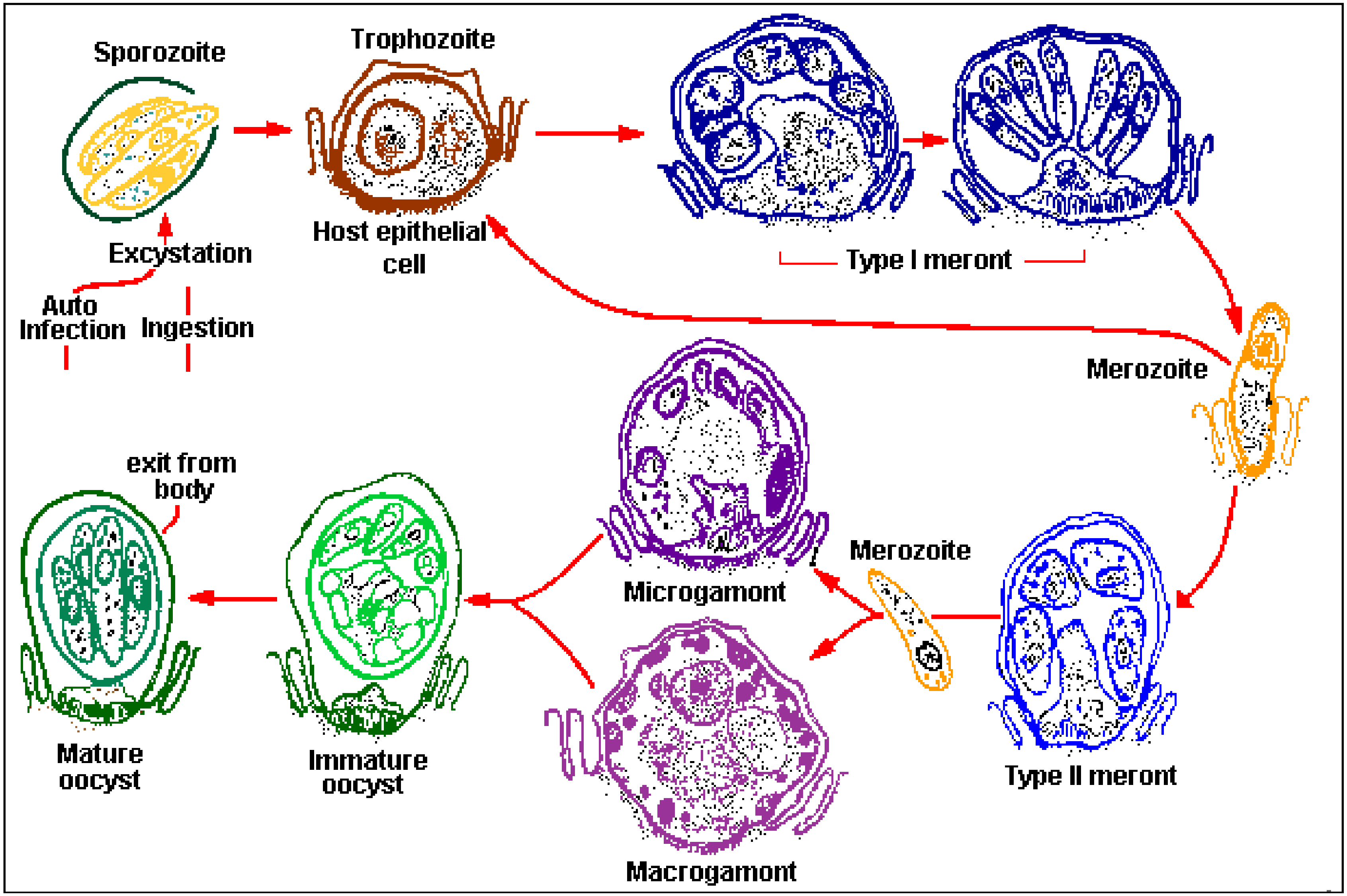


Figure 2.3 The life cycle of Cryptosporidium

2.3 Water Treatment

Water treatment plants supply thousands of people with drinking water from a single treatment facility. The typical water treatment process consists of coagulation, flocculation, sedimentation, filtration, disinfection, storage, and distribution. Coagulation is a process using coagulant chemicals and mixing by which colloidal and suspended materials are destabilized and agglomerated into flocs. Flocculation is a process that enhances agglomeration, or the collection of smaller floc particles into larger particles that are easily settled through gentle stirring by hydraulic or mechanical means. Sedimentation is a process used to remove solids before filtration by gravity or separation.

Filtration is a process for removing particulate matter from water by passage through porous media. There are five different types of filtration systems:

- Conventional – coagulation, flocculation, sedimentation, filtration
- Direct – coagulation and filtration; excludes sedimentation
- Slow Sand – raw water passes through a bed of sand at a low velocity
- Diatomaceous Earth – water passes through a cake of diatomaceous earth deposited on a support membrance, or septum
- Alternative – technologies other than conventional, direct, slow sand, and diatomaceous earth

Disinfection is the process that inactivates pathogenic organisms in water by chemical oxidants or equivalent agents. Chlorine, ozone, and UV light are examples of disinfectants used in the water treatment process. Treated water is pumped into a closed tank or reservoir for storage in order for disinfection to take place before being distributed through pipes to consumers. These terms are further defined in 40 CFR 141.2 (2003).

2.4 Controlling Cryptosporidium

2.4.1 Overview

In addition to boiling and disinfection, filtration has been used throughout history to prevent the spread of pathogens in drinking water and has been proven to be a very effective process for eliminating pathogens from drinking water (Schoenen, 2002). Before water treatment systems implemented filtration, the process was used in individual households. As effective as it may be, filtration does not eliminate the transmission of disease by pathogens entirely. For example, the cleaning capacity of the Howard Water Plant in Milwaukee was insufficient to remove Cryptosporidium resulting in the largest cryptosporidiosis outbreak in the history of the United States.

Hsu and Yeh (2003) analyzed the concentrations and determined the removal rates of Giardia cysts and Cryptosporidium oocysts in water samples taken from various treatment processes in a pilot water treatment plant. The conventional treatment process in this study simulated the actual water treatment process. The detection results of the conventional treatment pilot study found that Cryptosporidium oocysts in the finished water pose a potential risk for waterborne diseases. The study also found a significant correlation between water turbidity and Cryptosporidium oocysts.

The results from the conventional treatment process in the pilot plant indicated that coagulation and sedimentation followed by filtration was most effective in removing the microbial contaminants. The filtration process may prevent Giardia cysts from entering the finished water, but cannot completely intercept Cryptosporidium oocysts.

2.4.2 Chlorine Treatment

Traditionally, treating water with 0.5 mg/L of free chlorine for 30 minutes has been considered adequate disinfection for preventing waterborne diseases like cholera, typhoid fever, and cryptosporidiosis (Finch and Belosevic, 2002). However, chlorine does not provide an adequate barrier to Cryptosporidium oocysts. Despite the extensive use of chlorination to disinfect drinking water, waterborne disease outbreaks still occur repeatedly (Schoenen, 2002).

2.5 Monitoring Cryptosporidium

2.5.1 Turbidity as an Indicator

Waterborne disease outbreaks have prompted the reevaluation of turbidity measurements as a way to detect very low concentrations of particles in water. Originally, turbidity measurements were used mainly for aesthetic purposes. Now, this method is used to monitor the degree of undesirable particle removal from the water treatment process. Gregory (1998) suggests that by monitoring the removal of particles it is possible to estimate the degree of Cryptosporidium oocyst removal. Measuring low concentrations of particles in filtered water with conventional turbidity methods presents its own set of challenges. These methods are insensitive for particles that fall in size range of Cryptosporidium oocysts (4-6 µm). Gregory discusses traditional turbidity monitoring methods (light transmission and light scattering) and more sensitive alternative methods (particle counting and turbidity fluctuations).

2.5.2 Inadequate Detection

Ahmad et al. (1997) determined the occurrence of Cryptosporidium oocysts and Giardia cysts in the raw and treated waters of two conventional water treatment plants in Selanor, Malaysia. While Giardia cysts were detected in 90% of the raw water samples, no Cryptosporidium oocysts were detected. Cysts, oocysts, and fecal coliforms were not detected in the treated water samples. The presence of Cryptosporidium in the samples is possible although it was undetected.

Monitoring for Cryptosporidium is extremely difficult (Okun, 1996). These highly infective pathogens may cause disease with only a few cysts or oocysts. Monitoring data understates these risks. Allen et al. (2000) point out several disadvantages regarding tests used to detect Cryptosporidium. These tests are time consuming and require experienced technologists. Further, the tests can lead to false-positive or false-negative results and are limited in their ability to assess the spatial and temporal distribution of these parasites.

2.5.3 Seasonal Impacts

The works of Gibson et al., Hurst et al., and Lawler et al. demonstrate the importance of seasonal impacts on water treatment processes, specifically the effective removal of Cryptosporidium as measured by turbidity. An examination of water discharges from sewer outfalls during dry and wet weather conditions by Gibson et al. (1998) found that the number of Cryptosporidium increased considerably in the wet weather samples when compared to dry weather samples. Hurst et al. (2004) studied the turbidity removal at an England water treatment plant which receives raw water which is difficult to treat during rainstorm events. Lawler et al. (2006) focused on urban river water turbidity dynamics during rainstorm events.

2.6 The Long Term 1 Enhanced Surface Water Treatment Rule

2.6.1 Overview

In order to effectively control Cryptosporidium, the EPA (2002) has strengthened the regulations on turbidity control for filtration performance as imposed by the Long Term 1 Enhanced Surface Water Treatment Rule. The rule aims to control microbial contaminants, specifically addressing Cryptosporidium for the first time, in drinking water and address risk trade-offs with disinfection byproducts. The Long Term 1 Enhanced Surface Water Treatment Rule applies to all public water systems that use surface water or ground water under the direct influence of surface water and serve fewer than 10,000 people. The flowchart in Figure 2.4 shows the requirements of the Long Term 1 Enhanced Surface Water Treatment Rule (USEPA, 2004a). The requirements of this rule fall into the following four categories: cryptosporidium removal, enhanced filtration, microbial inactivation benchmarking, or enhanced filtration,

1. Cryptosporidium Removal
    - All systems must achieve a 2-log removal (99%) of Cryptosporidium measured between a point where raw water is not subjected to contamination by surface water runoff and a point downstream before or at the first customer
2. Enhanced Filtration
    - Filtered systems must comply with strengthened combined filter effluent turbidity performance requirements to ensure 2-log removal (99%) of Cryptosporidium

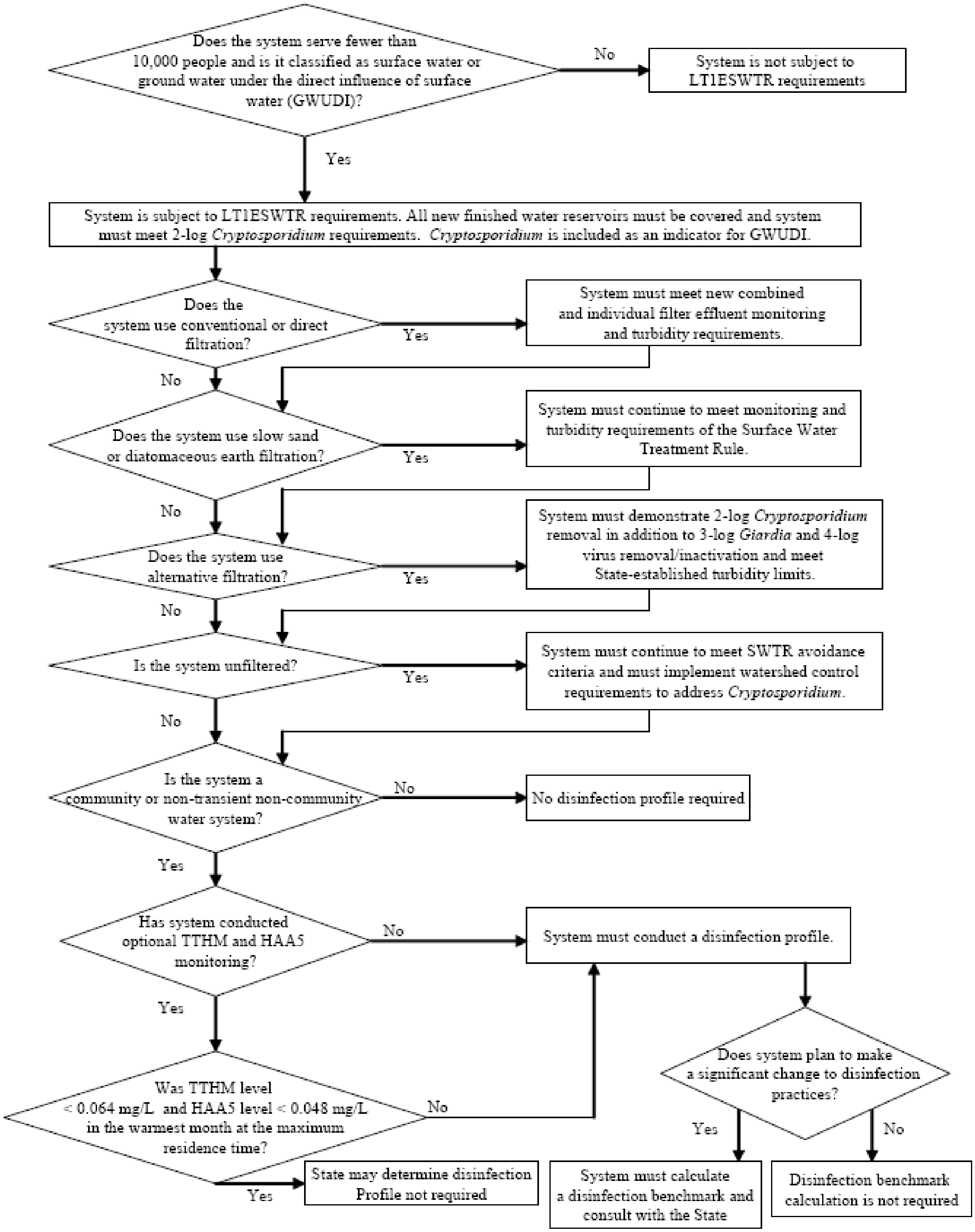


Figure 2.4 General requirements of the Long Term 1 Enhanced Surface Water Treatment Rule

- Conventional and direct filtration systems must continuously monitor the turbidity of individual filters and comply with follow-up actions based on monitoring results

3. Microbial Inactivation Benchmarking
    - Systems must develop a disinfection profile unless the State determines that the disinfection profile is unnecessary
4. Other Requirements
    - New, finished water reservoirs must be covered
    - Unfiltered systems must comply with updated watershed control requirements that now add Cryptosporidium as a microbial contaminant of concern

These requirements were developed based on the Interim Enhanced Surface Water Treatment Rule, but modified to reduce the burden on smaller systems.

2.6.2 Turbidity Requirements

The turbidity level of representative samples of a system's combined filter effluent water must be less than or equal to 0.3 NTU in at least 95% of the measurements taken each month. The turbidity level of the samples may never exceed 1 NTU. At the end of each month, systems must report the total number of turbidity measurements taken, the number and percentage of measurements that exceed the 95% turbidity limit, and the number of measurements that exceed the maximum turbidity limit. Systems meeting these filter performance requirements are presumed to achieve at least a 2-log removal (99%) of Cryptosporidium.

2.6.3 Monitoring Requirements

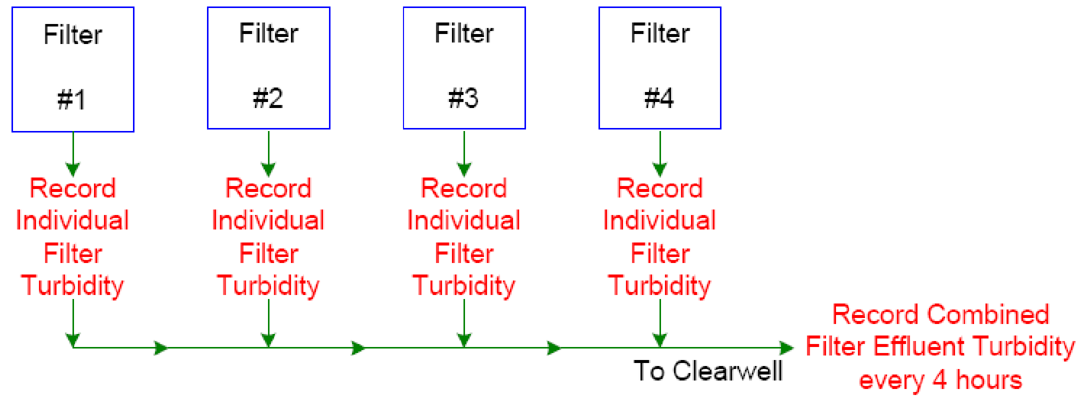
The individual filter effluent and combined filter effluent monitoring requirements are illustrated in Figure 2.5 (USEPA, 2004b). Monitoring requirements are based on the number of filters in the system. Recording readings at least every 15 minutes constitutes continuous monitoring. For systems with three or more filters, individual filter effluent is recorded continuously and combined filter effluent is recorded every 4 hours. Systems with two filters have two monitoring options:

1. individual filter effluent is recorded continuously and combined filter effluent recorded every 4 hours, or
2. combined filter effluent is recorded continuously and every 4 hours.

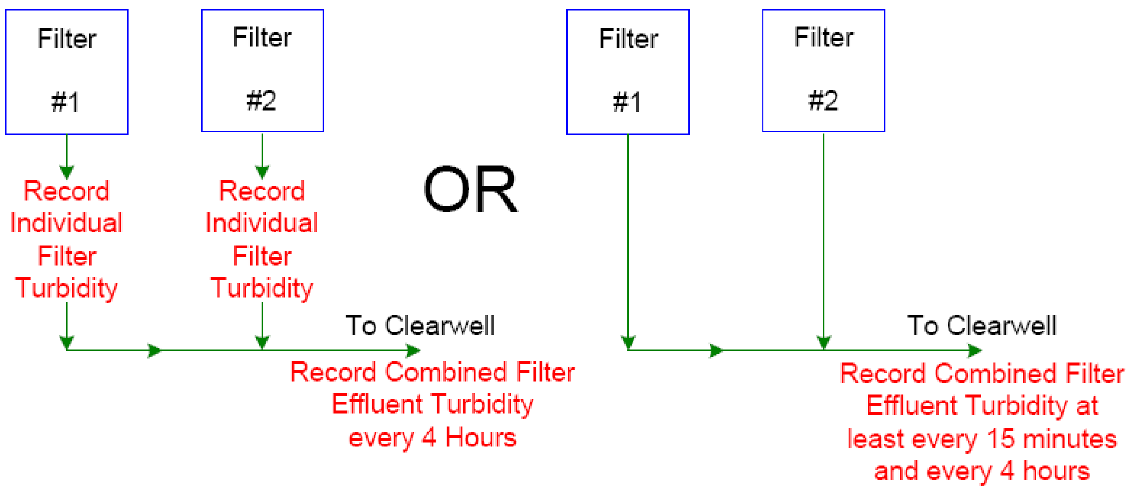
For systems with only one filter, individual filter effluent is record continuously and every 4 hours.

The following flowcharts provide guidance on combined and individual filter effluent turbidity monitoring as well as follow-up actions for conventional or direct filtration systems (USEPA, 2004a):

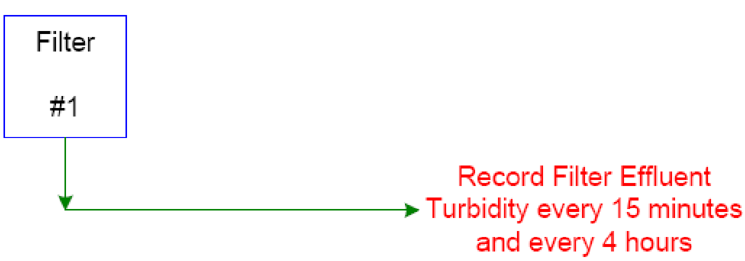
- Combined Filter Effluent Turbidity Monitoring (Figure 2.6)
- Individual Filter Effluent Turbidity Monitoring (Figure 2.7)
- Individual Filter Effluent Turbidity Exceedance Follow-Up Actions (Figure 2.8)



a) For conventional and direct filtration systems with three or more filters: individual filter turbidity effluent must be recorded at least every15 minutes and combined filter effluent must be recorded at least every 4 hours.



b) For systems with two filters: combined filter effluent turbidity or individual filter effluent turbidity must be recorded at least every 15 minutes. In addition, combined filter effluent turbidity must be recorded every 4 hours.



c) For systems with one filter: filter effluent turbidity must be recorded at least every 15 minutes and every 4 hours.

Figure 2.5 An illustration of individual and combined filter turbidity monitoring requirements

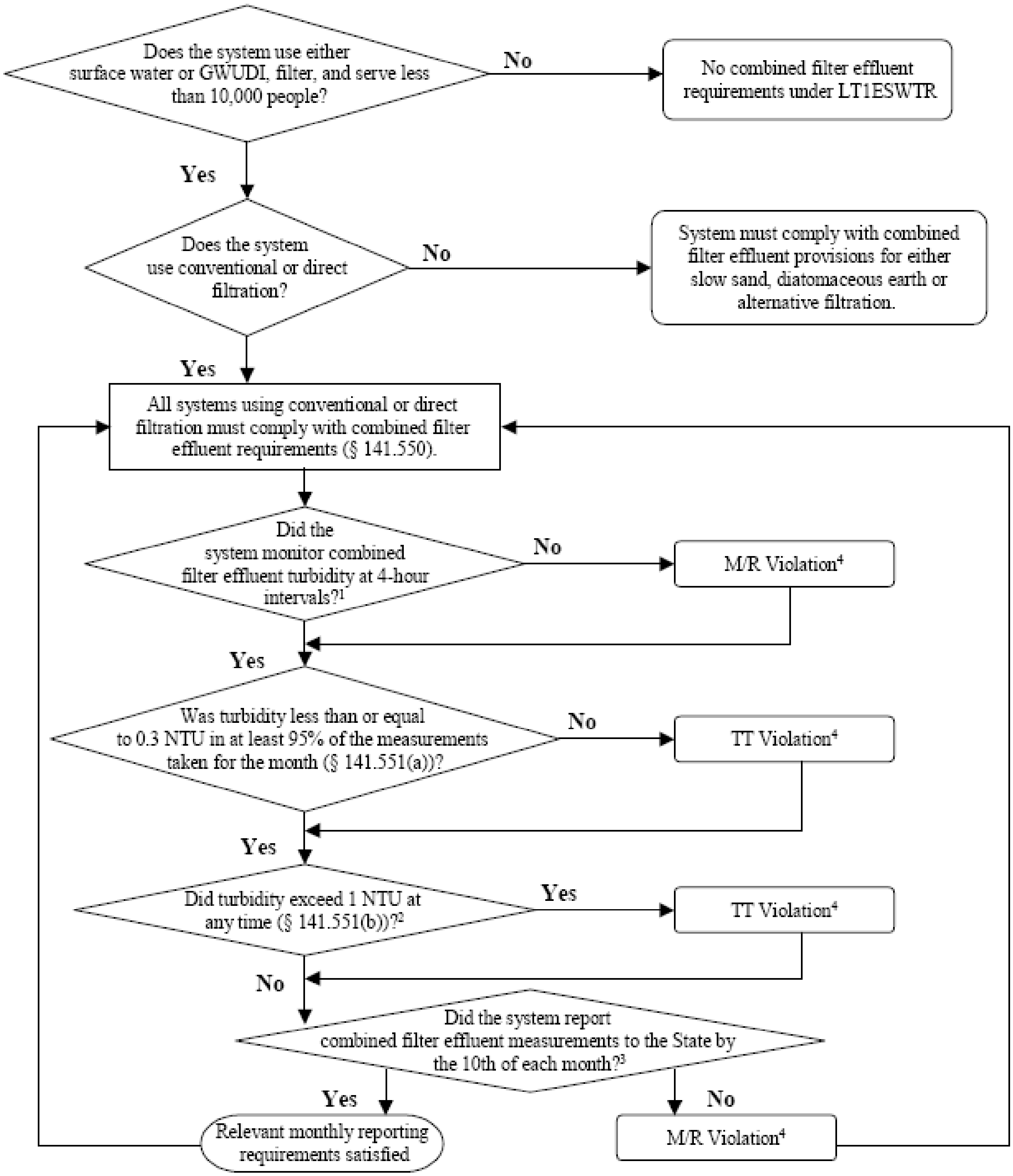


Figure 2.6 Combined filter effluent turbidity monitoring for conventional or direct filtration systems

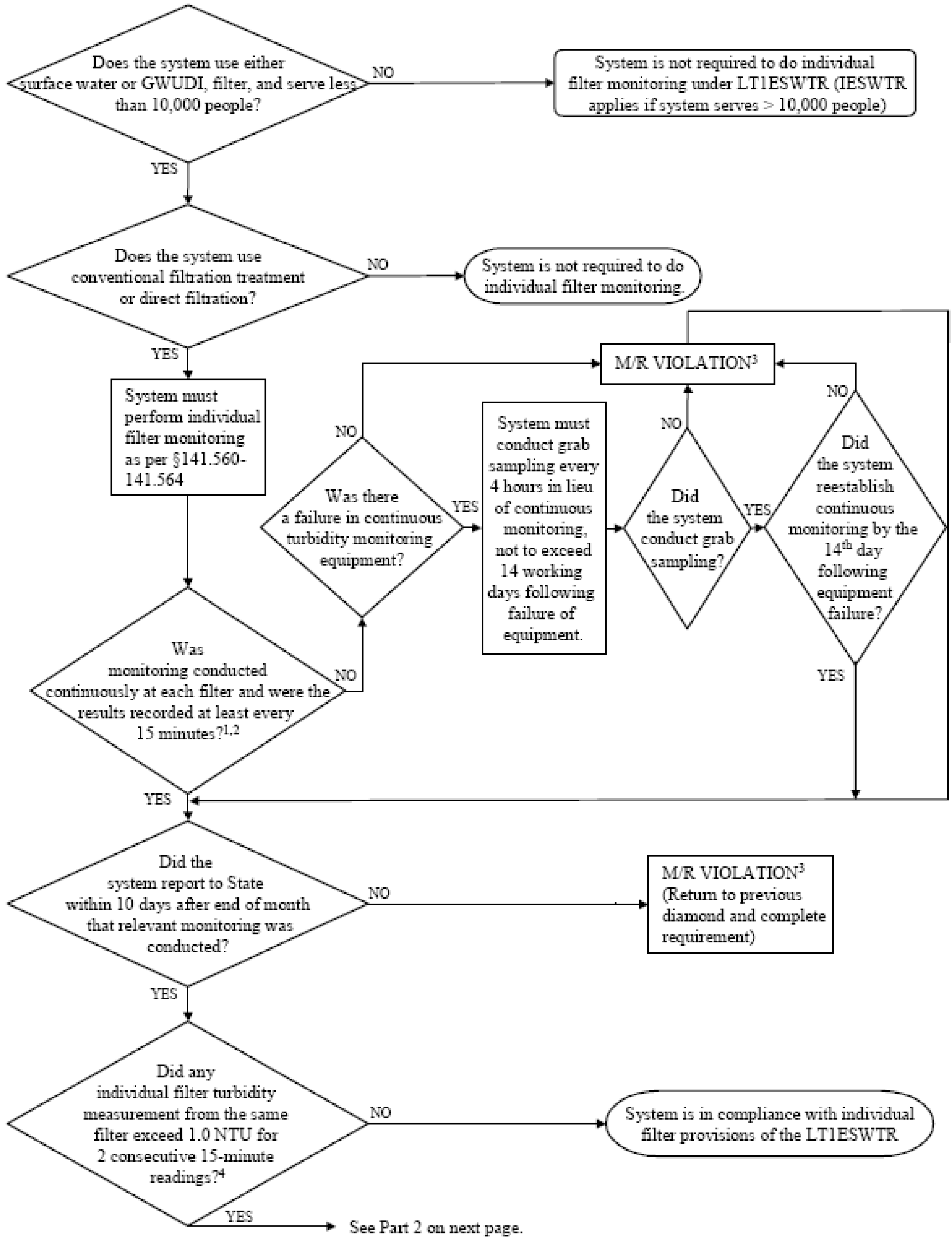


Figure 2.7 Individual filter effluent turbidity monitoring requirements for conventional or direct filtration systems (Part 1)

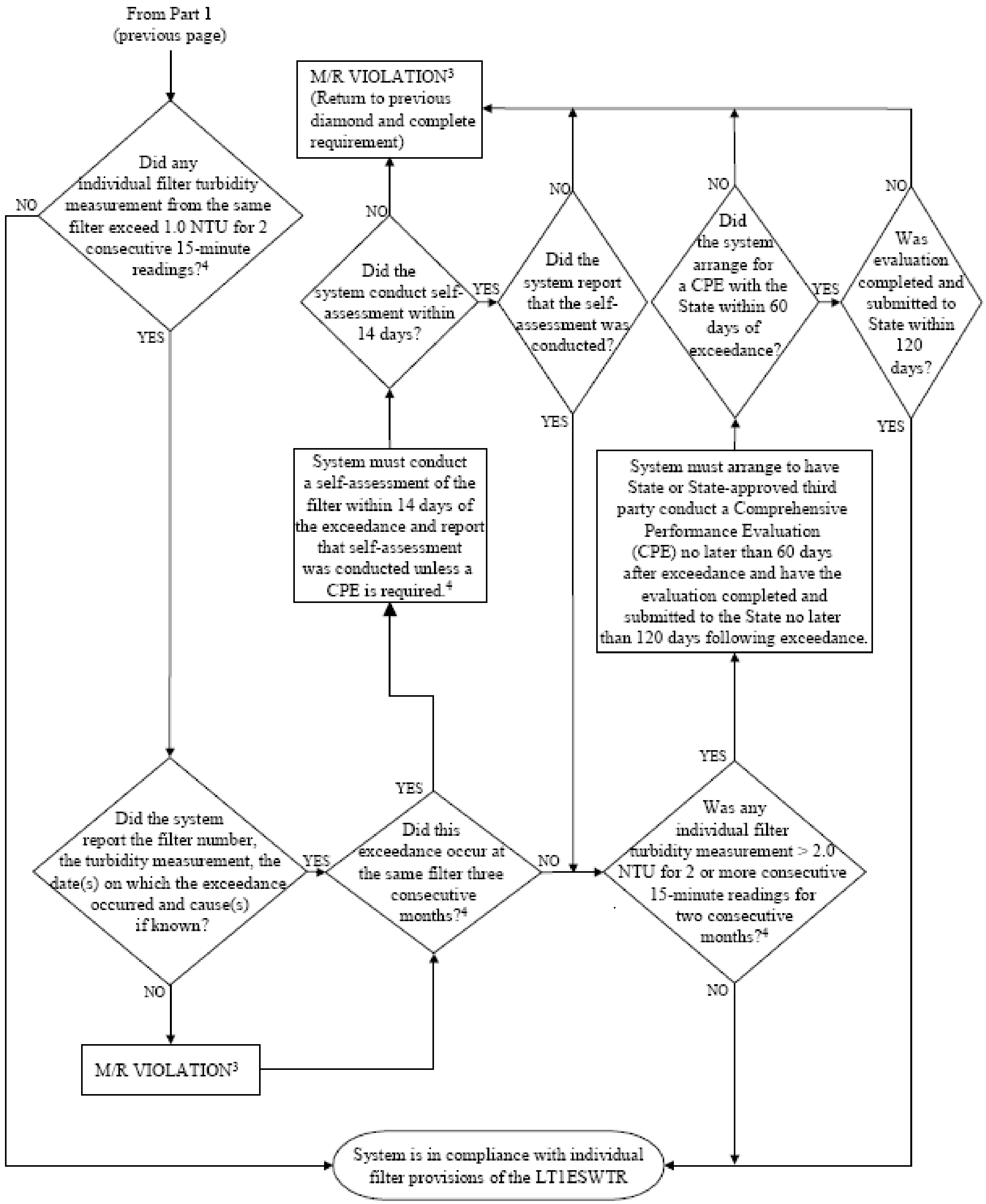


Figure 2.8 Individual filter effluent turbidity exceedance follow-up action requirements for conventional or filtration systems

2.6.4 Violations

There are four types of federally reported violations under the Long Term 1 Enhanced Surface Water Treatment Rule (USEPA, 2004a):

1. Treatment Technique (TT)
    a. combined filter effluent exceeds 1 NTU
    b. failure to achieve combined filter effluent turbidity level of 0.3 NTU in 95% of monthly measurements
    c. failure to develop a disinfection profile before making a significant change to a disinfection practice
    d. construction of an uncovered finished water storage facility
    e. failure of unfiltered systems to meet Cryptosporidium site specific conditions
2. Monitoring and Reporting (M/R)
    a. Major
        i. failure to conduct follow-up activities triggered by individual turbidity exceedances
        ii. failure to collect and report 90% of required combined filter effluent turbidity samples
        iii. failure to report all individual filter monitoring has been conducted
    b. Minor: any other failure to monitor or report

3. Recordkeeping: failure to maintain the results of individual filter monitoring for at least 3 years
4. Public Notification (PN): failure to notify public after a violation

2.6.5 Importance of Monitoring

Individual filter monitoring addresses two major concerns: masking and turbidity spikes. Poor performance and potential pathogen breakthrough of one filter can be masked by optimal performance of the remaining filters. The example in Figure 2.9 shows how Filter 4 is being masked by properly performing filters 1, 2, and 3 without exceeding the combined filter effluent turbidity performance standard (USEPA, 2004b).

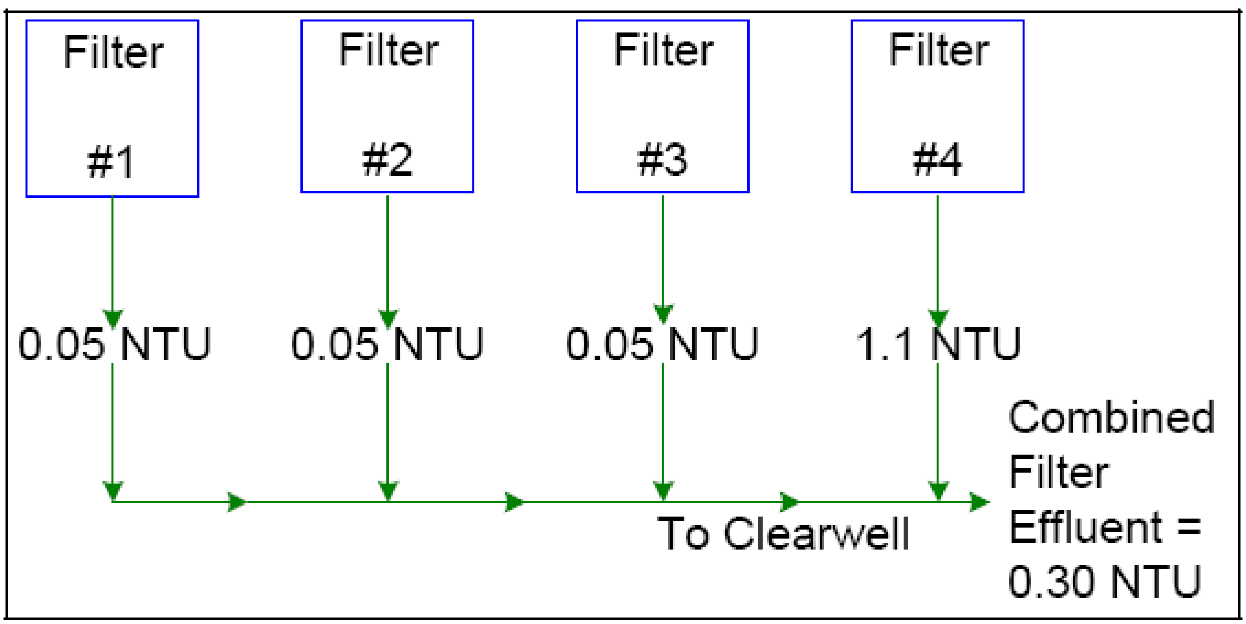


Figure 2.9 An example of masking in the combined filter effluent illustrating the need to monitor individual filters.

Individual filters are susceptible to short duration turbidity spikes that may not be captured by 4-hour combined filter effluent measurements. Individual filter turbidity monitoring addresses turbidity spikes, the potential for masking, and provides operators with advanced warning with regards to individual filter performance issues before they lead to treatment technique violations.

2.6.6 Disinfection Requirements

Public water systems that use filtration as part of their treatment process must meet certain disinfection requirements. Residual chlorine concentration in the water entering the distribution system cannot be less than 0.2 mg/L for more than 4 hours. Residual chlorine concentration in the distribution system must be detected in at least 95% of samples taken each month, for any two consecutive months that the system provides water to the public. For reporting purposes, non-detection is defined as water having a residual chlorine concentration less than 0.2 mg/L.

CHAPTER 3 METHODOLOGY

3.1 Facility Selection

Data from a potable water treatment plant operated by an oil refinery in southeast Louisiana was used to evaluate compliance with the Long Term 1 Enhanced Surface Water Treatment Rule. The potable water treatment plant had been experiencing turbidity spikes since February 2006. The Safe Drinking Water Act Categorization Worksheet in Figure 3.1 is a useful quick-reference that will aid in determining regulatory compliance (USEPA, 2003b). Systems are regulated according to the size of population served, public water system (PWS) category, source water, and treatment steps. The facility used in this study was selected based on the following criteria:

- Size: About 1,000 full-time and contract employees
- Source Water: Surface water from the Mississippi River
- PWS Category: Non-Transient, Non-Community Water System
- Treatment: Conventional Filtration
- Disinfection: Chlorine

3.2 Facility Water Treatment

The water treatment plant converts raw water from the Mississippi River into a grade that is acceptable for use within the facility. Plant water feeds the refinery utility stations, the zeolite softeners used in boiler feed water preparation, and the potable water system.

3.2.1 Pretreatment

Raw water, mixed with cationic polymers, from the Mississippi River is pumped to the clarifiers. An anionic polymer and a 25% lime solution are added to the clarifier to

SDWA Categorization Worksheet

♦ System Information

Name: ______________________________ Location: ______________________________

♦ Size

The requirements of many rules depend on the population served by a system. The term "small system" is defined differently in different rules, as either fewer than 10,000 people served or fewer than 3,300 people served.

Population Served: ______________________________

♦ Source Water Type

Some rules only apply to systems that use a specific type of source water.

• **Surface Water or GWUDI,** also called Subpart H systems. Surface water means all water open to the atmosphere and subject to surface runoff, such as rivers, lakes, and streams. GWUDI is water beneath the ground with 1) significant occurrence of insects, macroorganisms, algae, or other pathogens such as *Giardia lamblia*, or 2) significant shifts in water characteristics that closely resemble surface water conditions.

• **Ground Water.** Ground water includes water obtained from beneath the surface of the ground.

Check All That Apply

❑ Surface Water or GWUDI

❑ Ground Water

♦ PWS Category

A PWS serves an average of at least 25 people or 15 service connections for at least 60 days per year. EPA has defined three types of PWSs, and certain rules only apply to specific types of systems:

• **Community Water System (CWS):** A PWS that supplies water to the same residential population year-round. Examples include cities, towns, rural water systems, manufactured home communities, and home owners associations.

• **Non-Transient, Non-Community Water System (NTNCWS):** A PWS that regularly supplies water to at least 25 of the same people at least six months per year, but not to their residences. Examples include schools and factories that have their own water systems.

• **Transient Non-Community Water System (TNCWS):** A PWS that provides water in a place where people do not remain for long periods of time. Examples include restaurants, rest stops, and campgrounds that have their own water supplies.

Check One

❑ CWS

❑ NTNCWS

❑ TNCWS

♦ Treatment and Disinfection

Some rules apply only to systems that use certain types of treatment. For example, the Filter Backwash Recycling Rule applies to systems that use surface water or GWUDI sources, that use direct or conventional treatment, and that recycle spent filter backwash water, thickener supernatant, or liquids from dewatering processes.

Types of Filtration Include:

• Conventional Filtration (Coagulation - Flocculation - Sedimentation - Filtration)

• Direct Filtration (Coagulation - Flocculation - Filtration)

• Slow Sand Filtration

• Diatomaceous Earth Filtration

• Membrane Filtration

• Bag or Cartridge Filtration

Check All Treatment Processes That Apply

❑ Chlorine

❑ Chloramines

❑ Chlorine Dioxide

❑ Ozone

❑ UV Disinfection

❑ Aeration

❑ Lime/Soda Ash Softening

❑ Filtration
*Type:*______________________

❑ Corrosion Control
*Chemical:*____________________

❑ Fluoride Addition

❑ Other:______________________

Figure 3.1 A Safe Drinking Water Act categorization worksheet useful for determining regulatory compliance reduce hardness. These measures ensure that the coagulation and flocculation processes work effectively. Sludge is formed during the sedimentation process from the operation of the clarifiers. The sludge is pumped back to the Mississippi River and the clarified water flow gravitates from the top of the clarifier to the clearwell tanks. From the clearwells, clarified water enters a filtration system that uses pressure sand filters. The clarified and filtered water, or plant water, is stored in tanks.

3.2.2 Potable Water System

Plant water fed to the potable water system is further processed through two gravity sand filters, three carbon filters, and injected with chlorine for disinfection prior to distribution to consumers. The potable water system supplies the facility with water for drinking, safety showers, and use in all buildings. The system is designed to produce 188 gallons per minute.

3.3 Data Collection and Classification

3.3.1 Original Data

The Plant Information (PI) System from the PI data archive accommodates very large real-time and historical databases typically sized so that every recorded process point, called PI tags, are stored online for years. The Microsoft-based PI client application enables users to easily access this data to view a plant's current condition. PI also provides a very clear and accurate picture of the plant's past operations. PI-ProcessBook is the graphical user interface for the PI System; it provides real-time and historical plant information needed to monitor and improve the critical processes within the plant.

To comply with the Long Term 1 Enhanced Surface Water Treatment Rule, continuous turbidity monitoring is conducted on the combined effluent from the two gravity sand filters. Figure 3.2 is a snapshot of a PI tool used by operators at the facility to monitor the potable water system. The red arrow marks the location of the turbidity meter after the gravity filters and prior to a surge tank. The surge tank is used to regulate flow within the treatment system. This monitoring point has an associated PI tag that was used to compile the treated water turbidity data from January 2005 to September 2006. This data is referred to as original turbidity.

3.3.2 Reported Data

Potable water reports are submitted to the Louisiana Department of Health and Hospitals Office of Public Health each month. The monthly potable water reports include turbidity data for both treated water and raw water as well as disinfection data. Treated water turbidity is monitored continuously. The maximum combined filter effluent turbidity value recorded during each four hour monitoring period is used at the end of each month to determine turbidity compliance. This data is referred to as reported turbidity. Chlorine residual analysis is conducted each day every four hours. This data is referred to as disinfection. Raw water turbidity is recorded once per day. This data is referred to as raw water turbidity. Data was compiled from January 2005 to September 2006.

3.3.3 Corrected Data

A preliminary turbidity data correction technique was developed and applied to original treated water turbidity data for July 2006, August 2006, and September 2006.

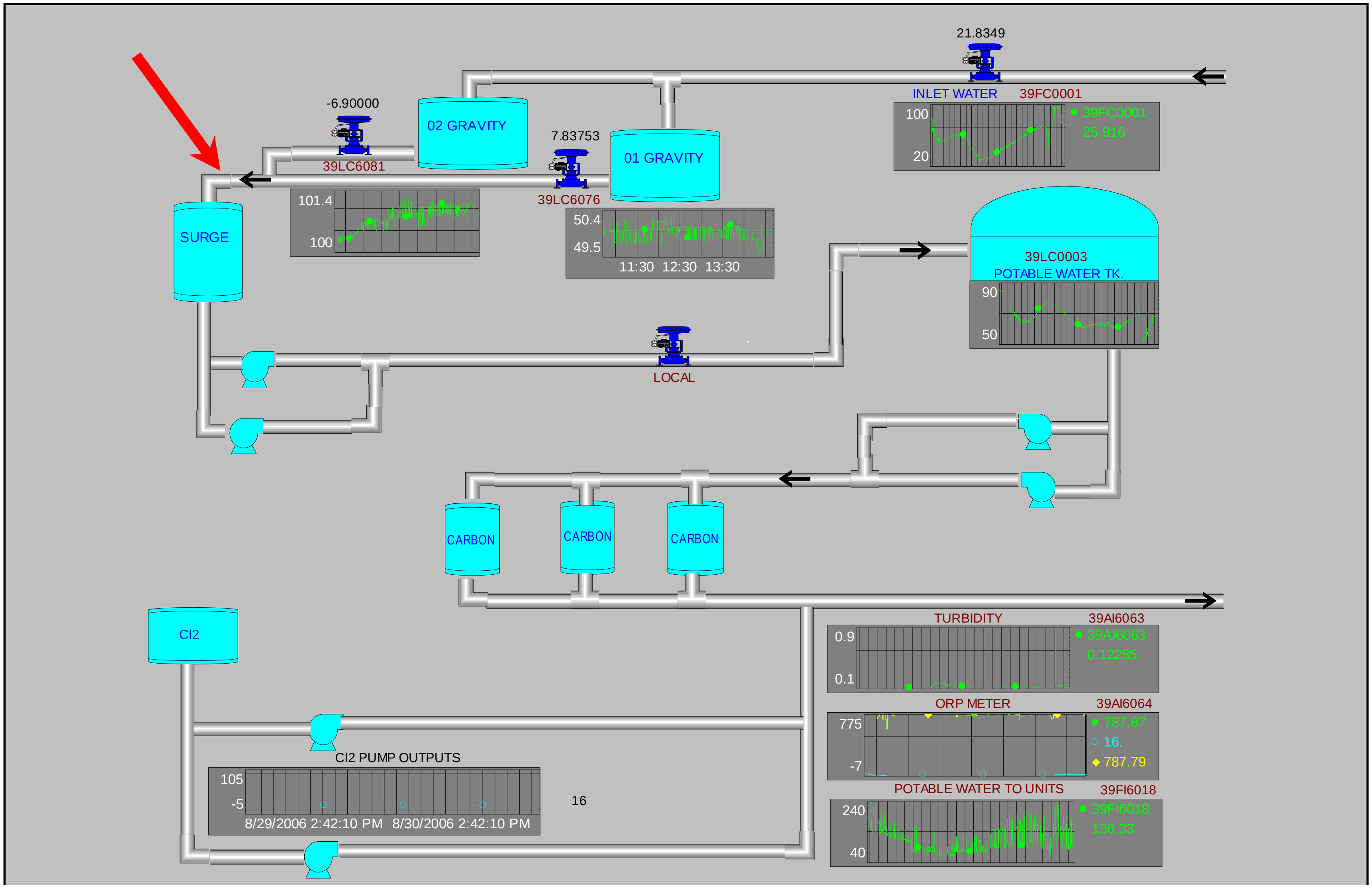


Figure 3.2 A snapshot of the potable water system compliance monitoring tool

Treated water turbidity data obtained using the preliminary data correction technique is referred to as corrected turbidity.

3.4 Preliminary Data Correction Technique

3.4.1 Description

PI was used to compile original turbidity data in one-minute increments for each month using a Microsoft Excel spreadsheet. Turbidity spike exclusions were determined based on documentation maintained by the facility's Environmental Department and logbooks maintained by the Operations Department. Compliance was then calculated in accordance with the Long Term 1 Enhanced Surface Water Treatment Rule.

3.4.2 Exclusion Criteria

All turbidity data exceeding a 0.349 NTU turbidity level was evaluated using the preliminary data correction technique. As per prior discussions and agreements with the Louisiana Department of Health and Hospitals, for turbidity spikes lasting less than 2 hours, turbidity data was excluded from the data set. For turbidity spikes exceeding 2 hours, turbidity data was substituted with grab sampling data until the system resumed normal operations. Based on these observations, turbidity spike data was excluded for one or more of the following reasons:

- Gravity sand filter backwash
- System hydraulic issues (high or low flow, carbon filter backwash)
- Maintenance (turbidity meter calibration, system repairs)
- Pumps not in service
- Other environmental factors (rain, lightning, meter hit by operator)

- Best professional judgment (for example, turbidity cannot drop from 6.0 to 0.2 NTU in one minute)

3.5 Data Analysis

General descriptive statistical analysis was conducted on all data sets. Microsoft Excel was used to determine the probability distributions, perform hypothesis testing, and conduct a regression analysis.

3.5.1 Compliance

Monthly turbidity and disinfection compliance was calculated using the following formula:

$$\text{Compliance (\%)} = \frac{\text{Compliant}}{\text{Total}} \times 100$$

"Total" refers to the number of monthly readings, while "Compliant" refers to the number of monthly readings which meet the specified limits. "Compliance" is the percentage of measurements meeting the specified limit. Turbidity data are compliant if they are less than or equal to 0.349 NTU. Disinfection data are compliant if they are greater than or equal to 0.2 mg/L.

3.5.2 Probability Distribution

The NORMDIST function in Microsoft Excel returns the normal distribution for the specified mean and standard deviation. The syntax for the function is:

f(x) = NORMDIST(x,mean,standard_dev,cumulative)

"X" is the value for which you want the distribution. "Mean" is the arithmetic mean of the distribution. "Standard_dev" is the standard deviation of the distribution. "Cumulative" is a logical value that determines the form of the function. If cumulative is TRUE (1), NORMDIST returns the cumulative distribution function; if FALSE (2), it returns the probability mass function.

Turbidity Data

The NORMDIST function was used to return the cumulative distribution function (cumulative=1) for the values above X=0.349 NTU and X=0.300 NTU for original, submitted and corrected turbidity data. For example, a completed function would appear in Microsoft Excel as follows:

f(x) =NORMDIST(0.349,B2,B6,1)

Disinfection Data

The 1–NORMDIST function was used to return the cumulative distribution function (cumulative=1) for the values below X=0.2 mg/L for disinfection data. For example, a completed function would appear in Microsoft Excel as follows:

f(x) =1-NORMDIST(0.2,B2,B6,1)

3.5.3 Hypothesis Testing

The Microsoft Excel z-Test: Two Sample for Means analysis tool performs a two-sample z-test for means with known variances. This tool is used to test the null hypothesis that there is no difference between two population means against the two-sided alternative hypothesis. This analysis is used to evaluate the effectiveness of the preliminary turbidity data correction technique.

3.5.4 Regression Analysis

The Microsoft Excel regression tool uses the LINEST function to perform linear regression analysis by applying the least squares method to fit a straight line through the data and returns an array that describes the line. The equation for the line is y=mx+b. The simple linear regression analysis of this study was used to predict average daily turbidity (dependent variable) from raw water turbidity (independent variable).

For simple linear regressions, there are three critical components of the output. The first component is the Model Summary. R square, or coefficient of determination, gives the proportion of variance of the dependent variable that can be explained by variation in the independent variable. It is also used to measure the relative predictive power of the model. The standard error of estimate gives the measure of dispersion for the prediction equation. Using the prediction equation, 68% of the data will fall within one standard error of estimate of the predicted value. Just over 95% will fall within two standard errors.

The second component of the output of interest is in the ANOVA summary table is the significance F level. If the significance F level is less than 0.05, then the simple linear regression is significant. If it significance F level is larger than 0.05, the simple linear regression is not significant.

The final component of the output is the table of coefficients. This is where the actual prediction equation can be found. Conclusions from simple linear regression analysis indicate the significance of the prediction equation obtained, the direction of the relationship, and the prediction equation itself.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Turbidity Compliance Analysis

The Long Term 1 Enhanced Surface Water Treatment Rule requires the turbidity levels to be less than or equal to 0.3 NTU in 95% of the samples collected each month with no samples having a turbidity value greater than 1 NTU. The turbidity value, recorded in NTU with three significant digits, is used for analysis because the regulations do not specify significant digits. Compliance is measured on the combined filter effluent of the two gravity sand filters as depicted in Figure 3.2. Probability distributions were determined for two turbidity levels, 0.349 NTU and 0.300 NTU.

4.1.1 Results

Compliance was calculated for original turbidity data taken directly from PI without modification. The results show 100% compliance from January 2005 through January 2006 (Table 4.1). However, the average turbidity began to increase in February 2006. The average turbidity began exceeding the 1 NTU limit in June 2006. This trend continued through September 2006. The probability distributions followed the same downward trend beginning February 2006. During this time period, compliance began to decrease.

For months having compliance less than 100%, further evaluation of monthly reports submitted to the Louisiana Department of Health and Hospitals was conducted. From February 2006 to September 2006, the facility established its own criteria to correct turbidity data to account for system maintenance, backwashing, and a variety of other activities. Despite these adjustments, the system was not 100% compliant as shown in Table 4.2.

Table 4.1 Compliance and probability distributions for original turbidity data taken from Plant Information Systems

Month	Mean (NTU)	S.D. (NTU)	Total	Compliant	Compliance (%)	Probability P(x=0.349 NTU)	Probability P(x=0.300 NTU)
January 2005	0.113	0.001	186	186	100.0	1.000	1.000
February 2005	0.115	0.012	168	168	100.0	1.000	1.000
March 2005	0.134	0.051	186	186	100.0	1.000	0.999
April 2005	0.118	0.000	180	180	100.0	1.000	1.000
May 2005	0.118	0.000	186	186	100.0	1.000	1.000
June 2005	0.119	0.012	180	180	100.0	1.000	1.000
July 2005	0.119	0.000	186	186	100.0	1.000	1.000
August 2005	0.137	0.050	186	186	100.0	1.000	0.999
September 2005	0.118	0.000	180	180	100.0	1.000	1.000
October 2005	0.118	0.000	186	186	100.0	1.000	1.000
November 2005	0.118	0.000	180	180	100.0	1.000	1.000
December 2005	0.117	0.000	186	186	100.0	1.000	1.000
January 2006	0.118	0.000	186	186	100.0	1.000	1.000
February 2006	0.352	1.831	168	163	97.0	0.499	0.489
March 2006	0.188	0.106	186	181	97.3	0.935	0.853
April 2006	0.375	1.604	180	163	90.6	0.493	0.481
May 2006	0.563	2.297	186	161	86.6	0.463	0.454
June 2006	1.123	3.443	180	130	72.2	0.411	0.406
July 2006	1.870	4.958	186	88	47.3	0.380	0.376
August 2006	1.662	4.059	186	87	46.8	0.373	0.369
September 2006	1.740	4.386	180	120	66.7	0.376	0.371
Average	0.449	1.086	182	165	90.7	0.806	0.800

Table 4.2 Compliance and probability distributions for turbidity data submitted to the Louisiana Department of Health and Hospitals

Month	Mean (NTU)	S.D. (NTU)	Total	Compliant	Compliance (%)	Probability P(x=0.349 NTU)	Probability P(x=0.300 NTU)
February 2006	0.146	0.126	167	164	98.2	0.946	0.889
March 2006	0.152	0.083	186	183	98.4	0.991	0.963
April 2006	0.148	0.050	180	180	100.0	1.000	0.999
May 2006	0.169	0.049	186	186	100.0	1.000	0.996
June 2006	0.184	0.106	180	178	98.9	0.940	0.863
July 2006	0.244	0.071	186	179	96.2	0.930	0.784
August 2006	0.257	0.069	186	183	98.4	0.910	0.735
September 2006	0.202	0.082	180	179	99.4	0.964	0.885
Average	0.188	0.079	181	179	98.7	0.960	0.889

Figure 4.1 shows a compliance comparison between the original turbidity data collected from PI and the reported turbidity submitted to the Louisiana Department of Health and Hospitals for all months with less than 100% compliance beginning February 2006. Of the 8 months analyzed in this study, only 2 were found to have 100% compliance. However, all the data submitted to the Louisiana Department of Health and Hospitals met the 95% compliance limit required by the EPA. The probability distributions followed the same trend of improvement.

The preliminary turbidity data collection technique was applied to the original turbidity data for July, August, and September 2006. Table 4.3 compares the compliance and probability distributions for turbidity data submitted to the LDHH and the corrected turbidity data. There was no difference between the average turbidity values for July and September 2006. However, the compliance for July 2006 improved by 3.3% and compliance for August 2006 improved by 0.5%. There was no change in the compliance for September 2006.

4.1.2 Discussion

The Long Term 1 Enhanced Surface Water Treatment Rule was implemented by the EPA to add protection from Cryptosporidium through strengthened combined filter effluent turbidity performance standards and individual filter turbidity requirements. The primary focus of the rule is to improve public health by increasing the level of protection from exposure to Cryptosporidium and other pathogens in drinking water supplies through filtration improvements in small water treatment systems.

The selection of Cryptosporidium as the microbial contaminant of concern, filtration as the required treatment technique, and turbidity as the monitoring parameter

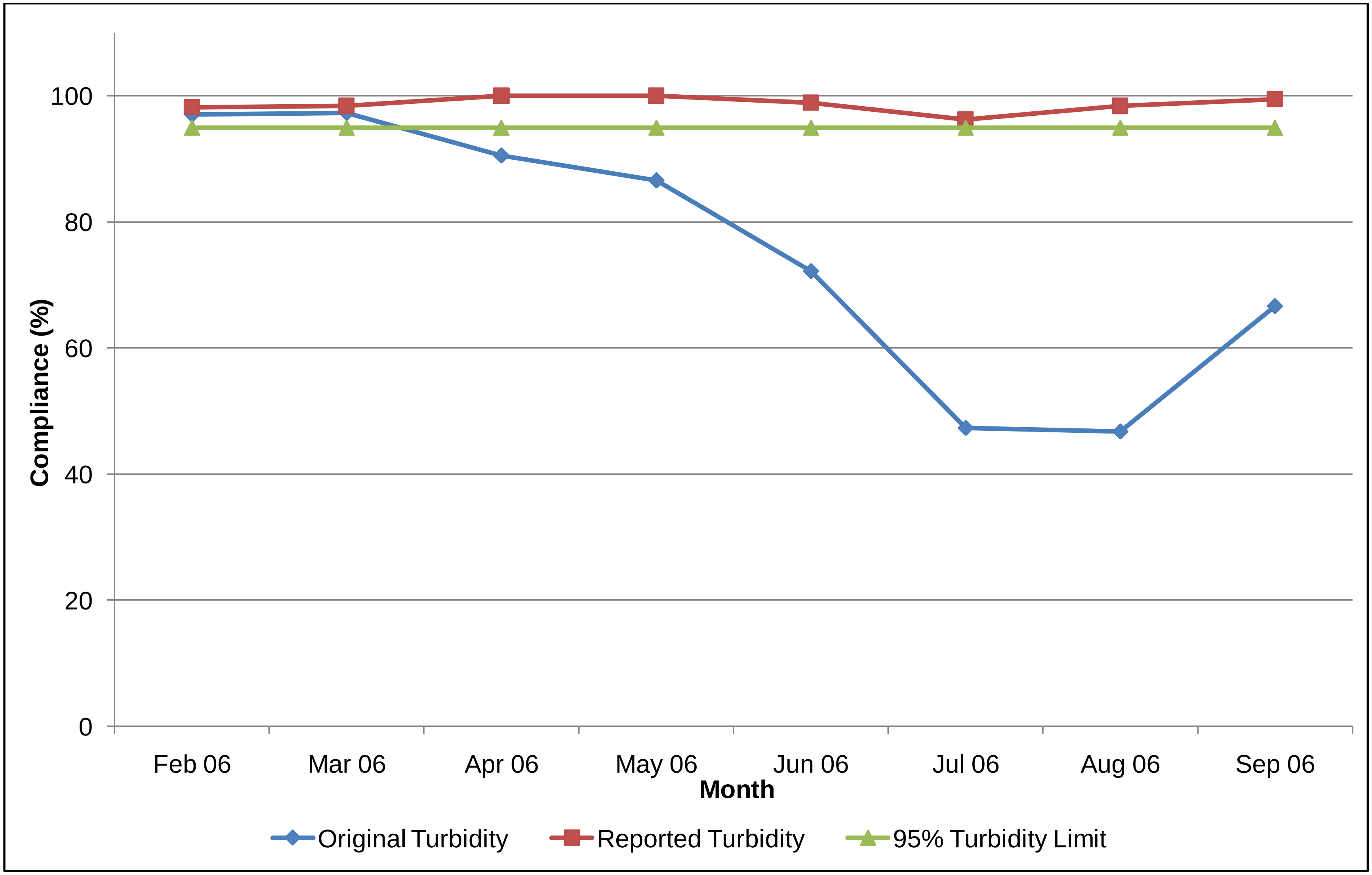


Figure 4.1 A compliance comparison between original and reported turbidity data from February 2006 and September 2006

Table 4.3 A comparison of compliance and probability distributions between turbidity data submitted to the Louisiana Department of Health and Hospitals and original turbidity data corrected using the preliminary data correction technique

Month	July 2006		August 2006		September 2006	
	Reported	Corrected	Reported	Corrected	Reported	Corrected
Mean (NTU)	0.244	0.244	0.257	0.235	0.202	0.202
S.D. (NTU)	0.071	0.053	0.069	0.060	0.082	0.082
Total	186	186	186	186	180	180
Compliant	179	185	183	184	179	179
Compliance (%)	96.2	99.5	98.4	98.9	99.4	99.4
P(x=0.349 NTU)	0.930	0.976	0.910	0.972	0.964	0.964
P(x=0.300 NTU)	0.784	0.854	0.735	0.861	0.885	0.885

is supported by the research of Hsu and Yeh (2003). Their study found a significant correlation between turbidity and Cryptosporidium oocysts. The results of their study show that turbidity is a suitable indicator of the presence of Cryptosporidium in water. The decision of the EPA is further supported by the works of Neumann et al. (2005), Schoenen (2002), and Okun (1996) whose works concluded that Cryptosporidium is the proper target for removal in drinking water, conventional treatment processes with filtration is the appropriate treatment technique, and turbidity monitoring is the best available parameter to measure the efficiency of Cryptosporidium removal from the treatment process. Utilizing the findings of their research is important as drinking water systems attempt to face the challenge waterborne disease threats.

However, Gregory (1998) and Ahmad et al. (1997) point out the difficulties of using turbidity as a monitoring parameter. Despite their conclusions, turbidity is the best available and most economical parameter widely available to monitor Cryptosporidium removal in the drinking water process. As new scientific and health information becomes available, the EPA develops regulations to continually increase the effectiveness of the multiple barrier approach. Figure 4.2 shows future regulations proposed by the EPA that will either strengthen barriers already in place or will require the establishment of new barriers (USEPA, 2003b).

For whatever reason, many facilities fail to recognize the importance of potable water as an essential component of their operations. However, it is still necessary to comply with all applicable regulations.

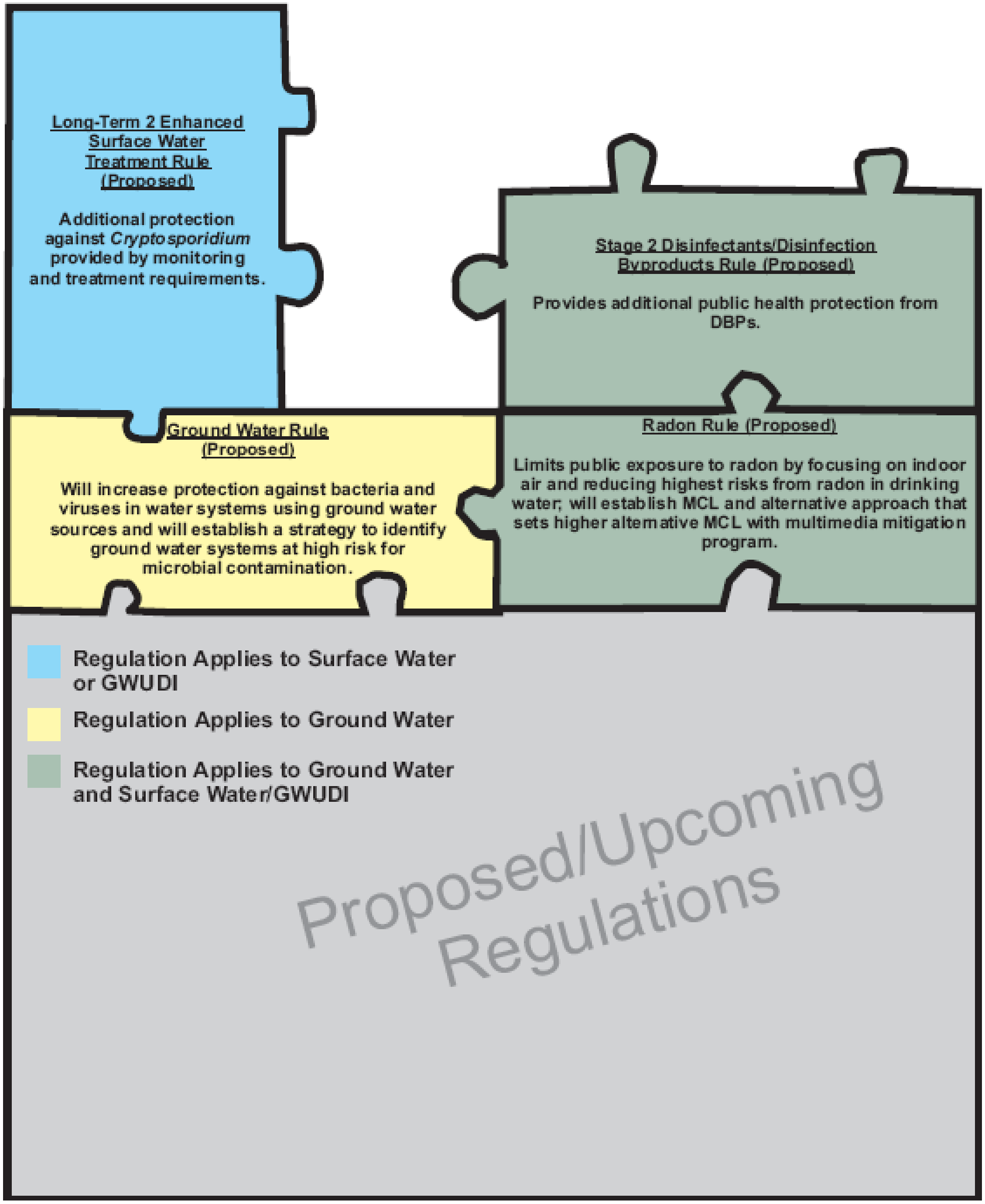


Figure 4.2 Proposed EPA regulations using the multiple barrier approach

Further examination of original turbidity data presented in Figure 4.1 revealed several areas of concern with the facility's aging drinking water system:

- hydraulic problems due to one gravity filter being built higher than the other
- misconfiguration of piping affecting the rinse cycle during filter backwashing
- broken valves and screens within the filtration system
- failure of filters and clarifiers causing breakthrough
- insufficient documentation of repairs, maintenance, and system issues

As one can see from this list, the original design of this system cannot adequately meet the current regulations. Meeting the requirements of the current drinking water regulations is asking this system to perform beyond its capabilities.

Because the regulations do not specify significant and rounding is allowed for reporting purposes, probability distributions were determined at two turbidity levels, 0.349 and 0.300 NTU. The probability distributions in Tables 4.1 and 4.2 showed that the facility in this study would have difficulty meeting the filtration requirements specified by the EPA. This suggests the facility would have problems meeting stricter requirements in the future. The treatment process with improvements would be effective in achieving the requirements of the regulations. Although this study concluded in September 2006, significant improvements were made to the gravity sand filters. In April 2007, an ultrafiltration system replaced the gravity sand filters in the potable water treatment system.

4.2 Hypothesis Testing

Hypothesis testing was conducted to evaluate the effectiveness of the preliminary turbidity data correction technique. The Null (H_0: $\mu_{reported} = \mu_{corrected}$) and

Alternative Hypothesis (H_A: $\mu_{reported} \neq \mu_{corrected}$) for each test are the same, with a 0.05 alpha value. Since the data collection technique had been implemented by the facility in September 2006, this analysis was only conducted for July and August 2006.

4.2.1 Results

The z-Test: Two Sample for Means results are found in Tables 4.4 and 4.5. No significant difference was found between the mean reported and the mean corrected for turbidity values for July 2006. However, there was a significant difference between the reported and corrected turbidity mean values for August 2006.

Table 4.4 Hypothesis Testing Results for July 2006

July 2006	Reported	Corrected
Mean	0.244	0.244
Known Variance	0.005	0.003
Observations	186	186
Hypothesized Mean Difference	0	
z	-0.007	
P(Z<=z) two-tail	0.995	
z Critical two-tail	1.960	

Table 4.5 Hypothesis Testing Results for August 2006

August 2006	Reported	Corrected
Mean	0.257	0.235
Known Variance	0.005	0.004
Observations	186	186
Hypothesized Mean Difference	0	
z	3.230	
P(Z<=z) two-tail	0.001	
z Critical two-tail	1.960	

4.2.2 Discussion

There was not enough data to determine whether the preliminary turbidity data collection technique used in this study was effective. However, this technique and the accompanying spreadsheets generated are both very useful as a documentation tools. This analysis did show the need for improved documentation and record maintenance. Compliance with drinking water regulations is time-consuming, especially when it comes to collecting, analyzing, reporting and managing large amounts of data. Effective data management involves formatting, storing, interpreting and analyzing data (USEPA, 2004b). Understanding the dynamics of the filtration system by effectively managing turbidity data makes it easier to troubleshoot turbidity spikes that deviate from the norm. Systems will be able to evaluate post-backwash turbidity spikes for individual filters, the effect of storm events on the filtration capabilities, and the impact of different chemical dosages on filter water effluent.

4.3 Regression Analysis

A simple regression analysis was performed to determine if raw water turbidity could be used to estimate daily average turbidity. A summary of the raw water data and daily average turbidity data from monthly reports to the LDHH used to conduct the analysis is presented in Table 4.6.

4.3.1 Results

The raw water turbidity and daily average turbidity were plotted over time as displayed in Figure 4.3. Due to Hurricane Katrina, data for August 28, 2005 was not available. This graph shows how the turbidity in the Mississippi River is higher during the spring and early summer months and lower in the fall and winter months.

Table 4.6 A summary of raw water data submitted to the Louisiana Department of Health and Hospitals and corrected daily average turbidity data

	Raw Water Turbidity	Daily Average Turbidity
Mean (NTU)	54.14	0.145
Standard Deviation (NTU)	45.30	0.052
Total Measurements	637	637
Compliant Measurements	637	636

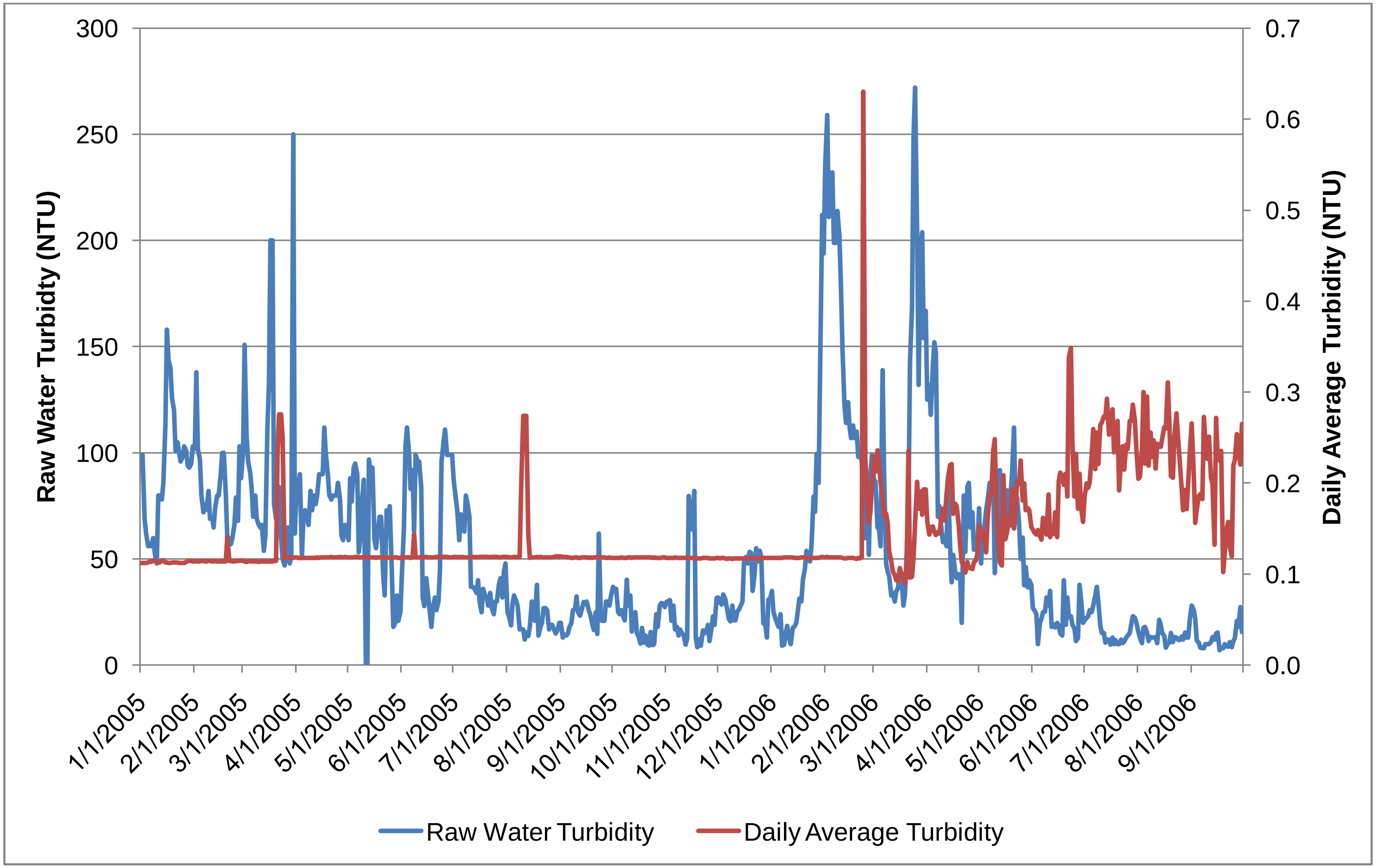


Figure 4.3 Raw water and daily average turbidity over time

The simple linear regression analysis conducted in Microsoft Excel generated three output tables: the model summary (Table 4.7), the ANOVA summary (Table 4.8), and coefficients (Table 4.9).

Table 4.7 Simple linear regression model summary

Multiple R	0.233
R Square	0.054
Adjusted R Square	0.053
Standard Error	0.051
Observations	637

Table 4.8 Simple linear regression ANOVA summary

	df	SS	MS	F	Significance F
Regression	1	0.094	0.094	36.313	0.000
Residual	635	1.650	0.003		
Total	636	1.745			

Table 4.9 Simple linear regression coefficients

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.160	0.003	50.755	0.000	0.154	0.166
Raw Water Turbidity	0.000	0.000	-6.026	0.000	0.000	0.000

A significant regression equation was found ($F, (1,635) = 36.313, p < 0.001$), with an r^2 of 0.054. The predicted equation was:

$$\text{Daily Average Turbidity} = 0.000 \times \text{Raw Water Turbidity} + 0.160$$

when raw water turbidity is measured in NTU. The regression analysis showed that there was a significant difference between raw water turbidity and daily average turbidity. However, the r-value (0.233) indicates the weakness and low correlation between the two variables.

4.3.2 Discussion

The regression analysis showed that raw water turbidity could not accurately predict daily average turbidity. This analysis was found to be insignificant. Further data collection and analysis is required to determine exactly how raw water turbidity affects the daily average turbidity of the treated water. Nevertheless, raw water turbidity could be used to determine if changes should be made to the treatment process. The EPA (2004) Long Term 1 Enhanced Surface Water Treatment Rule Turbidity Provisions Technical Guidance Manual is an excellent reference for treatment process optimization. Providing safe drinking water, achieving compliance with the required standards, and saving money without compromising safe drinking water are the goals of treatment optimization. There are three existing programs to aid with optimization: Composite Correction Program, Area-Wide Optimization Program, and Partnership for Safe Water.

4.4 Disinfection Compliance Analysis

Disinfection compliance is determined by measuring residual chlorine concentration at the boiler house sink, the first user in the distribution system of the facility. The analysis is conducted and recorded manually by the operators every 4 hours. The national primary drinking water regulations (USEPA, 2003) require the residual disinfectant concentration to be greater than or equal to 0.2 mg/L in 95% of the samples collected each month. Probability distributions were determined for a chlorine residual concentration for 0.20 mg/L.

4.4.1 Results

The facility met the 95% limit for the disinfection requirements each month Table 4.10. However, there were three points of non-conformance where residual chlorine concentration was below 0.2 mg/L in January and June 2005. There were also five missing readings in August 2005 due to Hurricane Katrina. The probability distributions adhered to the same pattern of compliance with all values above the 0.950 limit.

4.4.2 Discussion

Disinfection cannot fully guarantee the complete inactivation of pathogens, even in high concentrations. However, the contact time concept has created the illusion that successful disinfection can be achieved by increasing disinfectant concentration or extending contact time (Schoenen, 2002). The facility met the 95% compliance limit but should implement plans to ensure 100% compliance in the future. Although disinfection is not the only component of providing safe drinking water, it is a critical component after the treated water leaves the system.

Table 4.10 Compliance and probability distributions for disinfection data submitted to the Louisiana Department of Health and Hospitals

Month	Mean (NTU)	S.D. (NTU)	Total	Compliant	Compliance (%)	Probability P(x=0.2 mg/L)
January 2005	1.65	0.42	186	186	100.0	1.000
February 2005	1.51	0.55	168	167	99.4	0.992
March 2005	1.55	0.51	186	186	100.0	0.996
April 2005	1.65	0.46	180	180	100.0	0.999
May 2005	1.60	0.39	186	186	100.0	1.000
June 2005	1.50	0.47	180	178	98.9	0.997
July 2005	1.55	0.42	185	185	100.0	0.999
August 2005	1.36	0.46	181	181	100.0	0.994
September 2005	1.54	0.43	180	180	100.0	0.999
October 2005	1.67	0.44	186	186	100.0	1.000
November 2005	1.48	0.40	180	180	100.0	0.999
December 2005	1.48	0.46	186	186	100.0	0.997
January 2006	1.59	0.40	186	186	100.0	1.000
February 2006	1.66	0.49	168	168	100.0	0.999
March 2006	1.51	0.45	186	186	100.0	0.998
April 2006	1.54	0.46	180	180	100.0	0.998
May 2006	1.45	0.46	186	186	100.0	0.997
June 2006	1.51	0.48	180	180	100.0	0.997
July 2006	1.49	0.44	186	186	100.0	0.998
August 2006	1.51	0.44	186	186	100.0	0.998
September 2006	1.49	0.42	180	180	100.0	0.999
Average	1.54	0.45	182	182	99.9	0.998

CHAPTER 5 CONCLUSIONS

5.1 Summary

Filtration has proven to be the most effective treatment for Cryptosporidium removal. The EPA should require 100% compliance; the 95% limits are too lenient and encourage systems to become complacent in their efforts to improve treatment processes. Turbidity will continue to play a vital role in monitoring drinking water quality. However, with monitoring and testing concerns, turbidity is only a good initial indicator.

Disinfection cannot replace filtration. Instead, disinfection should only be used to minimize the residual risk of pathogens in drinking water, not to make contaminated water safe for human consumption.

Although the Long Term 1 Enhanced Surface Water Treatment Rule addressed filtration and turbidity, the Long Term 2 Enhanced Surface Water Treatment Rule will require Cryptosporidium monitoring. Although Cryptosporidium testing is more expensive, the analysis is more appropriate. This new rule also addresses the treatment process. Conventional filtration is still a good option for Cryptosporidium removal, but newer technologies like ultrafiltration may prove to be more efficient in removing microbial contaminants of concern.

As Cryptosporidium is prevalent in all surface and most ground water sources, drinking water systems should exercise caution and pay close attention to seasonal variations of source water, especially during rainstorm events where surface water runoff is a concern. Cryptosporidium is a major concern, but there are other contaminants that are emerging that will need to be addressed in future regulations by the EPA using the multiple barrier approach. These measures are necessary to avoid future waterborne disease outbreaks like the Milwaukee incident.

5.2 Recommendations

Recommendations were made regarding comprehensive system evaluation, monitoring, improved treatment technique, and best practices:

1. Comprehensive System Evaluation
    a. Develop a complete filtration and disinfection monitoring plan
    b. Perform filter self-assessments on each filter
    c. Perform a comprehensive performance evaluation
    d. Utilize treatment optimization tools
    e. Conduct annual comprehensive system audit
2. Monitoring
    a. Conduct individual filter monitoring on each filter instead of on the combined filter effluent until system concerns are resolved
    b. Modify and automate the preliminary turbidity data collection technique to examine data every 15 minutes and incorporate the turbidity data management tool into the monitoring plan
    c. Monitor and track compliance over time
    d. Form a drinking water task force
    e. Develop emergency procedures for turbidity and disinfection monitoring
    f. Monitor drinking water turbidity after carbon filters prior to entering distribution system or at the first user

3. Improved Treatment Technique

    a. Make improvements to system to ensure 100% compliance with the goal of the system being able to treat raw water of any quality

    b. Add additional treatment to system, consider newer technologies like ultrafiltration

    c. Consider dual media gravity filters to get added benefit of carbon filtration

4. Best Practices

    a. Review EPA guidance documents

    b. Develop formal drinking water compliance training for all operators

    c. Self-impose stricter turbidity and disinfection requirements

    d. Improve communication and documentation of system issues

    e. Address turbidity and disinfection issues immediately, not just at the end of the month when preparing reports

Implementation of these recommendations will aid the facility and similar facilities in achieving compliance with federal drinking water regulations, especially the Long Term 1 Enhanced Surface Water Treatment Rule. Drinking water systems should start preparing for the Long Term 2 Enhanced Surface Water Treatment rule today.

5.3 Suggestions for Future Research

Compliance with drinking water regulations requires understanding of complex regulations. Expanding the scope of this project to include current performance data would provide additional information needed to determine effective compliance. A thorough examination of communication, training, maintenance, documentation, and treatment system of the facility is necessary to gain understanding of how the system is functioning. An evaluation of compliance with all current drinking water regulations to identify any gaps is necessary to ensure compliance. Additionally, determining requirements for compliance with future regulations is necessary for proper planning. Seasonal variations of the Mississippi River turbidity and other parameters within the treatment process should be monitored and analyzed to determine the relationship between raw water turbidity and the efficacy of the water treatment process. An in-depth analysis of the disinfection process should also be conducted. This information would be helpful in determining compliance with the Stage 1 and 2 Disinfection and Disinfectant Byproduct Rules.

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VITA

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