McGill University
Department of Chemical Engineering

Technical Paper II 302-462A

The Replacement of Chlorination in the Treatment of Municipal Drinking Water

By: Marianne Salama (9526822)

Date: September 22, 1997

INTRODUCTION

In the past the general belief in the realm of water treatment was that chlorination was the method of choice. It, after all, was capable of killing bacteria as well as some viruses which was and still is a major factor when evaluating a drinking water treatment process. But today, in view of recent results of several studies examining the safety of chlorination, many municipalities are wanting to remove chlorine from their water treatment plants all together. The cause for this concern is the presence of chloroforms and other halomethanes in post-chlorine treated natural water. The most commonly encountered contaminants of this type are bromomethanes $CHCl_2Br$, $CHClBr_2$ and $CHBr_3$ along with the afore mentionned chloroform all of which are suspected carcinogens.

Instead of developing methods to remove the halomethanes produced by chlorination public officials, upon the advise of the scientific community, have opted to support the development and implementation of new, safer, more effective methods of water treatment. Among those available are filtration, distillation, ion exchange, reverse osmosis, ozonation, and ultraviolet radiation.

The objective of this study is to determine which method is best suited to safely treat municipal drinking water supplies. These methods will be compared to chlorination on their ability to kill bacteria as well as other commonly encountered contaminants found in pre-treated drinking water. Other points taken into consideration are their respective costs associated with the initial capital investment, operation, and maintenance.

<u>SELECTION CRITERIA</u>

The following criteria were considered to be important in the evaluation of the water treatment processes under scrutiny. Essential criteria are those which must be met by the process while desirable criteria are those whose fulfillment would be advantageous to the municipality but do not effect the acceptance of the process in the preliminary round of evaluation.

<u>ESSENTIAL CRITERIA</u> (Listed in order of importance)

As the actual carrying out of the experiments required to prove the following involve specialized equipment and resources the basis of their evaluation will be based on research found in literature. The term « removal » implies the conversion of the contaminant in question to a benign form or its precipitation and subsequent filtration through conventional media such as sand. Thus the studies performed must show conclusive results that prove that the process is capable of effectively attacking the pollutant and lowering its concentration to a level considered acceptable by the World Health Organization Water Norms (See Appendix A) from a level commonly found in pre-treated drinking water.

1. No Harmful By-Products

The treatment of water by the process must not result in the production of any substance that is harmful to the health.

This will be evaluated on a YES/NO basis.

2. Low Environmental Impact

The process should not further contribute to the pollution of the evironment by producing harmful residuals.

This will be evaluated on a LOW / MEDIUM / HIGH basis.

3. Disinfection of Water From Bacteria

The process must be known to kill all bacteria found in water.

This will be evaluated on a YES/NO basis.

4. Disinfection of Water From Viruses

The process must be able to kill viruses found in water.

This will be evaluated on a YES/NO basis.

5. Removal of Lead

The contamination of lake and river water with lead has been a prominant concern in the recent past. As lead has devastating effects on the nervous system and is a suspected carcinogen as well its removal from drinking water is essential.

This will be evaluated on a YES/NO basis.

6. Removal of Manganese

Commonly found in natural waters manganese as regulated by the World Health Association cannot exceed 0.05 ppm (See Appendix A).It is therefore important that the process be able to remove it.

This will be evaluated on a YES/NO basis.

7. Removal of Iron

Iron found in water stains bathtubs, toilets and sinks and is unfit for ingestion. The Hazardous Chemicals Desk Reference by Richard J. Lewis, Sr., lists it as a carcinogen.

This will be evaluated on a YES/NO basis.

8. Removal of Odour

Hydrogen Sulfide is commonly responsible for the « rotten egg » smell of some waters. As this is quite unpleasant and a prominant complaint of people claiming to have « bad water » its removal will be considered essential.

This will be evaluated on a YES/NO basis.

9. Removal of Colour

As clear water is more esthetically pleasing and will increase the public confidence in its water treatment plant the process must prove effective in the removal of color.

This will be evaluated on a YES/NO basis.

DESIRABLE CRITERIA (Listed in order of importance)

1. Lowest Relative Operational Cost

Although the lowest cost operation may not be capable of fulfilling the essential requirements listed above the process chosen will be that with the lowest relative operational cost among those which do meet all of the essential requirements.

As the actual process cost is a function of several variables mainly, the degree of pollution of the water to be treated, the flowrate required and the degree of automation desired it is difficult to calculate on a general basis and therefore the relative costs will be represented as either being LOW / MEDIUM / HIGH.

2. Lowest Relative Capital Investment

Obviously the lower the initial capital investment the easier it is to undertake and finance a project.

Again this criteria will be evaluated an a relative basis and denoted as LOW / MEDIUM / HIGH.

3. Low Maintenance

If the maintenance required is labour intensive the water treatment plant will become a financial burden. Therefore the process should be easy to maintain.

This will be evaluated on a LOW / MEDIUM / HIGH basis.

4. Simplicity of Process

If the process is too complex it will be difficult to troubleshoot should a system failure occur. This will entail a water shortage for the people of the municipality which would be a catastrophe. Therefore, the system should be as simple as possible.

The complexity of the process will be evaluated on a LOW / MEDIUM / HIGH basis.

5. Hardness Removal

Although hard water is not harnful to the health many people dislike having hard water as it increases their laundary, dishwasher and shower soap consumption. Therefore, it would be advantageous if the process chosen was capable of reducing water hardness.

This will be evaluated on a YES/NO basis.

ALTERNATIVES

The following lists and describes the most commonly used methods of water treatment. These will be compared and contrasted to determine which one would best replace chlorination in municipal water treatment as per their fulfillment of the essential and desirable criteria.

1. Ultraviolet Disinfection

Produced by very low pressure mercury vapour lamps, ultraviolet rays may be used to disinfect water. Bacteria as well as some viruses are irradiated and thus killed as the water flows as a thin stream through a pipe at the center of which runs a quartz tube containing a u.v. lamp. In order to achieve optimum results the raw water should be clear, colourless, odourless, free of turbidity, and must not contain any iron, organic colloids or planktonic microorganisms which are likely to deposit on the pipes, reducing the radiation transfer.

2. Ozonation

Ozonation is the process by which ozone is used as an oxidizing agent, in this case, to disinfect water. Ozone may be obtained by passing oxygen through a high energy field wherein the double bond of some of the oxygen molecules is severed resulting in the formation of atomic oxygen which inturn recombines with the molecules still intact forming ozone. This process is summarized by the following reactions,

$$O_2 + \text{Energy} \rightarrow 2O$$

$$O_2 + O \rightarrow O_3$$

The energy required to form ozone is most commonly supplied in the form of an electrical arc or ultraviolet radiation. Once formed, ozone acts as a powerful oxidizing agent second only to fluorine. This property has led to its extensive use in the field of water treatment.

Organic contaminants are converted to oxygen and carbon dioxide while metals are precipitated and subsequently filtered using sand or general filtration media such as

AG. Excess ozone may be catalytically destroyed or vented to the outside depending on the location of the plant and local regulations. In both cases ozone breaks down to oxygen.

3. Chlorination

Chlorine has been widely used to disinfect drinking water supplies and therefore its attributes will also be examined. This process usually effectively rids water of unpleasant tastes and odours but has been recently been shown to produce halomethanes which are extreme health hazards.

ANALYSIS OF ALTERNATIVES

The following comparative analysis table summarizes the results of this research.
(see Appendix A for CT values)

Table 1. Comparative Analysis of Municipal Drinking Water Treatment Methods

Criteria	U.V. Radiation	Ozone	Chlorine
ESSENTIAL			
Harmful By-Products	NO	NO	YES
Enviro. Impact	LOW	LOW	HIGH
Bacteria Removal	SOME	YES	YES
Virus Removal	NO	YES	SOME
Lead Removal	NO	YES	NO
Manganese Removal	NO	YES	Some
Iron Removal	NO	YES	YES
Odour Removal	NO	YES	YES
Colour Removal	NO	YES	SOME
DESIRABLE			
Op. Cost	MED	LOW	MED
Capital Cost	MED	HIGH	MED
Maintenance	HIGH	MED	MED
Complexity	MED	MED	MED
Hardness	NO	SOME	NO

CONCLUSION AND RECOMMENDATIONS

As chlorinated water has been shown to contain harmful halomethanes an effort is presently being made to eliminate chlorination from municipal drinking water treatment plants. This research has found ozonation to be the alternative of choice as due to its capability of removing bacteria, viruses, colour, odour as well as various metals from water. Most importantly it is environmentally friendly as ozone is produced an destroyed on site and is released as oxygen to the atmosphere. It is a simple process requiring an average amount of maintenance and entails low operating costs. It is therefore recommended that chlorination be replaced by ozonation in the treatment of municipal drinking water.

REFERENCES

Geankoplis, Christie J., Transport Processes and Unit Operations, Third Edition, Prentice-Hall Inc, 1993.

Lewis, Richard J. Sr., Hazardous Chemicals Desk Reference, Second Edition, Van Nostrand Reinhold, New York, 1991.

Schlesinger, H.I., General Chemistry, Third Edition, Longmans, Green and Co., New York, 1938.

Appendix A

CT values comparison

The lower the CT value the more disinfection power it has

Micro-organisms	Free Chlorine Cloramine NH_2Cl	Chlorine Dioxide ClO_2	Ozone O_3
E.Coli	0.034 – 0.05	0.4-0.75	0.02
Rotavirus	0.01 – 0.05	0.2 – 2.1	0.006 – 0.06
G. lamblia cysts	47 – 150	_____	0.5 – 0.6
G. muris cysts	30 – 630	7.2 – 18.5	1.8 – 2.0

* CT = Conc. O3 (ppm) x Contact Time (min)
* Established by EPA, 99.9% neutralisation of micro-organisms

OZO***MAX*** LTD