ICR, Treatment, and Methods Research Stakeholder Meeting For The Stage 2 DBPR and LT2ESWTR

Final Draft Meeting Summary Report

ICR, Treatment, and Methods Research Stakeholder Meeting For The Stage 2 DBPR and LT2ESWTR

March 10-12, 1999
Hyatt Arlington at Washington's Key Bridge
Arlington, VA

Prepared by:
ISSI Consulting Group, Inc.
8455 Colesville Road
Suite 915
Silver Spring, MD 20910

Prepared for:
U.S. Environmental Protection Agency
Office of Water
Health and Ecological Criteria Division
401 M. Street, S.W.
Washington, DC 20460

EPA Contract: 68-C-98-195

Original Submitted: March 22, 1999
Revised Submitted: June 17, 1999

Agenda

WEDNESDAY MARCH 10, 1999

Background

8:30 - 8:45	*Greetings from EPA and Overview of Agenda* Cynthia Dougherty, US EPA Abby Arnold, Resolve
8:45 - 9:15	*Overview of Key Questions and Data to Address Questions* Stig Regli, US EPA *Information Collection Rule (ICR)*
9:15 - 10:00	*Objectives of ICR and Overview of Implementation* Mike McGuire, McGuire Environmental Consultants, Inc.
10:00 - 10:30	*ICR Data Organization* Jennifer McLain, US EPA
10:30 - 10:45	*BREAK
10:45 - 12:15	*ICR Questions and Data Presentation* Michelle Frey, McGuire Environmental Consultants, Inc.
12:15 -	*LUNCH

1:15

1:15 - 1:30 *Overview of EPA's Approach for Using ICR Protozoan Data*
Heather Shank-Givens, US EPA
Mike Messner, US EPA

2:00 - 2:45 *Overall Data Sources/Compliance Forecast and Impact Estimates*
Stig Regli, US EPA

2:45 - 3:00 *BREAK

Microbial Pathogens: Measurement of Pathogens and Indicators

3:00 - 3:45 *Characterization of the Occurrence of Pathogens and Indicators in Source Water (AWWARF#488)*
Mark LeChevallier, American Water Works Service Company, Inc.

3:45 - 4:45 *General Overview of Current Science, Current and Future Research and Schedules for Completion*
Mark Sobsey, University of North Carolina at Chapel Hill

4:45 - 5:30 *Cryptosporidium Viability and Infectivity Research*
Ricardo DeLeon, Metropolitan Water District of Southern California

5:30 - 5:45 Wrap-Up

THURSDAY MARCH 11, 1999

8:30 - 8:45 Review of Agenda for Day 2
Microbial Pathogens: Treatment Research
Physical Removal

8:45 - 9:30 *Removal of Microbial Pathogens and Indicators by Conventional Treatment*
Eva C. Nieminski, Utah Department of Environmental Quality

9:30 - 10:00 *Research on Removal of Cryptosporidium and Indicators in a Conventional Water Treatment Pilot Plant*
Kim Fox, US EPA

10:00 - 10:30 *Cryptosporidium Physical Removal in Pilot and Full-Scale Plants*
Dave Cornwell, Environmental Engineering and Technology (EET)

10:30 - 10:45 *BREAK

Inactivation

10:45 - 11:45 *Inactivation of Microbial Pathogens in Water Treatment*
Gordon R. Finch, University of Alberta, Canada

11:45 - 1:00 *LUNCH

1:00 - 1:30 *Research on Inactivation of Cryptosporidium Using Single and Multiple Disinfectants*
Benito Marinas, University of Illinois at Urbana-Champaign

1:30 - 2:00 *Ultraviolet (UV) Inactivation of Microorganisms*
Karl Linden, University of North Carolina at Charlotte

Small Systems

2:00 - 2:30 *Overview of Treatment Processes for Microbial Pathogens in Small Systems*
Robin Collins, University of New Hampshire

2:30 - 3:00 *Small Systems Microbial and Disinfection By-Products (DBP) Research Studies*
Jim Goodrich, US EPA

3:00 - 3:15 *BREAK

Watershed

3:15 - 4:00 *What are the Major Sources of Pathogens in Surface Water?*
Joan Rose, University of South Florida

4:00 - 5:30 *Panel Discussion on Physical Removal and Disinfection*

Bob Clark, US EPA
Dave Cornwell, EET
Gordon Finch, University of Alberta
Ray Letterman, University of Syracuse
Eva C. Nieminski, Utah Department of Environmental Quality
Benito Marinas, University of Illinois

5:30 Adjourn

FRIDAY MARCH 12, 1999

8:30 - 8:45 Summary of Day 2
DBP Methods

8:45 - 9:15 *Analytical Methods: Overview of Available Analytical Methods for DBPs and On-going and Future Research*
Pat Fair, US EPA
DBP Treatment Research

9:15 - 10:15 *DBP Formation*
David Reckhow, University of Massachusetts at Amherst

10:15 - 11:15 *Treatment Technology Impact on DBP Formation*
Scott Summers, University of Colorado

11:15 - 12:15 *Evaluation of Granular Activated Carbon (GAC) and Nanofiltration under the ICR*
Steve Allgeier, US EPA

12:15 - 1:15 *LUNCH

Distribution Systems/Cross Connection Control

1:15 - 1:45 *Distribution Systems Risk Management Research*
Don Reasoner, US EPA

1:45 - 2:15 *State Cross Connection Control Programs*
Dan O'Lone, US EPA, Region 4

2:15 - 2:45 *Control of Microbial Contamination in Drinking Water Distribution* Systems
Mark LeChevallier, American Water Works Service Company, Inc.

2:45 - 3:00 Wrap-Up

3:00 Adjourn

WEDNESDAY MARCH 10, 1999

Welcome and Introduction

Cynthia Dougherty of the U.S. Environmental Protection Agency (EPA) - Dougherty welcomed this second gathering of stakeholders and made introductory remarks about the purpose of the meeting. The focus of this meeting was to cover the research being done on the topics that will help make decisions about Stage 2 rules (i.e., Stage 2 Disinfectants/Disinfection By-Products Rule [DBPR2] and Long Term Enhanced Surface Water Treatment Rule [LT2ESWTR]). This included analytical methods, distribution systems (cross-connection), microbial and disinfectant-by-product treatment, and the scope of research and information gathering that's under way to help with the decision making. Comments were made in regard to the success of last month's "Health Effects" meeting. Dougherty thanked everyone who attended the meetings and recognized the presence of EPA personnel from Office of Water, the Office of Research and Development, and others who help in the decision making process.

Background

Overview of Key Questions and Data to Address Questions - Stig Regli (EPA) [Attachment 1]

Stig Regli addressed the purpose of the meeting and provided an overview of the information available for answering key questions. He gave a framework of Stage 2 rules, the issues concerning the rules, and how the issues should be resolved and answered (Slides 2-3). Three possible LT2ESWTR regulatory frameworks (Slide 4) and the eight key questions for this rule (Slides 5-8) were discussed. Possible DBPR2 regulatory frameworks (Slide 9), as well as the key DBPR2 questions, (Slides 10-12) were also presented.

The main sources of information available for addressing LT2ESWTR and DBPR2 were described (Slides 12-13) by Regli. A time line was provided for several rules which will be promulgated in year 2000, pointing out that the process is very long. Discussions of the issues will occur through April of next year; the rule will be proposed in February 2001; the final rule will be established in May 2002. This time line will give the stakeholders the opportunity to provide new information to be considered for the final rule (Slides 14-15).

Information Collection Rule (ICR)

Objectives of ICR and Overview of Implementation - Mike McGuire (McGuire Environmental Consultants, Inc.) [No Handouts]

What is the ICR and how will it affect committee members? McGuire presented basic ICR information, data analysis, data sources, and compliance estimates in order to answer this question (Slide 2).

The ICR regulation-negotiation process took a long time; the process began in 1992 and the ICR was finalized in 1996. Detailed information was collected on how distribution systems are operated (Slide 3). The ICR is a collaborative effort, and utilities are beginning to understand that the information being collected is an invaluable source of data with respect to being in compliance with pathogens and other rules (Slide 5). Part of the commitment by the EPA is to make sure that all of the information was collected.

There are many components to the ICR; the main focus is disinfectant-by-products (DBPs) in the distribution system, the micro-focus is on the source water. DBP precursor removal studies are a component of the ICR. Before this work was done, there was a limited amount of information on removal. Significant advances have been made as a result of these studies for synthesizing and presenting information (Slide 6). The data collection component of the ICR is complete for utilities and labs, although labs still have time for submitting the information (Slide 7). The ICR FED is a database and it is ready to receive data. The validation process is the quality control (QC) of the data. When quality assurance/quality control (QA/QC) is finished, the database will be a high quality tool which will be available to the public.

Stakeholders were involved in formulating the questions to be answered with the ICR data. Based on the questions, it was realized that the ICR FED database was too big (20 gigabytes). McGuire added that the ICR FED database queries would be so complex that only a few people would be able to execute them. Therefore, auxiliary databases were created that were much smaller and could be queried in Microsoft Access and other databases, in order to be able to answer questions immediately (Slides 8-10).

Auxiliary database 1 would be used to do a vertical analysis of water quality data. A sample question for ICR vertical data analysis may be "What is the level of DBP (organic) precursors (like total organic carbon [TOC]) in treatment plant influent (not source water)?" Cumulative frequency is a tool that will be very useful (Slides 13-14). A free form query tool was developed for ad hoc horizontal analyses of water quality data. Sample questions for this type of analysis may be "How well is total organic carbon removed in water treatment plants?" Many things can be done to modify treatment. ICR captured data from 18 points in time over 18 months for treatment plants. The TOC and the production of DBPs were measured horizontally (Slides 16-17).

Sample questions which were posed were "What is the distribution of microbial occurrence in plant influent (protozoa, virus, indicator organism)?" "What is happening on the microbial end?" Messner will answer these questions in his presentation. This is all a part of the QA/QC effort to ensure that the data describe what is actually going on; issues will be examined by a technical workgroup (informal group) with the Federal Advisory Committee (FACA). Another question raised was "What is the impact of a particular set of constraints?" (there are a number of pathogens that will be looked at as well as DBP occurrence). These questions will be answered by the FACA process (Slide 21). Other questions include "How will enhanced coagulation affect levels of DBPs (Slide 22)?" and "how will Stage 2 treatment be assessed (Slide 23)?"

McGuire added that information regarding overall data sources and compliance estimates will be addressed by Stig Regli (Slide 24) and Jennifer McLain will talk about ICR data and discuss the schedule for ICR development (Slide 20, Slide 25).

Questions/Answers:

Q: Were labs that analyzed data preapproved?
A: Yes

Q: Was the horizontal analyses tool available for utilities so that they can analyze there own data?
A: This is being worked on for groups of utilities. There is not a tool for individual utilities.

Q: What will be the turnaround time for the data analysis?
A: Some databases can sort information overnight. This will be done in some cases. [We] are striving to create tools that will give a more rapid response.

ICR Data Organization - Jennifer McLain (EPA) [Attachment 2]

Jennifer McLain talked about the ICR database and the schedule for ICR development. The ICR FED database had to be divided into smaller auxiliary databases in order to make queries easier (Slide 2). McLain discussed the structure of these databases. A query tool will be associated with auxiliary database 1 (Slide 3). The query tool was designed to make analysis simple. It complements auxiliary databases 2-7 (Slide 7).

The interconnection between treatment data and sampling results data is the most important facet of regulatory analyses (Slide 4). Auxiliary 1 is the primary database for vertical analysis. It is accompanied by a query tool that will allow horizontal analysis (Slide 5). All tables are interconnected in the Auxiliary 1 database structure; tables can be joined to answer specific questions (Slide 6). Auxiliary 2 was designed to answer contact time (Ct) and disinfection decay questions (Slide 8). Auxiliary 3 was designed for enhanced coagulation questions. It may be used to compare TOC removal to enhanced coagulation treatment (Slide 9).

Auxiliary 4 works with the enhanced coagulation database--it characterizes sludge production (Slide 10). Auxiliary 5 is used to examine information on water quality in the plant and the impact of wash water return (Slide 11). Auxiliary 6 performs a horizontal analysis of DBPs in the distribution system. It was noted that it is not necessary to go back to Auxiliary 1 database to answer questions about DBPs (Slide 12). Auxiliary 7 is used to assess the impact of additional water sources on water quality of the plant (Slide 13).

The water treatment plant model will be used as one tool, and must be compatible with the Auxiliary 1 database. The Auxiliary 8 database was created to do this; it will be the model interface between the model and Auxiliary 1 (Slide 14).

The ICR schedule outlines when all of the tools will be available. Utilities and labs have already submitted their data to the database. A review of the quality of the data is now going on. This review will impact the amount of data that will be available to the database. The first 6 months of data will be available in June 1999 for analysis. The final Auxiliary 1 database will be available in the May-June 1999 time frame. The Auxiliary 1 query tool will be ready in July 1999. The remaining auxiliary databases will be available in the fall (Slide 16).

Question/Answers

Q: Regarding Auxiliary 6, will the final database be available after the fact?
A: Auxiliary databases will receive information from Auxiliary 1, and analyses will be done using this information. But there will be a delay.

Q: How long will the delay be? How much time will the databases need to answer the questions?
A: Should not be very long. In some cases, it just takes a couple of minutes.

Q: Using the ICR data (analyzing the data to answer the questions), will this be available in the fall?
A: There will be two quarters of data that will be available to answer questions.

Q: Will 9 months of ICR data be available in the fall to answer the questions?
A: Nine months will be available in July 1999 in the QA/QC database. Auxiliary 1 will be ready in May or June 1999 to download into the other auxiliary databases. Substantial part of analysis will be for occurrence. This can be done in the July-August time frame. As more information is downloaded, it will be able to answer specific questions.

Q: Regarding enhanced coagulation database, has this already been refined?
A: This database will calculate TOC removal, and will look at information in the rule. Based on water quality, it will tell you where you are in the matrix.

Q: What is the definition of enhanced coagulation for this database?
A: It is based on the matrix and determines removal

Q: Many people practicing enhanced coagulation are not successfully removing TOC, but the matrix said you should. Will these systems be included in the database?
A: All information is included in the database. It will not answer questions for step 2.

Q: Is there a time frame for answering the questions? Have questions been prioritized according to how much information is needed to answer them?
A: Yes.

Q: Regarding the table that shows what questions can be answered, will it be updated since it is in the draft stage?
A: Green means questions that can be answered with 6 months of information,

Q: What does blue mean in the table?
A: Can't remember.

Q: Were risk assessment people involved in the development process in order to balance the exposure and final outcome?
A: The purpose of the ICR is to collect information on occurrence and treatment.

ICR Questions and Data Presentation - Michelle Frey (McGuire Environmental Consultants, Inc.) [Attachment 3]

Michelle Frey is working with the Technical Workgroup. The question was raised "What happened in 1997 regarding the ICR data analysis plan (Slide 2)"? Frey explained that questions have been prioritized according to how they can be answered based on the information that is available (Slide 3). Priority is being set on timeliness. There are two components involved: 1) how quickly can we get data and 2) availability of data (Slide 4). These are to set the stage for other questions.

The foundation has been set for understanding public water supplies (PWS) (Slide 5). "What are the geographic features of these utilities?" Regions are divided into water quality, source water, or regions (for EPA) (Slide 6). Other questions on characteristics of ICR water treatment plants include "what type of source is out there?", "What type of disinfection is out there?", and "What are the residuals that are out there (Slide 7)?" Note: All of the data presented is hypothetical. Big categories of water treatment plants can yield important information (Slide 8). Learning about differences in water treatment is important. Probabilistic vs. imperialist data (Slide 9). In the box and whiskers diagram presented, the diamond is the mean value. The whiskers give the uncertainty and variability in the data (Slide 11).

What is driving the boat? A pie diagram of compliance capabilities was presented by Frey. If a limit is exceeded, it will be shown in this graph (Slide 12). A correlation analysis (Slide 15) will show if one variable can explain how the other variables are affected. There is a good understanding of how parameters behave according to each other. A positive correlation means that as one increases the other increases. A negative correlation means that as one increases the other decreases. If there is no correlation they don't affect one another.

The data management system is the focus in dealing with the "state of the union" type questions (Slide 16). Data has been stored and everything is vertically arranged. It is hard to determine how treatment is used across the system. Auxiliary 2 puts everything on the same line to answer the questions (Slide 17) and to calculate how much inactivation is going on before filtration (Slide 18). A strategic point of view was used to look at the system. The first thing to do in compliance is to define the initial baseline. "How many people will meet or exceed regulatory standards (Compliance Assessment with regulatory option)?" Assessment from utilities is gathered in order to compare actual information with the predictions that were made (Slide 20).

Data from the ICR can generate information to determine who will be in compliance among the large systems. It is very comprehensive for large systems: one may look at the disinfection profiling/benchmark. To generate the information that we don't have, we must go elsewhere (Slide 21). Could this table be developed based on disinfection practices? Can we see who is meeting TOC removal requirements (Slide 22)?

There are seven sets of annual averages. The disinfection benchmark will have the average of the 7 upper and lower levels. On average, only 10 percent of systems have a disinfection benchmark below 1 (Slide 23).

A Decision Tree (Slide 25) was introduced. It is an algorithm that represents the logical sequence of tasks that a utility can do in order to determine what treatments are best for the plant. Logical treatment can be programmed based on the technology of the plant. What is the performance of the technology, and is it feasible for the plant? If the technology is not sufficient, a different technology should be used. The sequence of technology is cost effective. The Decision Tree is designed for ICR surface water systems. Not all plants will go through all of the 16 steps. ICR data will be transformed to use water treatment plant data.

A sensitivity analysis gives all of the information that is needed in regard to sensitivity. Validation is important the water treatment model must be validated (Slide 26).

Auxiliary 8 will be the information management system. It will be used to generate, perform and extract information (Slide 27). Details were given concerning how Auxiliary 8 will work. The Surface Water

Assessment Tool (SWAT) generates outputs, and the interface makes sense of the SWAT output (Slide 28) (i.e. sorts the output in a meaningful way).

Frey explained how SMART SWAT works (Slide 29). She added that data management will be summarized. "0" means that treatment was not selected; "1" means the treatment was selected (Slide 30). Examples of what would happen if utility requested information (Slide 31), of the SENSITIVE SWAT (Slide 32), and of the output that results from the SENSITIVE SWAT (Slide 33) were provided.

Changing criteria can show the difference from high cost technology to low and medium criteria (Slide 34). It was suggested that the analysis be smart, rather than the program. Outputs give a lot of flexibility (Slide 35). One must do a lot of work to in order to get specific information and can become overwhelmed by the process of getting information.

High priority questions will be looked at repeatedly, based on ongoing information, and discussed in detail (Slide 36). Questions that the ICR data can answer include "Can we evaluate large systems with respect to Stage 1 (Slide 37)?" and "Is this ICR data a good indicator of non-ICR systems (Slide 38)?"

All of the questions cannot be answered very well by the ICR data. An example was given by Frey pertaining to site-specific estimates. Predictions cannot reliably be made on what individual systems will do; cannot give a list of other information that needs to be collected under the ICR (Slide 39).

Questions/Answers:

Q: Regarding regionality, how do you select the number of systems that will be used per region for the ICR data?
A: System size was used to determine which systems had to submit information for ICR. Information was collected from systems with more than 100,000 served, therefore some regions will be weighted more heavily than others.

Q: Can this program find matched systems across geographical regions (i.e. can you use the ICR data system to get the best match to your system's problems)?
A: It can create classification for data that is available, and get matched systems. You can do a cluster analysis.

Q: Water quality issues can persist for more than 18 months; considering that 18 months of data was collected, how will you extrapolate data to take that into consideration?
A: Cannot take cycle changes into account at any one site. Rich spatial and temporal database. Should provide good national estimate.

Q: What was the range of the plant size from which the data was collected?
A: Data was based on population. Plant level data does not include distribution system data. Plant represents much smaller clusters of the population.

Q: Is there a concern that the data is from a broad scope of geographical areas, with different types of treatment used, etc.? May this create problems with the database?
A: There will be anomalies in the database. The database will be cut up to determine mechanism for DBP formation, treatment applicability, etc. The data was collected for empirical observations, not necessarily mechanistic observations. It will be used to make observations, not to determine how DBPs are formed or to answer specific research questions.

ICR Laboratory Spiking Program - Heather Shank-Givens (EPA) **[No Handouts]**

The program objectives and long term goals of the ICR Spiking Program were discussed.

Shank-Givens also gave background information on why the program was conducted and discussed the design of the program. There were 70 ICR plants in the program from which raw water samples could be obtained. Random sampling was done and two samples were collected per plant. The way in which the samples were collected, as well as how the apparatus was used, were explained for the analysis. The status of the program was also was discussed. It was conducted from May--December 1998. Participating plants and labs are scheduled to receive validated data by the end of March 1999.

Questions/Answers:

Q: How long did it take for the samples to be collected?
A: It takes the same amount of time it takes to run through the filter.

Overview of EPA's Approach for Using ICR Protozoan Data - Heather Shank-Givens (EPA), Mike Messner (EPA) [Attachment 4]

Questions regarding the understanding of protozoan data quality were presented (Slide 2). These questions will be answered during the presentation as well as additional questions. "What makes protozoan measurement difficult (unlike chemical measurements) (Slide 3)"? When a chemical method is utilized, a small sample volume of water is analyzed with billions of molecules in a small volume. The number of molecules does not vary much for a single water from sample to sample. For protozoans the situation very different. The amount of oocysts found in samples varies; there is a very large variability in samples.

Volume analyzed (VA), mean recovery (MR), and variability of recovery (VR) are criteria that determine method performance (Slide 4). MR is the probability that a protozoan in sample is counted by the analyst. VR varies from sample to sample and the accuracy depends on may factors such as water quality, analytic method, etc.

EPA had limited information on protozoan measurement performance, and therefore had to make a number of assumptions in designing the ICR survey (Slide 5). Did it perform as well as EPA had hoped? For volume analyzed and recovery, the answer is yes. The y-axis in the graph (Slide 6) is logarithmic; the distribution of the volumes being analyzed is log normal.

Recovery is the probability that an oocyst will make it through the counter. Measured/true is just an estimate. What is the underlying truth? It can be different than what is actually seen (Slide 7). "Peeling back the layers"-the information that measured/true gives (Slide 8) was discussed. There is a great difference between the estimate and true values. Blue=Giardia; Red=Cryptosporidium. No temporal pattern was seen in the data.

All of the validated data are not available to do the analysis properly. Don't take these numbers as gospel. Maximum likelihood fit is the beta-distribution. The beta-distribution fits the data best. This describes the median recovery, which is 10 percent, and the mean recovery, which is 12 percent. Recovery is less than 16 percent, 75 percent of the time (Slide 9). A 12 percent mean recovery is good because EPA expected 8 percent recovery (Slide 10).

The performance evaluation (PE) data tests the ability of the analyst (Slide 11). In the PE samples, oocysts were spiked directly onto the filter. As a result, only a part of the measurement system is examined. There was a mean of 12 percent for Cryptosporidium in the Lab Spiking Study (LSS) (Slides 12-13). It shows that there is a loss during the filtration. The distribution of measured/true for Cryptosporidium PE results in a beta-distribution. PE information and lab spiking data show that there is a greater than assumed VA, MR, VR. "Why is the ICR database so full of zeros?" The national occurrence of Cryptosporidium in source water is lower than expected (Slides 14-15). The data can be used in the following ways: do not substitute non-zero numbers for zeros. If this is done, the results will be biased (Slide 16).

The issue of how the LSS data will be used and an example of this was discussed (Slide 17-18). Heather Shank-Givens explained how ICR data can be used (Slide 20). She added that it was not practical to get individual information from utilities with 18 months of information.

EPA has an approach for Data Quality objectives to answer the question "How accurate does a method have to be to adequately characterize pathogens in a source water (Slide 21)?" The criteria used to define accuracy were presented (Slide 22) as well as the assumptions used in determining the accuracy of the method (Slide 23). Method 1622 will be used for the analysis (Slide 24). The simulation results received using the Method 1622 were provided (Slide 25).

A comparison of the two methods showed that the ICR method is not as favorable as the Method 1622 (Slide 26). It was noted that the numbers provided on Slides 25 and 26 are incorrect and the correct numbers were provided.

Shank-Givens concluded the presentation with conclusions (Slide 27). She noted that uncertainty assessment will be a key component of any ICR protozoan analysis.

Questions/Answers:

Q: Confusion with "keeping zeros as zeros", from what I understand a lot of the zeros are not zeros, but non-detect values?
A: Zeros tend to underestimate, and non-zeros tend to overestimate. In order to get an unbiased estimate of the mean, add all of the zeros to the non-zero values. Copies of statistics report are available. In the workshop, it was stressed that zeros should not be treated as non-zero values.

Q: How many labs were used to determine the 1622 method?
A: Twelve

Q: Is this the type of data that goes into the auxiliary database, or is there other information?
A: Data will not be adjusted in any way. Zeros will go in as zeros in the database. The observed distribution will be more variable than the true distribution. We will have to determine what the true distribution is.

Q: In the spiking study, there was no recovery over 100 percent, for PE study some over 200 percent, how do you interpret this?
A: Some of the oocysts were lost in the filter. In one study water was forced through the filter, but in the other study it wasn't. It doesn't particularly make sense scientifically, but it does make sense statistically.

Overall Data Sources/Compliance Forecast and Impact Estimates - Stig Regli (EPA) [Attachment 5]

Stig Regli began with an overview of the presentation (Slide 2). The overall perspective of how data sources will be pulled together to do the compliance forecast and impact analysis was presented. A lot of information feeds into doing the impact analysis, including the cost and benefits estimates (Slide 3). A major issue to consider in the Stage 2 Impact analysis includes the time when ICR data was collected. This does not reflect what the utilities are doing to come into compliance with DBPR1 and IESWTR. Pre-stage 2 rules will be promulgated before the Stage 2 rules (Slide 4).

Regli emphasized that there is a need to get a handle on what data are saying. [We] need to take into account how the existing databases will be changed by the rules. What will it take to get to Stage 2 rule, based on the existing baseline? The difference between Stage 1 and Stage 2 baseline will show the true impact of the rules (Slide 5-6).

There is a very skewed distribution for the number of surface water (SW) systems by population for small systems (Slide 7). The distribution of households served by SW systems by population category (Slide 8), the distribution of the number of groundwater (GW) systems by population category (Slide 9), and the distribution of households served by GW systems for each population (based on category) (Slide 10) were presented graphically.

The data and tools needed to do the regulatory impact analysis (RIA) were discussed. These include the national distribution of the different types of treatment and operational characteristics associated with the treatment, predicting pathogen removal/inactivation, treatment costs, extrapolating risk, and estimating benefits and risks avoided (Slide 11-12). Regli added that one needs to see the big picture in order to perform the cost/benefit analysis (Slide 18). The various data sources for doing Stage 2 RIAs (Slide 19) and the curve of occurrence for pathogen/DBPs in source water (Slide 20) were described.

The ICR supplemental survey was initiated by EPA. Samples will be used to determine precursor information. Only samples of *Cryptosporidium* and indicators will be collected initially. Giardia data will not be collected until later due to method problems. The collection effort will go into the year 2000. Stig Regli added that [we] should have good insight into the occurrence of these parameters by this time (Slide 21).

The Ground Water Supply Survey data were collected in the 1980s. The focus was on the volatile organic carbons (VOCs), and as a result, information on TOC and trihalomethanes (THMs) (Slide 22) was obtained. A compilation of the Ground Water Supply Survey data from systems with greater than and less than 10,000 persons was used to estimate the TOC in GW systems. This simplifies the analysis of what can be done for large and small systems (Slide 23). The Water Community System Survey is more recent and gives a tabulation of treatment characteristics. It covers all different types of systems (Slide 24). The AWWA Disinfection Survey data are currently being analyzed. More than 2,000 systems recorded disinfection data on the frequency and amount of disinfectant that were used (Slide 25). The AWWA Water Industry Database (Water/Stats) statistics were used during the Stage 1 rule development (water quality and treatment information) (Slide 26). The AWWARF Bromide Survey represents the bromine (Br) concentration in surface water and groundwater from 100 utilities (Slide 27).

The Unregulated Contaminant Information System is EPA's effort to get more data on the occurrence of unregulated contaminants which may be regulated in the future. The problem with this database is that the samples were taken at the point of entry and people were not consistent with where the samples were taken. Further analyses will have to be done to get the true results (Slide 28) and fundamental assumptions will have to be made when the analyses are done.

Questions/Answers:

Q: ICR supplemental survey, how will systems be chosen?
A: Random selection of possibilities, followed by phone interviews to determine willingness to participate.

Q: Based on the goal of the regulations ... What will you do?
A: More occurrence information is available. [We] will be able to see the national distribution of the pathogens from the information that we have. [We] will not be able to determine actual count. Research information and occurrence information will result in better impact analysis.

- **Take home message for ICR: Examine the information that was presented and determine whether we are asking the right questions or should we ask other questions. These questions will be used for rule-making process. The Federal Advisory Committee will provide guidance on how the information will be analyzed and interpreted.**

Microbial Pathogens: Measurement of Pathogens and Indicators

Project 488: Source Water Assessment: Variability of Pathogen Concentrations - Mark LeChevallier (American Water Works Service Company, Inc.) [Attachment 6]

Background on AWWA's Project 488 was provided. It was funded last year, and is scheduled to begin in the Fall. Indicator monitoring will be done in the lab. Statistical consideration for the study is a big part of the project. A number of utilities have been contacted to do the analyses (Slides 1-2).

Microbial, physical, chemical, and meteorological data were collected in the New Jersey Department of Environmental Protection (NJDEP) study (published in J. AWWA) (Slide 3).

The first part of the two part study included 10 minute turbidity measurements were collected (light blue on the graph). Levels of Giardia and Cryptosporidium were found to be affected by meteorological events that may wash them into the watersheds. Turbidity and flow can be used to predict what may happen in other watersheds (monthly and daily samples were collected). The second part of the study is a statistical approach. Le Chevallier also discussed the bottom line of the study (Slide 4). How does one sample when the volume that is sampled is more important than analytical method used?

The current project (AWWARF 385) can be broken into 3 phases. These phases were discussed (Slide 5). The analytical method performance has a negligible impact once the average recovery reaches 40 percent; recovery of >40 percent is not statistically significant. How you sample and where you sample is more important (Slide 6). Le Chevallier discussed Phase 1-3 of the study. Phase 1 has already been done and 6 categories were created based on hypothetical data; it may be used to develop a different sampling program. Phase 2 of the study is currently in progress (Slide 7).

All of the data were analyzed, and resulted in 12 sites. The data were sorted based on coliform numbers. One may compare reservoirs with high coliform counts and with low coliform counts and determine that different things are occurring at the watersheds (Slide 8-9). This gives a good characterization of candidate sites (Slide 10). The participants from different groups and agencies were given the data and were asked to review characterization data, select participating sites, and review the sampling approach (Slide 11, Slide 12). The criterion used to select sites for the study (Slide 13) were described.

A schematic showing the distribution of a watershed among different planes in a cube--blue planes are rivers, and the red planes are the reservoirs, was presented (Slide 14). Mark Le Chevallier interpreted the graph and added that sites will be chosen which will give a variety of information.

The sample collection plan was discussed. The question was raised if turbidity is an indication of variability of the watershed, how accurately will the sampling plan capture the variability of the watershed? Random sampling will be done every Monday (sample will be collected, and data will be analyzed). There is a lesser degree of error than with time series of sampling. Time series sampling is based on the turbidity levels (Slide 15). Analysis methods that will be used (Slide 16) were discussed.

Two analytical methods for protozoa, Method 1622 and cell culture polymerase chain reaction (CC-PCR), were compared. Immuno-magnetic separation (IMS), involves splitting the sample using magnetic beads (Slide 17). Spike samples will be split between two labs. Le Chevallier discussed the QA/QC measures that will be taken (Slide 18). Sources analyzed are in the same range as the Ohio River (Slide 19). Grand River is located in Canada; they have many monitoring stations at this site. All analytical methods will be done at one point. This model is exploratory, Le Chevallier added that [we] could take the data and apply it to a model (Slide 20).

The schedule for the study is based upon the availability of the data. Six different sites will be used to compare Method 1622 and CC-PCR (Slide 21). Comparison methods used for Cryptosporidium analysis (Slide 22-23) will also be provided.

Questions/Answers:

Q: Will the subculture PCR method be used to measure Giardia?
A: No, only to measure Cryptosporidium.

All analyses try to predict the occurrence of the Cryptosporidium versus the density of the Cryptosporidium.

General Overview of Current Science, Current and Future Research and Schedules for Completion - Mark Sobsey (University of North Carolina at Chapel Hill) [No Handouts]

Mark Sobsey began the presentation by noting that people have been detecting pathogens in water for a long time (Slide 2). There are classes or categories of microorganisms which make up the microbial world. This presentation focused on Cryptosporidium and viruses (Slide 3).

Pathogen analysis, monitoring, and surveillance (Slide 4) were discussed. The detection of pathogenic microbes in water (Slide 5) involves three steps; 1) recovery and concentration; 2) purification and separation and; 3) assay and characterization.

Previous, current, and in-progress Cryptosporidium analytical studies were described. Over 26 projects are being done or were done-- in excess of 7 million dollars. A huge investment is being made to look at Cryptosporidium (Slide 6). The status of research progress on methods to detect, quantify, and characterize Cryptosporidium and viruses in water were summarized (Slide 7). The estimated costs of detecting Cryptosporidium, and enteric viruses in water were also presented. The detection methods to detect Cryptosporidium and enteric viruses are expensive (Slide 8).

Mark Sobsey described the ICR Supplemental Survey method for Cryptosporidium (1622 was not used in ICR) in detail (Slides 9-11). There was a recovery of -100 seeded *C. parvum* oocysts from 10-L volumes of regent water and raw water using Method 1622 in the interlaboratory validation study (Slides 12-13). There was a recovery of -100 seeded *C. parvum* oocysts from 10-L volumes of regent water by Method 1622 during third party testing (by the Sobsey lab). The results of the third party testing were lower than what was seen for interlaboratory validation study (Slide 14). The results of the study were presented and the means and standard deviations that were seen were also discussed. The assessment of Cryptosporidium Method 1622 was provided. The criteria that EPA has proposed for methods are high -- no current methods can meet them (Slide 15).

An alternative method for the initial recovery and concentration of Cryptosporidium from water using centrifugation was discussed. This method would result in the recovery of Cryptosporidium in a small volume of aqueous solution from a "large" initial volume of water (Slide 16).

A picture/schematic diagram of filters used to recover and concentrate microbes from water and different filters that can be used were presented (Slide 17).

The filtration methods for the initial concentration and recovery of Cryptosporidium with several different filters are being evaluated in various studies (Slide 18). Membrane filters are being tested for the recovery of Cryptosporidium, viruses, and indicators. EPA has also approved methods for *C. perfringens* (Slide 19). Virus filtration by adsorption was discussed; electropositive filters are now being used, while other filters are being researched (Slide 20). Virus elution from adsorbent filters with alkaline buffer solutions was discussed, as well as what is used to elute the viruses (Slide 21). The absolute filtration (ultrafiltration) of viruses is widely used in Australia (Slide 22). Sobsey presented the initial recovery and concentration of pathogens from water by chemical precipitation methods. Polyethylene glycol (PEG) precipitation is currently being evaluated (Slide 23).

Separation and purification methods were also discussed (Slide 25). Immunomagnetic Separation (IMS) (immuno-capture or antibody capture) was described. It was noted that research is currently being done

on these methods (Slide 26). Other pathogen recovery, isolation, and concentration methods were also mentioned (Slide 27).

Assay methods for waterborne pathogens and culturing waterborne microbes were presented (Slides 28-29). Microbial assays have been used historically for Cryptosporidium. A linear regression of dose-response data for cell culture infectivity of untreated control Cryptosporidium oocysts was presented graphically (Slide 33). A 5 mg/L dose of mixed oxidants and a 6.1 mg/L dose of free chlorine and mixed oxidants may be used to inactivate Cryptosporidium (Slide 34).

The detection of viral pathogens by cell culture was examined (Slide 35). Cells look different when they are infected with a virus. However, viruses are not always detected this way (Slide 36-37). The detection of hepatitis A virus in cell culture was done by radioimmunoassay. Cells may look normal. However with radioactive assay one can see which cells are infected (Slide 38).

Other viruses are not detected in cell culture. These include some enteroviruses, caliciviruses, parvoviruses, coronaviruss, picobirnaviruses and hepatitis E virus (Slide 39). Combined cell culture and nucleic acid detection and amplification of waterborne viruses is more costly than cell culture or PCR alone, but this can be used to detect non-cytopathogenic, infectious viruses (Slides 40-41). Detection of waterborne pathogens by viability or activity assays was discussed. This assay does not work for viruses (Slide 42). Viability or activity assays for Cryptosporidium oocysts were presented. Viability staining is poorly associated with infectivity (Slide 43). A picture of stained Cryptosporidium parvum oocysts was shown. Blue are viable, red are not viable (Slide 44).

Detecting active or viable pathogens using nucleic acid targets was examined (Slide 45). Mark Sobsey discussed PCR and RT-PCR in detail (Slide 48). RT-PCR and oligoprobes can be used to detect enteroviruses concentrated from water. An example of how the results may look was provided (Slide 49). The microbial detection of Cryptosporidium in water was presented (Slide 51). A microscopic analysis of Cryptosporidium oocysts after immunofluorescent staining was shown (Slide 52) .

Cryptosporidium detection by biochemical methods is currently being investigated; Sobsey noted that it might work, but it is tricky (Slide 53). A microscope picture of Cryptosporidium parvum oocysts was shown (Slide 54).

The detection of microbial indicators of fecal contamination of water (Slide 55) is an alternative or additional approach to the detection of pathogens in water. Some current and candidate bacterial indicators of fecal contamination of water and wastes were described. There is research on new alternative bacterial indicators currently being done (Slide 57). The new methods for total coliform and E. coli analysis include those listed in Fed. Reg., Vol. 64, No. 9, 01/14/99 (Slide 58). DNA fingerprinting and other methods can be used to characterize indicator bacteria for source identification (Slide 59). In regard to candidate viral indicators of fecal contamination of water, the most attention is given to coliphages (male specific) (Slide 60). Male-specific and somatic coliphage hosts and phages were described. Both of these can be detected with simple, rapid methods such as the single agar layer plaque assay (Slide 61). Microbial indicators of fecal contamination relevant to Cryptosporidium and enteric viruses include the male-specific and somatic coliphages and *Clostridium perfringens* spores (Slide 62). Bar graphs of microbial indicator levels in raw and treated municipal sewage and effects of sewage treatment (Slide 63) and microbial indicators and turbidity at drinking water intakes and low vulnerability watersheds were presented. Sobsey added that one can get useful information by measuring microbial indicators (Slide 64).

Is there a role for microbial indicators of fecal contamination to determine source water quality and treatment requirements? Efforts should be focused on indicators and specific pathogens. It was noted that all microbial pathogens of public health concern will not be reliably, rapidly, and economically detected and quantified in source waters in the near future (Slide 65).

Questions/Answers:

Q: Can you repeat Microbial Indicator Levels slide information?
A: Raw sewage have high levels of bacterial indicators (male coliphages, E. coli, enteric viruses). Treated sewage have much lower levels. *C. perfringens* and male coliphages have higher concentrations in treated sewage effluents than in the raw water, therefore one wants to test for them in the receiving waters. Look beyond usual indicator and look at others.

Q: Have reagent water analyses been done for 1622 methods in your lab?
A: Yes.

Q: Did you use the meridian stain?
A: No, used the waterborne stain. We used whatever method EPA specifies. Unspiked waters are being used simultaneously for background levels.

Q: How will oocysts be diluted?
A: Was not clear in 1622 methods.

Cryptosporidium Viability and Infectivity Research - Ricardo DeLeon (Metropolitan Water District of Southern California) **[No Handouts]**

Richard DeLeon continued from where Mark Sobsey left off. He began the presentation by addressing the status of a contaminating organism. Questions about organisms that were isolated are being studied, and infectivity is becoming an issue.

A diagram of a Cryptosporidium oocyst was presented. Method 1622 stains the nuclei and looks at the surface and the body of the oocyst. DeLeon raised the question: Can the sporozoites come out of the surface membrane and infect? In order to examine this, the life cycle of Cryptosporidium was described. This cycle occurs in humans and animals, but it is a little different in cell culture.

On the horizon of viability and infectivity research are molecular methods. Speciation and sub-speciation tools will be talked about. In regard to the specificity of PCR primers, the specificity of primers and probes, and the specificity of detection of *C. parvum*--this amplification is from the primers. Molecular characterization or fingerprinting is needed to determine the source of an organism. This may be used to determine if Cryptosporidium came from just humans or humans and other animals.

The number of Cryptosporidium and Giardia DNA sequences in the database has increased dramatically since 1996. The type of method used to purify DNA will result in the different bands produced in Cryptosporidium RAPD profiles. What some people did not realize was that DNA sequences are not peer reviewed, and therefore method/typographical errors are common. Conclusions are often based on non-verified information in the database which aren't correct; inferences can be made based on a typographical error.

Other alternatives to the random banding include PCR-RFLP. Using PCR-RFLP, two different labs should get the same banding pattern profiles of *C. parvum*. If the banding patterns are different, then the method used needs to be changed. However, the banding pattern was found to be the same across different countries.

Polymorphic markers may be used to differentiate *C. parvum* in humans and in animals. It was concluded that there are several markers that are available to look at Cryptosporidium.

In terms of viability surrogates, it is not necessary to measure the viability of cells. Wall permeability may be measured instead because the dye will enter an oocyst under some conditions. Isolates come from

different suppliers, therefore oocysts may not be infective because of the detection method used or the supplier.

Why is it necessary to determine infectivity of waterborne Cryptosporidium? De Leon gave a historical perspective--several studies have been done with human volunteers to determine infectivity of *C. parvum,* different isolates resulted in different rates of infectivity.

Two animal models have been used to do Cryptosporidium infectivity assays. Other animal models are being developed by the University of Ohio using pigs. Cryptosporidium infectivity has been studied in in vitro cell culture because is not practical to run human studies, and animal studies are very expensive. Practical methods are in vitro and several cell lines are being currently being used. There are four selected cell lines which are being focused on for the in vitro studies.

Several methods are being used for in vitro cell culture infectivity. The procedure used to do in vitro testing was described by Richard DeLeon.

A slide which showed cell infection using the colorimetic method was presented; initial infection, then reproduction, and the resulting multiple infections in the same location. DeLeon noted that the advantages of the colorimetic method is that one doesn't have to use an electron microscope.

There is a concern of formally fixing oocysts on the plate--one needs a sensitive negative control for the detection of infectious *C. parvum* oocysts. This is being used to determine the current state of treatment inactivation.

Method 1622, detection of infectious *C. parvum* by RT-PCR, and IMS/1622 purification were discussed. The purification of oocysts improves infectivity, it can enhance infectivity. The advantages of using nucleic acid techniques compared to antibody-based methods were discussed.

The Cryptosporidium parvum life-cycle diagram was presented. Future Biotechnology Techniques were also examined; DeLeon noted that one method can be done at room temperature and one doesn't need to use salt.

Questions/Answers:

Q: How reassured should we be when we find that oocysts are not viable? How important is infectivity?
A: (After treatment) oocyst exposed to ozone, look the same; however, they are dead after treatment. Can only have treatment that removes 100 percent of oocysts....membrane treatment. Not starting with 100 percent infected oocysts. May even have oocysts that cannot infect humans, doesn't make sense to overtreat the water in those cases.

Comment: some organisms that don't fit in paradigm of genotype 1 and 2 that are organisms of concern.

Q: Does Cryptosporidium need a host to reproduce?
A: Yes

Q: What is general magnitude of environmental oocysts that are infective?
A: Will change according to conditions. Over time infectivity drops (in oocysts).

THURSDAY MARCH 11, 1999

Microbial Pathogens: Treatment Research

Physical Removal

Removal of Microbial Pathogens and Indicators by Conventional Treatment - Eva C. Nieminski (Utah Department of Environmental Quality) [Attachment 7]

Eva Nieminski commented that there is currently too much contradictory information concerning microbial pathogens. She raised the question: How much can we remove Cryptosporidium surrogates? AWWAARF 437 deals with answering this question. Quality assurance details behind the existing information will be presented, which will give more critical information. A model will be developed to provide more information; this model will be ready shortly.

What are we removing? How many contaminants are in natural waters? A study was done that used 25 sites (very carefully selected to represent different geographical regions, different types of treatment, different types of water sources). The project lasted one year. Some sources had over 95th percentile populations of Giardia. Cryptosporidium and Giardia are difficult to find, therefore they are difficult to remove. Aerobic (AER) spores are attractive because in the spore form they are very resistant to disinfection, especially Bacillus (which is found in soil and everywhere else). Anaerobic spores (waste water type organism) are not commonly present in source waters (e.g. *Clostridium perfringens* are typical anaerobic spores). Different types of coliforms are present in high concentrations in the sources (Slide 2).

Coliphage (male specific) are the accepted surrogate for viruses. It is more difficult to remove viruses from sources because they are not found in high numbers (Slide 3). Conventional treatment can remove 2 .5 log of Giardia and 2 log of Cryptosporidium. Removal is limited by the number found in source water; there is a sensitivity of detection limit. The best way to do removal is to seed in the intake pipe. A pilot scale project will be used to determine efficacy of this approach (Slide 4).

Results of pilot studies done by EPA 5 years ago are available. Important information has been found such as the removal of Cryptosporidium is .5 log less than the removal of Giardia; the difference between low and high removal is 2 log. Removal depends on how the plant is working (treatment optimization). Eva Nieminski added that too much importance should not be placed on the log removal scale (Slide 5).

The estimation of the initial concentration of cysts was explained. Many studies that show pilot removal are based on initial concentration come from seeding removal vs. the receiving waters. The detection limit varies from analyst to analyst and from analytical method to analytical method. Normally enough cysts are spiked into the influent to determine removal efficiency. To adjust for recovering efficiency, the amount that was spiked will have to double. The loss between the amount of Cryptosporidium seeded and the amount in the effluent determines the true log removal at the endpoint of the experiment (i.e. over estimation of removal) (Slide 6).

It is important that the effluent concentration is the concentration of the cysts after introduction into the water. Cysts must be spiked high enough to allow detection on the other end, or else the experiment is not valid. Nieminski added that one should assume the same recovery in raw and treated water instead of being conservative (Slide 7).

There are problems with calculating removal because there are not enough cysts so surrogates are used instead. However, when surrogates are used, there are limitations (Slide 8).

An ideal surrogate should be ubiquitous and at a detectable level. Additionally, an ideal surrogate should be able to predict a local, and maybe national, average (Slide 9). Examples of surrogates that are currently used (Slide 10), surrogates that can be used for detection of Cryptosporidium (Slide 11), and different types of spores that are measured at different times were presented. An example of frequency would be medium concentration found at least 50 times; low concentration found at less times. This says that concentration are relatively high (Slide 12).

A graph was presented to show that there is no relation between number of aerobic spores and the number of Giardia and Cryptosporidium (Slide 13). Another graph illustrated that there is no relation

between turbidity and aerobic bacillus spores (Slide 14). The correlation between raw water particles and spores is low (Slide 15).

There are three types of water; clean, not so clean, and dirty. A bar graph was used to examine raw water protozoa and turbidity. The vertical lines are the 95th and 25th percentile of the population (Slide 16). The light bars are detection limits--cannot detect most bacteria at more than 100 ml. At this limit one sees mostly aerobic spores. Cryptosporidium and Giardia are mostly undetectable in filtered water (Slide 17). A graph was presented to depict the indicators of removal. A wider band means bigger removal ability (band between detection limit and source water concentration) (Slide 18). The difference between low and high is 1.5 to 2 logs. The distribution is based on the detection limit. More than 2 log removal implementation for Giardia and Cryptosporidium cannot be documented. Another graph was used to show Giardia in raw and filtered water. There is a wider range of working with spores because a log 4 removal is in place. The Y-axis title is 1000 L, not 100 L (Slide 19). There is a 2 log difference between filtered Cryptosporidium and Giardia vs. raw Cryptosporidium and Giardia, and a 4 log difference between filtered water spores and raw water spores (Slides 20-21).

Log removal vs. detection limits was graphed. The upper curve is Giardia and the lower curve is Cryptosporidium (Slide 22). Graphs were used to show that there is no relationship between spore and cyst removal (Slide 23) nor between spore removal and turbidity (Slide 24). Removal is based on detection limit for Giardia and Cryptosporidium (Slide 25).

The effectiveness of different types of treatments was discussed. The numbers on the table that are shaded belong in the same range of removal; there was no significant difference found (Slide 26). The differences between different oxidants are not great. The longer the Ct, the higher the removal (Slide 27). Nieminski commented that the dirtier the water, the more removal we can show (Slide 28).

Primary removal can be attributed to filtration (Slide 29), less removal due to coagulation. With disinfection, removal of heterotrophic plate count (HPC) is considerable. For others, removal is not significant, and it is limited to physical removal. Ozonation doesn't really work; aerobic spores do not grow in filters of plants using ozonation (Slides 30-31). Aerobic spores could be used as indicators for measuring plant performance (Slide 32). For a low concentration spores can be used as presence/absence to determine a plant's effectiveness. They are good in studies because they are easy to handle, and inexpensive to analyze (Slide 33).

Questions/Answers

Q: Current laws -- removal and inactivation -- can you distinguish between the two?
A: Inactivation is oxidation of the contaminant -- cannot distinguish because it is a combination of the two -- if there is any oxidation in place it is a combination of the two -- if you have chlorination with out mechanical removal then you have inactivation.

Q: Surrogate wish list -- can it represent organisms in size in terms of weight for velocity for settling?
A: Yes, majority of removal is through filtration, it is a factor that must be considered.

Q: Was this presented before? How many studies were used in the beginning?
A: 25 sites were used -- study presented in different stages.

Q: For these study sites, were seeding of spores done?
A: No

Q: Have synthetic surrogates been considered for evaluation of a plant?
A: Yes, problem can be done in pilot scale, but cannot be done in real life.

Q: Was enumeration done with the 1622 method?
A: No, it was the ICR method. With the 1622 method -- can get more of a range, but the ICR method was used at full limit for this study.

Q:What was the range used for this method?
A: 40 to 45 percent

Research on Removal of Cryptosporidium and Indicators in a Conventional Water Treatment Pilot Plant - Kim Fox (EPA) [Attachment 8]

Kim Fox presented a study that is going on in-house at EPA. Most times Cryptosporidium is not found in raw waters because it is present at such low levels. In the study, a flow rate of 450 ml per minute was used so that Cryptosporidium could be spiked for a long time--which resulted in getting actual measurements throughout the treatment process.

Surrogates were looked at because they are easy to monitor. None of the surrogates are good direct surrogates for Cryptosporidium. There is a need to look for surrogates for treatment efficiency. If the surrogates for Cryptosporidium are present and removed, then the likelihood of removing Cryptosporidium is great (Slide 2).

The Office of Research and Development does the following: develops log credit removal guidance; suggests filter operating criteria; suggests controlling parameters and plant operational practices; and proposes surrogates for monitoring treatment efficiency (Slide 3).

A low flow pilot plant was used in the study. The feed water had to have a 10^6 concentration in order to follow Cryptosporidium through the plant to observe changes. Cryptosporidium was not inactivated--parvum was used (which infects humans) (Slide 4).

The steps taken in the study were presented. The plant was operating with drastically changing waters. The slide also depicted a treatment plant (for surface water) (Slide 5). Kim Fox described the specifications of the low flow plant. The plant is small, but it simulates larger pilot plans. There are problems that occur when you miniaturize plant, therefore the study was paralleled with other pilot studies (larger ones) to determine its effectiveness (Slide 6). The numbers seen showed that the smaller plant was mimicking a larger one (Slide 8). Other techniques are being evaluated to reduce the volume of sample which is needed (Slide 7). It is easier to detect Cryptosporidium with a large sample volume than for analysts to deal with a lower concentration (Slide 10).

Fox added that the researchers are trying to control for QA; the numbers for the average recovery are considered to be preliminary numbers (Slide 11). They are also trying to emulate slug dosing. There is an inherent problem--it is difficult to follow slug in a treatment plant, therefore continuous dosing was done instead (Slide 12). The total particle count (TPC) is a parameter of concern. It is easy to operate a pilot plant to remove something to the n^{th} degree--the challenge is to operate a pilot plant like a real plant. As a result, the system was challenged in a different way. The water was not treated very well intentionally, and at other times the water was over-treated, and the parameters were measured in all occurrences. This was done to emulate how raw water changes (Slide 13). High levels of oocysts were handled, therefore there was a 93 percent level of recovery. Fox [and the other researchers] was confident that a good analytical job was done.

The levels of Cryptosporidium were measured at every point in the plant (Slide 16). The researchers looked at what happened at different times of the treatment; at raw to settled (no filtration yet) there was less than 1 NTU, which resulted in over dosing; at 1- 4 NTU was optimal; more than 4 NTU was not being treated properly. A graph of oocyst removal vs. raw water quality and treatment (raw to settled) was presented. 1 log removal was achieved (Slide 18-19). Filters account for the bulk of removal. From settled

water to filters, there is a 4 log removal of Cryptosporidium for waters with an original turbidity of 10-50 NTU (Slide 19).

The relationship between surrogate to spore removal was discussed and Fox commented that [we] need to get away from oocyst vs. particle removal/count removal. The log removal of surrogates for turbidity 10 percent of time results in a 2.2 log reduction of turbidity that is greater than the removal of Cryptosporidium. The r^2 will be poor because there is not a direct correlation. This data is currently being looked at (Slide 22).

Future work was also discussed. All of the parameters are ones that people use at the water treatment plant, so the researchers are looking at what happens when these are adjusted (Slide 29).

Questions/Answers:

Q: In the 3D graph -- low turbidity resulted in a dramatic removal of Cryptosporidium when the water was over treated to below 1 NTU -- is that a trend?
A: All of the data points may not be over treatment. Over treatment does not always give the best removal. One does see a difference in effective removal in optimal treatment vs. over treatment -- however not always the case.

Q: How were the pilot plants simulated, was temperature considered?
A: Huge span of time was used to get the data. Temperature was a significant part. We are looking at chilling water to see the results.

Q: Was particle removal done?
A: Yes. Total particle count was looked at.

Q: Did you respike after the clarifier?
A: No, everything was in the raw water coming in.

Q: Was the settled water turbidity a result of settling?
A: Yes

Q: Coagulation conditions -- how was it defined, was pH control involved in coagulation?
A: pH change was not evaluated in this program, and it was not controlled for in the program.

Q: Isn't the down scaling of a settlement basin difficult?
A: Yes

Q: Was short circuiting test done?
A: Yes

Cryptosporidium Physical Removal in Pilot and Full-Scale Plants - Dave Cornwell (Environmental Engineering and Technology) [Attachment 9]

This study was a compilation of several pilot plants. Dave Cornwell added that almost everything presented has been published and peer reviewed. Four studies were run simultaneously, all treating between 2-35 gallons of water/minute (Slide 2). Low turbidity raw water was used, slug dosing was not done, and there was a continuous feeding of Cryptosporidium (Slide 4).

In a test to compare sub-optimal vs. optimal coagulation, pH was held at a steady state. The results of the test were presented graphically (Slide 5). Optimal pH for this plant was found to be 6.2--no significant effects occurred with pH changes (Slide 6).

Almost the same removal was achieved across the board when mixing velocity was changed (Slide 7). There is little difference between optimal treatment and change in flocculation (Slide 8) or for Cryptosporidium removal between mixed media and granular activated carbon (GAC) (Slide 9).

There are some pilot plants that do 5 log removal of Cryptosporidium. There was a study that had good Cryptosporidium removal when the cysts were added pre-coagulation (Slide 10).

Bench scale jar tests pump water through .5 filter in order to see what happens in the filter, the slopes are about 1 to 1. Bench scales can do direct measurement--perhaps this can be done in the future (Slide 13). What happens when cyst loading goes up (Slide 14)? The log removal remains the same (Slide 15). The log removal is also the same with different media (Slide 16). What do the numbers mean? The log removal process was done regardless of the number of oocyts going in, there was still log removal (Slide 17); up to 4 log removal was seen (Slide 18).

Two types of flocculation were looked at. How well does the change in the surrogate effect change in data? The plant does better with tapered flocculation vs. constant flocculation. A pH lowered to 5 with a low particle count resulted in 4 log removal of Cryptosporidium (Slide 20). Log removal of Cryptosporidium did not change with change in alum and particle count. Removal is not predicted by particle count (Slide 21). Particle counters do not pick up cysts (Slide 22).

Log turbidity is affected slightly by initial turbidity levels (Slide 23). There was a one to one removal of Giardia and Cryptosporidium (Slide 24, Slide 26). There is no linear correlation between log removal of particles and log removal of Cryptosporidium (Slide 27).

One hundred water treatment plants were used for a national database of surrogates. All of the tests were done using the same the instruments and analysts (Slide 28). Settling tanks were found to remove 1 log of Cryptosporidium; filters remove 3 log of Cryptosporidium; sediment tanks remove 90 percent of cysts; filters remove 10 percent of cysts. Therefore, sediment tanks were found to be the best for removing oocysts (Slide 29).

The trend seen was as particle count gets higher in raw water, Cryptosporidium gets higher--but this trend was not statistically significant. What happens to filtered water from these plants? This information was taken out (Slide 30). Higher raw water turbidity show higher Cryptosporidium levels trend (Slide 31). There was no difference in Cryptosporidium levels for plants that had different levels of filtered particle count (Slide 33). There was a good correlation between log removal of Cryptosporidium and Giardia (Slide 34). Dave Cornwell concluded with the question: Is the removal of spores and Cryptosporidium correlated? Based on the results of this study, Cornwell answered no (Slides 36-37).

Questions/Answers:

Comment: Problems will occur when oocysts concentration in raw water gets very high -- however, plants are pretty forgiving.

Q: Regarding particle count, did you look at specific size ranges?
A: Yes, did not see anything. For this data base no particle size were above 10.

Q: What was the turbidity for these studies?
A: 2-3 NTU.

Q: Did you adjust for the changes made in the studies?
A: Yes

Q: Impact of mixing for coagulation -- was that the equivalent for chloride removal?
A: Yes

Inactivation

Inactivation of Microbial Pathogens in Water Treatment - Gordon R. Finch (University of Alberta, Canada) [Attachment 10]

An overview of the presentation was given by Gordon Finch. The point was emphasized that disinfection is not the same as sterilization. The terms *removal* and *inactivation* were defined (Slide 6). Log removal was also discussed. For 100,000 organisms, 1 log means that 90 percent are removed. Log units are measures of large numbers. Bacteria and viruses occur in large numbers, but parasites don't occur in large numbers. Therefore log numbers cannot be used for expressing removal of parasites.

A graph of the relative scale of equipment complexity vs. relative biocidal effectiveness was presented. Chlorination is a simple water treatment method (Slide 8). The terms *breakpoint* and *biocidal* were defined. Monochlorine methods were discussed (Slide 10). The electrolysis and chemistry of brine solutions as well as the methods of electrolysis were also discussed (Slide 11).

Giardia is everywhere--large numbers are not needed to result in adverse health effects (Slide 25).

The effects of disinfection on enteric bacteria and landmark work which was done in the 1940s for E. coli were discussed (Slide 27). Cryptosporidium is a big problem to the current disinfection technology (Slide 35). There is no actual strain, so where do test parasites come from? Bacteria produce enzymes that destroy the parasites, therefore stored test parasites are important. The *viability* definition of parasites was discussed. The term *parasites* was also defined (Slide 36).

Finch emphasized that there is a strong need for a secondary reference (Slide 38). He illustrated that a long Ct for chlorine is needed to get any kill (Slide 39). It was added that the effectiveness of chlorine dioxide is determined by temperature--not necessarily by Ct (Slide 41). Huge assumptions have to be made to get this assay (Slide 42).

Cold water is problematic when using chlorine dioxide (Slide 43). Research on oxidants from the electrolysis of brine solutions is a work in progress. Finch noted that there are limitations to what we know (Slide 44). Ozone and temperature are not a linear Ct problem (Slide 47). Cryptosporidium is the most difficult to kill (Slide 48).

Worldwide data were consolidated on ozone disinfection in the International Ozone Project (Slide 49). The problem with the data was the definition of the Ct value from study to study. All data of the Ct plot were discussed, either it didn't work or it gave a really good kill. For Cryptosporidium, a 9-fold difference in kill was seen for the same temperature in different studies (Slide 51). Gordon Finch raised the question: Which data are comparable? Selected data were discussed. With this analysis, effect of temperature on the chemicals' effectiveness was seen--a model was needed to show these effects (Slide 50). A model that includes temperature, Ct, and disappearance of disinfectant would be a good model for Cryptosporidium. With the data, one can almost produce a proposed model for ozone (Slide 53).

The results of mixtures for killing Cryptosporidium were shown. The amount of synergy from free Cl_2 is problematic- it is all over the place; this is not understood (Slide 58). Good synergy is seen here, but the mechanism is not understood (Slide 59).

Disinfection barriers and an integrated disinfection design framework were discussed (not included in handouts). The simple Ct concept may have overestimated and underestimated the design (Slide 64).

Some kinetic models were presented and Finch added that the calculations account for shoulders and tails of survival curves (Slide 66). A slide on how to present design data was discussed. Finch concluded that calculating temperature, amounts of disinfection levels, and Ct are needed for killing Cryptosporidium using different disinfectants (Slides 71-72).

Questions/Answers:

Q: Residual -- was it residual chlorine or ozone in the spreadsheet?
A: It was the starting point concentration.

Q: Your definition of Ct was reasonable, must you always calculate the Ct or can you just use the last residual seen in the system?
A: Must always calculate Ct. With ozone or chlorine dioxide, it is a big mistake to use the final residual especially for waters that use up a lot of oxidants.

Comment: problem with consolidating data from different studies is that not all studies used the same measurements.

Q: Regarding the quality of the water does it have an effect on disinfection -- or did the location of the disinfectant in the disinfection process (on a global level) made a difference?
A: Chlorine and monochloramine stay around for a long time; chlorine dioxide is similar to chlorine; ozone is dependent on the water quality -- it may disappear or it may not -- it is more susceptible to location; UV - turbidity will adversely affect it; mixed oxidants (where there is more free chlorine) is similar to free chlorine.

Research on Inactivation of Cryptosporidium Using Single and Multiple Disinfectants - Benito Marinas (University of Illinois at Urbana-Champaign) [No Handouts]

Benito Marinas' presentation focused on the results of research being done at the University of Illinois. He noted that some of the work is in progress. Not all of the data will be discussed in this presentation because some of the data are in the process of being published (Slide 2).

Viability assessment is considered to be the Achilles tendon of this process-- discrepancies were encountered between different types of viability assessments, so Ct counts are not available. In vitro and animal infectivity did not work as anticipated. A new method was developed that is effective, with a log removal up to 3 (Slide 3).

Inactivation kinetics and exposure variables were discussed (not included in handout). A figure was presented that showed the inactivation kinetics of C. parvum with free chlorine (Slide 4). Hypochlorite ion does not inactivate Cryptosporidium. The research includes a family of data sets; at a higher temperature there are faster kinetics; at lower temperatures there are slower kinetics--this data is their baseline. A lower temperature decreases the slope (the effect of the disinfectant) and increases the shoulder (where the disinfectant is ineffective).

A figure (not included in handout) was presented to illustrate the inactivation of the Iowa strain C. parvum oocysts with monochlorine. There is a significant shoulder--more than half of disinfectant was not doing anything.

Marinas added that pH did not affect the activity of ozone. Ozone is more powerful than monochlorine for killing Cryptosporidium. A very high demand of ozone is needed to get a 3 log removal of Cryptosporidium. However, ozone has a very small shoulder compared to weaker disinfectants (Slide 5).

A figure (not included in handout) showed the effect of the temperature on the kinetics of different disinfectants. Marinas added that all of the disinfectants have a similar mechanism.

Primary inactivation with ozone was discussed. A shoulder was seen (2 log removal is 99 percent of the inactivation range). To inactivate by 1 log, a Ct count of 0 to 1 is needed. Inactivation with ozone for different Ct values was discussed in order to determine the level of Ct needed for inactivation. Once that point is reached, secondary disinfection should be used (Slide 6).

Sequential inactivation with ozone and HOCl was discussed (not included in the handout). Primary disinfection was done with ozone and secondary disinfection was done with HOCl. A reduced shoulder for ozone results in a reduced shoulder for HOCl. If there is a shoulder with the primary disinfectant, then there is no shoulder with the secondary disinfectant. Sequential effect is not synergistic. At few hundred Ct at 1 log removal was achieved with secondary disinfection.

Sequential inactivation with ozone and Chloramine NH_2Cl discussed (not included in handout). Ozone eliminates the shoulder-- there is a 300 percent improvement with the slope. Chloramine picks up where ozone leaves off.

Benito Marinas concluded with the practical application of the results; if just ozone is used, a Ct of 5.2 is needed to get a log 2 inactivation. An analysis with free chlorine was also done. With a pH of 6, chlorine is more effective than monochlorine, but at a higher pH, monochlorine is more effective. Ozone used at the beginning reduces the shoulder, which results in a synergistic effect (Slide 8).

Question/Answers:

Q: Is the shoulder analogous with chlorine or ozone demand?
A: Absolutely not -- Don't understand the mechanism.

Q: Have the same work been done with chlorine dioxide showing sequential effects?
A: Yes.

Q: As pH goes up -- does not affect inactivation of ozone, but does pH affect the formation of hydroxy radicles?
A: Yes, there should be a difference in radical formation.

Q: When were assays done after the experiment?
A: At different time frames.

Ultraviolet (UV) Inactivation of Microorganisms - Karl Linden (University of North Carolina at Charlotte) [Attachment 11]

Karl Linden provided an overview of the presentation. The pathogens of concern include *Cryptosporidium parvum, Giardia lamblia, Cyclospora, E. coli* 0157:H7, coxsackie virus, adenovirus, and the Norwalk virus (Slide 3). Waterborne outbreaks which occurred in the U.S. between 1989 and 1994 and in the summer of 1989 were presented (Slides 4-5). Pictures of *Cryptosporidium parvum* oocysts and *Escherichia coli* cells were presented. The effect of UV radiation on DNA was described. Photons of energy are absorbed by the DNA of the microorganism--this prevents the organisms from replicating (Slide 9). Linden emphasized that DNA absorbance is the strongest around 260 nanometers (nm) (Slide 10).

Low pressure UV is the most commonly used form. Germicidal UV range is 220 -- 290 nm range. Pulsed UV tends to radiate across the whole spectrum, it is continuous-spectrum (Slide 11). The relative absorbency across the germicidal range was presented. Pulse energy peaks at 400 nm (Slide 12). No

disinfection byproducts are formed for low intensity UV, the effects have not been studied for high absorbency (Slide 13).

Linden presented a picture of a bank of UV lamps submerged in a channel (Slide 15) and of medium pressure (mp) UV lamps (bulbs for mp lamps are different than bulbs for low pressure lamps) (Slide 16).

Time is also important in UV disinfection (Slide 17). To understand how UV kills, you have to track its course, and figure out how much dose is in the DNA of the pathogen (Slide 18).

The "effective germicidal intensity" was discussed. The average germicidal intensity (AGI) is how much UV is absorbed (Slide 19). Data on UV efficacy for bacteria has been out for a while (Slide 20). MS-2 is an indicator organism for virus inactivation (Slide 21).

For the Lorenzo study the amount of UV dose was unclear. UV effectiveness is sensitive to the method used to determine viability. For pulse UV, data are poorly defined, but it is effective in inactivating Cryptosporidium. Karl Linden added that the numbers seen are questionable (Slide 22). For the Karanis study the dose used was impractical (Slide 23). The bottom line is that UV is effective for Cryptosporidium inactivation (Slide 24).

A block diagram summarizing UV dose understanding was provided. It is a simple scenario, the block can be moved up and down the y-axis and the absorbency can be measured. Point B is what you want to get (Slide 25).

Currently, researchers don't have a good handle of what lamps are putting out (Slide 26).

Related research projects were discussed. One was a two year study on the fate and persistence of pathogens subjected to disinfection. This study will look at mechanisms of UV disinfection, morphology of resistance, etc. (Slides 27-29).

Questions/Answers:

Q: Because UV acts directly on DNA, does it cause mutations in DNA that will make the pathogen more resistant to UV and other disinfectants?
A: This should not be a problem for UV. With UV, we do not see mutations occurring because it is not mutating effect on the DNA of the pathogen per se, but a physical effect.

Q: What pressure UV was used to kill bacteria?
A: Low pressure.

Q: Does temperature have an effect on UV? Please comment.
A: Temperature and pH have not shown to have an effect on UV -- these results are based on waste water studies. We want to do studies using UV with Cryptosporidium while changing temperature for fresh water. This should not be a problem -- but [we] want to a look at it.

Small Systems

Overview of Treatment Processes for Microbial Pathogens in Small Systems - Robin Collins (University of New Hampshire) [Attachment 12]

Package treatment plants (PTP) rely on chemical filtration (Slide 2).

A photograph depicting a membrane filtration plant was presented (Slide 4). There are lots of advantages in having packaged compressed systems. A close up picture of a hollow fiber was also presented (Slide

6). There are four types of membrane systems. They are not well characterized, and they overlap at some points. These membrane systems are: 1) nano- 2) ultra- 3) micro- and 4) particle-filtration systems. Nano-, ultra-, and micro-filtration systems are not well defined (Slide 7). Characteristics between micro filtration and reverse osmosis, and other filtration methods were discussed.

The term *recovery* was defined as the ratio between permeate and feed water (Slide 8). New models of filters come out as technology changes (Slide 10).

A graph was shown that explains how viruses and bacteria can be hung up in the filter membrane. The way in which a filter system works was explained (Slide 14). Collins noted that in the diagram presented in Slide 15, the precoat step is in the wrong place. It should be behind the filter feed pump (Slide 15). The term *precoat* was defined (Slide 16). Over time, the precoat becomes plugged up, which results in a lower filtration time (Slide 18). A picture was shown depicting the *precoat* during the filter run (Slide 19).

A leaf filter can treat a lot of water, and it only takes up a small space in the plant (Slide 21). Collins presented a picture that depicted the inside of a leaf filter (Slide 22). The spent cake may be used for earth reconditioning (Slide 23). As for organic precursor material, nothing has been seen (Slide 24).

Collins noted that clarity needs to be balanced with flow rate in order to make the technique economical (Slide 26). All of these modifications have been looked at (Slide 29). A picture of diatomaceous earth was shown (Slide 30). Slow sand filtration and the way it works was described--most of the removal takes place at the surface (Slide 32).

A picture of slow sand filters in New England was presented. Robin Collins commented that the best way to operate a slow sand filter is by managing the media (Slide 33). A picture depicting core of sand was also shown; it is like a membrane filter but it is more like a skin (Slide 35). Thirty to forty days are needed to ripen a slow sand filter, because it works biologically. Time is a function of the clarity of the water (Slide 36). The typical design criteria of slow sand filters was described. Many states have their own standards for the bed depth (Slide 38). A picture of how the bed of slow sand filters cleaned was shown (Slide 41). The limitations of slow sand filters were also discussed (not included in handout). There is a long filter down time, and a low TOC removal. The proven modification to enhance slow sand filter performance was discussed (not included in handout). The way a GAC layer can also improve the effectiveness of slow sand filters was discussed (not included in handout).

A graph (not included in handout) showing TOC removal for micro pilot filters was presented.

The common factors affecting acceptance of slow sand filters in northern New England were examined (not included in handout). In order for acceptance of slow sand filters to occur the ability of the filters must be introduced to water system operators; state and regulators need to be supportive; visits are needed at the plant and; pilot studies are needed to confirm the effectiveness of slow sand filters.

Questions/Answers:

Q: Comment on turbidity standards and how applicable are they to slow sand filters?
A: Regulations are more relaxed for turbidity -- 1 NTU for slow sand filters vs 0.3 NTU for conventional treatment. Turbidity generated in slow sand is passed out in the effluent. However, heterotrophic organisms are not removed with slow sand.

Q: Point out major difference between bank filtration and slow filtration?
A: Bank filtration is used mainly for ground water and is found on the banks of rivers -- need river that scoured itself -- cannot go to any river to apply bank filtration -- it must be used at a river that self cleans.

Small Systems Microbial and DBP Research Studies - Jim Goodrich (EPA) **[No Handouts]**

Jim Goodrich began the presentation by explaining that there are in-house and field disinfection studies that are currently going on for small systems. An overview of the presentation was given. Studies that are currently being done were discussed.

A picture of a bag filter was shown and the cost and the pore sizes of bag filters were discussed. Holders for bag filters and a close up of the bags were also shown; all of the bag filters are very different. A microscopic view of pores in bag filters was presented by Jim Goodrich.

A graph that showed turbidity log removal vs. pressure drop was discussed; the greater the turbidity, the bigger the pressure drop. Another graph showing influent vs. effluent particle count illustrated how something is getting through for all of the size ranges. A graph showing turbidity vs. pressure drop was discussed. Filters with NTU of 8-9 and 1-2 were compared; both resulted in finished water that was the same regardless of the starting point.

A graph to show pressure drop vs. time was discussed. Goodrich asked the question: How long does the bag last? When pressure drops, one has to discard the bag. Bag filtration can get expensive if bags are changed every day. He explained that when pressure gets to 10 psi the bag is getting fouled up, and should be changed. A graph showing what happens when bag breaks was discussed.

A microscopic view of bag being repaired with needle was shown, the needle left a 5 micron hole (which is big enough to let Cryptosporidium to pass through). A picture showing a bag repaired with heat seal was also presented. Heat sealing is better, but the bag particles may separate.

The percent removal of Cryptosporidium for bag filters was discussed. A graph to show pressure drop and turbidity vs. time for a bag filter run at 45, and 5 NTU, at 40 gpm was discussed. Influent was the same as the effluent. A microscopic picture of the inner and lower layer of the bag was shown.

A graph representing pressure drop and turbidity vs. time was discussed. Goodrich added that there is a trade-off at run time.

A picture of a cartridge filter was shown and different types of cartridge filters were discussed. They normally result in a 2-3 log removal of Cryptosporidium. There are studies in the U.S. being done on the effectiveness of Cryptosporidium removal with cartridge filters.

The storm event slide was discussed. The number of beads in effluent was examined--4 days later, beads were still working their way through the filter.

A picture of forest service filtration was shown, this is considered to be a good set up for a small system.

A picture of pulse UV system was also shown. Phoenix water systems were discussed-- they use reverse polarity to kill Cryptosporidium. The Ozone/UV Point of Entry (POE) unit was discussed. This unit is normally used for iron and manganese oxidation, but the researchers are now looking at this application for removing Cryptosporidium.

The project and site visit were described by Jim Goodrich. They are looking at 48 systems. The percentage of facilities and the turbidity readings for utilities were discussed. A comparison of actual operator skills was discussed; a high skill level is needed for operators. Goodrich also talked about demonstration projects including the U.S. and other countries. This would require money to be spent in order to build good package plants vs. linking individual systems that are flowed together (which is better?)

The term *remote telemetry* was defined as plants that are being operated from remote location, i.e. a full time operator is not needed. Different pictures showing how remote telemetry can be achieved were

shown. A picture of a remote system in West Virginia was shown. A computer system that shows where the problem is within the package plant is used for remote systems.

Questions/Answers:

None

Watershed

What are the Major Sources of Pathogens in Surface Water? - Joan Rose (University of South Florida) [Attachment 13]

Joan Rose provided an overview of various hazards, and their transport and fate, which result in waterborne outbreaks. Outbreaks of waterborne disease were described. Some states do a better job of documenting outbreaks than others. Recent data showed that in 1995-1996, 22 outbreaks occurred in 13 states (Slide 1). Source waters cited with these outbreaks were 60 percent well water, 20 percent surface supplies, 13.3 percent springs, and 6.7 percent partially treated sewage (Slide 2).

Researchers do not exactly know exactly the origin of the bacteria, viruses, and protozoa that caused the outbreaks (Slide 3). A picture of a sewage treat plant was shown (not included in handout). Sewage treatment plants treat to the secondary level. For some states advanced treatment is required, although not all requirements are the same (they differ from state to state.) People are considered to be a source of contamination (Slide 4). This is an issue because reservoirs are used for different functions, such as swimming, etc. Animals and storm waters are also sources of microbial contamination (Slides 6-7). In some states, systems are combined where untreated waste water is discarded with storm water--this is not an issue for all states. Rose added that regular runoff is also a source of contamination.

Water has different types of known and unknown microbes (not included in handout). There are different types of pathogens that are of concern in wastewater. There are 4 groups: viruses, bacteria, protozoa, and helminths (not a big concern in drinking water) (not included in handout). The emerging water borne pathogens were discussed. High numbers are fecal/oral, which makes up the majority of concern (not included in handout).

Different sources of contamination that enter into water sources were discussed. Once contaminants go into water, it results in the contamination of drinking water and the contamination of food--from water (like shellfish), antibiotic resistance (mainly for animals), and contamination of recreational water (not included in handout).

The spread of waterborne infectious disease was discussed (not included in handout). The primary factors are rainfall, runoff, etc. Models are being used to look at rainfall, changes in rainfall, El Nino effects, and land use to assess contamination caused by runoff. These problems will be looked at using a hydrologic model. Rose raised the question: How do we go from quantity to quality, especially for contamination of concern using these models (Slide 5)?

An outbreak map of the U.S. was shown (not included in handout). The outbreaks were plotted by GIS. Nebraska had a high density of reported outbreaks. Using Pennsylvania as an example, one can look at the watersheds at risk on the state level. Pennsylvania had low outbreaks, so water treatment is pretty effective. In Colorado, the data set showed areas that are at a higher risk for potential outbreaks.

Extreme precipitation events were defined (not included in handout). Outbreaks are normally associated with rainfall events. Results showed that 70 percent of outbreaks occurred at the extreme end of precipitation (10 percent range of gauge). Outbreaks are occurring at the higher end of precipitation for both ground and surface water.

In regard to indicators, Joan Rose commented that there is comfort with using coliforms historically (not included in handout). The problems with coliforms are the poor indication of viruses, which are less resistant to treatment. The advantages of bateriophage as an indicator was discussed (not included in handout). Alternative indicators were also looked at (not included in handout). Clostridium better reflects human waste better than animal waste. The benefits of alternative indicators are that they can identify human pathogens, and they are better at identifying the pathogen level in raw wastewater vs. fecal coliform.

Potential pathogens of concern were discussed (not included in handout). There is a problem with viruses surviving in drinking water after treatment--[one] may have to look directly for pathogen of concern because the indicator may not be found.

The range of Cryptosporidium oocyst levels found in animal feces was presented (not included in handout), the highest source is seen in calves.

Protozoan levels in various types of water were discussed (not included in handout). Secondary treatment is not considered to really reduce levels of pathogens, there is a need for a higher level of treatment. The amounts of Cryptosporidium and Giardia found in storm water is comparable to untreated waste water. Storm water data for Giardia and Cryptosporidium showed that after a rain event, the levels were raised to up to 100 times higher than before the event (not included in handout).

Cyclospora found in humans was discussed (not included in handout). The source and transport is different than in Cryptosporidium. Microsporidium in water was discussed (not included in handout). Microsporidium is much smaller than Cryptosporidium which is smaller than Giardia.

Viruses are a big concern because they are found in different types of waters (not included in handout). Charlotte Harbor Study discussed (not included in handout): the septic system was the primary source of fecal contamination. The water quality of Charlotte Harbor was described (not included in handout).

Binary Logistic regression can be used to predict the level of human viruses based on coliphage levels. The presence of enteroviruses (don't have to look at indicator) can be observed based on actual rainfall (Slide 6). These parameters can model the influx of enteric pathogens (Slide 5).

Animal wastes are an issue, since they contain many organisms that present a risk to humans. Antibiotic resistance is also a concern because antibiotics are used in animal feed (Slide 7). Salmonella DT104 is an example of a bacterium which carries antibiotic resistance. The hospitalization rate is 36 percent and it is found in farm animals and domestic pets.

An approach consisting of methods, monitoring, and modeling to determine exposure to microorganisms was presented (Slide 9).

Question/Answers:

Q: Drinking water exposure for microorganism contamination was looked at -- did they look at other types of exposure?
A: Recreational water exposure has been underestimated; food -- different mechanisms involved; we should do better job of determining recreational water exposure.

Comment: Recreational water outbreak -- when and how often are they seen, for example at water parks, swimming pools, etc.?

Q: How do you compare salmonella to Cryptosporidium?
A: They are similar to fecal coliform in terms of disinfection -- outcome can be much more severe if watershed is contaminated with antibiotic resistant bacteria.

Q: How do you detect salmonella vs. Cryptosporidium?
A: It can be grown.

Q: How resistant is salmonella to chlorine?
A: No different than fecal.

Q: Have a lot of studies been done regarding combined sewer overflows (CFOs) for storm water?
A: Data that is published show that for storm water -- the source of human viruses could be figured out. This is a temporal issue. How often do these storm events occur--there is not good handle on this. Storm water can have dramatic impact.

Q: Reduction of risk by controlling sources upstream is it a technical or policy question?
A: Both. Technical approaches are being tested -- UV is being looked at for waste water. Policy approach -- how do we merge CWA and SDWA. Both of these acts are looking at watershed issues.

Panel Discussion on Physical Removal and Disinfection - Bob Clark, US EPA; Dave Cornwell, EET; Gordon Finch, University of Alberta; Ray Letterman, University of Syracuse; Eva C. Nieminski, Utah Department of Environmental Quality; Benito Marinas, University of Illinois

Panel Questions

1.) Which parameters appear most significant in influencing inactivation by ozone, UV and chlorine dioxide of Cryptosporidium? How do you envision the development of disinfection design and operation criteria?

2.) To what extent will available research enable us to define generic guidelines for estimating physical removal and inactivation credit by disinfection for Cryptosporidium by filtration and disinfection processes?

3.) To what extent can the removal of surrogates (turbidity, spores, etc.) indicate the removal of pathogenic microorganisms?

4.) How does source water quality (i.e., turbidity levels) influence inactivation/removal efficiencies?

Question #1

Karl Linden (KL): Water quality issues and absorbents -- need to control UV absorbents.

Eva Nieminski (EV): Cannot be translated into a regulation (tool) -- the IDDF has 4 components, all are site specific.

Benito Marinas (BM): Temperature plays a role in chemical activation -- organic matter for water quality will affect the concentration of the disinfectant. The nature of OACs will be critical -- limited to tracer tests when going from full scale to smaller scale.

Gordon Finch (GF): Cost of different techniques is the issue -- want to add mechanism of inactivation... should not separate chemicals from other things. There is more discretion in development and design. The IDDF will work because they are separate and different components.

Dave Cornwell (DC): I will go one step further than GF... full scale implementation is needed.

Bob Clark (BC): I echo BM comments on water quality issues.

Questions from audience:

Q: Are there complications using these treatment techniques -- will they pose more challenges downstream?

BM: More complex to measure these treatment techniques vs. conventional treatment. Chlorine and chlorine dioxide result in other (different) problems.

KL: Operators like UV -- big concern is the lack of residual so they will combine UV with chlorine. There are also problems with the design of big systems -- we are looking at this now.

Q: Won't there need to be a huge investment for operator training for other treatment techniques? Won't this be an issue?

GF: Disagree, ozone is widely used around the world -- don't see as a big issue.

EN: Disagree with GF -- ozonation is a very complicated process for small systems -- does require training and it is a capital investment. Chlorine dioxide must be produced on site. Operators are afraid of this based on experiences with it being produced wrong on the site --requires time, knowledge and education.

Q: What will the effects of this new technology be on the ecosystem and on humans, for example how will UV change organisms? What are the potential effects of these new technologies?

BM: We need to look at these risks, will not discuss now. These treatments have problems, for example there are many DBPs that we were not able to identify.

Comment from audience: Perception of ozone in small systems is scary... from standpoint where guy sells small ozone systems it is not scary. This perception is based on the type of plan and type of system.

KL: DBPs are not an issue for low pressure UV however, post chlorination after UV needs to be explored further.

Question 2

BC: Research will give insight

DC: Will need a pilot plan data. Cannot measure log removal at full scale plants. Can determine what plants can do based on pilot plants...plants are showing that we can get 3-4 log removal...it takes 1000 cysts in raw water to detect 1 in finished -- not much ICR data that will show plant with 1000 in raw water...looking at events that will exceed the removal now seen.

GF: How do we think about performance...why not make them as target indicators -- more should be invested into current systems that have performance targets.

RL: Turbidity and Particle Counting can be used to measure performance will take time and effort to make measurements meaningful; focusing on these measures are feasible but will take time.

BM: I am more optimistic. Will these new techniques be more stringent than what were used in the past? A Risk Assessment will have to be done.

EN: I agree with Gordon. Why do we have to assume that credit be given to log removal? It is difficult to document removal of protozoa with log removal -- it will be difficult to prove that plant can effectively remove these pathogens. For filtered water quality -- water had gone through water system. If the system did not do a good job, it will cause more disappointment having to shut down the plant because of treated water quality. We currently don't have good records of waterborne outbreaks -- all documented outbreaks were associated with an upset in the treatment system...Why does this occur? Is it because something is causing the upset with the raw water quality? We need to focus on local understanding with challenges understanding raw water quality. We should invest in water quality monitoring.

KL: For UV it is hard to monitor Cryptosporidium viability. We need to answer which method is best and correct -- will have to see what research is. Regarding indicators for UV -- will have an indicator for Cryptosporidium soon for UV, as well as for other indicators.

Questions from audience:

Eva are there many outbreaks for crypt -- what information do we have for endemic disease?

Gordon -- should we not design plants that take care of rainfall patterns?

EN: I don't know enough to make big conclusion for cause and affect. Common sense answer -- optimizing treatment at unit process level -- steady operation is the best guarantee -- how to make sure that operation will be smooth -- need to know the changes that are occurring.

Q: Please comment on the limitations of the techniques used in pilot studies being used in the field?

GF: Utility that measured 10K oocysts in raw and had 1 oocysts in the finished (i.e. 4 log removal) that actually occurred. Some of the utilities have run their operations based on lab research.

EN: Answer is not straight across -- if small scale study is based on large scale plant -- can trust the numbers.

Comment: Full scale plants do well. Based on indirect evidence we are doing better. Our research show that plants can be away from optimal and they do very well (in terms in removal).

Q: How will research be scaled up to maintain level of treatment seen in worst case scenarios? How do pilot studies reflect what is going on in the real world? Should we concentrate on steady state or should we look at other sites?

DV: No-steady state conditions -- more susceptible to oocysts breakthrough.

EN: Difficult thing to do -- will not try to mimic what occurs in the full scale plant. Difficult to use small study results for none steady state.

GF: I agree with Eva -- multi barrier approach should be looked at to address no-steady state events.

Q: Conventional treatment varies from plant to plant -- is there any hope for assigning credits or are we constrained to giving generic credits?

Chuck (he was in the audience): There is a study that shows that we can develop reasonable correlations (removal for parameter can be specified) -- will be out in Summer.

Q: Minimum 2 log assumption for filtration -- how can we go beyond that in being more specific?

GF: 2 logs is conservative -- it is reasonable. There is new data that show where 1 log is being removed .

Q: Can turbidity levels be used to determine log removal?

GF: No

DC: Yes

3rd Question

EV: Regarding the relationship of Giardia and Cryptosporidium with removal of spores -- no linear relationship (no matter how data are analyzed will always look the same) ...cannot describe mathematically -- does not mean that it is not occurring. There is hope to attach the removal of indicators for removal of pathogens.

4th question

GF: There is an AWWARF project on artificial neural networks -- showing a great deal of progress. If we start thinking in these terms, we can adapt water treatment to source water quality.

EN: Full scale studies do not prove this -- will not put direct filtration plant on high turbidity waters. We need to know what designs are important based on the water quality at the source. There is a threshold where we can upset technology -- buffer that we have is very high.

BC: Source water quality issue should be raised. There are policies and practices under the SDWA and CWA that need to be integrated in the future.

Comment from audience: What are the implications of different turbidity levels on disinfection for Cryptosporidium? Can you speak on how well turbidity has been addressed for ozonation and UV?

GF: Preoxidation was done a lot -- people realized that much of the Ozone was used up with this process. The savings come in where the type of disinfectant is placed in system -- some countries use ozone after filtration. Ozone demand is much lower at the middle and end points of the system. In general -- good to take as much stuff out of water first before adding oxidant.

EN: Microbes are why kill them up front at a cost. Use them to remove precursors from the water, then kill them.

Questions from audience:

Q: I am a utility that is interested in new technology, but when I look at the available information, e.g. the timeliness of similar work, I get uncomfortable when I hear of UV, ozone, etc. as technology for drinking water. Will information regarding these technologies be timely so that they are implemented in the regulatory process? Is there enough information available to incorporate them into this process?

KL: UV is in the exploratory stage -- impact of water quality and UV have not been shown. There is a lot of operation experience for UV for waste water -- we can target studies to get good feel of where the technology is. (There are UV plants in Europe -- can draw on this experience.)

GF: Chlorine dioxide is well understood.

EN: I am nervous also. We should design new plants to allow new technology -- and leave it up to the local facilities whether to apply new technology. We want what we do to be foresighted -- don't want to block [our]selves in.

BM: I am impressed with Gordon's presentation -- breakthrough with the technology.

Q: Regarding combining CWA and SDWA -- getting nervous that panel is suggesting that CWA should be amended to fit SDWA standards? Should waste water effluent be drinkable?

GF: Disagree with concept -- We can design new drinking water plants to remove contamination in source water -- not a difficult concept to put into place. The problem is cost and politics-- from technical point of view, nothing is stopping us from drinking waste water.

BC: No.

Q: Dave -- regarding credits -- is it reasonable to give credits to backwash and filters when seeing particle breakthrough?

DC: Good idea yes -- not from regulatory stand point but from a practical standpoint.

EN: Credits should be on the local level -- we cannot give a generic standard. Generic standards are hard to extrapolate to many different systems.

RL: Particle counting for credit -- need to be careful with the range that is being used -- needs to be determined until we know more should not use a window.

Comment: Might be surrogate that can be used based on multiple parameters. Any comments on multiple variables being used in a surrogate?

EN: Yes they should be used, as long as cheap, and quick.

GF: Current modern technology can measure many things that were not measured before. There are studies that can predict the capability of coagulation process -- as water changed, the plant changed for it. For a plant to do this will cost up front -- but will be optimal.

Comment: [We should] look at process control data -- how does it measure up to what is being removed? Understanding real time effects at the plant is difficult -- [we are] not at the point yet of understanding plant, real time, real process control.

FRIDAY MARCH 12, 1999

DBP Methods

Analytical Methods: Overview of Available Analytical Methods for DBPs and On-going and Future Research - Pat Fair (EPA) [Attachment 14]

An overview of the presentation was provided by Pat Fair. Identification of DBPs and their analysis were described (Slide 2). When comparing different DBPs [one] must use the same analytical process for undisinfected and disinfected waters (Slide 3).

A spike analysis for DBP identification in untreated and chlorinated water was presented. Each spike represents a compound. There were more peaks found in chlorinated waters--it is challenging to identify each peak. The detection process gives clues to identify peaks. Fair added that one must begin with this process (Slide 4).

As analytical techniques get more sophisticated, it becomes harder to apply them to the soup of DBPs. A workshop on the identification of new and uncharacterized DBPs in drinking water was done and research work will develop from it. The Athens and Cincinnati labs are doing research to identify DBPs (Slide 5).

Once you have an idea of what a compound is, you must synthesize to verify because uncertainty is involved. Once a standard is set, the compound is spiked to test the procedure. [One] may then challenge the methods in different waters. The next hurdle in developing methods is to check the sample stability--[you] must have the ability to fill the bottle and send it to a lab somewhere, i.e. ability to stabilize the compound (Slide 6). The disinfectant residual must be removed from the bottle to prevent additional formation of DBPs. The vulnerability of the sample must be taken into consideration.

Accuracy may be evaluated by spiking a known amount into a sample and then observing how much is recovered. DBPs have an 80 percent recovery. The sensitivity issues for DBPs are not as great as they are for microbes (they are pretty detectable at low levels). The method must be free from interference because some compounds in the sample can mimic DBPs, which may result in a false positive. All of the interferences must be documented (Slide 7).

The aldehyde sample stability was discussed. A graph illustrating the stability of aldehyde in a sample when various compounds are added was presented.

Fair added that DBP methods can be taken from the development lab to the production lab. In regard to the Stage 1 DBP rule--only 5 haloacetic acids (HAAs) are measured. All of the methods can measure for 6 HAAs. Fair added that they encourage people to measure for all 9 HAAs. Cyanogen chloride is measured in the ICR, but there is a sample stability issue (Slide 8).

Fair presented methods for surrogates and new bromate methods. The Stage 1 rule sensitivity method was an issue; if detection < 10, then the method would not be developed. The method used in the ICR will not be used in the real world because of all that is involved, but new methods will be available soon. The new bromate methods were developed. Method 302.0: IC-PCR was developed and used with Stage 1. This method is considered to be very sensitive. The problem with the method is that the compound which is used reacts with chlorite, therefore bromate is difficult to quantify (Slide 10). Fair described Method 321.8: IC-ICP/MS as a state-of the-art method because specific detection of bromate is achieved (Slide 11).

A comparison of the bromate methods was presented. 300.1 Stage 1 method (IC), 302.0 Stage 1 with includes an extra step, and 321.8. The method detection limit (MDL) numbers presented are what one lab achieved, these will vary from lab to lab and instrument to instrument. The numbers are only used for comparison in detection of bromate. The RSD gives the precision of the method (Slide 12).

Pat Fair concluded by noting that although in the past methods were promulgated with the rule, [EPA] is now moving towards performance based criteria (Slide 13).

Questions/Answers:

Q: Performance criteria -- THM samples were sent to 3 labs -- there was 40 percent difference in levels seen from the different labs? How will this be resolved (difference in levels of same samples)?
A: Hard look will be taken at different methods -- statements will be made for variability and accuracy.

Q: Where is the state of the science with regard to being able to detect highly polar oxygenated species?
A: Much progress has been made in identifying polar DBPs--more work is needed -- in trying to quantify them -- even more work is needed.

Q: Will database be able to go from MDL to practical quantification limit (PQL)?
A: DBPs can be seen in most waters, except for bromate. The ICR looked at occurrence and then set reporting limits -- THM minimum reporting limit was 1 µg/L.

Q: Comment on efforts to characterizing DBPs that have not been characterized.
A: Primary work is in Athens lab -- determined effort is being made to identify non-halogenated DBPs.

Q: Interferences -- can they drive results higher or lower?
A: For bromate -- drive it lower because they mask effects.

Q: What confidence does EPA have in results received for DBPs from the ICR?
A: Strict QA for ICR -- confidence in results seen -- States certify labs and make sure that proper QC is in place.

DBP Treatment Research

DBP Formation - David Reckhow (University of Massachusetts at Amherst) [Attachment 15]

David Reckhow's presentation was on DBP formation. Specifically, what are the DBP's and what factors affect their concentrations (Slide 1)? An outline of the presentation was provided. A graphic describing the point of addition of disinfectants was shown. Disinfectants are added in different areas of the plant-- pre, mid and post. There is a different array of disinfection used, in each location which may result in different DBPs (Slide 3).

A chemists view of disinfection was presented; including reactants (HOCl, O_3, NH_2Cl, and ClO_2) and products (Cl^-, OH^-, NH_4^+, ClO_2^-) (Slide 3). Reactions with chlorine result in 20 percent of chlorinated organics, and the other 80 percent oxidized natural organic matter (NOM) and inorganic chlorides (Slide 5).

The origins and behavior of natural organic matter was discussed. Non-humics may be formed by algae (Slide 6). The hydroxy form of organic compounds is very reactive and the origin of natural organic matter (NOM) is unknown. The molecular structure of an aquatic humic was presented (Slide 7).

The organic reactivity, the potential of THM and different product formation for different kinds of NOM, was also discussed. Coagulation removes substances that form the highest levels of THM (Slide 8). The best method to identify THM precursors was found to be with UV absorption (Slide 9).

The specific UV absorbance (SUVA) was discussed. The SUVA is related to the character of the NOM; SUVA>4, high humic character; SUVA=2-4, intermediate humic content and; SUVA<2, mostly humic (Slide 10). Reckhow presented a picture of DBPs--haloacetic acids (Slide 11), haloacetonitriles (Slide 12), halopropanones (Slide 13), and other neutral compounds ("MX" is the big player in mutagenic activity for chlorinated waters) (Slide 14).

A summary of work that was done in identifying DBPs was presented in tabular form (Slides 15-18). Reckhow added that there is not much known about compounds with halogens.

A table showing DBP yields was shown--normalized by organic compounds as precursors. It was noted that low numbers come from the DBP model. The formation potential can give higher numbers than is actually seen; the major compounds are the total organic halogens (TOX), total trihalomethanes (TTHM), and THAA (Slide 19). The TOX method is considered to be very helpful (Slide 20).

A graph depicting the breakdown of known and unknown TOX in waters was shown. Only 1/3 can be identified, a little more than .5 are unknown (Slide 21). The average ozonation byproduct yields were discussed. Ozone does not have an indicator as good as TOX (Slide 22).

There are various measures of biodegradability (Slide 23). TOC and Biodegradable organic matter (BOM) were discussed. The known compounds are small part of the known and unknown BOM (Slide 24).

Time determines the type of DBPs formed. Factors which affect DBP formation were described, these include time, pH, dose, temperature, bromide, ammonia, and pretreatment (Slide 25). Chemical degradation, not biodegredation, occurs over time (Slide 26-27).

Ozone forms DBPs quickly (early on). As more and more chlorine added more DBP formation is observed. Until one reaches the point of chlorine demand, DBP formation drops. Ozone does not maintain residual (ozone limits DBP formation) (Slide 28). pH was found to have the biggest impact on DBP formation (Slides 30-31). The effect of hydrolysis on DBP profiles (Slide 32) and the half-life of halogenated DBPs under different conditions were presented (Slide 33).

The effect of pH and ozonation were presented. For ozone, as pH goes up, some DBPs go down; however, bromate increases with high pH (Slide 34).

David Reckhow introduced the topic of DBP Modeling. There are two types: 1) power function model (a demonstration of the model was given--computer program that allows to temperature, pH, and chlorine level changes, in order to see which DBPs are formed) and 2) kinetic model.

The significance of bromide (Slide 35) and the chemical reaction of brominated THMs was illustrated (Slide 36). THM and THAA formation in chlorinated waters with different levels of bromine was presented graphically (Slide 37). A data set that shows major DBPs formed as a function of time in chlorinated waters was also shown. Unknown TOX formed quickly then leveled off (Slides 39-40). Unknown TOX was found to be insensitive to doses of chlorine (Slide 42-43).

Dichloroacetic acid (DCAA) and trichloroacetic acid (TCAA) should be separated because they are very different in their formation (Slide 44). A data set illustrating differences in DCAA and TCAA formation was presented. At a low chlorine dose THM formation continues after the residual is lost (Slide 45).

The formation of DCAN (Slide 47) and TCP (Slide 48) were presented graphically. As chlorine is increased, the concentration of DCP drops--after the residual is lost, it rapidly decomposes in the chlorine (Slide 49). Reckhow presented a profile of DBP formation in different areas of a plant. The complicating factor is precursor removal with DBP formation (Slide 50). The results of a 21 system survey (1989-1991) on typical levels of DBPs was shown. The Distribution System model showed variability of DBP formation within a single distribution system.

Conclusions on DBP formation were provided. Alternative oxidants will need less chlorine, which will result in lower halogenated DBP formation (Slides 52-53). Uses of ozone and the growth of ozone plants in the U.S. were discussed (Slides 54-55).

A close-up of ozone generator was presented (Slides 56-57). Ozone contactor was described as well as common by products of the method were given (Slide 58-59). Recent data shows that it is possible to

monitor the concentration of aldehydes formed in a system. Reckhow added that this is a complicated picture, and [we are] not sure of formation (Slide 60).

A graphic which depicted the route of ozonated by products in a system (Slide 60), subsequent filtration (Slide 61), and the reaction of ozone with bromide were shown (Slide 62). Ozone can destroy DBP precursors, although there is only about 10-20 percent precursor destruction (Slide 64). The kinetics of TCAA and DCAA formation were presented. The conclusions for ozonation were presented. There are secondary benefits of ozonation, oxygenated byproducts dominate, some halogenated byproducts are a concern for waters with high Br-. Some DBPs are formed in a greater concentration because of ozonation (Slides 70-71).

Questions/Answers:

Q: Ozone -- confused with data shown -- some show low levels of aldehyde formation, some show high levels of aldehyde.
A: Depends on perspective.

Q: Is there data on degradation of bromate after it is formed?
A: Not known -- Scott-some degradation, but only under anaerobic conditions.

Q: Kinetics model -- did you test with very low levels of pH?
A: No.

Q: Is there any research on the chemistry of DBPs (what happens at very low pH)?
A: Don't know.

Q: Is the conclusion that more ozonation leads to more DBP formation?
A: Yes, ozone is very reactive -- after a while it decomposes its own DBPs.

Q: Comment on the mixing of CSTR versus plug flow for DBP formation; will this have an impact?
A: Not important for chlorine; however, there are some important impacts with ozone and with chloramines.

Treatment Technology Impact on DBP Formation - Scott Summers (University of Colorado) [No Handouts]

Objectives of the presentation were given by Scott Summers. An overview on impact of DBP formation was discussed (Slide 2).

Treatment, disinfectant, and modeling approaches were presented. The water treatment plant (WTP) model has been used (Slides 3-4). Factors affecting DBP formation and treatment assumptions were discussed. A TOC value of 3 is the median of waters in the ICR study. Bromide: 70 µg/L, is the 70th percentile, and 200 µg/L is the 90th percentile (Slides 5-6).

Disinfection assumptions were provided for chlorine alone, chlorine/NF, chloramines, ozone, and temperature. Summers added that these will be used as guidelines (Slide 7).

There are important conditions in the plant with respect to DBP formation--residence and pH are important. Conditions were chosen to represent what occurs in plants. pH was adjusted after filtration to represent corrosion control practices (Slide 8). An example of different scenarios used in the model were given (his was a chlorine-based scenario) (Slide 9).

A look at a combination of pre- and post-chlorine addition was provided. Pre-chlorination is used for oxidation purposes vs. disinfection (Slide 10). Some plants don't need pre-chlorination (Slide 11). Chloramines were used in the distribution system (Slide 12).

A graph showing the formation of THMs based on post-chlorine and post-chlorine + chloramines was shown. The latter was shown to lower the amount of THM formation (Slide 14).

The impact of different technologies on DBP formation in a plant were described. Some TOCs are removed with the different technologies--as well as some organic precursors (Slide 17). In the plant shown, bromide was not removed because there was no addition of the oxidant.

The formation of DBP based on different disinfection scenarios was shown (Slide 18).

The impact of enhanced coagulation (removes TOC) on DBP precursors was presented (Slide 19), as well as the impact of enhanced coagulation + disinfection on DBP formation (Slide 20).

The impact of changing TOC levels and alkalinity on DBP formation was discussed. Enhanced coagulation reduces TOC, therefore what is the impact of THM formation? The reduction of TOC reduces THM. Bromide has a large impact on conditions seen in treatment, not just for speciation (Slide 21-22). Activated carbon does not remove DBPs, however it can remove precursors. Summers added that plants should not add chlorine before activated carbons (Slide 24). Ozone does not remove TOC, one must combine ozone with enhanced coagulation for the best results (Slide 25). The Ct for chlorine is only 15 minutes (Slide 26).

The impact of different filters on DBP precursors was shown. The biggest impact was seen for nanofiltration (Slide 27).

The effects of temperature and residence time had a significant effect on DBP formation. As the temperature increased, the DBP levels increased. Time and temperature had a big impact. As residence time increased, DBP levels also increased (Slide 28).

Granular activated carbon (GAC) and nanofiltration (NF) were discussed (Slide 29). Summers showed the impact of treatment on THM speciation using GAC or NF. NF removed bromide (Slide 30).

There were some cases where dibromoacetic acid (DBAA) was increased when TOC was removed (Slide 31). A graph was used to show the related costs of different treatment technologies. The baseline cost of conventional treatment for large systems is between 50 cents and $1 per 1000 gallons of water treated (Slide 32). The cost of additional treatment for small PWS was discussed. The baseline cost is about $8 per 1000 gallons, for conventional treatment (Slide 33). The point was made that it is not simple for utilities to change their treatment technique--they may have physical and cost constraints (Slide 34).

Questions/Answers:

Comment: Concern -- enhanced coagulation and reducing pH levels -- effect on a concrete basin.
A: Cost should be factored in for these.

Q: Initial scenarios -- pre- and post-chlorination: in the model, [you] just carried a residual in the sedimentation basin -- should the amount of residual have been altered because this is what happens in real life?
A: According to model, this would not have made much difference in levels seen.

Comment: Some of the scenarios are very narrow -- specifically of post chlorination with chloramines added; Ct is only 2 hours.
A: Normally, would need longer Ct.

Q: How many utilities does model represent?
A: Not many.

Q: Is there anything in ICR information that tells us what type of treatment that was used?
A: Yes.

Q: What is the time line to have data finalized, i.e. validated?
A: A tool is being developed to mesh the model with the ICR database. Data can be pulled out for validation. Mesh can be done by next month -- validation is subjected to mesh --maybe by June.

Comment: Add chlorine to distribution system after filters.

Q: What is the flexibility of the model to be tweaked?
A: Can be done.

Suggestion: find out what most utilities do under extreme conditions (*i.e.* winter time) design model accordingly.

Evaluation of GAC and Nanofiltration under the ICR - Steve Allgeier (EPA) [Attachment 16]

The information presented by Steve Allgeier was based on a series of studies that were done. Pertinent questions for the workshop were posed regarding ICR data (Slide 4). The ICR treatment studies were designed to evaluate the effectiveness of GAC and nanofiltration for DBP precursor removal (Slide 5).

Influent for the studies was where the samples were collected. The study design assumed that techniques were added on to the conventional treatment (especially for GAC). Membranes were considered to be an option for new construction rather than retrofit to the existing system (Slide 6). Both of the studies' results were scaled to full scale performance. Quarterly samples were collected to capture seasonal variation (Slide 7). Membrane testing protocols were presented (Slide 8). Free chlorine was used as the residual for worst case scenario. The samples were taken as a representation of where DBPs were formed in the plant (Slide 9).

Water quality data was discussed (Slide 10). The treatment study was mandated by the ICR--participants of the study were based on the size of the populations (Slide 11). Plants with TOC>4 mg/L had to participate in the study. 78 percent of plants had TOC>4 mg/L (Slide 12). 84 percent of the groundwater plants could avoid participation in the study because they had TOC <2 mg/L (Slide 13). A graph was presented to illustrate plants pursuing different study options (Slide 14). The distribution of studies by state shows where the study data are coming from. Florida and Texas are doing most of the studies (Slide 15).

A breakdown of study types based on technology was presented graphically. More utilities did pilot and full scale studies than bench studies --Allgeier added that this was encouraging because these results can be applied to the real world (Slide 16).

Allgeier raised the question: How will data be analyzed? More information can be obtained using raw data (Slide 18). The influent water quality gives baseline; the effluent shows breakthrough trends (Slide 19). The baseline for water quality effluent data can stand by itself. Insight can be gained on DBPs formed with this type of treatment (Slide 20).

The reactivation frequency (which is done after breakthrough occurs) is considered to have a significant impact on the cost of treatment (Slide 21). Blending analysis saves money because blending extends the life of the GAC (Slide 22). A membrane base analysis was discussed (Slide 23). This is scalable to the full size process. The model exercise was performed to compare data seen in the different studies (Slide 24).

A question was presented regarding how the data will be managed. A flow chart to show how data moves through the analytical process was shown (Slide 27). A system to manage the spreadsheet and summary files submitted by utilities was described. Allgeier added that this feature was added because assumptions were being made that could limit the use of the data (Slide 28).

The database will be in Access, the concept of relational database is that related information will be stored together--query features will be available which will allow the sorting and aggregation of the data to answer many of the questions (Slide 29).

The final question asked: When will the data be available (Slide 30)? The availability of data is tied to the information received from the treatment studies (Slide 31). The data will be analyzed as it comes in. Analyses of the study data on hand have already begun and all of the studies should be analyzed by February of 2000 (Slide 32).

The intention of the treatment study was to support the Stage 2 regulations (Slide 33).

Questions/Answers:

Q: Are models central to process?
A: Models are used with respect to formatting the data -- they are descriptive models. GAC model is a logistic function; Membrane model -- scale up tool.

Q: Using model to describe data does not take bias into consideration; how will data be verified?
A: Experiments are being done to verify data. Statisticians are working to deal with bias, and possibilities of bias.

Comment: Don't agree that costs of installing nano filtration is coming down.

Q: Reject water from Reverse Osmosis (RO) -- drives up the cost of RO because of the reject water -- is there a mechanism in place to get an alternate classification for RO reject (since classified as industrial waste)?
A: Answer cannot be given by me.

Q: Conventional treatment followed by NF is not good -- elaborate?
A: Not sure what is going on -- different mechanisms involved, but fouling is seen when this occurs. Effective pre-treatment is micro filtration then nano filtration and treatment with chloramines -- very expensive though.

Comment: need to emphasize that there is a lot information available with preceding conventional treatment with nano filtration. Many problems have arisen -- technical side and cost need to be reevaluated.

Distribution Systems/Cross Connection Control

Overview of Distribution Systems: Risk Management Research - Don Reasoner (EPA) [Attachment 17]

Don Reasoner presented the areas of interest for ongoing distribution system studies. Characteristics of distribution systems were discussed (Slide 5). Many of the conventional systems are very large--adverse effects arise when there is long residence time (Slide 6).

Waterborne disease outbreaks in relation to distribution systems were described (Slides 3-4). There is a waterborne disease component that results from problems with treatment and distribution.

Two types of human health effects result from distribution systems: 1) endemic illness, and 2) waterborne disease outbreak. Reasoner added that [we] need a powerful epidemiological study to determine if endemic illness is from water or food--this may be hard to determine (Slide 7).

Deaths resulting from a disease outbreak in Cabool, Mo. in 1989 were primarily elderly people in nursing homes (Slide 8). Birds contaminated the water in an outbreak in Gideon, Mo. in 1993 because they had access to the water tower (Slide 9).

Reasoner commented that this research is being done because of problems that can arise from distribution systems (Slide 2). The proposed distribution system studies were discussed (not included in handout). Studies that may be done for distribution systems were listed--there are 8 studies in the works. The studies will look at biofilms, effects of pollution, nutrient removal, real-time monitoring and control, effects of pH changes (on biofilm growth), and bacteria growth (to compare disinfectants). The problem with experiments is that it takes a long time to reach a steady-state condition.

A picture that shows a distribution system was shown (not included in handout)--the areas where coupons are inserted to measure biofilm were pointed out. This project has been underway for 7 months. A model has been created to study biofilm (Slide 13). A major factor is organic matter on biofilm--this study just started (Slide 16).

The Remote Telemetry Studies slide (not included in handout) were also described. A study to determine Remote Telemetry is being done in sewage systems for Washington, DC.

The Urban Infrastructure Testing Facility in New Jersey(not included in handout) was discussed. This facility uses an acoustic leak detection system to detect leaking in underground pipes. A diagram of acoustic system to detect and locate leaks in pipes was shown.

AWWARF has large number of projects that are being done or have been done. There is a lot of information available from these studies (Slide 18).

A number of simultaneous approaches are needed to maintain good water quality in the water system (Slide 10). It is beneficial for water utilities to know how the water moves in the system. A model will provide information for managing the distribution system (Slide 11).

Questions/Answers:

Q: Can we connect water borne disease outbreak with the role of biofilms?
A: Some studies are available that show that biofilms play a role in disease outbreak -- there is a link that should be examined. Mechanical disruption of system can result in disease outbreak.

Studies have shown different ways that disinfection system can be breached.

Q: Elaborate on results of DC study -- are you only looking at coliform?
A: Not looking at microbiological parameters -- looking at pH, physical parameters for remote sampling.

State Cross Connection Control Programs - Dan O'Lone (EPA, Region 4) [No Handouts]

Dan O'Lone began the presentation by defining the term *cross connection* and the terms associated with cross connection, such as back flow. Back flow occurs by backpressure or backsiphonage. Note: check valve is not a back flow preventer. *Backpressure* was described as a situation which results from an increase in the customers' system pressure (Slide 3). Back pressure is considered to be multi-factorial. The pressure in a system can range from 20-100 psi. A change in pressure can occur for many reasons (Slide 5). Backsiphonage occurs when there is reduction in system pressure. *Containment* refers to the isolation of the backflow to the premises.

PWSs have no jurisdiction beyond the premises--their jurisdiction ends at the water meter. There is often confusion regarding jurisdiction and implementation. EPA has a cross connection document. O'Lone added that this is a good guidance document, but may be hard to apply (Slide 6). PWS obligation ends at the meter; no PWS is required to report to primacy the incidence of back flow, therefore extracting information is going to be difficult (Slide 7).

A survey of how are states handling (the cross connection control rule) was discussed by O'Lone. This survey was done to find out what is going on in the states. The information was collected from March 1996 to April 1997. Forty states responded: 72.5 percent require a cross connection control program; 32 percent don't accept/approve program; 46 percent don't have minimum elements for a program. The information presented will be updated. It was added that currently 80 percent of states have plumbing codes.

Questions/Answers:

No questions.

Control of Microbial Contamination in Drinking Water Distribution Systems

Mark LeChevallier (American Water Works Service Company, Inc.) [Attachment 19]

The presentation focused on a survey that was sent to states to determine how contamination could be prevented. The objective of the project was to produce a guidance manual to prevent contamination.

Le Chevallier raised the question: How do we prioritize where greatest level of effort should be? (Slide 3). A comprehensive approach was needed to prevent contamination in order to maintain good water quality, i.e. "A Code of Best Practices" (Slide 4). This survey was done before the study--the survey was limited. It only provided an overall idea of what is going on (Slide 5). It was sent to 50 utilities, and 26 of them responded. Le Chevallier added that more research is needed if stakeholders want to pursue this (Slide 6).

The survey results show the types of the distribution pipes. (CI=cast iron, DI=ductile iron, AC=asbestos cement). A large survey done had the same distribution of pipe material (Slide 7). Results of survey for CCC (cross connection control) were presented. There are 14 states that require back flow prevention devices; question was how many of the devices do they actually test (Slide 8)? Results for failure of backflow prevention devices were given (Slide 9).

Causes of backflow device failure included device age, improper installation, lack of maintenance, lack of strainer, obstruction, rubber part failure, and mechanical failure (Slide 10).

Problems due to cross connections were presented (Slide 11). Obstacles to CCC were also discussed. The biggest problems cited were manpower and budget. Lack of support, no state mandate, no plumbing code, etc. were also cited (Slide 12). The CCC training of the utilities was examined (Slide 13). Leak detection issues in the survey revealed that meter sales are more reliable data for leak detection (Slide 14). These results were shown graphically (Slide 15).

The following terms were defined--*circumferential*: breaks around the pipe; *longitudinal*: break along length of the pipe; *pinhole*: hole in the pipe (Slide 16). The factors contributing to leaks were pipe material, age, and size, cold weather, corrosion, and installation (Slide 17). Another issue raised in the survey was: How far is supply water line from the sewer lines (Slide 18)? The typical separation was 10 feet. The minimum distance was 2-5 feet.

Information on the impact of orifice size on intrusion comes from modeling by Jim Funclin. The results from different modeling scenarios were presented (Slide 19).

The following terms were defined--*unidirection*: systematic way of identifying pipes: all pipes are flushed; *conventional*: problem in area, isolate problem and flush that section out and; *dead-ends*: done when water quality degrades or chlorine residual is low (Slide 20-21).

Control strategies provided were monitoring of additional locations and monitoring additional parameters. (UV-254 nm measures organic material) (Slide 22). Inspection was also discussed as a control strategy as well as the development of operational procedures (Slides 23-24).

Le Chevallier presented the conclusions drawn from the survey. The "Code of Best Practices" was needed to help utilities get the resources that they need. State regulations are currently variable, as well as the implementation of protection barriers. It was added that more research and additional surveys are needed (Slide 25).

Questions/Answers:

Q: Did not include how utility make decision to completely rehabilitate a main -- was this question asked?
A: Not part of the survey -- will be variable -- some states do not have a program response for this area -- more research is needed.

Q: When a decision is made to either clean or reline a pipe, how do they make this decision?
A: Wasn't part of survey -- research is being down now.

Q: is there a fine line of balance to account for water losses, and push to conservation?
A: Up to states -- decisions must be made together to determine what practice is best to maintain pipe quality.

Q: 30 percent loss of water -- is this balanced into the cost estimate in producing the water?
A: Good to do planning -- most states will look at benefits of have unidirection program, so that they will know where all of the pipes are.

Q: Regarding cross connection control -- utilities that did not test every year -- did you get from survey how they managed risk of not checking backflow devices?
A: Cross connection control is geared to industrial account -- didn't have -- managing risks -- did not indicate in survey how risks where managed.

Q: Regarding limited resources -- can you balance resources to check bigger risk factors?
A: Did not ask in survey -- need to follow up.

Comment from audience: cost of flushing program -- annual program cost $125K per year -- over million gallons/day utility.

Q: If sewer water is biggest cause of disease causing organisms -- will you change mind of using chloramines for disinfection?

A: This is an issue -- no easy answers -- trade off -- if research show transients are important --then need bigger grasp

Q: Is there a difference in pipe materials for regrowth?
A: With PVC -- less of a biofilm; coated PVC with corrosion products -- looked like unlined cast iron pipes -- PVC can promote regrowth like other pipes. It is not efficient to have program that targets 90 percent of pipes when problem occurs in 10 percent.

Closure by Ephraim King (EPA):

Information on health research was presented for the past six days, DBP formation and a range of technical subjects were examined over the last 3 days in February. [We] will return to them over the next year. [We now] turn to FACA members and ask how to evaluate the information that was heard: what questions should be asked next; what is the risk we are trying to address; how much risk has been addressed; what can be done to protect public health? King emphasized that this is the beginning, and it will be a rich and exciting process over the next six months. The next meeting will be held on March 30th.

Presenters were thanked.

Meeting Adjourned

LIST OF ATTACHMENTS

A. Meeting Agenda

B. Meeting Participants

1. Overview of Key Questions and Data to Address Questions - *Stig Regli, US EPA*

2. ICR Data Organization - *Jennifer McLain, US EPA*

3. ICR Questions and Data Presentation - *Michelle Frey, McGuire Environmental Consultants, Inc.*

4. Overview of EPA's Approach for Using ICR Protozoan Data - *Mike Messner, US EPA*

5. Overall Data Sources/Compliance Forecast and Impact Estimates - *Stig Regli, US EPA*

6. Characterization of the Occurrence of Pathogens and Indicators in Source Water (AWWARF#488) - *Mark LeChevallier, American Water Works Service Company, Inc.*

7. Removal of Microbial Pathogens and Indicators by Conventional Treatment - *Eva C. Nieminski, Utah Department of Environmental Quality*

8. Research on Removal of *Cryptosporidium* and Indicators in a Conventional Water Treatment Pilot Plant - *Kim Fox, US EPA*

9. Cryptosporidium Physical Removal in Pilot and Full-Scale Plants - *Dave Cornwell, Environmental Engineering and Technology, Newport News, VA*

10. Inactivation of Microbial Pathogens in Water Treatment - *Gordon R. Finch, University of Alberta, Canada*

11. UV Inactivation of Microorganisms - *Karl Linden, University of North Carolina at Charlotte*

12. Overview of Treatment Processes for Microbial Pathogens in Small Systems - *Robin Collins, University of New Hampshire*

13. What are the Major Sources of Pathogens in Surface Water? - *Joan Rose, University of South Florida*

14. Analytical Methods: Overview of Available Analytical Methods for DBPs and On-going and Future Research - *Pat Fair, US EPA*

15. DBP Formation - *David Reckhow, University of Massachusetts at Amherst*

16. Evaluation of GAC and Nanofiltration under the ICR - *Steve Allgeier, US EPA*

17. Distribution Systems Risk Management Research - *Don Reasoner, US EPA*

18. Control of Microbial Contamination in Drinking Water Distribution Systems - *Mark LeChevallier, American Water Works Service Company, Voorhees, NJ*

19. Additional Papers on *Giardia* and *Cryptosporidium:*

19.a Sources and Fate of *Giardia* Cysts and *Cryptosporidium* Oocysts in Surface Waters

19.b *Giardia* Cyst and *Cryptosporidium* Oocyst Survival in Watersheds and Factors Affecting Inactivation

19.c Combined Sewer Overflows: A Source of *Cryptosporidium* and *Giardia?*