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13. ABSTRACT (Maximum 200 words) DURING THE PREVIOUS LIMITED FIELD-SCALE STUDY (1977), THREE RUNS WERE MADE ON WATER FROM PW 118 USING THE ULTROX UNIT. THIS WORK WAS CONDUCTED TO DETERMINE IF ANY OPERATIONAL PROBLEMS WOULD OCCUR WHEN TREATING WATER WITH ABOVE NORMAL CONCENTRATIONS OF IRON AND MANGANESE. IT IS ANTICIPATED THAT OTHER SOURCE WATERS AT RMA WILL CONTAIN METALS IN A REDUCED STATE AND THEREFORE THE ADDITIONAL REQUIREMENTS FOR THE REMOVAL OF THE PRECIPITATE NEED TO BE ADDRESSED. IN ORDER TO SATISFY THIS REQUIREMENT, A FIELD-SCALE SYSTEM WILL BE DESIGNED, BUILT AND PLACED IN OPERATION AT RMA. THIS SYSTEM WILL PROVIDE THE VERSATILITY NEEDED FOR FIELD-SCALE EVALUATION OF THE UV/OZONE PROCESS IN TREATING SOURCE WATER AT RMA. IN SUPPORT OF THE OVERALL FIELD-SCALE STUDY. AN INITIAL INVESTIGATION OF THE PRECIPITATION ASSOCIATED WITH UV/OZONE TREATMENT OF WATER FROM WELL 118 WILL BE UNDERTAKEN. THE LABORATORY BENCH-SCALE UNIT WILL BE USED TO PROVIDE SUPPORT AS NEEDED FOR THE FIELD-SCALE SYSTEM.	
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TEST PLAN
for
FIELD-SCALE SYSTEM STUDY
(Ultraviolet/Ozone Process)

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by

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INTRODUCTION

1. Groundwater at Rocky Mountain Arsenal (RMA) has been found to contain certain organic contaminants as a result of various past and ongoing activities at the arsenal. An initial bench scale treatability study* identified a combined ultraviolet light and ozone oxidation process as having a high potential for removing the organic contaminants. As a result of this study, a 1000 gpd field unit was obtained on a short term basis and placed in operation at RMA during the summer of 1977 to further assess the potential of the UV/ozone treatment process in removing organic contaminants from RMA groundwater. In this study, the UV/ozone process proved very successful in removing organic contaminants from the particular groundwater tested.

2. The field-scale study was limited in scope by the configuration of the UV/ozone field unit used. The unit configuration did not allow for variable control of certain parameters such as temperature, pH, pressure, and mechanical mixing. These parameters must be evaluated as to their effect on process efficiency for the various source waters at RMA.

3. During the limited field-scale study, three runs were made on water from PW 118 using the ULTROX unit. This work was conducted to determine if any operational problems would occur when treating water with above normal concentrations of iron and manganese. The water from PW 118 was found to contain iron and manganese in a reduced state.

*Buhts, et al, "Evaluation of Ultraviolet/Ozone Treatment of Rocky Mountain Arsenal Groundwater (Treatability Study)", March 1977.

The oxidation of these metals by the ozone/oxygen mixture in the UV/ ozone process unit resulted in the formation of a precipitate that settled to the bottom of the reactor vessel. This precipitate interfered with the transmittance of the UV light which resulted in a decrease in process efficiency. The precipitate accumulated in the bottom of the reactor vessel since the field unit was not equipped for sludge handling and removal. It is anticipated that other source waters at RMA will contain metals in a reduced state and therefore the additional requirements for the removal of the precipitate need to be addressed.

4. The limited field-scale study indicated a need for a very versatile field-scale treatment process system that can be used on different source waters. In order to satisfy this requirement, a field scale system will be designed, built, and placed in operation at RMA. This system will be composed of three separate reactor units, each with a different configuration, and a precipitate removal unit. The system will provide the versatility needed for field scale evaluation of the UV/ozone process in treating source water at RMA. A field-scale study will be conducted at RMA using the new system to evaluate the treatment potential of UV/ ozone on various source waters.

5. In support of the overall field-scale study, an initial investigation of the precipitation associated with UV/ozone treatment of water from Well 118 will be undertaken. This study will provide information needed in the design of the precipitate removal unit. RMA personnel from the Process Development and Evaluation Division (PDED) will conduct this study with WES personnel providing technical assistance. A detailed

program outline is presently being developed by RMA but a general discussion of the study will be included in this plan. The completed program outline will be distributed as an amendment to this plan.

6. The laboratory bench-scale unit will be used to provide support as needed for the field-scale system. Information gained in the bench-scale study will be used to verify the design and to develop the initial operating procedures and parameters for the field-scale system.* The laboratory unit will also be available on an as-needed basis during actual operation of the field system during the third and fourth quarters of FY 78.

OBJECTIVES

7. The overall objectives of the field scale study are as follows:
- a. Assess the potential of the UV/ozone system in removing organic contaminants from various RMA source waters.
 - b. Investigate the precipitation associated with UV/ozone treatment of water from PW 118 to provide the necessary information for design of a precipitate removal unit.
 - (1) Determine the effect of air, oxygen, and oxygen/ozone mixture on the formation of precipitate in water from PW 118.
 - (2) Determine the chemical characteristics of the precipitate.
 - (3) Determine the physical settling characteristics of the precipitate.
 - c. Evaluate the effectiveness of the different reactor configurations with regard to different source waters.
 - d. Determine the optimum operating conditions for the UV/ozone system with regard to different source waters.

*The bench-scale study is discussed in a test plan titled "Test Plan for Laboratory Bench-Scale Study (Ultraviolet/Ozone Process)", January 1978.

- e. Define any modifications in procedures or design that need further evaluation.
- f. Provide additional data for use in refining and calibrating a mathematical model of the UV/ozone treatment process.
- g. Obtain the necessary information for design of a pilot plant along with an estimate of treatment costs for the various source waters.

MATERIALS AND METHODS

Equipment

8. The UV/ozone field scale system will include a precipitate removal unit, any one of three separate reactor units, and a ozone generator. Additional equipment such as flow meters, thermometers, and a ozone measuring system will be obtained and used to provide complete monitoring of all operational parameters.

9. The precipitate removal system will be designed based on information obtained in the study being conducted by RMA. The final unit design will probably include a contactor system using air or exhaust gas from the UV/ozone reactor vessel and a particulate removal system such as a clarifier or filter. The precipitate removal system will be an add-on device to facilitate its use only as needed on particular source waters.

10. Three separate reactor units with different configurations will be investigated. These three units will provide the versatility needed in the study due to the variation in characteristics of the source waters being tested. None of the units as configured are commercially available but the designs will incorporate off-the-shelf available components to decrease costs and delivery times. Construction costs will be covered by funds appropriated during FY 77; FY 78 funds will be used

to conduct studies at RMA. The designs for these three units have not been completed, but a general discussion of the units will be given in this plan.

11. The first reactor unit will consist of six separate stages each containing a gas sparger and a UV lamp. Each stage will be constructed from a six-foot section of eight-inch ID stainless steel pipe. A single UV lamp will be placed down the center of the pipe. Mixing will be accomplished by means of the sparged gas mixture. The unit is designed for use of cocurrent or countercurrent flow. This unit is similar to a test unit used by OTSG in their work on hospital wastes but will have additional features such as precipitate removal ports and variable flow capability. The author has visited Ft. Detrick where the hospital waste test program was conducted.

12. The second reactor unit will be a single mechanically mixed reactor. The reactor vessel will be constructed of stainless steel and will contain a variable speed impeller mixer. Two to four UV lamps will be inserted in the reactor vessel so as to surround the mixer.

13. The third reactor unit will use the dissolved air/pressure relief principle for gas introduction. The unit will consist of pressure vessels where the ozone/oxygen mixture will be introduced under pressure into a side stream of the water to be treated. This side stream will then pass through a pressure relief valve into a reaction chamber with the remainder of the water. Very small gas bubbles are formed as a result of the decrease in pressure. The unit will provide for water recirculation and will have UV light sources in both the pressure vessel and in the reactor chamber. The unit will be constructed of stainless steel.

14. All three units will be configured so as to be extremely adaptable. The units will allow for variable control of temperature, pH, and pressure along with the standard operational parameters. The three units will have similar volumes of approximately 300 to 350 liters. The units will be skid mounted and highly portable.

15. These three units incorporate three different types of gas introduction, since it is anticipated that the effectiveness of a particular gas introduction system will vary with the type of water being treated. Sparged gas systems are inclined to clog when used to treat water with high concentrations of metals in a reduced state. In waters with high organic contaminant concentrations, the mass transfer of ozone across the air/liquid interface can become a limiting factor. In this case, a decrease in gas bubble size will generally result in a better ozone mass transfer rate due to the increase in area of the air/liquid interface.

16. The problems previously discussed indicate that one type of reactor unit will probably not efficiently treat all types of source water. The use of three separate reactor units allows for better optimization of the treatment process on a variety of source waters.

Investigation of Precipitation in Water from PW 118

17. The precipitation study being conducted by RMA (under the technical direction of WES) will include three major tasks. These tasks have been tentatively identified as follows: (1) a measure of precipitate generation with respect to gas sparging time, (2) a chemical characterization of the precipitate, and (3) an investigation of the

physical settling characteristics of the precipitate. The information gathered will be used to design the precipitate removal system to be used in the UV/ozone field scale system.

18. Precipitate Volume vs Time. A determination will be made of precipitate volume generated with respect to sparging time for the following gases: (1) air, (2) oxygen, (3) oxygen/ozone mixture. Each gas will be sparged for increasing periods of time and the precipitate volume generated will be recorded for each test. Precipitate volume will be plotted against time to determine optimum contact time for maximum precipitation for each gas. This information will be expressed as gas flow per unit volume of water.

19. Chemical Characterization. Sparging tests will be conducted using times obtained in the first procedure. After settling, the liquid will be decanted and an additional test run made with ozone to determine how much more precipitate is formed. Liquid and precipitate samples will be collected from these runs for metals analysis and organic analysis. These tests will indicate the metals being precipitated along with the amount and identity of organic matter being removed with the precipitate.

20. Physical Settling Characteristics. A standard settling chamber* with side sampling ports will be used in determining settling characteristics. Gas will be sparged into the chamber for the appropriate time and then the gas shut off to allow the precipitate to start settling. Samples will be taken periodically from the sample ports and suspended

*Camp, T. R., "Sedimentation and the Design of Settling Tanks," Trans. ASCE, 111 (1946), 895-936.

solids analysis conducted on each sample. The percent removal of solids will be computed for each sample and plotted against time and depth.

21. All information generated in this study will be furnished to WES personnel for evaluation. WES will be responsible for final design approval and construction of a unit to be incorporated into the UV/ozone field scale system.

Field Scale System Operation

22. The UV/ozone field scale study will begin with a series of break-in and calibration runs conducted on PW 3 source water. Initial operating parameters will be determined by extrapolation from existing data.

23. A factorial type experiment will be conducted using a variety of parameter settings. Experimental runs on each source water will be made with various reactor units until the optimum unit can be determined. At that point, a series of additional runs will be made on the source water in order to optimize operational parameters associated with the unit.

24. Water from PW 118 will be tested first due to the availability of data from previous studies. Other source water as identified by the PMO will then be tested. It is anticipated that three to four runs per unit per week can be conducted at RMA.

25. The data generated in this study will be used to assess the effectiveness of the UV/ozone treatment process in removing organic contaminants from various source waters at RMA. This assessment will include estimated costs for treatment of the source water.

Sampling and Analysis

26. The field scale system will be instrumented to facilitate continuous monitoring of operating parameters. Parameters to be monitored include:

- a. Ozone concentration in the feed gas.
- b. Oxygen concentration in the influent and effluent.
- c. pH of influent and effluent.
- d. Liquid and gas flow rate.
- e. Temperature.

27. As in previous studies, DIMP (diisopropylmethylphosphonate) will probably be used as a representative constituent on which to base treatment efficiency. Analyses will be conducted as follows:

a. Organic

- (1) DIMP
- (2) DCPD
- (3) Pesticides
- (4) Organosulfur compounds
- (5) Organophosphorus compounds
- (6) TOC (Total Organic Carbon)
- (7) COD (Chemical Oxygen Demand)

b. Metals

- (1) Iron
- (2) Lead
- (3) Mercury
- (4) Arsenic

(5) Manganese

(6) Sodium

c. Others

(1) Total dissolved solids

(2) Conductivity

(3) Chloride

(4) Fluoride

(5) Bromide

(6) Hardness

(7) Alkalinity

(8) Sulfate

(9) Nitrite

(10) Nitrate

(11) Phosphate

The aforementioned analyses will be conducted throughout the study. Not all analyses will be conducted on every sample, but sufficient testing will be conducted to insure a thorough characterization of the different source water samples. Samples will be collected and analyzed according to Standard Methods.

28. The Analytical Laboratory Group (ALG) at WES will conduct metal analysis on the various samples. The Material Analysis Laboratory Division (MALD) at RMA will be responsible for organic analysis of samples except for TOC and COD. WES personnel will be responsible for any other analyses to be performed on site. Approximately 50 to 60 samples per week will be submitted to MALD for DIMP analysis. Approximately 10 to 15 samples

per week will be submitted for analysis for each of the other organic species. Approximately 10 to 15 samples per week will be submitted to ALG for metal and other analysis.

Scheduling

29. A time schedule for operation of the UV/ozone field scale system during FY 78 is presented in Figure 1. Test plan development is scheduled for completion by January 1978. The RMA test plan for the precipitation study is scheduled for completion by 20 January 1978. The initial phase of the precipitation study is scheduled for start-up at that time and should be completed by 1 April 1978. The remainder of the precipitation study will be conducted concurrently with the field studies from June to September. The procurement of field scale equipment is scheduled from January through May 1978. Starting in June, the field scale system will be in operation at RMA. A final summary report on work completed in FY 78 on the field scale system is due 1 October 1978.

FIGURE 1

UV/Ozone Field Scale Work Schedule

Task	Dec	Jan	Feb	March	April	May	June	July	August	Sept
A. Test Plan (WES)	▬									
B. Test Plan (RMA)		▬								
C. Precip. Study				▬						
D. Procure Equip.										
E. Field Scale Study at RMA										
F. Prepare Summary Report of FY 78 work.										