IEPA ATTACHMENT NO. NN

Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago
100 EAST ERIE STREET CHICAGO, ILLINOIS 60611-3154 312·751·5600

John C. Farnan, P.E.
General Superintendent

312·751·7900 FAX 312·751·5681

November 8, 2005

Mr. Toby Frevert
Division of Water Pollution Control
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9278

Dear Mr. Frevert:

Subject: Evaluation of Management Alternatives for the Chicago Area Waterways: (a) Investigation of Alternative Technologies for Effluent Disinfection and (b) Estimation of the Cost of Effluent Disinfection

The Metropolitan Water Reclamation District of Greater Chicago submitted a report entitled "Technical Memorandum 1WQ: Disinfection Evaluation" to the Illinois Environmental Protection Agency on August 31, 2005. The report included conceptual level cost estimates for the design, construction, operation, and maintenance of the recommended effluent disinfection technology(ies), ozonation and ultraviolet radiation (UV). Tables 1.26 and 1.27 summarize the opinion of probable costs for UV and ozone disinfection, with and without filtration. This letter addresses the changes that need to be made to these tables since our submittal, dated August 31, 2005. Change No. 1 will address the possibility of potential future electrical rate changes. Change No. 2 will address a table labeling correction and a missing line item. The details of these changes are presented below:

CHANGE NO. 1

1. Since the conceptual level cost estimates as presented in the report were based on current electrical rates, the cost estimates may change significantly should the electrical

rates increase in the future. Therefore, Tables 1.26 and 1.27 (Pages 79 and 80, respectively) were revised, with an additional footnote describing the possible cost impacts based on electrical rates. Added footnote is as follows:

> "* Total Annual O&M Cost is based on current electrical rate at $0.075 per kilowatt-hour. This cost may change significantly should the electrical rates increase in the future."

CHANGE NO. 2

2a. A line item was missing in Table 1.26. A new line item "Total Annual O&M Cost" was inserted below "D. Disinfection System". Note that this change does not affect the Total Present Worth.

2b. The line item "Total Present Worth O&M Cost" in Table 1.27 should have been "Total Annual O&M Cost". A new line item "Total Present Worth O&M Cost" was inserted below the revised "Total Annual O&M Cost". Note that these changes do not affect the Total Present Worth.

Attached are the revised pages. Please replace Page 79 and 80 of the report with the attached.

If you have any questions, please contact Mr. Richard Lanyon at (312) 751-5190.

Very truly yours,

John C. Farnan
General Superintendent

TK:ECB:RKO
Attachments

cc: R. Sulski, IEPA

TABLE 1.27
OPINION OF PROBABLE COSTS OF UV AND OZONE DISINFECTION FOR NORTH SIDE WRP, STICKNEY WRP, AND CALUMET WRP (WITHOUT FILTRATION)

	NORTH SIDE WRP		STICKNEY WRP		CALUMET WRP	
Capital Cost Estimates, in millions	UV	OZONE	UV	OZONE	UV	OZONE
A. General Site Work	$ 4	$ 8	$93	$97	$14	$14
B. Low Lift Pump Station	$ 54	$ 54	$174	$174	$59	$59
C. Disinfection System	$ 25	$ 100	$91	$226	$31	$110
Total Capital Cost	$ 83	$ 162	$358	$497	$100	$180
Operation and Maintenance Cost Estimates, in millions						
A. General Site Work	$ 0	$ 0	$0	$0	$0	$0
B. Low Lift Pump Station	$ 1.1	$ 1.1	$4.1	$4.1	$1.7	$1.7
C. Disinfection System	$ 3.2	$ 6.4	$8.5	$14.9	$3.1	$6.4
Total Annual O&M Cost*	$4.3	$ 7.5	$12.6	$19.0	$4.8	$8.1
Total Present Worth O&M Cost	$84	$146	$245	$369	$93	$157
Total Present Worth, in millions	$167	$ 308	$603	$866	$193	$337
Annual Debt Services Cost, in millions**	**($ 7)**	**($ 14)**	**($30)**	**($42)**	**($9)**	**($15)**

* Total Annual O&M Cost is based on current electrical rate at $0.075 per kilowatt-hour. This cost may change significantly should the electrical rates increase in the future.
** Based on interest rate of 5.5% for 20 years.

SUMMARY OF OPINIONS OF PROBABLE COST

As discussed previously, disinfection cost opinions for North Side, Stickney, and Calumet WRP were developed based on a low-lift pump station, a filtration facility, and a disinfection system. Filtration was included for both disinfection alternatives because of the uncertain effects of TSS on disinfection efficiency. Table 1.26 presents a summary table of the opinion of probable costs for both UV and Ozone disinfection facilities for the three WRPs, including filtration.

TABLE 1.26
OPINION OF PROBABLE COSTS OF UV AND OZONE DISINFECTION FOR NORTH SIDE WRP, STICKNEY WRP, AND CALUMET WRP (WITH FILTRATION)

	NORTH SIDE WRP		STICKNEY WRP		CALUMET WRP	
Capital Cost Estimates, in millions	UV	OZONE	UV	OZONE	UV	OZONE
A. General Site Work	$ 4	$ 8	$93	$97	$14	$14
B. Low Lift Pump Station	$ 54	$ 54	$174	$174	$59	$59
C. Tertiary Filtration	$ 168	$ 168	$642	$642	$208	$208
D. Disinfection System	$ 25	$ 100	$91	$226	$31	$110
Total Capital Cost	$ 251	$ 330	$1,000	$1,139	$310	$390
Operation and Maintenance Cost Estimates, in millions						
A. General Site Work	$ 0	$ 0	$0	$0	$0	$0
B. Low Lift Pump Station	$ 1.1	$ 1.1	$4.1	$4.1	$1.7	$1.7
C. Tertiary Filtration	$ 2.3	$ 2.3	$4.2	$4.2	$2.3	$2.3
D. Disinfection System	$ 3.2	$ 6.4	$8.5	$14.9	$3.1	$6.4
Total Annual O&M Cost*	$ 6.6	$ 9.8	$16.8	$23.2	$7.1	$10.4
Total Present Worth O&M Cost	$128	$ 190	$326	$451	$138	$202
Total Present Worth, in millions	$379	$ 520	$1,326	$1,590	$448	$592
Annual Debt Services Cost, in millions**	**($ 21)**	**($ 28)**	**($84)**	**($95)**	**($26)**	**($33)**

* Total Annual O&M Cost is based on current electrical rate at $0.075 per kilowatt-hour. This cost may change significantly should the electrical rates increase in the future.
** Based on interest rate of 5.5% for 20 years.

As shown from Table 1.26, filtration facilities contribute more than half of the probable construction costs for all three WRPs. Since it is uncertain if filtration will be needed prior to either one of the disinfection alternatives, Table 1.27 presents a summary of the opinion of probable costs for both disinfection alternatives **without** filtration.

Protecting Our Water Environment

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John C. Farnan, P.E.
General Superintendent

312·751·7900 FAX 312·751·5681

August 31, 2005

Mr. Toby Frevert
Division of Water Pollution Control
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9278

Dear Mr. Frevert:

Subject: Evaluation of Management Alternatives for the Chicago Area Waterways:
a. Investigation of Alternative Technologies for Effluent Disinfection
b. Estimation of the Cost of Effluent Disinfection

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), at the request of the Illinois Environmental Protection Agency (IEPA), hereby submits the enclosed reported entitled "Technical Memorandum 1WQ: Disinfection Evaluation".

The MWRDGC formed a committee of experts from academia to investigate possible effluent disinfection technologies and recommend a technology or technologies appropriate for the MWRDGC's Calumet, North Side and Stickney Water Reclamation Plants (WRPs). Further, the MWRDGC had conceptual level cost estimates prepared for the design, construction, operation and maintenance of the selected effluent disinfection technologies.

Using the services of Consoer Townsend Envirodyne Engineers, Inc. (CTE), this committee of experts reviewed and evaluated effluent disinfection alternatives for the Calumet, North Side and Stickney WRPs. Based upon the findings of these experts, the MWRDGC selected ozone and ultraviolet radiation as the environmentally acceptable preferred alternatives. The investigation and selection process was presented to a meeting of the Chicago Area Waterways (CAWs) Use Attainability Analysis (UAA) Study Stakeholders Advisory Committee (SAC) on June 22, 2005.

Subsequently, cost estimates for each selected disinfection technology were prepared for each WRP by the three engineering consulting firms developing master plans for these WRPs.

On October 18, 2005, another meeting of the UAA Study SAC is scheduled and CTE will give a power point presentation summarizing the cost estimating portion of the enclosed report. The MWRDGC believes that this report will be useful in the development of appropriate and cost-effective water quality management strategies for the CAWs.

If you have any questions, please contact Mr. Richard Lanyon at (312) 751-5190.

Very truly yours,

John C. Farnan
General Superintendent

JS:TK
Enclosure

cc: R. Sulski, IEPA

FINAL
8/26/05

TECHNICAL MEMORANDUM
TM-1WQ

DISINFECTION STUDY

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

MASTER PLAN
NORTH SIDE WATER RECLAMATION PLANT

Submitted by:

CTE | AECOM

MWRDGC Project No. 04-014-2P
CTE Project No. 40779

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INTRODUCTION

Background

Consoer Townsend Envirodyne Engineers, Inc. (CTE) was retained in 2004 by the Metropolitan Water Reclamation District of Greater Chicago (District) to provide engineering services to prepare a comprehensive Infrastructure and Process Needs Feasibility Study (Feasibility Study) for the North Side Water Reclamation Plant (WRP) and a Water Quality (WQ) Strategy for affected Chicago Area Waterways.

The WQ strategy includes determining the potential technologies, costs and impacts associated with:

- Disinfection
- End of Pipe Treatment of Combined Sewer Overflow (CSOs)
- Supplemental Aeration of Chicago Area Waterways
- Flow Augmentation for the Upper North Shore Channel and Bubbly Creek

Scope of Study

This report documents the results of a CTE study of effluent disinfection alternatives for the District's North Side, Calumet and Stickney WRPs.

CTE assembled a task force of national experts to review technologies for wastewater disinfection and prepare a recommendation for the technologies most suitable for cost estimating purposes at the District's three largest WRPs.

The task force of experts includes:

Dr. Charles Haas
Department of Civil, Architectural and Environmental Engineering
Drexel University
Philadelphia, PA

Dr. Benito Marinas
Dept of Civil and Environmental Engineering
University of Illinois
Urbana, IL

Dr. Kellogg Schwab
Johns Hopkins Bloomberg School of Public Health
Department of Environmental Health Sciences
Division of Environmental Health Engineering
Baltimore, MD

The task force reviewed different effluent disinfection technologies and their range of pathogen destruction efficiency, disinfection byproducts and impacts upon aquatic life and human health. Their investigation also included an examination of the environmental and human health impacts of the energy required to operate the facility and for the processing and production of process chemicals.

Ultimately the task force recommended a disinfection technology(s) for possible implementation at the North Side, Stickney and Calumet WRPs.

The scope of work for the disinfection study included the following subtasks:

Subtask	Description
1.	Description and Summary of Disinfection Technologies
2.	Evaluation of Alternatives
3.	Workshop on Recommended Disinfection Technologies
4.	Prepare Final Technical Memorandum

This report contains the Final Technical Memorandum (TM-1WQ) document for the CTE study of effluent disinfection for the MWRDGC.

Study Objective

- Provide a final recommendation for one or more disinfection technologies which is the best fit for the District's North Side, Stickney and Calumet WRPs.
- Prepare capital and operation and maintenance (O&M) cost estimates for the construction of the recommended technology or technologies for the North Side, Stickney and Calumet WRPs. The cost estimates for the Stickney and Calumet WRPs will be provided by Black & Veatch and Metcalf & Eddy, respectively. CTE will prepare the cost estimate for the North Side WRP.

LONG LIST OF DISINFECTION TECHNOLOGIES

Introduction

There are a number of effluent disinfection alternative technologies that should be considered for potential implementation by the District at its major treatment plants. To properly evaluate and select disinfection alternatives, two levels of review will be used. This section of the report will describe the first level of review. Based upon this first review, a number of alternatives will be eliminated and the remaining acceptable alternatives will be evaluated in a second, more detailed level of review.

Potential Disinfection Alternatives

Based upon the experience of the Task Force, the scientific literature textbooks, and manuals of practice, the following disinfection alternatives were selected for the long list evaluation.

1. Chlorination (alone)
   - 1.1 Calcium Hypochlorite
   - 1.2 Sodium Hypochlorite (commercial grade)
   - 1.3 Sodium Hypochlorite (on-site generation)
   - 1.4 Chlorine Gas

2. Ozone
   - 2.1 Ozone generated from air
   - 2.2 Ozone generated from oxygen

3. Ultraviolet (UV) Radiation
   - 3.1 Low Intensity UV
   - 3.2 High Intensity UV

4. Chlorination-Dechlorination
   - 4.1 Calcium Hypochlorite + Sodium Bisulfite
   - 4.2 Calcium Hypochlorite + Sulfur Dioxide
   - 4.3 Sodium Hypochlorite + Sodium Bisulfite
   - 4.4 Sodium Hypochlorite + Sulfur Dioxide
   - 4.5 Sodium Hypochlorite (on-site) + Sodium Bisulfite
   - 4.6 Sodium Hypochlorite (on-site) + Sulfur Dioxide
   - 4.7 Chlorine Gas + Sodium Bisulfite
   - 4.8 Chlorine Gas + Sulfur Dioxide

5. Chlorine Dioxide
6. Bromine Compounds
7. Sequential Disinfection Processes
8. Membrane Processes

Chlorination

Today chlorine (in its many forms) is the most widely used disinfectant at both water and wastewater treatment plants in the U.S. Chlorine reacts rapidly with water and can inactivate a range of pathogens present.

The inactivation mechanism appears to be damage to nucleic acids in the cell. Chlorine reacts rapidly with ammonia and certain organic compounds to form chloramines and chlorinated organic compounds. The combined chloramines are lower in germicidal value compared to free chlorine.

The use of chlorine disinfection of wastewater can result in several adverse environmental impacts, due to total chlorine residual in the receiving water and the formation of toxic chlorinated organic compounds.

Chlorine Gas

Elemental chlorine gas has a density greater than air at room temperature and pressure. When compressed, chlorine gas condenses into a liquid with the release of heat and a reduction of volume of approximately 450 fold. Hence, commercial shipments of chlorine gas are made in pressurized tanks to reduce shipment volume. Chlorine gas is an extremely volatile and hazardous chemical and proper safety precautions must be exercised during all phases of chlorine shipment, storage and use.

Federal air pollution regulations require that wastewater treatment plants using chlorine gas comply with strict requirements to prevent accidental release including stringent record keeping and emergency response measures. These federal accidental release requirements have caused many municipal wastewater treatment plants to abandon chlorine gas as a disinfectant. Most have chosen to use liquid sodium hypochlorite which is exempt from the accidental release requirements.

Hypochlorite (Sodium Hypochlorite and Calcium Hypochlorite)

Chlorine can also be added to wastewater effluents using hypochlorite as the disinfecting agent. The active compounds are the same as gaseous chlorine. The mechanism for bacterial kill is also the same. Adverse environmental impacts are the same as gaseous chlorine.

Sodium hypochlorite is available commercially in solution form in solution strengths up to 16% by weight. Typically solution strength is 12 to 15%. It is not practical to provide higher solution strength since chemical stability rapidly diminishes with strengths above 16%. At ambient temperatures, the half-life of sodium hypochlorite solution varies between 60 to 170 days for solutions of 18 and 3 percent respectively. Sodium hypochlorite solution can be generated by continuous electrolysis of brine solutions. The basic principle is the use of a direct current electrical field to affect the oxidation of chlorine ion with the reduction of water to gaseous hydrogen. The electrolysis operation consumes large amounts of electrical energy usually about 1.5 kilowatt-hours are required to produce one kilogram of chlorine.

Calcium hypochlorite, sometimes referred to as powdered bleach, is a dry material typically consisting of 65% chlorine. Often called high test hypochlorite (HTH), 1 kg of calcium hypochlorite is equivalent to 0.65 kg of elemental chlorine. This solid is a white, hydroscopic material that emits a strong, chlorine odor.

Advantages and Disadvantages of Chlorination

Whatever the form of chlorine, chlorination systems are reliable and flexible and the equipment is not complex. It is relatively easy to apply and control chlorine in wastewater treatment. Even when dechlorination required, it is normally the lowest cost disinfection alternative in most cases.

Worker safety is a real issue with gaseous chlorine but the hypochlorites are relatively safe.

The chlorination process for wastewater produces excellent reduction for many, but not all pathogen and can negatively impact aquatic life unless dechlorination is practiced. Even with dechlorination, there is a potential for discharge of toxic organic compounds which could negatively affect aquatic and human health.

Figure 1.1 shows a picture of a chlorination disinfection system.

Later in this report, there is a section on chlorination-dechlorination. This later section summarizes (Table 1.3 and 1.4) the advantages and disadvantages of the chlorination process.

Ozone

Ozone (O_3) is an unstable gas that is produced when oxygen molecules are disassociated into atomic oxygen (O) and subsequently collide with an oxygen (O_2) molecule. For commercial production of ozone, an electrical discharge in a gas containing oxygen (air or pure oxygen) is used to create the atomic oxygen.

At ordinary temperatures, ozone is a blue colored gas which has a distinctive odor. The gas is commonly detected by individuals in close proximity to electrical equipment that produce a spark discharge.

Ozone is a very strong oxidizing agent and will react with many organic and inorganic compounds in the wastewater. These reactions are typically called “ozone demand”. This demand is important because the reacted ozone is no longer available for disinfection. Wastewaters which have significant concentrations of organics or inorganics may require very high levels of ozone to achieve disinfection.

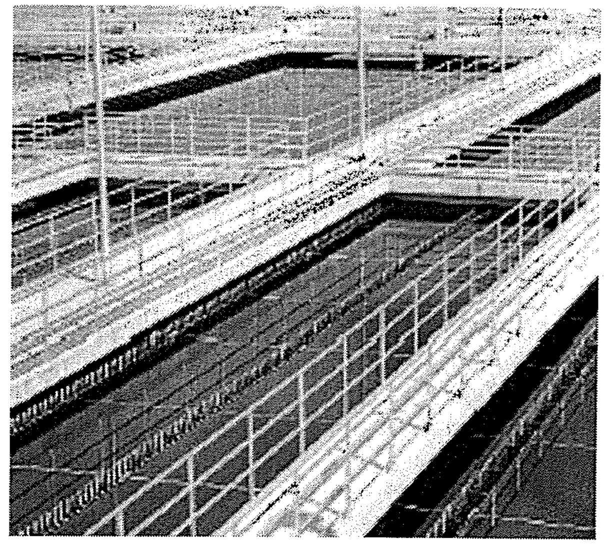
The inorganic compounds in wastewater that can react with ozone include sulfite, nitrite, ferrous iron, manganese and ammonia. The organic compounds that react with ozone include aromatic aliphatic compounds, humic acids and pesticides.

<u>Ozone Process</u>

Figure 1.2 shows a simplified process diagram for an ozone disinfection system. Transfer of ozone into the wastewater is the first step in meeting the disinfection objective, since ozone must be transferred from the gas to the liquid before effective disinfection can begin. Once transferred, the residual ozone must make contact with the pathogens in order for disinfection to occur. Figure 1.3 shows a picture of an Ozone disinfection system.

Figure 1.1 - Chlorination Disinfection System

Chlorine Contact Tanks



Sodium Hypochlorite
Disinfection

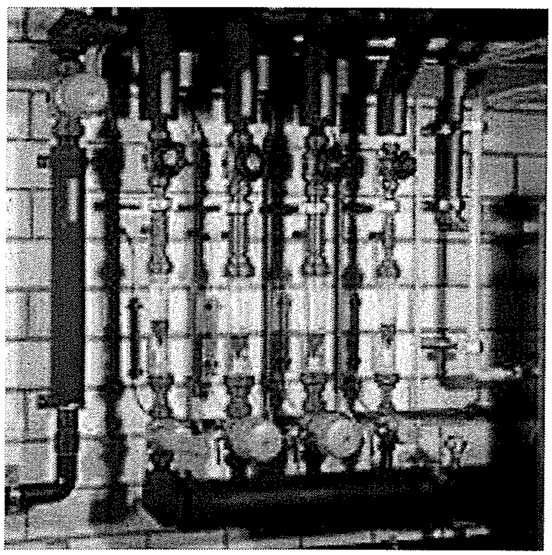


Figure 1.2 – Ozone disinfection process schematic

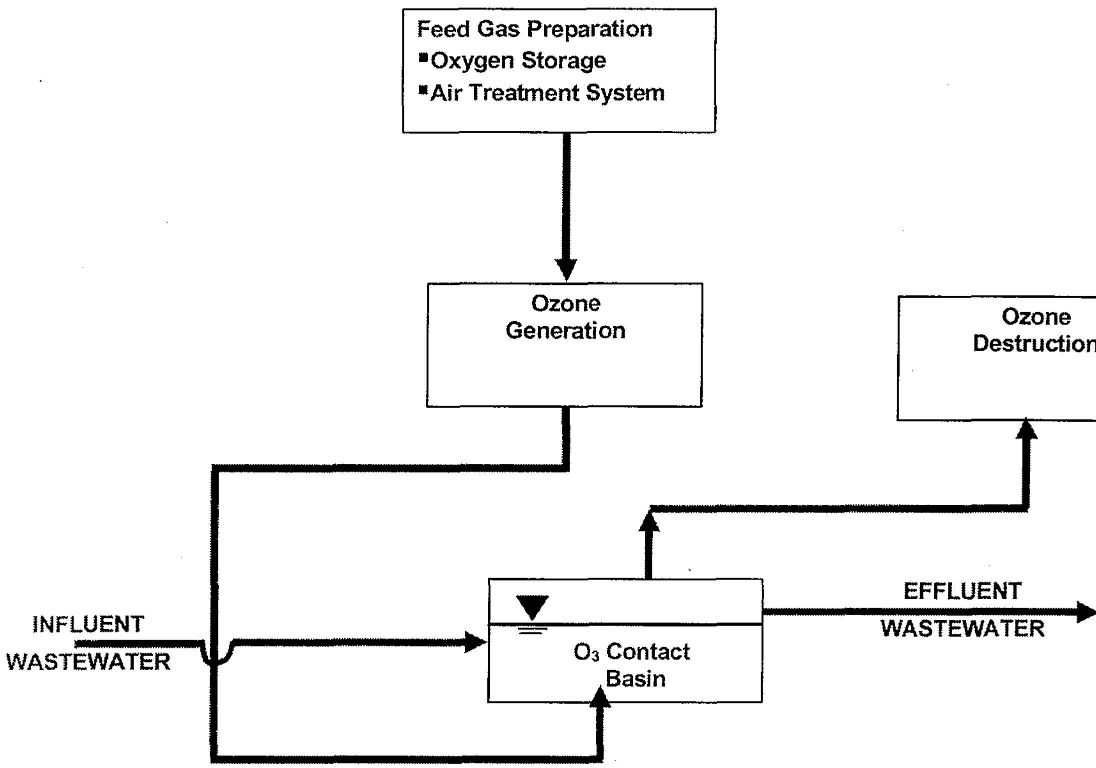
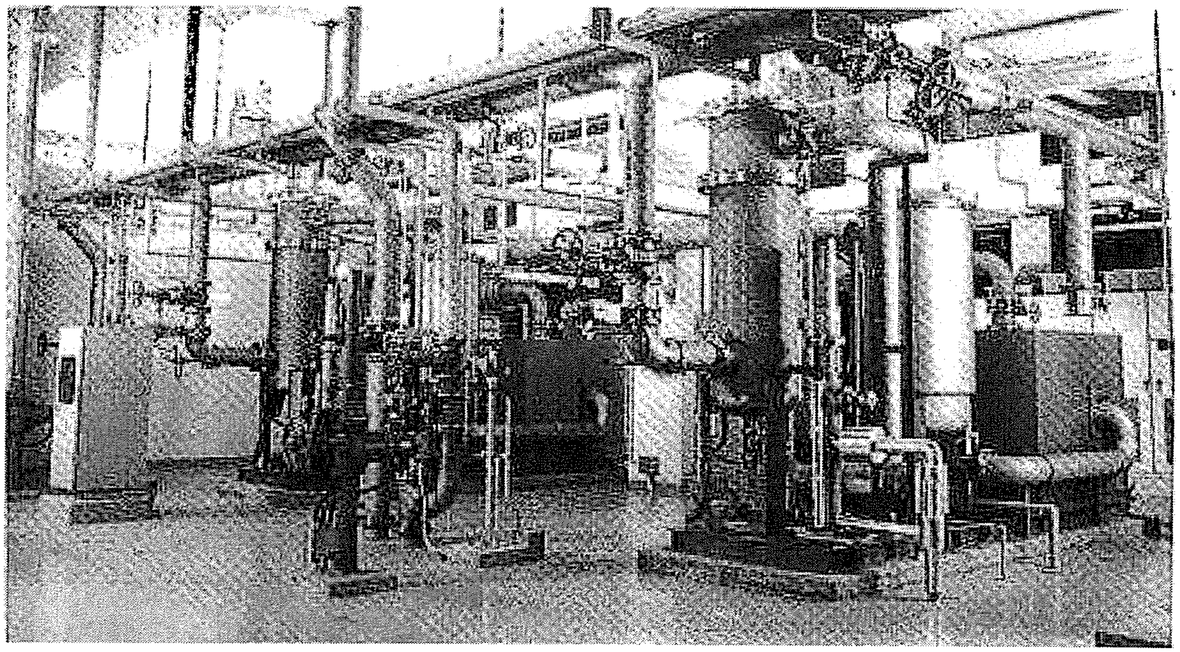


Figure 1.3 - Ozone Disinfection System



Contact time is usually about 10 to 15 minutes and ozone dosages of about 6.0 to 8.0 mg/l are usually sufficient to achieve effluent target bacterial levels.

Ozone is generated from either commercially pure oxygen or ambient air.

The estimated power for pure oxygen ozone generation is 9.0 kilowatt hours per pound of ozone produced. Ozone generated from air requires about 11.0 kilowatt hours per pound of ozone produced. Additional power is required for the gas preparation and drying system (air feed) or for the oxygen generation system.

No matter what the source of the feed gas, the quality of the feed is critically important. The feed gas must be oil-free, particle-free and dry. To achieve this, the feed gas must be pretreated to remove moisture, particles and oil (if present). For oxygen feed systems, it is usually necessary to pretreat for particles only since oil and moisture are usually not present in significant quantities.

Cooling is a major aspect of ozone generation since the electrical discharge produces considerable heat. Cooling is accomplished with either water, oil or Freon. For water cooling, about 1.0 gallon of water is required for every gram of ozone produced. Typically, potable water in a closed loop system is used which is in turn cooled by plant non-potable water. The closed loop system is often treated to obtain "boiler water" quality water.

Ozone destruction is used to remove excess ozone in the contact basin off-gases prior to venting. Safety is a major issue for such ozone destruction equipment since explosive conditions can occur. The primary methods for ozone destruction are thermal destruction and catalyst destruction.

Advantages and Disadvantages of Ozone

Table 1.1 contains a summary of the advantages and disadvantages of ozone.

Ozone equipment is complex to maintain and operate. Process control is difficult compared to chlorination since changes in ozone demand cannot be monitored on a real time basis.

Ozone disinfection does add dissolved oxygen to a wastewater effluent but this may not be an advantage if the effluent is already high in dissolved oxygen. Ozone has been shown in certain instances to produce toxic and/or carcinogenic compounds but little is known about these compounds.

Ozone is an excellent viral disinfection agent but since current disinfection standards are based upon bacterial measurements, this advantage may not be of significant regulatory benefit.

Ozone gas can be toxic to humans, plants and animals if inhaled in sufficient quantities. Care must be taken in the handling of the gas to prevent accidental release.

Ozone disinfection is relatively expensive with the cost of the ozone generation system being the main cost item. Operating costs are very high due to the power demand since ozone is a power intensive process.

TABLE 1.1
OZONE

ADVANTAGES

- Adds dissolved oxygen
- Excellent virus kills
- Short contact time (5 to 15 minutes)
- No residual control required
- No significant regrowth
- No chemical storage required
- Reacts with endocrine disruptors (reduction to some degree)
- No increase of truck traffic

DISADVANTAGES

- High capital costs
- Equipment is complex to operate and maintain
- Reduced *Cryptosporidium* inactivation at low effluent temperatures
- Little is known about ozone disinfection-by-products (only 8% of ozone by-products have been identified.)
- Ozone can increase formation of biodegradable organic compounds such as aldehydes and keto-acids or bromate (if bromine is present)
- Ozone gas is toxic to humans, animals, and plants
- Ozone systems must have IEPA air permit
- High electrical power costs
- Least used wastewater disinfection method in U.S.
- Corrosion resistant materials required
- Ozone destruction unit required

Ultraviolet Disinfection

Although chlorination has been the disinfection method of choice in the U.S. for over 100 years, ultraviolet (UV) irradiation has become the next most common alternative for effluent disinfection. The emergence of UV irradiation may be attributed to the drawbacks of chlorination and improvements in UV equipment.

Due to the problems with chlorination, UV disinfection has increased in U.S. For example, only 50 wastewater plants used UV in 1986 but by 1990 over 500 plants used the process. In 1998, more than 1,000 treatment plants in the U.S. used UV disinfection.

Ultraviolet irradiation is a physical disinfection process. UV irradiation achieves disinfection by inducing photo-biochemical changes within pathogens. Approximately 85% of the germicidal output from UV lamps have a wavelength of about 254nm. The visible blue light emitted by the lamps has a wavelength of 400 nm but this wavelength has no germicidal power. It is believed that the disinfection power of UV irradiation is caused by damage to nucleic acids in the cell.

Lamp output

Lamp UV output changes with time. In general, output falls off quickly after about 1,000 to 2,000 hours of operation followed by a gradual decline. Most municipalities replace their UV lamps after 5,000 to 10,000 hours of operation.

Fouling

The ability to deliver radiation from the source to the target is critical to the performance of UV systems. Accumulation of insoluble materials on the surface of the UV tubes limits the UV radiation dose. Control of lamp fouling is usually accomplished using a combination of physical and chemical methods. Physical methods include mechanical wipers or brushes – as integral components of individual manufacturer's devices. Chemical cleaners include acids and detergents. The solutions can be applied by either wiping individual lamps or physical immersion in tanks containing the cleaners. Some manufacturers have in-situ cleaning systems which do not require removal of the lamps from the effluent flow.

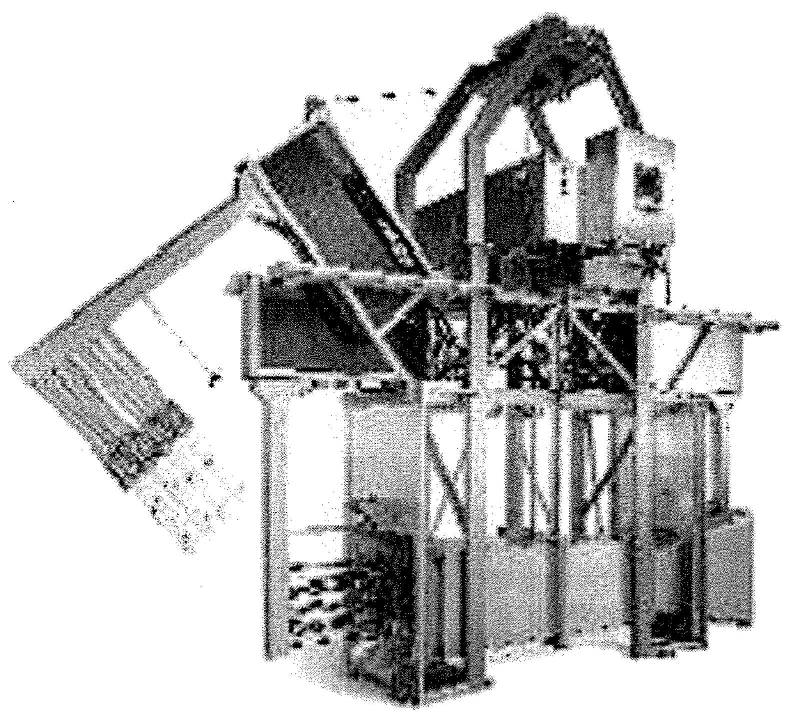
Current System Designs

Original systems offered by manufacturers in the 1980's consisted of enclosed chambers using either a submerged lamp system or a non-contact system. The technology has now evolved into a modular, submerged lamp system installed in an open channel which has significantly improved maintenance and afforded better hydraulics. Lamps are usually either low intensity, low pressure mercury systems or high intensity, medium pressure systems.

Low pressure mercury lamp systems are the most common bulb system used in wastewater treatment plants. However, the output UV intensity is low. These systems require relatively large numbers of lamps in a fairly dense bank spacing (2 to 5 inch spacing). But these lamps are widely available at relatively low cost with an effective lamp life about 10,000 hours.

The UV output of high intensity, medium pressure lamps is 8 to 16 times greater than low-pressure bulbs. Therefore, lamp spacing is significantly greater with the need for fewer lamps so that capital costs are lower. However lamp life is shorter (less than 8,000 hours) and the electrical energy requirements are higher.

Figure 1.4 – High Intensity-Medium Pressure UV Disinfection Process



Advantages and Disadvantages of UV Disinfection

Table 1.2 contains a summary of the advantages and disadvantages of UV.

The UV process is relatively simple. The hardware is simple and maintenance does not require high skill levels. The hazards to the process are low and only relate to electrical shock hazards. The major advantage is the absence of a residual in the wastewater and no known impact upon aquatic or human health.

The process is difficult to monitor since there is no residual germicide concentration. Electrical energy requirements are high. Fouling can be a significant problem. Also, high suspended solids, color, turbidity and soluble organic matter in the water can react with or absorb the UV and affect effluent quality. Some facilities have experienced difficulties in meeting target effluent bacterial levels due to the periodic presence of UV blockers from industrial wastes. UV blockers are water soluble compounds which absorb UV spectrum light. Design of systems to deal with these discharges can be difficult without pilot plant studies.

Chlorination – Dechlorination

In a previous section, the various forms of chlorine used to disinfect wastewater effluents were discussed. Chlorination results in a significant residual chlorine concentration usually 1 to 3 mg/l. Because the level of residual is toxic to some aquatic species, most state agencies require the chlorine residual to be reduced to about 0.05 mg/l before effluent discharge.

Dechlorination is the chemical removal of most traces of residual chlorine remaining after chlorination. This is typically accomplished with sulfur dioxide (SO_2-gas) or sodium bisulfite ($NaHSO_3$-liquid).

In addition to the equipment and facilities required for chlorination, dechlorination requires the following equipment and facilities:

- Storage tanks (Liquid or Gas)
- Pumps and other equipment for dosing
- Rapid mixing for effective dispersal in the liquid
- Analyzers and controllers for dose control

The reaction of the dechlorination chemical is very rapid and no contact tank is required. The contact time between the dosing point and the point of effluent discharge is usually sufficient.

Sulfur Dioxide

Sulfur dioxide is the most popular method for dechlorination. Sulfur dioxide is a colorless gas with a characteristic biting odor. The gas is stored as a liquid in a pressurized container.

Sulfur dioxide is not flammable or explosive. In the presence of moisture, SO_2 is extremely corrosive. It is therefore necessary to use corrosive resistant materials for storage and dosing equipment.

TABLE 1.2
ULTRAVIOLET (UV) IRRADIATION

ADVANTAGES

- No significant by-product discharge to receiving stream
- Relatively simple equipment
- Second most widely used disinfection process
- No chemical storage required: worker safety is excellent
- Low potential for neighborhood impact
- No significant increase in truck traffic
- Can inactivate *Cryptosporidium, Giardia*
- Inactivation efficiency unaffected by temperature

DISADVANTAGES

- High capital costs
- High operating costs for electricity
- No germicidal residual – operational control can be difficult
- Does not react well to change in transmittance or flow
- Fouling is a significant issue and causes maintenance and performance problems
- Intermittent presence of UV blockers can cause permit violations
- Certain viruses are poorly inactivated
- Need reliable power sources
- Labor and cost intensive for lamp replacement and disposal
- Possible permit issues (hazardous waste)
- No impact on endocrine disruptors

The chemical reaction of SO_2 results in the conversion of the chlorine and chloramines ions to chloride ions. A small amount of sulfuric and hydrochloric acid is formed from the reaction but the pH of the wastewater is rarely affected. If some organics are present, an excess of sulfur dioxide may be needed, but excess dosages are to be avoided because it may cause a dissolved oxygen reduction and a drop in pH.

The chemical reaction of sulfur dioxide and chlorine is 1:1. That is, one mg/l of sulfur dioxide will remove a chlorine residual of one mg/l.

Exposure Hazard to SO_2

Sulfur dioxide is extremely hazardous and must be handled with caution. If you inhale sufficient sulfur dioxide gas, it will cause significant damage to mucous membranes and the lungs. Exposure to high levels of sulfur dioxide gas can cause death. The gas is heavier than air and can concentrate in low areas.

Method of SO_2 Control

Residual sulfur dioxide in plant effluent should be measured to ensure that over dosing does not occur. A residual sulfur dioxide level of 0.5 mg/l is sufficient to reduce residual chlorine concentrations to near zero.

Sulfur Dioxide Equipment

Sulfur dioxide containers and handling facilities are nearly the same as those for gaseous chlorine. However, the materials should be carefully selected due to the aggressive corrosive action of sulfur dioxide.

Municipal wastewater treatment facilities with sulfur dioxide storage facilities are subject to stringent federal accidental release regulations. These regulations have caused many facilities using sulfur dioxide to convert to the use of liquid sodium bisulfite.

Sodium Bisulfite

Sodium bisulfite is also used for dechlorination. Upon dissolution in water, this salt produces sulfite (SO_3) ion which is the active dechlorinating agent. The salt is available as a dry powder or liquid. However, municipal wastewater treatment plants typically utilize the liquid form of the salt.

The sodium bisulfite salt is typically more expensive per pound of active dechlorination agent than SO_2. But often the safety and handling of the liquid outweigh the cost in comparison to sulfur dioxide.

Advantages/Disadvantages of Chlorination/Dechlorination

The choice of SO_2 versus sodium bisulfite is dictated by similar considerations to those that govern the selection of gaseous chlorine versus the hypochlorites. If sulfur dioxide is used, the same types of issues (safety, accidental release) associated with gaseous chlorine apply. Because of the safety and accidental release issues, it is often decided to use liquid sodium bisulfite for dechlorination.

Both SO_2 and sodium bisulfite produce the same active agent, the sulfite ion. Thus both have the same environmental impacts and decisions between these alternatives are based almost solely upon safety, accidental release risk and cost. The storage and dosing of SO_2 is also more complex to maintain and operate than sodium bisulfite equipment, therefore this may influence the decision as well.

Table 1.3 and 1.4 contain summaries of the advantages and disadvantages of Gas Chlorination/Gas Dechlorination (Table 1.3) and Liquid and Dry Chemical Chlorination/Liquid Dechlorination (Table 1.4).

Chlorine Dioxide

Chlorine dioxide (ClO_2) has been used on a full-scale at drinking water plants. It is especially useful for waters containing phenols or other taste and odor producing compounds. It is a proven disinfectant equal to or greater than chlorine.

The environmental impacts of chlorine dioxide are not well established. There is a belief that it produces lower amounts of toxic chlorinated organic compounds but further research is needed to confirm this.

Production of Chlorine Dioxide

Chlorine dioxide is an extremely unstable and explosive gas. Therefore, it cannot be transported and must be generated on-site.

The most commonly used on-site production process for chlorine dioxide is shown in Figure 5. Gaseous chlorine is reacted with sodium chlorite to produce gaseous chlorine dioxide which is then dissolved in water and applied to the wastewater.

Sodium chlorite is very combustible with organic compounds. Skin should not come in contact with this chemical to avoid burns.

Chlorine dioxide has not received a great deal of attention as a wastewater disinfectant due to the on-site generation requirement and the high chemical costs. The overall system is complex to operate and maintain even compared to gaseous chlorination. Safety hazards include handling two dangerous chemicals (gaseous chlorine and sodium chlorite). There is no known full-scale use of this process at municipal wastewater treatment plants.

Advantages/Disadvantages of Chlorine Dioxide

Table 1.5 contains a summary of the advantages and disadvantages of chlorine dioxide.

Bromine Compounds

Bromine will form monobromamines and dibromamines when added to wastewater. Bromamines have been found to be very effective as a disinfectant with shorter lived residuals than chloramines. Because bromamines are stronger disinfectants than chloramines, shorter contact times are needed compared to chlorine. Environmental impacts associated with bromine are believed to be less adverse than those associated with chlorine since lower amounts of bromine compounds are formed. However, more research is needed to determine

TABLE 1.3
GAS CHLORINATION/SULFUR DIOXIDE GAS DECHLORINATION

ADVANTAGES

- Chlorination/Dechlorination is most widely used wastewater disinfection method
- Operational control is excellent
- Maintenance requirements are low
- Very reliable systems
- Reacts well to changes in effluent quality
- Produces some viral inactivation if adequate contact time and dose are achieved
- Chlorine gas is low cost form of chlorine
- Sulfur dioxide gas is low cost dechlorination chemical

DISADVANTAGES

- Gaseous chlorine and sulfur dioxide gas present regulatory and security issues (accidental release)
- Gaseous chlorine and sulfur dioxide gas present significant worker and neighbor safety issues
- Low inactivation of *Giardia* and other protozoa and no inactivation of *Cryptosporidium*
- Chlorine byproducts toxic to aquatic community and humans
- Inactivation efficiency decreases with decreasing temperature and increasing pH
- Combined chlorine, formed during occurrence of high ammonia nitrogen, is a weaker disinfectant compared to free chlorine

TABLE 1.4
LIQUID AND DRY CHEMICAL CHLORINATION/LIQUID DECHLORINATION

ADVANTAGES

- Many plants have switched to liquid-dry chlorination/liquid dechlorination because of accidental release regulations
- Operational control is excellent
- Maintenance requirements are low
- Liquid and dry forms of chlorine and liquid dechlorination pose little hazard to workers and neighbors
- Very reliable systems
- Reacts well to changes in effluent quality
- Produces some viral inactivation if adequate contact time and dose are achieved

DISADVANTAGES

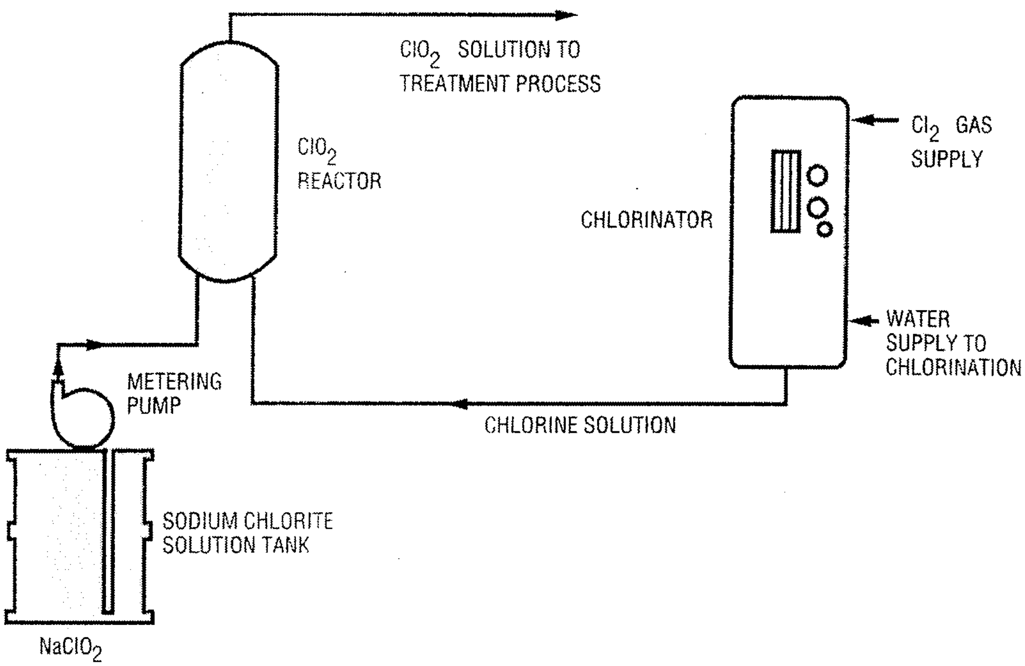
- Significant liquid chemical storage required
- Liquid/dry chlorination/liquid dechlorination is typically higher in cost than gas chlorination/gas dechlorination
- Dry chlorine form presents operational issues (dissolution in water)
- Low inactivation of *Giardia* and other protozoa and no inactivation of *Cryptosporidium*
- Chlorine byproducts toxic to aquatic community and humans
- Inactivation efficiency decreases with decreasing temperature (below 10 – 12^{0}C) and increasing pH (above pH 7.6)
- Combined chlorine, formed during occurrence of high ammonia nitrogen, is a weaker disinfectant compared to free chlorine

TABLE 1.5
CHLORINE DIOXIDE

ADVANTAGES
- Higher oxidation potential than chlorine
- Removes phenols and other organics better than chlorine
- More effective viricide than chlorine
- Does not react with ammonia

DISADVANTAGES
- Complex on-site generation process
- On-site generation requires gaseous chlorine use
- No known full-scale use in wastewater plants
- By-product formation is relatively unknown
- Inactivation efficiency decreases with decreasing temperature
- Has the same neighbor and worker safety disadvantages as gas chlorination

Figure 1.5 – Chloride Dioxide Disinfection Process Schematic



Source: U.S. Environmental Protection Agency, EPA – 600/8-78-018, October 1978.

if these bromine compounds may be toxic at high concentrations. If bioaccumulation occurs, these compounds could have toxic/carcinogenic effects.

The uses of bromine compounds (such as sodium bromide) have been studied at the research and pilot level for wastewater disinfection. Brominated organics such as bromoform and mixtures of chlorinated and brominated organics are formed when bromine compounds are used as a disinfectant.

Advantages/Disadvantages of Bromine Compounds

Table 1.6 contains a summary of the advantages and disadvantages of bromine compounds.

There is no full-scale experience with the use of bromide compounds for wastewater disinfection. Mr. G.C. White in his latest (1999) edition of the "Handbook of Chlorination and Alternative Disinfectants" states: "there is insufficient field experience for proper evaluation."

Emerging Wastewater Disinfection Technologies

The disinfection technologies evaluated in the preceding sections were selected based on current regulatory requirements for wastewater effluent discharge regarding indicator organisms. However, more advanced technologies might be required in the event that specific pathogens become regulated in the future. Although this is not of concern now, a brief review of emerging sequential disinfection and membrane technologies that could be used in the future for the control of emerging pathogens in wastewater are presented in this section for the purpose of completeness.

Sequential Disinfection Processes

Although many specific viral, bacterial, and protozoan pathogens would be controlled adequately with the technologies described in previous sections, they will not be generally effective for controlling all potentially emerging pathogens. For example, UV disinfection might be the only technology capable of inactivating protozoan cysts in wastewater effluents. Chlorine is practically ineffective to control *Cryptosporidium parvum* cysts, and achieving the required control in the case of ozone and chlorine dioxide might be generally difficult and unreliable due to the occurrence of a relatively high disinfectant demand. In contrast, specific enteric viruses such as adenoviruses have relatively high resistance to inactivation by UV light, but they are controlled adequately with chemical disinfectants with the exception of combined chlorine. Consequently, controlling all pathogens of interest might require the use of sequential disinfection processes.

The use of sequential disinfection processes such as UV light followed by free chlorine, and ozone followed by free or combined chlorine might provide adequate protection against a wide range of viral, bacterial and protozoan pathogens. Such sequential disinfection approaches might be the focus of greater attention if specific pathogens become the target of future regulatory efforts. However, these concepts have not operated tested or operated on a full-scale.

Table 1.7 contains a summary of advantages and disadvantages of sequential disinfection processes.

TABLE 1.6
BROMINE COMPOUNDS

ADVANTAGES

- Shorter contact times compared to chlorine
- Because of shorter lived residuals than chlorine by-products, should have lower toxicity than chlorine
- Physical equipment similar to chlorination
- Maintenance and operation issues similar to chlorination

DISADVANTAGES

- Environmental effects of by-products is relatively unknown (bromine not acceptable for drinking water treatment)
- No full-scale experience in wastewater plants
- Expensive chemical
- Usually used in conjunction with chlorine to reduce cost
- Inactivation efficiency decreases with decreasing temperature
- Careful handling is required by workers

TABLE 1.7
SEQUENTIAL DISINFECTION PROCESSES

ADVANTAGES

- Can control wide range of pathogens:
  - Viruses
  - Bacteria
  - protozoans

DISADVANTAGES

- Current disinfection targets are bacteria only
- Not tested on full-scale
- No full-scale operating experience
- Increased complexity, maintenance, and possibly costs due to multiple processes

Membrane Processes

Membranes are currently being used in wastewater treatment applications for the tertiary removal of dissolved salts, organic compounds, phosphorus, colloidal and suspended solids, and pathogens. Membrane technologies for wastewater treatment include the use of membrane bioreactors as a replacement for secondary clarifiers, low-pressure membranes to provide a higher degree of solids removal following secondary clarification, or high-pressure membranes for treatment and production of high-quality product water suitable for indirect potable reuse and high-purity industrial process water.

The biggest single technical challenge with the use of membranes for wastewater treatment is the high level of unavoidable fouling. Membrane fouling is mainly due to colloids, dissolved organic material, and bacteria that are present in secondary effluent with resultant decreases in product water flux at constant feed pressure (or increases in feed pressure at constant product water flux) and frequency of membrane cleaning, dramatically reducing membrane operational life . The nature of this fouling is poorly understood and stands as a key impediment to developing improved methods for membrane cleaning. Other technical barriers include the difficulty and expense of managing the concentrate from high pressure membranes, and the undefined ability of low pressure membranes to effectively remove all chemical contaminants and pathogens of concern that are found in municipal secondary effluent. Although substantial current research is directed toward producing the ideal membrane system, little effort has been made for standardization, which is needed to increase interchangeability among membranes and membrane systems produced by different manufacturers. Sensitivity analyses on design and operating parameters for membrane systems suggests that costs are also quite sensitive to product water flux. Accurate estimates of flux are necessary to compare membrane application cost with the cost of other technologies. Presently, site-specific fluxes can only be obtained through pilot studies.

Treating wastewater with membranes is a viable option when considering urban, agricultural, or industrial reuse, groundwater recharge, salinity removal, or to meet very low effluent water quality limits for nutrients. However, there has been no full-scale use of the technology as a method for effluent disinfection.

Table 1.8 contains a listing of the advantages and disadvantages of membrane process.

TABLE 1.8
MEMBRANE PROCESSES

ADVANTAGES

- Removes pathogens, salts organics, phosphorus, suspended and colloidal matter

DISADVANTAGES

- Typically used for industrial waste and reclaimed water treatment
- Fouling may be significant and is a poorly understood phenomena
- Membranes are expensive
- Management of concentrate is an issue
- No full-scale experience for wastewater disinfection

EVALUATION OF LONG LIST DISINFECTION ALTERNATIVES

An evaluation of the long list of disinfection alternatives was conducted with the objective of constructing a medium list of alternatives for a further detailed evaluation. The task force and the District reviewed the long list and eliminated those alternatives which would have no practical application to the District's major WRPs.

In an effort to summarize the relevant issues associated with the various long list technologies and assist in the evaluation of the long list alternatives, Table 1.9 was constructed.

The North Side and Calumet Plants rank among the largest WRPs in the U.S. while the Stickney WRP is the largest in North America. Thus, because of a lack of large-scale wastewater treatment plant effluent disinfection experience, the task force eliminated the following long list technologies from further consideration:

1. Chlorine Dioxide
2. Bromine Compounds
3. Sequential Disinfection Processes
4. Membrane Processes

Because of District concerns with the potential hazards to humans and the environment due to accidents or terrorism, either at the plant or during transportation, gas chlorination/gas dechlorination options were also eliminated from the long list. Because the task force believes that chlorination alone will not meet forecasted future water quality standards for chlorine residual, chlorination alone was also eliminated from the long list.

TABLE 1.9 – SUMMARY OF DISINFECTION TECHNOLOGY ISSUES

Technology	Pathogen Destruction Efficiency	Byproducts and impact on aquatic life and human health and safety	Energy required to operate the facility	Energy required for processing and production of chemicals	Relative Impacts of Energy Production on the Environment
Chlorination	Reacts rapidly with water and can inactivate many pathogens. Will kill some viruses depending upon operating conditions.	Can result in adverse environmental impacts due to formation of toxic chlorinated organic chemicals. As a gas, it is extremely volatile and hazardous.	Energy required for chlorination at the treatment plant is low if commercially available chlorine is used.	On-site generation requires 1.5 kwh per kg of chlorine. Off-site commercial chlorine production also has similar energy demands.	Medium impact
Ozone	Will kill many pathogens. Produces excellent virus kills.	Little information known about byproducts. Ozone gas is toxic to plants, animals and humans.	High demand for electrical energy to generate ozone.	Ozone is generated on-site.	Medium impact
Ultraviolet	Kills pathogens by damage to nucleic acids. Can inactivate some parasites.	No known significant byproducts. UV disinfection is relatively safe to operate.	Electrical energy to operate lamps is higher than ozone generation.	UV light is produced on-site.	High impact
Chlorination-Declorination	Comments same as above for chlorination.	Same as chlorination.	Somewhat higher than chlorination alone.	Commercially available dechlorination chemicals require high electrical energy for production.	Medium impact
Chlorine Dioxide	More effective viricide than chlorine.	Byproduct formation is relatively unknown. An unstable and potentially explosive gas.	Generated on-site.	Commercial chlorine gas and other compounds required for on-site production have high energy demands.	High impact
Bromine Compounds	Very effective as a disinfectant and requires less contact time than chlorine.	Byproduct toxicity relatively unknown. Similar safety issues as chlorine.	Same as chlorine.	Commercial bromine production requires similar energy to chlorination.	Medium impact
Sequential Disinfection Processes	Potential approach to achieving a wide range of potentially emerging specific pathogen standards.	Byproduct toxicity and safety issues depend upon disinfection processes used.	Depends upon processes being used.	Depends upon processes being used.	Depends upon processes being used.
Membrane Processes	Could be used for removal of most human pathogens.	No byproducts formed. No significant safety issues.	Pumping energy at the plant is high.	Membrane production does not require large electrical energy.	Medium impact

MEDIUM LIST OF ALTERNATIVES

Based upon the evaluation of the long list by the task force, the following technologies constitute the medium list:

1. Ozone
   - Generated from air
   - Generated from oxygen
2. Ultraviolet Disinfection
   - Low Intensity
   - High Intensity
3. Calcium hypochlorite plus sodium bisulfite
4. Sodium hypochlorite plus sodium bisulfite
5. Sodium hypochlorite (on-site) plus sodium bisulfite

These alternatives were evaluated using a matrix with the following criteria and weights:

Criteria	Weight Group Total	Weight Item Total
1. Desirable Performance Requirements		
1.1. Safety	15	
1.1.1. Low Risk to Operators from Accidental Releases and Waste Products		3
1.1.2. Low Hazard Potential to Neighbors		3
1.1.3. Low Level of Onsite Chemical Storage		3
1.1.4. Low Potential for Malicious Adverse Occurrences		3
1.1.5. Low Hazard Potential for Transportation Spills and Releases		3
1.2. Operational Flexibility	15	
1.2.1. Can Be Readily Adjusted for Variation in Flow		5
1.2.2. Can Be Readily Adjusted for Variation in Quality (Upstream Operational Upsets)		5
1.2.3. Demand Easily Measured		5
1.3. Operational Reliability	15	
1.3.1. Predictability of Performance		8
1.3.2. Reliability of Operations (Low Down Time)		7
1.4. Byproducts (DBP's)	12	
1.4.1. Low Potential for Byproduct Formation		4
1.4.2. Low Ecotoxicity of Byproducts		4
1.4.3 Low Human Toxicity		4
1.5. Modification for Future Concerns	6	
1.5.1. Can Be Adjusted to Achieve High Level Pathogen Reduction		3
1.5.2. Compatible with Possible Further Needs for Byproduct Minimization		3
2. Qualitative Economic Requirements	14	
2.1. Existence of Multiple Vendors for Equipment		4
2.2. Can Be Operated by Operators with Normal Training Levels		5
2.3. Low Sensitivity to Cost of Electricity		5
3. Indirect Environmental and Health Impacts	12	
3.1 Environmental and Human Health Impacts of Energy Required to		4

Operate the Facility		
3.2 Environmental and Human Health Impacts of the Energy Required for Processing and Production of Process Chemicals (Including Byproducts)		4
3.3 Indirect Environmental and Health Impact of the Conversion and Degradation of Process Chemicals		4
4. Public Perception Issues	11	
4.1. Low Negative Perception by Environmental Organizations and Public		11
OVERALL TOTAL	100	

Each alternative was scored for each of the above criteria according to the following scale:

Good – 3
Average – 2
Poor – 1

Each alternative was then evaluated relative to the weighting factor for each criteria. For each alternative, the score for each alternative is multiplied by the criteria's weight to arrive at a total score for that criteria. For example if an alternative receives a score of 3 for a criteria with a weight of 10, the total score for that criteria is 3x10 = 30.

The evaluation criteria were a consensus decision of the District and the task force. It should be noted that the evaluation criteria do not include estimated capital nor estimated operation and maintenance costs. It was a consensus decision by the task force and the District that the alternatives should be evaluated using qualitative economic and non-economic criteria without regard to the numerical costs associated with the alternatives.

SCORING OF QUALITATIVE ECONOMIC AND NON-ECONOMIC CRITERIA MATRIX

The criteria and weights discussed above were placed into a spreadsheet and scores were assigned by the task force.

Below is an explanation of the scoring shown in Table 1.10.

1. Desirable Performance Requirements

1.1 Safety

1.1.1 - Low Risk to Operators From Accidental Releases and Waste Products

Liquid chlorine reacts with aluminum, tin, mercury, arsenic and gold at ordinary temperatures. Hence chlorine in the liquid form can have an adverse effect on its surroundings. Technologies involving the solid and on-site generated liquid forms of chlorine with sulfite dechlorination were assigned the score of 2 because although they present a lesser hazard than the gaseous form of chlorine there are still safety concerns associated with these highly concentrated strong oxidizing agents, such as metal corrosion and the associated risk of spills. Purchased liquid hypochlorite was assigned a score of 1 since there is an increased chance of spills due to the transportation of this chemical. Ozone was also assigned the intermediate score of 2 because although it is a gas, it is produced in relatively low concentrations (less than 10 percent by weight) which probably would not present a high hazard to workers. Finally, UV based technologies are assigned a score of 2 in the case of low-intensity UV and the highest score of 3 in the case of high-intensity UV. A higher score of 3 was assigned to the high-intensity technology because the risk of releasing mercury is minimized by having to handle a much lesser number of lamps as well as working with more secure and smaller reactors.

1.1.2 – Low Hazard Potential to Neighbors

The scores assigned to the various candidate technologies based on this criteria were similar to those in section 1.1.1 except that the scores for UV low-intensity and dry calcium hypochlorite were increased to 3 because UV is produced on site and thus does not require transport through neighbor areas while the dangers from transport of the dry form of chlorine is minimal.

1.1.3 - Low Level of Onsite Chemical Storage

Dry and wet forms of purchased chlorine would require a similarly significant greater level of chemical storage capacity compared to on-site generation of chlorine or ozone, or UV. Accordingly, the score of 1 was assigned to these candidate technologies. On-site generation of chlorine would require some storage of chemicals from which chlorine is generated and thus was assigned a score of 2. Ozone and UV technologies, not requiring chemical storage, were assigned the maximum score of 3.

TABLE 1.10 – SCORING OF QUALITATIVE ECONOMIC AND NON-ECONOMIC CRITERIA MATRIX

	Group Total	Item Total	Ozone-Air	Ozone - Oxygen	UV-Low Intensity-Low Pressure	UV-High Intensity -Medium Pressure	CaOCl + Sodium Bisulfite	NaOCl + Sodium Bisulfite	Onsite Generation + Sodium Bisulfite
1. Desirable performance requirements									
1.1. Safety	15								
1.1.1. Low risk to operators from accidental releases and waste products		3	2	2	2	3	2	1	2
1.1.2. Low hazard potential to neighbors		3	2	2	3	3	3	2	2
1.1.3. Low level of onsite chemical storage		3	3	3	3	3	1	1	2
1.1.4. Low potential for malicious adverse occurrences		3	3	2	3	2	2	2	3
1.1.5. Low hazard potential for transportation spills and releases		3	3	3	2	2	1	1	2
1.2. Operational flexibility	15								
1.2.1. Can readily be adjusted for variation in flow		5	2	2	1	1	3	3	2
1.2.2. Can readily be adjusted for variation in quality (upstream operational upsets)		5	2	2	1	1	3	3	2
1.2.3. “demand” easily measured		5	2	2	3	3	3	3	3
1.3. Operational Reliability	15								
1.3.1. Predictability of performance		8	2	2	2	2	2	2	2
1.3.2. Reliability of operations (low down time)		7	2	2	3	2	2	3	2
1.4. Byproducts (DBP's)	12								
1.4.1. Low potential for byproduct formation		4	2	2	3	3	1	1	1
1.4.2. Low ecotoxicity of byproducts		4	2	2	3	3	1	1	1
1.4.3 Low human toxicity		4	2	2	3	3	1	1	1
1.5. Modification for future concerns	6								

	Group Total	Item Total	Ozone-Air	Ozone - Oxygen	UV-Low Intensity-Low Pressure	UV-High Intensity -Medium Pressure	CaOCl + Sodium Bisulfite	NaOCl + Sodium Bisulfite	Onsite Generation + Sodium Bisulfite
1.5.1. Can be adjusted to achieve high level pathogen reduction		3	3	3	2	3	1	1	1
1.5.2. Compatible with possible further needs for byproduct minimization		3	2	2	3	3	1	1	1
2. Qualitative economic requirements	14								
2.1. Existence of multiple vendors for equipment		4	2	2	3	2	3	3	2
2.2. Can be operated by operators with normal training levels		5	2	2	2	2	3	3	3
2.3. Low sensitivity to cost of electricity		5	2	2	1	1	3	3	2
3. Indirect Environmental and Health Impacts	12								
3.1 Environmental and human health impacts of energy required to operate the facility		4	2	2	1	1	3	3	2
3.2 Environmental and human health impacts of the energy required for processing and production of process chemicals (including byproducts)		4	3	3	1	2	1	1	2
3.3 Indirect environmental and health impact of the conversion and degradation of process chemicals		4	2	2	3	2	1	1	1
4. Public Perception issues	11								
4.1. Low negative perception by environmental organizations and public		11	2	2	2	3	2	2	1
5. Economic Impacts									
5.1 Low Estimated Capital Cost	0	0							
5.2 Low Estimated Annual O&M Costs		0							
OVERALL TOTAL	100		**216**	**213**	**221**	**224**	**204**	**205**	**180**

1.1.4 - Low Potential for Malicious Adverse Occurrence

All options were given a score of either 2 or 3 because none of the technologies offer significant opportunities for malicious occurrences. Ozone using high purity oxygen was given a lower score then ozone using air since oxygen offers an opportunity for creating an explosive condition. Since storage of the liquid and dry forms of purchased chlorine is necessary, purchased chlorine was given a lower score than chlorine generated on-site. High-intensity UV was given a lower score than low-intensity UV since the smaller number of lamps may be more readily secured from those wishing to misuse them.

1.1.5 - Low Hazard Potential for Transportation Spills and Releases

The higher risk associated with the transport of chlorine liquids and solids was the basis for assigning a score of 1 to these alternatives. On-site generated chlorine was given a higher score of 2 since the chlorine produced is not transported. Ozone was considered less hazardous than UV since ozone release would be less hazardous then mercury release from broken bulbs. Ozone was given a score of 3 and UV was given a score of 2.

1.2 Operational Flexibility

1.2.1 - Can Be Readily Adjusted for Variation in Flow.

UV cannot be readily adjusted for flow and was given a score of 1. UV lamps are either on or off so it is usual practice to design a UV system in modules which can be added or take in out of service when flow variations occur.

When flow variations occur in ozone systems, it is necessary to adjust the ozone output both in terms of gas concentrations and gas flow rate. Operation and control of ozone dosing systems is much more difficult compared to chlorine systems. Ozone was assigned a score of 2, while purchased chlorine was assigned a score of 3. On-site liquid chlorine systems were assigned a score of 2 because of the need to adjust chlorine production to flow.

1.2.2 - Can Be Readily Adjusted for Variations in Quality.

UV lamp systems are either on or off and it is necessary to take modules off or on-line to adjust for changes in effluent quality. UV was given a score of 1.

Ozone systems are less difficult to control than UV systems since ozone exit gas concentrations can be used as a control variable. Purchased liquid and dry forms of chlorine can be easily adjusted for changes to quality and were given a score of 3. On-site generated liquid chlorine requires adjustment of chlorine production to match changes in effluent quality and was given a score of 2.

1.2.3 - Demand Easily Measured

All alternatives were given a score of 3 except for ozone. Ozone was given a score of 2 since equipment to measure ozone residuals in solution, particularly in the wastewater matrix, is less developed than for chlorine UV.

1.3 Operational Reliability

1.3.1 – Predictability of Performance

All options offer predictable performance if operated properly. But no option is better or worse than another. A score of 2 was assigned to all options.

1.3.2 - Reliability of Operations

All options were given a score of 2 except for UV low intensity and purchased hypochlorite. UV low intensity bulbs have been known to deteriorate rapidly with time while hypochlorite solutions decrease in strength during storage.

1.4 Byproducts (DBPs)

1.4.1 - Low potential for Byproduct Formation

Chlorination produces the most known toxic disinfection byproducts thus all chlorination processes were given a score of 1.

UV adds no significant toxic byproducts to effluents so it was given a score of 3.

Ozone has the potential to produce byproducts but it is believed that these are potentially less toxic than chlorine byproducts. Ozone was given a score of 2.

1.4.2 - Low Ecotoxicity of Byproducts

The scoring for this criteria was the same as for criteria 1.4.1 because ecotoxicity is directly related to the amounts and types of byproducts formed by the disinfection alternatives.

1.4.3 - Low Human Toxicity

Research studies show that chlorination produces known human toxic compounds. Thus chlorination alternatives are given the lowest score.

Scores for UV were the highest since this alternative does not produce toxic byproducts. Ozone has reduced human toxic byproduct formation compared to chlorine but the byproducts levels are not zero. Thus ozone was given a score of 2.

1.5 Modification for Future Concerns

1.5.1 - Can Be Adjusted to Achieve High Level Pathogen Reduction

None of the technologies can achieve reduction in all the potential pathogens present in sewage. There are simply too many pathogens in sewage that are resistant to certain disinfection alternatives and no single technology can reduce all pathogens to low levels.

Both ozone and high intensity UV treatment provide disinfection for a relatively wider range of pathogens compared to all the chlorination options. Thus, high intensity UV and ozone were given a score of 3 while all chlorination options were given a score of 1. UV low intensity was given an intermediate score of 2.

1.5.2 - Compatible with Possible Further Needs for Byproduct Minimization

All the chlorination options produce more known toxic amounts of byproducts than ozone or UV. Thus all chlorination options were given a score of 1. UV forms no significant byproducts while ozone does. Thus UV was given a score of 3 while ozone was given a score of 2.

2. Qualitative Economic Requirements

2.1 - Existence of Multiple Equipment Vendors

Although multiple equipment vendors are available for all technologies evaluated (scores of 2 or 3), the highest score of 3 was given to technologies more commonly in use in municipal wastewater treatment plants of similar capacities. Purchased forms of chlorine and low-intensity UV were given a score of 3 since these are the most commonly used effluent disinfection technologies.

2.2 – Can Be Operated by Operators with Normal Training Levels

Because of the relative simplicity and degree of automation of chlorine-based technologies, they were all assigned the highest score of 3 in this category.

In contrast, because ozone and UV technologies require somewhat more complex operation skills, these technologies were assigned an intermediate score of 2.

2.3 - Low Sensitivity to Cost of Electricity

Except for on-site generation, chlorine based technologies require the lowest level of energy and thus were assigned the highest score of 3. Chlorine based technology with on-site generation and ozone have intermediate energy requirements and thus were assigned the intermediate score of 2. UV requires the highest level of energy and thus this process was assigned the lowest score of 1 in this category.

3. Indirect Environmental and Health Impacts

3.1 – Environmental and Human Health Impacts of Energy Required to Operate the Facility

Actual energy requirements for each proposed disinfectant are complex and difficult to directly compare. Based on the fact that wastewater plants usually purchase chlorine compounds used for disinfection from outside vendors, the energy consumption for production of these disinfectants is not part of the plant energy balance but energy used during production, handling and shipping can be substantial. However, during wastewater treatment, energy uses for chlorine based technologies produced off-site, require the lowest energy requirements and were assigned the highest score of 3. On-site generation of chlorine requires additional energy and thus was assigned a score of 2. UV processes were the most energy intensive and were assigned the lowest score of 1. Ozone has a lower energy requirement than UV and was given a score of 2.

3.2 – Environmental and Human Health Impacts of the Energy Required for Processing and Production of Chemicals (Including Byproducts)

The use of chlorine based treatment requires substantial chemical use with resulting high production and transportation costs. The chlorine processes that use chemicals that are transported to the facility, were all given the lowest score of 1. On-site generation of chlorine reduced the energy for shipping and thus was given a score of 2. Ozonation does not require the use of commercial chemicals and was given the highest score of 3. The production of high intensity UV bulbs requires less energy then that for low intensity bulb production. Thus UV high intensity was given a score of 2 and low intensity was given score of 1.

3.3 – Indirect Environmental Health Impacts of the Conversion and Degradation of Process Chemicals

Chlorine based disinfection systems all produce the highest level of known toxic byproducts and were given a score of 1. Ozone produces some known toxic byproducts but less than chlorine and was given a score of 2. UV produces no significant byproducts but high-intensity UV has the potential to produce potential changes in the constituents in wastewater while low-intensity UV does not. Thus high-intensity UV was given a score of 2 while low-intensity UV was given a score of 3.

4. Public Perception Issues

4.1 - Low Negative Perception by Environmental Organization and the Public

The use of chlorine based treatment requires substantial chemical use with resulting transportation and safety concerns. Chlorination processes that use chemicals that are transported to the facility were all given the score of 2. On-site generation of chlorine increased the potential for neighbor negative reaction and thus was given a score of 1. Ozone and UV do not require the use of chemicals but ozone has the potential for a toxic gas release and was give a score of 2. High-intensity UV has a smaller footprint than low-intensity UV and was given a score of 3 while low-intensity UV was given a score of 3.

As can be seen in Table 1.10, the UV-High Intensity disinfection alternative received the highest scores.

SELECTION OF RECOMMENDED ALTERNATIVE(S)

After a careful consideration of matrix scores, it was a consensus decision on the part of the task force and the District that both UV (High Intensity-Medium Pressure) and Ozone (Oxygen) disinfection alternatives will be carried forward by the three master plan consultants for detailed cost estimation.

Although scores for both UV (High Intensity-Medium Pressure) and UV (Low Intensity-Low Pressure) alternatives are close, the decision was made to consider UV (High Intensity-Medium Pressure) only for detailed cost estimation. This is due to the concern of handling the large numbers of low intensity UV lamps as compared to the numbers of high intensity UV lamps. Similarly, although scores for Ozone (Air) is slightly higher than Ozone (Oxygen), the capital and O&M costs for Ozone (Air) systems are approximately three to four times higher than the Ozone (Oxygen) systems. Therefore, the decision was made to consider Ozone (Oxygen) only for detailed cost estimation. Additionally, it is believed that there is no full-scale Ozone (Air) system operating at a size similar to those being considered by the District.

OPINION OF PROBABLE COSTS FOR RECOMMENDED ALTERNATIVES

In order to evaluate the impacts associated with disinfection at the North Side, Stickney, and Calumet WRP's, this section presents assumptions, unit costs, and cost opinions for the three WRPs. The District asked each of the engineering firms who are currently developing master plans for these plants to prepare cost opinions for UV (High Intensity-Medium Pressure) and Ozone (Oxygen). Below is a list of these firms and the WRP master plans which they are currently developing.

Engineering Firm	WRP Master Plan
CTE	North Side
Black & Veatch/Greeley and Hansen	Stickney
Metcalf & Eddy	Calumet

Introduction

In addition to the technical evaluation of disinfection technology alternatives discussed previously, the costs of constructing and operating the facilities required for disinfection is another important factor in selecting a disinfection alternative. To provide an economic basis of comparison for the two short-listed alternatives, opinions of cost were developed based on a standard set of design criteria among the North Side, Stickney, and Calumet WRP. This section discusses how the cost opinions were developed for the three WRPs. Each WRP will be discussed separately, considering both disinfection alternatives and the associated disinfection-related issues at each plant. Note that cost opinions and the associated section for each WRP were completed by the corresponding engineering firm. A cost summary table for all three WRPs is presented at the end of this Technical Memorandum (TM). Detailed costs breakdown are included in Appendix A.

Assumptions and Unit Costs

Two disinfection technologies, oxygen-generated ozonation and high intensity-medium pressure UV irradiation, were selected to assess the cost impacts for implementation. Details of technology descriptions and evaluation were discussed in previous sections.

In an effort to generate consistent cost opinions among the three WRPs, the District and the engineering firms conducted a series of meetings to establish a common set of assumptions to govern development of the costs at each plant. These meetings also established unit costs for specific items that would be incorporated into all three cost opinions. The list below summarizes the assumptions made and unit costs used to develop the cost opinions:

- Design Criteria:
  - Design Flow: Maximum design flow was used. The specific flow rate chosen for each plant will be discussed separately.
  - Proposed Effective Disinfection Limit (E. Coli, cfu/100 ml):
    - 1,030 monthly geo-mean for North Side and Calumet
    - 2,740 monthly geo-mean for Stickney

    These disinfection limits assume that the proposed Use Attainability Analysis

(UAA) bacteria water quality standards for the receiving streams will be achieved at end-of-pipe at each WRP.

UV Disinfection:
- UV Transmission: 65% minimum per IEPA standard

Ozone Disinfection:
- Ozone dosage: 8 mg/l
- Ozone contact time: 10 minutes

- The cost for a low-lift pump station and filtration facility was included in both disinfection alternatives as separate items. Filtration design criteria shall follow the Illinois Recommended Standards for Sewage Works (IRSSW) design standard with filtration flow rates not to exceed 5 gallons per minute per square-foot (gpm/sf) with one unit out of service under peak hourly condition.
- Each plant will disinfect effluent from March through November. However, operation for the low-lift pump stations and filtration facilities was assumed to be all year round.
- Filters will be enclosed in a Filter Building.
- Cost opinions were divided into the following categories:
    - Site Work
    - Low Lift Pump Station
    - Filtration
    - Ozone/UV facilities
- Costs for major equipment at each plant (filters and ancillary filter equipment, oxygen generation equipment, ozone generation equipment, UV equipment) were obtained from one vendor for all three plants:

Technology/Process	Vendor
UV Irradiation	Trojan Technologies, Inc.
Ozonation	Fuji Electric Systems Co., Ltd.
On-site Oxygen Generation	Praxair Inc.
Filtration	US Filter (Zimpro Products)

- An all inclusive capital unit cost of $60,000 per MGD was used for the low lift pump station.
- A cost of $200 per square-foot was used for buildings other than the low lift pump station. This unit cost includes slab on grade, architectural, mechanical, and building electrical equipment. Major substructures such as tanks below grade were estimated separately.
- UV channels were enclosed in a UV building.
- Poured-in-place concrete costs were as follows:
    - Base slabs - $400 per cubic yard
    - Walls - $650 per cubic yard
    - Elevated slabs - $700 per cubic yard
- A present worth factor of 19.42 was used for all present worth calculations, based on a 3% interest rate for 20 years with a 3% inflation factor.
- A power cost of $0.075/kW-hr was used for all three WRPs for consistency.
- Labor costs and staffing were provided by the District.
- Annual UV lamp replacement and disposal costs were based on service contracts with the UV manufacturer.
- Redundancy

- Contact chambers
  - Ozone – multiple channels were used in a single tank to meet peak flow. No redundant tank necessary.
  - UV – multiple channels were used to meet the effluent limit at peak flow with one channel out of service.
- Equipment
  - All major equipment was designed to meet peak capacity with the largest unit out of service.

Filtration

The effluent disinfection cost estimates for each of the three District WRPs includes sand filtration. This is included as a potential unit process for effluent pretreatment prior to disinfection. However, in the opinion of the task force, it is not possible to reach a conclusion regarding whether filtration should be part of the final design of a UV or ozonation disinfection system for the three WRPs until additional laboratory and/or pilot plant testing is conducted.

Removal of additional total suspended solids (TSS) from the effluent of the District's three major WRPs plants by filtration could have the following possible benefits for the UV and ozone disinfection processes:

1) Removal of pathogenic microorganisms associated with suspended solids which would be more resistant to inactivation by ozone and would not be inactivated by UV light radiation;

2) Reduction of maintenance and operation costs; and

3) Reduction in the required UV and ozone dosage and thus reduction in the capital and operating costs for the disinfection system.

The task force believes that properly designed and operated ozonation and UV effluent disinfection systems for the District's three major WRPs can meet the proposed UAA bacteria water quality standards without filtration. However there may be capital and operating cost benefits for filtration. These benefits can be determined through laboratory and/or pilot plant testing. Therefore, laboratory and pilot plant tests are recommended by the task force to determine whether filtration is a cost-effective addition to the disinfection alternatives.

Since it is unclear whether filtration should be included as part of the UV and ozone disinfection systems, the associated costs for the filtration facilities have been presented as separate line items. Table 1.26 shows the probable cost opinions with filtration. Table 1.27 shows the probable cost opinions without filtration.

Low Lift Pump Station

A low lift pump station is included for all three facilities to enable flow through the disinfection and filter systems. It is assumed that low lift pumps will also be required even if filters are not provided in order to accommodate high levels in the receiving streams.

North Side WRP

Ultraviolet Disinfection

Background

The North Side WRP (NSWRP) is rated at a capacity of 333 MGD design average flow and 450 MGD of design maximum flow. Flows above 450 mgd are diverted to the Tunnel and Reservoir Plan system (TARP). Therefore 450 mgd is the design flow for sizing the UV disinfection facilities. As presented in TM-5, the NSWRP permit limit for TSS is 12 mg/l under monthly average conditions. These two parameters, along with the 65% UV transmittance as stated previously, were used as the basis for sizing the UV disinfection facilities and obtaining price quotes from equipment vendors. Table 1.11 presents the UV disinfection system sizing for NSWRP.

TABLE 1.11
NSWRP – UV DISINFECTION SYSTEM SIZING DATA

Item	Data
Design Flow	450 MGD
Number of Channels	4 (3 operating, 1 standby)
UV Reactors Per Channel	1
UV Lamps Per Reactor	288
Total Number of Lamps	1,152
UV Channel Liquid Level Control	Motorized weir gate
Channel Dimensions	40.5' L x 8.1' W x 14.3' D
Total Power Requirement	2,764.8 kW

As discussed earlier, a filtration facility has been included prior to the disinfection system. Table 1.12 presents the filtration system sizing.

TABLE 1.12
NSWRP – TERTIARY FILTRATION SYSTEM SIZING DATA

Item	Data
Design Flow	450 MGD
Filter Loading at Peak Hourly, with one filter unit (2 filter cells) out of service	4.24* gpm/sq. ft.
Number of Filter Trains	4
Number of Filter Cells Per Train	10
Total Number of Filter Cells	40
Filter Area (each cell)	2,304 Sq.Ft.
Total Filter Area	92,160 Sq.Ft.

* IRSSW recommends filter loading rates not to exceed 5 gpm/sf with one unit out of service under peak hourly condition. Due to module design of filter cells, actual loading rates deviate from the recommended loading rates.

Location on site

The NSWRP has very limited area for new facilities. Based on the location where the final effluent discharges into the North Shore Channel, the disinfection facilities will be located in the northeast corner of the plant. Combined final effluent from Battery A, B, C, and D will be diverted into a wet well of a low-lift pump station just north of the proposed Filter Building. From the pump station, final effluent will be pumped through the filters, and the filtered effluent will then pass through the proposed UV channels by gravity. Motorized weir gates will be used in the UV channels for level controls. A UV building will be provided for the UV channels and for housing all electrical equipment such as power distribution centers and system control centers. Disinfected effluent will be re-connected to the existing final effluent conduit for North Shore Channel discharge. Figures 1.6 and 1.7 present an overall site plan and a partial site plan for disinfection facilities based on UV disinfection. As shown from the figures, the facilities will occupy most of the area available in the northeast part of the plant.

Site specific issues

Due to the space required for the filtration facility, available land east of the existing plant fence (east of old railroad track where four radio towers are currently located) will be needed. Construction of the UV disinfection facilities will create little interference with existing facilities and operations. The only significant disruption to normal plant operation will occur during the tie-in of the existing and the new effluent conduits to and from the disinfection facilities. This

Figure 1.6

Figure 1.7

work will require by-pass pumping. Existing plant fence and the gas cylinder storage just north of the Service Building will need to be relocated. Other construction will have minimal impacts on the operation of the existing plant.

Cost Summary

Table 1.13 presents the opinion of probable costs for the UV disinfection facilities.

TABLE 1.13
NSWRP-OPINION OF PROBABLE COSTS FOR
UV DISINFECTION FACILITIES

Capital Cost Estimates	**UV**
A. General Site Work	$ 4,000,000
B. Low Lift Pump Station	$ 54,000,000
C. Tertiary Filtration	$ 168,000,000
D. Disinfection System	$ 25,000,000
Total Capital Cost	$ 251,000,000
Operation and Maintenance Cost Estimates	
A. General Site Work	$ 0
B. Low Lift Pump Station	$ 1,100,000
C. Tertiary Filtration	$ 2,300,000
D. Disinfection System	$ 3,200,000
Total Annual O&M Cost	$ 6,600,000
Total Present Worth O&M Cost	$ 128,000,000
Total Present Worth	$ 379,000,000
Annual Debt Services Cost	($ 21,000,000)

Ozone Disinfection

Background

Similar to UV disinfection, a peak flow of 450 mgd was used for sizing the ozone disinfection facilities. Due to safety issues in transporting and difficulties in supplying such large amount of liquid oxygen required for ozonation, the decision was made to use on-site oxygen generation for ozone disinfection. Table 1.14 presents system sizing for the ozone disinfection facilities for NSWRP.

TABLE 1.14
NSWRP – OZONE DISINFECTION SYSTEM SIZING DATA

Item	Data
Design Flow	450 MGD
Ozone Required	30,024 lbs/day
Number of Ozone Generators	8 (7 Operating, 1 Standby)
Ozone Capacity Per Generator	4,289 lbs/day
Oxygen Flow Rate Per Generator	448 SCFM
Total Oxygen Consumption	428,900 lbs/day
Total Power Requirement	6,272 kW
Cooling Water	830 GPM
On-site Oxygen Generation	
Number of Vacuum Pressure Swing Adsorption (VPSA) Units	2
Capacity Per VPSA Unit	100 tons/day
Contactor Tank Size	3.125 million gallons

Location on Site

Similar to the proposed location of UV disinfection facilities, the ozonation facilities will be located in the northeast comer of the NSWRP where the final effluent conduit is located. Combined final effluent from Battery A, B, C, and D will be diverted into a wet well of a low-lift pump station just north of the proposed Filter Building. From the pump station, final effluent will be pumped through the filters, and the filtered effluent will then pass through the proposed ozone contactors by gravity.

The ozone disinfection system consists of an on-site oxygen generation system, ozone generators, power supply units, and ozone destruction system. Vacuum Pressure Swing Adsorption (VPSA) will be used for on-site oxygen generation. Ozone generators, power supply units, ozone destruction units, and the associated electrical equipment such as local control panels will be housed in the proposed Ozone Generation Building. The ozone contactors will be constructed with all concrete. Similar to UV disinfection, disinfected effluent from the ozone contactors will be re-connected to the existing final effluent conduit for North Shore Channel discharge. Figures 1.8 and 1.9 present an overall site plan and a partial site

Figure 1.8

Figure 1.9

plans for the ozone disinfection facilities. As shown from the figures, the facilities will occupy almost all of the vacant area in the northeast corner of the plant.

Site Specific Issues

Oxygen generation presents several new challenges at the NSWRP. Oxygen is flammable and a very strong oxidizer. The chemical processing industry has developed procedures for designing safe plants and ensuring safe operation of oxygen generation facilities, but the on-site generation of oxygen still presents new challenges to plant staff. For such a large on-site oxygen generation plan, extensive training will likely be required for the District staff to develop familiarity with the procedures for operating and maintaining the oxygen generation equipment and to become accustomed to the necessary safety procedures.

Disruption to normal plant operation will occur during the tie-in of the existing and the new effluent conduits to and from the disinfection facilities. This work will require by-pass pumping. Existing plant fence and the gas cylinder storage just north of the Service Building will need to be relocated. Other construction will have minimal impacts on the operation of the existing plant.

An estimated 10 to 12 MVA of transformer capacity is required to provide electric service for the ozone disinfection facilities. As the existing substation transformers do not have sufficient excess capacity for this additional load, new transformers will be required and were included in the cost estimate.

Cost Summary

Table 1.15 presents the opinion of probable costs for the ozone disinfection facilities.

TABLE 1.15
NSWRP-OPINION OF PROBABLE COSTS FOR
OZONE DISINFECTION FACILITIES

Capital Cost Estimates	**OZONE**
A. General Site Work	$ 8,000,000
B. Low Lift Pump Station	$ 54,000,000
C. Tertiary Filtration	$ 168,000,000
D. Disinfection System	$ 100,000,000
Total Capital Cost	$ 330,000,000
Operation and Maintenance Cost Estimates	
A. General Site Work	$ 0
B. Low Lift Pump Station	$ 1,100,000
C. Tertiary Filtration	$ 2,300,000
D. Disinfection System	$ 6,400,000
Total Annual O&M Cost	$ 9.800,000
Total Present Worth O&M Cost	$ 190,000,000
Total Present Worth	$ 520,000,000
Debt Services Cost	($ 28,000,000)

Stickney WRP

<u>Ultraviolet Disinfection</u>

Background

Ultraviolet (UV) light can be utilized for effluent disinfection with or without upstream filtration, depending on effluent turbidity and extent of disinfection required to meet the assigned effluent limitation. For UV equipment sizing and costing purposes, it was assumed that filtration was not in place. The basis of design for the UV facilities is summarized in Table 1.16. The Stickney WRP permit limit of 12 mg/l of TSS under monthly average condition has also been considered for UV sizing. The UV facilities must be sized for the peak hydraulic flow rate, whereas operation and maintenance costs are based on the average flow rate and hours/year that the disinfection facilities will be operated. The Stickney WRP is significantly impacted by the pumpback from the TARP and, once the McCook Reservoir is on-line, the plant will operate at or near capacity for extended periods. For costing purposes, a future annual average flow of 1,000 mgd was assumed.

TABLE 1.16
SWRP – UV DISINFECTION SYSTEM SIZING DATA

Item	Data
Design Flow	1,440 MGD
Number of Channels	12
UV Reactors Per Channel	1
UV Lamps Per Reactor	240
Total Number of Lamps	2,880
UV Channel Liquid Level Control	Motorized weir gate
Channel Dimensions	40.5' L x 9.0' W x 14.3' D
Total Power Requirement	9,216 kW

For the purposes of costing, the UV equipment and facility layouts are based on the experience of reputable manufacturers and installations elsewhere of similar scope, although no other facility is of similar size to the Stickney WRP. To achieve the required capacity for Stickney, multiple process trains would be required.

For the Stickney WRP, the UV facility would likely consist of a single structure, housing all of the required ancillary equipment along with the channels where the flow passes between the UV lamps. The channels are planned to be constructed of concrete, with influent and effluent channels at the ends. Sluice gates will be used to control flow into each channel, with weirs controlling the flow out of each channel. Major pieces of equipment include the electrical power supply and distribution system and the UV lamps. Flow splitting would be required to evenly distribute the flow between the multiple channels, along with flow meters or other flow measuring devices. It was assumed that all of the channels and equipment would be located indoors to facilitate maintenance and replacement of the UV lamps, which must be performed on an annual basis. The structure would be a single-story building overlying the UV channels, with architectural features to match the existing facades of nearby buildings.

The UV equipment is quite power intensive, and would require a new electrical substation, drawing power from the Main Switch Gear Building nearby. New feeders and step-down transformers would be required to power the new UV facility. In general, all of the channels would be in operation most of the time; however, the lamp intensity would be modulated to meet the flow conditions, thereby reducing overall power consumption.

Location on Site

Due to the limited space available near the existing plant outfall and the large space requirements for the new disinfection and related facilities, the UV disinfection facility would have to be located to south of the planned Southwest primary clarifiers and west of the Main Switch Gear Building, in the extreme southwest corner of the plant site, as shown on Figures 1-10 and 1-11. Except for several large interceptor sewers, this portion of the plant site is mostly unused at this time.

Site Specific Issues

Preliminary hydraulic calculations indicate that, even without filtration, pumping would be required to ensure that plant effluent could discharge to the Sanitary and Ship Canal under all flow conditions. Therefore, effluent would be diverted just upstream of the existing outfall and routed through a new effluent conduit to a low lift pumping station. After pumping, the effluent would flow by gravity through the filters and UV disinfection facility, before being discharged to the Sanitary and Ship Canal via a new outfall.

A new junction chamber would be constructed around the existing outfall conduit, with flow control gates to divert the flow into the new conduit. The effluent conduit would be routed under the rail lines to a location north and west of the Main Switch Gear Building, using an inverted siphon under-crossing of the Northwest Interceptor Sewer, and connecting directly to the new low lift pumping station.

The low lift pumping station would act in a similar role as the current West Side and Southwest side influent pumping stations--that is a relatively low lift, high capacity application. For purposes of preliminary costing, a smaller footprint facility with vertical turbine/propeller pumps was assumed. This pumping station capacity would meet the flows indicated in the table above.

Effluent filtration may be required at some point in the future if a high degree of disinfection and/or nutrient removal is necessary. For facility sizing and costing purposes, shallow-depth sand media filters with conventional loading rates were assumed. The basis of design for the filtration facilities is summarized in Table 1.17. Hydraulic and space needs were considered in laying out the facilities. Filtration may not be required initially. Therefore, the low lift pumping station would be designed such that future hydraulic conditions could be met by changing the pump impellers and, possibly, the pump motors. This would reduce the current required head on the pumps, significantly reducing the electrical power consumption.

Figure 1.10

Figure 1.11

TABLE 1.17
SWRP – TERTIARY FILTRATION SYSTEM SIZING DATA

Item	Data
Design Flow	1,440 MGD
Filter Loading at Peak Hourly, with one filter unit (2 filter cells) out of service	4.34* gpm/sq. ft.
Number of Filter Trains	10
Number of Filter Cells Per Train	12
Total Number of Filter Cells	120
Filter Area (each cell)	2,304 Sq.Ft.
Total Filter Area	276,480 Sq.Ft.

* IRSSW recommends filter loading rates not to exceed 5 gpm/sf with one unit out of service under peak hourly condition. Due to module design of filter cells, actual loading rates deviate from the recommended loading rates.

Disinfection would follow filtration, and would be the final unit process prior to discharge from the plant. Because the disinfection facilities are located on the far southwest corner of the plant, continued use of the existing outfall would be impractical. Therefore, a new outfall was assumed. This new outfall would be west of the existing Northwest Interceptor outfall to avoid a second under-crossing of this older sewer. Alternatively, to avoid constructing an additional outfall, the NW Interceptor outfall could possibly be modified or reconstructed to act as the new plant outfall.

The new disinfection and related facilities would be located close to the existing Main Switch Gear Building, the source for all power at the Stickney WRP site. An extension of the existing high voltage switch gear will be required to meet the substantially increased power load associated with these new facilities. New high voltage cable in conduit would be needed to feed the new step-down transformers near the new facilities, along with a new switch gear building.

Cost Summary

The opinion of probable construction cost for the UV disinfection alternative is presented in Table 1.18. This opinion was prepared based on the concepts presented above and as shown on the figures herein. A detailed breakdown of the opinion of probable construction cost is included in the Appendix. The Operation and Maintenance Cost Estimates are also presented in Table 1.18.

TABLE 1.18
SWRP-OPINION OF PROBABLE COSTS FOR
UV DISINFECTION FACILITIES

Capital Cost Estimates	**UV**
A. General Sitework	$93,000,000
B. Low Lift Pumping Station	$174,000,000
C. Tertiary Filtration	$642,000,000
D. Disinfection System	$91,000,000
Total Capital Cost	$1,000,000,000
Operation & Maintenance Cost Estimates	
A. General Sitework	$0
B. Low Lift Pumping Station	$4,100,000
C. Tertiary Filtration	$4,200,000
D. Disinfection System	$8,500,000
Total Annual O&M Cost	$16,800,000
Total Present Worth O&M Cost	$326,000,000
Total Present Worth	$1,326,000,000
Annual Debt Service Cost	($84,000,000)

<u>Ozone Disinfection</u>

Background

The bases of design for the ozone disinfection facilities are summarized in Table 1.19. The ozone facilities must be sized for the peak hydraulic flow rate, whereas operation and maintenance costs are based on the average flow rate and the hours/days per year that the disinfection facilities will be operated. The Stickney WRP is significantly impacted by the pumpback from TARP and, once the McCook Reservoir is on-line, the plant will operate at or near capacity for extended periods. For costing purposes, a future annual average flow of 1,000 mgd was assumed.

TABLE 1.19
SWRP – OZONE DISINFECTION SYSTEM SIZING DATA

Item	Data
Design Flow	1,440 MGD
Ozone Required	97,077 lbs/day
Number of Ozone Generators	24 (20 Operating, 4 Standby)
Ozone Capacity Per Generator	4,003 lbs/day
Oxygen Flow Rate Per Generator	437 SCFM
Total Oxygen Consumption	960,770 lbs/day
Total Power Requirement	27,216 kW
Cooling Water	908 GPM
On-site Oxygen Generation	
Number of Vacuum Pressure Swing Adsorption (VPSA) Units	4
Capacity Per VPSA Unit	150 tons/day
Contactor Tank Size	10 million gallons

For the purposes of costing, the ozone equipment and facility layouts are based on the experience of reputable manufacturers and installations elsewhere of similar scope, although no other facility is of similar size to the Stickney WRP. To achieve the required capacity for Stickney, multiple process trains would be required.

For the Stickney WRP, the ozone disinfection facilities would likely consist of two separate buildings. The Ozone Generator Building would house the ozone generating equipment and the ozone destruct units, and would probably be constructed above the ozone contactors. A separate Oxygen Generation Facility building would house the vacuum pressure swing adsorption (VPSA) equipment to convert air to a high concentration oxygen stream, which would be fed to the nearby ozone generating equipment. The high concentration ozone stream would be dissolved in the effluent using diffusers located on the floor of the concrete ozone contactor tanks. Unused ozone in the off gases would be collected and sent to an ozone destruct catalyst in order to prevent free ozone from discharging into the atmosphere. Other major pieces of equipment include the electrical power supply and distribution system.

Flow splitting would be required to evenly distribute the flow between the multiple contact tanks, along with flow meters or other flow measuring devices. It was assumed all of the equipment would be located indoors, to provide easy maintenance. The Ozone Generator Building would be a one story building mostly overlying the ozone contactor tanks below, with architectural features to match the existing facades of nearby buildings. The Oxygen Generation Facilities would typically be a vendor supplied facility, including the building and all required equipment.

As the ozone equipment is very power intensive, a new electrical substation would be required, drawing power from the Main Switch Gear Building nearby. New feeders and step down transformers would be required to power the new ozone facilities. In general, all of the ozone contactors would be in operation most of the time; however, the ozone flow could be modulated to meet the required concentration, thereby reducing overall power consumption.

Location on Site

Due to the limited space available near the existing plant outfall and the large space requirements for the new disinfection and related facilities, the ozone disinfection facilities would have to be located to south of the planned Southwest primary clarifiers and west of the Main Switch Gear Building, in the extreme southwest corner of the plant site, as shown on Figures 1-12 and 1-13. Except for several large interceptor sewers, this portion of the plant site is mostly unused at this time.

Site Specific Issues

The site specific issues associated with the ozone disinfection facilities would be similar to those described for the UV disinfection facilities above. The low lift pumping station would be required regardless of whether filtration is constructed.

Cost Summary

The opinion of probable construction cost for the ozone disinfection alternative is presented in Table 1.20. This opinion was prepared based on the concepts presented above and as shown on the figures herein. A detailed breakdown of the opinion of probable construction cost is included in the Appendix. The Operation and Maintenance Cost Estimates are also presented in Table 1.20.

Figure 1.12

Figure 1.13

TABLE 1.20
SWRP-OPINION OF PROBABLE COSTS FOR OZONE DISINFECTION FACILITIES

Capital Cost Estimates	**OZONE**
A. General Sitework	$97,000,000
B. Low Lift Pumping Station	$174,000,000
C. Tertiary Filtration	$642,000,000
D. Disinfection System	$226,000,000
Total Capital Cost	$1,139,000,000
Operation & Maintenance Cost Estimates	
A. General Sitework	$0
B. Low Lift Pumping Station	$4,100,000
C. Tertiary Filtration	$4,200,000
D. Disinfection System	$14,900,000
Total Annual O&M Cost	$23,200,000
Total Present Worth O&M Cost	$451,000,000
Total Present Worth	$1,590,000,000
Annual Debt Service Cost	($95,000,000)

Calumet WRP

Ultraviolet Disinfection

Background

The main components of the ultraviolet disinfection facilities for the Calumet WRP include the UV disinfection building (containing UV reactors in channels), tertiary filtration system, and low lift pump station. Critical plant flow rates used as a basis for sizing components and for the development of capital costs and annual O&M costs are:

- Average day flow – 305 mgd
- Maximum day flow – 480 mgd

Disinfection at the Calumet WRP has been based on the need to meet an anticipated effluent limit of 1,030 e.coli/100ml. The Calumet permit limit for TSS is 15 mg/l (monthly average). This limit along with the 65% UV transmittance was used to size the UV disinfection system.

System sizing data for the UV disinfection system is as shown in Table 1.21.

TABLE 1.21
CALUMET WRP – UV DISINFECTION SYSTEM SIZING DATA

Item	Data
Design Flow	480 MGD
Number of Channels	4 (3 operating, 1 standby)
UV Reactors Per Channel	1
UV Lamps Per Reactor	308
Total Number of Lamps	1,232
UV Channel Liquid Level Control	Motorized weir gate
Channel Dimensions	39.5' L x 8.83' W x 13.8' D
Total Power Requirement	3181 kW

The UV channels are planned to be constructed of concrete within an influent and effluent channel on either end of the UV channels. Sluice gates at the head end of the UV channels will be used to control flow to the channels. The UV channels are proposed to be housed within a building enclosure, with additional building space provided for mechanical building systems equipment and electrical equipment associated with the disinfection system. The anticipated land area requirement for the UV system is 80 feet by 100 feet.

Sizing data for the proposed tertiary filtration system is included in Table 1.22.

TABLE 1.22
CALUMET WRP – TERTIARY FILTRATION SYSTEM SIZING DATA

Item	Data
Design Flow	480 MGD
Filter Loading at Peak Hourly, with one filter unit (2 filter cells) out of service	4.52* gpm/sq.ft.
Number of Filter Trains	4
Number of Filter Cells Per Train	10
Total Number of Filter Cells	40
Filter Area (each cell)	2,304 Sq.Ft.
Total Filter Area	92,160 Sq.Ft.

* IRSSW recommends filter loading rates not to exceed 5 gpm/sf with one unit out of service under peak hourly condition. Due to module design of filter cells, actual loading rates deviate from the recommended loading rates.

The resulting filter facility is anticipated to occupy an area of approximately 280 feet by 550 feet. Building space within the filter enclosure to house associated mechanical and electrical equipment has been allowed. To accommodate the filter backwash, a dedicated conduit was included to return the backwash flow to the Calumet WRP influent pump station as an internal plant recycle flow. To provide gravity flow to the filters within the plant's existing hydraulic grade line the filters are being proposed to be constructed mostly below existing plant grade.

The low lift pump station will be utilized to lift the filtered effluent to the disinfection system. The pumping capacity would be sufficient to pump the maximum day flow of 480 mgd. The pump station is estimated to occupy a space of approximately 100 feet by 160 feet. New pressure conduits have been included to convey the filtered effluent to the disinfection system. Electrical energy costs for the station have been based on the average day flow and an anticipated static lift of approximately 25 feet.

Location on Site

At the Calumet WRP, secondary effluent flows from the five secondary treatment and nitrification batteries, referred to as Batteries A, B, C, E1 and E2, to the southwest corner of the plant site and through an outfall conduit to the Little Calumet River. Secondary effluent from Batteries A, B, and C is collected in a conduit system and conveyed to Control Structure No. 5 which is located at the southwest corner of the plant site. From Control Structure No. 5, Battery A, B and C secondary effluent can be routed to the plant outfall or to the existing chlorine contact chambers. Secondary effluent from Batteries E1 and E2 is routed through a conduit system to the existing 12' x12' conduit between Control Structure No. 5 and the chlorine contact chambers, from where it can be routed either to the contact tank structure or through Control Structure No. 5 to the plant outfall with secondary effluent from the other three batteries. While the chlorine contact chambers are not currently used for disinfection purposes, secondary effluent is typically routed through the tank and on to the outfall conduit. Alternatively, existing gate structures at the chlorine contact chambers can be closed and all of the plant effluent flow can be routed directly to the plant outfall through Control Structure No. 5, bypassing the contact tank.

For planning purposes it has been assumed that the area currently occupied by the chlorine contact chambers and the unused open area on the south side of the main plant road would be utilized for the proposed ultraviolet disinfection system and associated filtration system and low lift pump station. Figure 1.14 and Figure 1.15 are site plans which illustrate the proposed location of these facilities.

The existing chlorine contact chambers would be demolished while the inlet structure to the chlorine chambers would be maintained to allow for flow control during construction and then ultimately to route flow to the new facilities. A new conduit would be installed to convey the secondary effluent flow from the chlorine chambers inlet structure to the tertiary filtration system. Flow through the filters would be by gravity. The filtered effluent would then be pumped by a new low lift pump station to the UV disinfection system, allowing gravity flow through the disinfection system and a new conduit conveying the disinfected effluent back to the existing plant outfall conduit.

Site Specific Issues

Site specific issues associated with the potential implementation of a UV disinfection facilities at the Calumet WRP are outlined below:

- Demolition of the existing chlorine contact chambers would be required.
- Existing chlorine contact chambers influent and effluent control structures would be salvaged and utilized for bypassing of the chlorine chambers during its demolition.
- Conduit tie-ins to the existing chlorine chambers influent structure and to the existing outfall conduit would need to be constructed.
- Plant perimeter security fencing would be extended to enclose the new facilities.
- Screening of the proposed new facilities from 130th Street may be determined to be necessary by the District.
- Electrical power is delivered to the Calumet WRP from the local utility through the two existing transformers and the 13.2 KVA switchgear located in the existing switchgear building at the northwest corner of the plant site. Two new circuit breakers will be required to be installed in the existing switchgear. A large electrical ductbank would need to be extended from the substation approximately 2,500 feet south to the proposed facilities. Ductbank routing issues, such as conflicts with existing utilities may result.

Figure 1.14

Figure 1.15

- The substantial power requirements of the disinfection facilities will likely consume the remaining available capacity of the existing transformers. In addition a cooling fan package my be required to increase the capacity of the transformers.
- The start-up of large motors at the Calumet WRP reportedly results in a voltage drop of approximately 10%. The equipment manufacturers have indicated that such voltage swings can be accommodated.
- Periodic, high flow rate recycle flows will result from backwashing of tertiary filters requiring a dedicated conduit to convey the recycle flow to the head end of the Calumet WRP. Although the Harvey Interceptor sewer is located near the proposed filtration system, it does not appear that this sewer has the reserve capacity to accept this recycle flow rate.
- The currently unused open area at the southwest corner of the plant site that is identified for use for possible construction of disinfection facilities may contain wetland areas. A determination regarding the presence of wetlands and actions required if wetlands are proposed to be disturbed, needs to be addressed by the District. At this time no cost associated with this issue have been included in the capital cost estimate.

Cost Summary

Table 1.23 presents an opinion of probable capital costs itemized for general sitework, the low lift pump station, tertiary filtration, and the UV disinfection system. In addition, estimated annual operation and maintenance costs are shown for each component and as a total annual cost. Present worth of the total annual O&M costs, total present worth, and the annual debt service cost are also reflected in Table 1.23.

TABLE 1.23
CALUMET WRP – OPINION OF PROBABLE COSTS
FOR UV DISINFECTION FACILITIES

Capital Cost Estimates	**UV**
A. General Site Work	$14,000,000
B. Low Lift Pump Station	$ 59,000,000
C. Tertiary Filtration	$ 208,000,000
D. Disinfection System	$ 31,000,000
Total Capital Cost	$ 310,000,000
Operation and Maintenance Cost Estimates	
A. General Site Work	$ 0
B. Low Lift Pump Station	$ 1,700,000
C. Tertiary Filtration	$ 2,300,000
D. Disinfection System	$ 3,100,000
Total Annual O&M Cost	$ 7,100,000
Total Present Worth O&M Cost	$ 138,000,000
Total Present Worth	$ 448,000,000
Annual Debt Services Cost	($ 26,000,000)

Ozone Disinfection

Background

The main components of the ozone disinfection facilities would include the ozone generator building, oxygen generation plant (vacuum pressure swing adsorption, VPSA), ozone contactor, tertiary filtration system, and low lift pump station. Critical plant flow rates used as a basis for sizing components and for the development of capital costs and annual O&M costs are:

- Average day flow – 305 mgd
- Maximum day flow – 480 mgd

Disinfection at the Calumet WRP has been based on the need to meet an anticipated effluent limit of 1,030 e.coli/100ml.

System sizing data for the ozone system is as shown in Table 1.24.

TABLE 1.24
CALUMET WRP – OZONE DISINFECTION SYSTEM SIZING DATA

Item	Data
Design Flow	480 MGD
Ozone Required	32,026 lbs/day
Number of Ozone Generators	8
Ozone Capacity Per Generator	4,792 lbs/day
Oxygen Flow Rate Per Generator	500 CFM
Total Oxygen Consumption	468,055 lbs/day
Total Power Requirement	6,985 kW
Cooling Water	906 GPM
On-Site Oxygen Generation	
Number of Vacuum Pressure Swing (VPSA) Units	2
Capacity Per VPSA Unit	100 tons/day
Contactor Tank Size	4.8 million gallons

The facilities associated with the ozone system are proposed to be located in the area of the existing chlorine contact chambers. The three main structures needed for the ozone system and their approximate overall dimensions are the contact tank (100 feet by 230 feet), ozone building to house the ozone generators and associated electrical and mechanical (building services) equipment (100 feet by 140 feet), and the oxygen generation plant (150 feet by 150 feet).

The tertiary filters and low lift pump station associated with the ozone disinfection system would be the same as required for UV disinfection and have been previously described in the UV disinfection section. The flow routing between facilities would follow the same pattern as in the UV disinfection facilities, filtration, low lift pump station, and disinfection.

Location on Site

For planning purposes it has been assumed that the area currently occupied by the existing chlorine contact chambers and the unused open area on the south side of the main plant road would be utilized for the proposed ozone disinfection system and associated filtration system and low lift pump station. Refer to Figures 1.16 and 1.17 which illustrate the proposed location of these facilities.

The collection of secondary effluent at the Calumet WRP and routing of the secondary effluent to the plant outfall conduit is described in the UV disinfection section. A new conduit would be constructed to convey the secondary effluent flow from the chlorine chambers inlet structure to the tertiary filtration system. Flow through the filters would be by gravity. The filtered effluent would then be pumped by a new low lift pump station to the ozone contactor, allowing gravity flow through the contactor and a new conduit conveying the disinfected effluent back to the existing plant outfall.

Site Specific Issues

Site specific issues associated with the ozone disinfection facilities would be the same as those outlined in the UV disinfection section with additional considerations listed below:

- Sound attenuation provisions may be necessary to control noise from the VPSA oxygen plant and the resulting noise level at plant property line.

- The electrical distribution system for the ozone facilities would require a new 13.2 KVA double ended switchgear located locally at the new facilities.

- An oxygen gas pipeline owned by Praxair exists along 130th Street in front of the Calumet WRP with an available service lateral to the plant. Preliminary discussions with Praxair have indicated that the pipeline could support the needs of the Calumet plant for ozone disinfection. Supply of oxygen gas from the pipeline versus construction of an on-site oxygen generation system may be an option that the District can pursue with Praxair if ozone disinfection is to be implemented at Calumet. It is possible that this may be a more cost-effective means of oxygen supply.

Cost Summary

Table 1.25 presents an opinion of probable capital costs itemized for general sitework, the low lift pump station, tertiary filtration, and the ozone disinfection system. In addition, estimated annual operation and maintenance costs are shown for each component and as a total annual cost. Present worth of the total annual O&M costs, total present worth, and the annual debt service cost are also reflected in Table 1.25.

Figure 1.16

Figure 1.17

TABLE 1.25
CALUMET WRP – OPINION OF PROBABLE COSTS
FOR OZONE DISINFECTION FACILITIES

Capital Cost Estimates	**UV**
A. General Site Work	$14,000,000
B. Low Lift Pump Station	$ 59,000,000
C. Tertiary Filtration	$ 208,000,000
D. Disinfection System	$ 110,000,000
Total Capital Cost	$ 390,000,000
Operation and Maintenance Cost Estimates	
A. General Site Work	$ 0
B. Low Lift Pump Station	$ 1,700,000
C. Tertiary Filtration	$ 2,300,000
D. Disinfection System	$ 6,400,000
Total Annual O&M Cost	$ 10,400,000
Total Present Worth O&M Cost	$ 202,000,000
Total Present Worth	$ 592,000,000
Annual Debt Services Cost	($ 33,000,000)

SUMMARY OF OPINIONS OF PROBABLE COST

As discussed previously, disinfection cost opinions for North Side, Stickney, and Calumet WRP were developed based on a low-lift pump station, a filtration facility, and a disinfection system. Filtration was included for both disinfection alternatives because of the uncertain effects of TSS on disinfection efficiency. Table 1.26 presents a summary table of the opinion of probable costs for both UV and Ozone disinfection facilities for the three WRPs, including filtration.

TABLE 1.26
OPINION OF PROBABLE COSTS OF UV AND OZONE DISINFECTION FOR NORTH SIDE WRP, STICKNEY WRP, AND CALUMET WRP (WITH FILTRATION)

	NORTH SIDE WRP		STICKNEY WRP		CALUMET WRP	
Capital Cost Estimates, in millions	UV	OZONE	UV	OZONE	UV	OZONE
A. General Site Work	$ 4	$ 8	$93	$97	$14	$14
B. Low Lift Pump Station	$ 54	$ 54	$174	$174	$59	$59
C. Tertiary Filtration	$ 168	$ 168	$642	$642	$208	$208
D. Disinfection System	$ 25	$ 100	$91	$226	$31	$110
Total Capital Cost	$ 251	$ 330	$1,000	$1,139	$310	$390
Operation and Maintenance Cost Estimates, in millions						
A. General Site Work	$ 0	$ 0	$0	$0	$0	$0
B. Low Lift Pump Station	$ 1.1	$ 1.1	$4.1	$4.1	$1.7	$1.7
C. Tertiary Filtration	$ 2.3	$ 2.3	$4.2	$4.2	$2.3	$2.3
D. Disinfection System	$ 3.2	$ 6.4	$8.5	$14.9	$3.1	$6.4
Total Annual O&M Cost*	$ 6.6	$ 9.8	$16.8	$23.2	$7.1	$10.4
Total Present Worth O&M Cost	$128	$ 190	$326	$451	$138	$202
Total Present Worth, in millions	$379	$ 520	$1,326	$1,590	$448	$592
Annual Debt Services Cost, in millions**	**($ 21)**	**($ 28)**	**($84)**	**($95)**	**($26)**	**($33)**

* Total Annual O&M Cost is based on current electricity rate at $0.075 per kilowatt-hour. This cost will change accordingly should the electricity rate increase in the future.
** Based on interest rate of 5.5% for 20 years.

As shown from Table 1.26, filtration facilities contribute more than half of the probable construction costs for all three WRPs. Since it is uncertain if filtration will be needed prior to either one of the disinfection alternatives, Table 1.27 presents a summary of the opinion of probable costs for both disinfection alternatives **without** filtration.

TABLE 1.27
OPINION OF PROBABLE COSTS OF UV AND OZONE DISINFECTION FOR NORTH SIDE WRP, STICKNEY WRP, AND CALUMET WRP (WITHOUT FILTRATION)

	NORTH SIDE WRP		STICKNEY WRP		CALUMET WRP	
Capital Cost Estimates, in millions	UV	OZONE	UV	OZONE	UV	OZONE
A. General Site Work	$ 4	$ 8	$93	$97	$14	$14
B. Low Lift Pump Station	$ 54	$ 54	$174	$174	$59	$59
C. Disinfection System	$ 25	$ 100	$91	$226	$31	$110
Total Capital Cost	$ 83	$ 162	$358	$497	$100	$180
Operation and Maintenance Cost Estimates, in millions						
A. General Site Work	$ 0	$ 0	$0	$0	$0	$0
B. Low Lift Pump Station	$ 1.1	$ 1.1	$4.1	$4.1	$1.7	$1.7
C. Disinfection System	$ 3.2	$ 6.4	$8.5	$14.9	$3.1	$6.4
Total Annual O&M Cost*	$4.3	$ 7.5	$12.6	$19.0	$4.8	$8.1
Total Present Worth O&M Cost	$84	$146	$245	$369	$93	$157
Total Present Worth, in millions	$167	$ 308	$603	$866	$193	$337
Annual Debt Services Cost, in millions**	**($ 7)**	**($ 14)**	**($30)**	**($42)**	**($9)**	**($15)**

* Total Annual O&M Cost is based on current electricity rate at $0.075 per kilowatt-hour. This cost will change accordingly should the electricity rate increase in the future.
** Based on interest rate of 5.5% for 20 years.