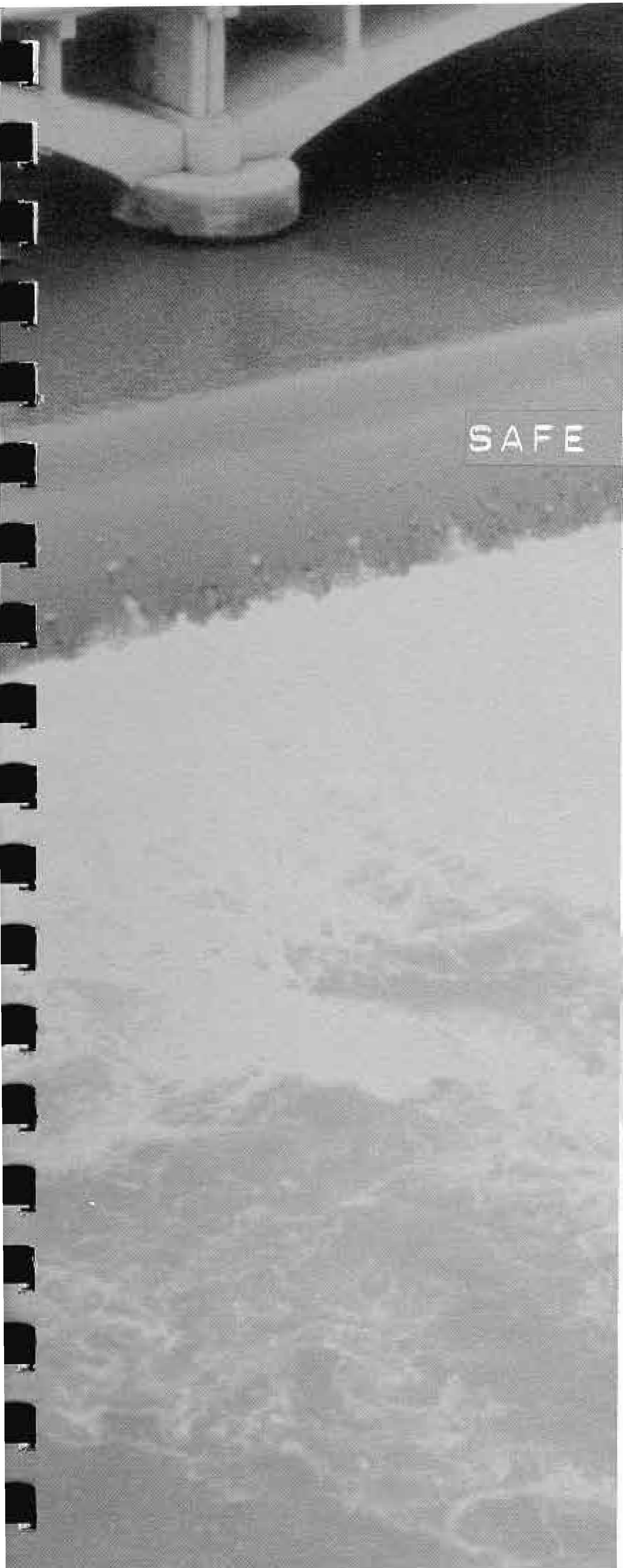

SAFE DRINKING WATER: IOWA'S FUTURE

Kirkwood Community College
Cedar Rapids, Iowa

NOVEMBER 4, 1994

PROCEEDINGS

SPONSORS:

Kirkwood Community College
Department of Environmental Sciences

Iowa State University
Leopold Center for Sustainable Agriculture
Iowa State Water Resources Research Institute

The University of Iowa
Center for Health Effects of Environmental Contamination

Contents

PREFACE

On November 4, 1994, a conference on ***Safe Drinking Water - Iowa's Future*** was held on the campus of Kirkwood Community College in Cedar Rapids, Iowa. The conference was sponsored by the Kirkwood Department of Environmental Sciences, the Leopold Center for Sustainable Agriculture and the Iowa State Water Resources Research Institute (ISWRRI) at Iowa State University, and the Center for Health Effects of Environmental Contamination (CHEEC) at the University of Iowa.

The conference was organized to provide a forum for discussion of the potential impacts of proposed Safe Drinking Water Act regulations on Iowa communities from economic and public health perspectives. Conference goals were to familiarize the public with the possible health risks associated with contaminants in drinking water supplies, particularly those substances which may be newly regulated; to provide information on current research on water treatment technologies which might be utilized in community treatment systems; and to discuss research projects related to minimizing contaminant inputs from various sources including agricultural, rural, and urban areas as a means of pollution prevention and waste reduction.

The conference also provided an opportunity for the University of Iowa and Iowa State University to work together on a project that benefited all Iowans. This was particularly appropriate as the Leopold Center and CHEEC were established by the 1987 Iowa Groundwater Protection Act; providing public education on water issues is inherent in the mission of both Centers. Working in cooperation with Kirkwood Community College afforded the best possible venue to conduct the conference, and assured that a diverse audience would participate.

Special thanks to Dr. Dennis Keeney, Dr. Gene Parkin, Rich Pirog, Jill Smart and Gloria Wenman for their efforts planning the event, lining up presenters, and facilitating and moderating the day's activities. Very special thanks to Dr. Ann Valentine, Cynthia Root and Doug Feil for planning and handling all logistics at the conference site at Kirkwood. Finally, thanks to my co-Editors on these proceedings: David Riley, Jill Smart and Gloria Wenman.

Peter Weyer
co-Editor
Program Coordinator, CHEEC

Welcoming Address

The Honorable Senator Tom Harkin (D-Iowa)

Greetings to you at the *Safe Drinking Water - Iowa's Future* Conference at Kirkwood Community College. I hope this conference can help us build bridges in Iowa--the bridges from old habits of pollution and over consumption to new habits of a cleaner and sustainable living.

Protecting our earth's fragile environment is essential as we approach the 21st Century. For too long, we have dumped waste into the environment without regard to the ecosystem's ability to absorb our refuse. And for too long we have consumed nonrenewable resources as if their supply would never end. For too long, we have polluted the atmosphere that protects us from above and the earth that nurtures us from below.

Your conference today will help remind everyone that our natural resources are limited, that the earth's capacity to absorb our waste is limited. The human race already has significantly affected the earth's ecosystems, often in dramatic and seemingly irreversible ways. Thankfully, your conference will go beyond discussing the problem of impure water to the important and difficult task of addressing remedies. Many would have us believe that protecting the water we drink and the air we breathe is too costly. They argue that imposing regulations working to cut pollution will put companies out of business and create economic hardships and unemployment. But I say just the opposite is true. The costs of health care and reduced labor caused by polluted water and air greatly exceed, in the end, the cost of clean air and clean water, particularly if we are judicious in solving our environmental problems. Cutting down excessive use of pesticides and fertilizers not only protects the water supplies downstream, but can reduce farmer costs. Planting buffer strips between row crops and streams can simultaneously cut runoff, provide shelter for wildlife, and reduce the effects of floods. I know that creative solutions to pollution can provide win-win situations for all of us here in America.

The water quality incentive program, which I fought to have included in the 1990 Farm Bill, is a good example of such a win-win situation. This program rewards farmers as they reduce the potential for contaminating water supplies. Although it needs more funding, which I will fight for in the future, this incentive program serves as a model for future environmentally sound agricultural policy. It is a policy that finds common ground without selling out our environment. We must, in this country, find common ground between people if we are to achieve the environmental goal of sustainable living.

So, I would challenge all of you gathered in Cedar Rapids today to work diligently toward sustainability in all of our activities and toward making it possible for your friends and neighbors. For instance, I have long been a fan of sustainable energy sources like solar hydrogen. In this system, hydrogen gas can be generated from renewable energy sources such as solar, wind, or biomass to store the energy from intermittent renewable energy resources such as wind and solar. This hydrogen will then be used in place of natural gas to power our homes, our factories, and our vehicles. Burning hydrogen does not produce acid rain or ozone smog or toxic pollutants or greenhouse gases, or radioactive waste. Burning hydrogen produces just pure, clean water. A solar hydrogen energy system would be totally sustainable and nonpolluting. It would neither consume natural resources nor create any pollution during operation. It is one of my long-term visions for the future of our country and the world.

You are addressing the more immediate question of providing for safe drinking water for our families and our communities. I think yours is a more difficult challenge, since you must deal with the pollutants that are already in the ground. So I applaud each of you for addressing the issue of safe drinking water. I wish you well in helping Iowa and the nation in finding solutions to the problem of water supply contamination. Because of your concerns, because of your talent and dedication, our children and our grandchildren will have more healthy and more productive lives. So thank you for this opportunity to share my thoughts with you and best of luck for a productive and useful conference.

What is safe drinking water? The laboratory perspective

George Breuer, The University of Iowa

Dr. Breuer is Chief of the Bureau of Environmental Quality at the University Hygienic Laboratory. In this capacity he supervises more than 40 chemists and technicians who perform analyses of various contaminants in air, water, soil, sludge, foliage and other environmental or occupational matrices. Previously, he worked in air pollution and reaction kinetics at the Statewide Air Pollution Research Center in Riverside, California, and as a research chemist for NIOSH, where he developed monitoring methods and instruments for physical and chemical agents in the workplace. Dr. Breuer is a Certified Industrial Hygienist in the chemical aspects of industrial hygiene. He holds a Ph.D. in physical chemistry from the University of California-Irvine.

It's interesting to take on a topic like the laboratory perspective of safe drinking water. We do a lot of analytical work, of course, but seldom do we sit down and look at these things from a distance and think about the perspectives that we ought to have? So I hope to give you some thoughts today to think about and elaborate on in some of the other sessions.

We do get a lot of questions at the Laboratory. In fact, John Kempf was here earlier from our water laboratory, environmental microbiology area, where they get a lot of questions from private supplies and other folks. Some questions are fairly straightforward, the kinds of things you expect from people: "We have an old well on the farm. How do I know whether it's safe to drink it or not? Should we be looking for something else?" There are some simple, fairly inexpensive tests that we do at the Hygienic Laboratory--the microbiology and nitrate tests--which give a good indication of whether that supply should or should not be used. There are other considerations as well. If it's a poorly constructed old well pit that floods periodically, then probably the people ought to be looking at a different water system, something that could be reliable over the long term. My favorite question is this one: "Is there anything toxic in my water?" Actually, the answer is fairly simple. Yes, if we look at a low enough level, certainly there is something there that we'll find. We might find a few more molecules of atrazine or a few atoms of lead or other things that are fairly common in the environment these days. Whether they're at any sort of level that is of real concern to the health of the people drinking that water poses an entirely different question. That's where you get into the laboratory perspective. What do we look for? How low do we need to look for these various kinds of analytes? That's where <u>we</u> get involved in it.

My apologies to Ed Moreno for this next question. "Iowa City water tastes awful. Is it really safe to drink?" The aesthetic qualities of water, taste, odor, and color, are not necessarily related to the safety of that water. In fact, Iowa City water is regularly tested--and is a good product. It does occasionally have a little protein content to it which we may not appreciate. "What about the pesticides in our rivers?" I think that everybody has seen headlines like this one in the *Daily Iowan*, "Iowa City Water Hazardous." I think we have the same media coverage here in Cedar Rapids, as a result of the Environmental Working Group report that came out just recently. A lot of questions came into the Laboratory at that time about pesticides in the river. They are of concern. We are concerned about those levels, whether they're going up or down. How many compounds are there? How many compounds simultaneously? A lot of questions are being asked--some of which we don't have good answers for at this point, but it is of concern to us. That's not to say that because pesticides are there that they present a hazard at the levels we ordinarily find them. Of course, the favorite alternative to our public drinking water supply is bottled water. In Iowa City, quite a bit of it is sold in the stores, either shipped in from various places around the country or prepared in the store. We did some testing a few years ago on representative bulk bottled waters and found that they are not all that different from the public water supplies you may be drinking. Economically they cost a lot more. So, you're not necessarily getting anything for your money if you buy bottled water. I don't drink bottled water, I drink the stuff out of the tap in Iowa City. I'm thankful to Ed for making it available at a reasonable cost. But the questions do reflect a concern with our drinking water and I'd like to talk about the general types of water contaminants that a modern laboratory must deal with.

Where do those contaminants come from? What are the sources of these things in our water? I'll then look at some of the future concerns in water testing in the United States. The first thing to think about is what is "safe." The American Heritage Dictionary defines the word safe as "free from risk." I don't know that anything is totally free from risk. There's a little bit of risk with almost everything. In fact, is water itself safe? Consuming an excessive quantity of plain water can cause an electrolyte imbalance. Occasionally you read about someone trying to purge their body by consuming a lot of water--causing an electrolyte imbalance, which can be fatal. Usually, when we're talking about safe drinking water, we're talking about it from a laboratory perspective. We tend to think of safe drinking water in terms of test results showing water either to have or not to have certain contaminants at the concentrations that may be of concern. We're talking about whether it is "safe" for normal consumption with the contaminants in the water. The question is "what is the desirable level of contaminants? How much atrazine do we want in our water?" The answer is we don't want any there. Atrazine is supposed to prevent weeds from growing in the farmer's field. When it's in the water, it's in the wrong place and we'd like to have it down to zero concentration. It took some time working in the laboratory to discover that if you look low enough, you'll find some. Some of the hard minerals may be desirable to have as far as human health goes. I don't want to focus just on what we do in the laboratory and leave you with the thought that "well, that's all that counts." There are a lot of other factors regarding the Safe Drinking Water Act, such as the type of source you have. We emphasize a safe source at the Hygienic Lab. If the source isn't any good, the post treatment may be a risky process. We'd like to have a good source. We'd like to have a well-constructed water supply--whether it's a well or a surface water supply.

Let's talk about some of the contaminants we look for in drinking water and their significance with respect to the safety of drinking water. Sometimes we lose the perspective that historically thousands of people have died from various waterborne diseases, such as typhoid and cholera. In certain parts of the world those are still a concern in drinking water. Obviously, one of the things we want to be rid of is this kind of illness--waterborne illnesses that cause large numbers of deaths. One way to check for the organisms that cause cholera, typhoid, and other disease is to look for indicator organisms. Coliform bacteria (passive bacteria that are very common in the environment) indicate if there's a pathway by which pathogenic organisms might be getting into the drinking water. Doing the coliform bacteria test is what we traditionally think of as measuring the safety of the drinking water. That is an important factor from a public health laboratory standpoint. We might say THE most important factor, in terms of the health of the human population. There are other organisms besides cholera and typhoid. EPA is now focusing on *Cryptosporidium*, which was a problem in Milwaukee--possibly as a result of some lapses in their municipal water treatment process. Something like 370,000 people wound up with diarrhea as a result of that lapse. *Giardia lamblia* is another potential waterborne disease organism. There are various viruses that might be in the water as well. EPA is focusing on them because they are resistant to the normal types of disinfection we do with drinking water. *Cryptosporidium* and *Giardia* tend to form cysts which are very resistant to chlorination. They can be filtered out, and EPA is looking at filtration of surface water in order to remove those cysts from the water supply. In the future, we may be using the ICR (Information Collection Rule) to test for some of these things in the water. Unfortunately it's a very involved test, very difficult to do with fairly poor recovery. Sometimes the results are equivocal: the cysts are infectious, or they actually knock them dead--unable to cause an infection. In any case, a major focus of safe drinking water clearly must be the elimination or at least the minimization of any of these disease organisms that may cause a serious waterborne disease. If we filter and disinfect our drinking water we ought to be in good shape. That's probably the case, at least from the standpoint of the infectious organisms and the acute illnesses because we face those with the use of chlorine or other disinfectants.

These raise the possibility of the generation of other sorts of contaminants that might risk the safety of our drinking water. For example, trihalomethanes (these include chloroforms and related compounds that are formed as a result of the reaction of organic materials with the residual chlorine that disinfects the water), that are present in the water; proteins, chemic, and pyruvic acids. They are a major product of that reaction. There may be other disinfection byproducts such as the haloacetic acids, chlorols, di-chlorols, tri-chlorols, acetic acid, the chlorol-acetyl-nitrals and some other compounds that are formed as a result of this reaction. Chlorine is not alone as a disinfectant with a byproduct but it is the one we probably know the most about. The other disinfectants also have byproducts that may be of concern. EPA is looking at these closely and we will be focusing on them in the future, so we may be hearing more about that as time goes on.

The pesticides are a major concern, especially here because Iowa is a major agricultural state. We've had a range of these used over the years: the old chlorinated hydrocarbon insecticides, DDT, and breakdown products; Endrin, and heptachlor for example were used for years. DDT has been banned, many of the others are now limited use pesticides, if they are used at all these days. Chlordane, for example, was used for years as a termiticide for treatment of houses. We found it in a number of places where it shouldn't be, like Cedar Lake here in

Cedar Rapids. Most of these things are decreasing in usage. However, they are accumulated in the body. We commonly see DDE (a breakdown product of DDT) in biological specimens. These have been largely replaced by new insecticides, the carbamates like Furidan and organophosphates like Lorsban and Encounter. Occasionally, we see traces of these but generally they are much shorter lived in the environment.

Some of the herbicides are more durable in the environment. Triazines and anilides are probably the most widely used herbicides today in agriculture in Iowa. I list these specifically because they are the ones of concern in Iowa and were covered by the Environmental Working Group report, *Tap Water Blues.* Certainly atrazine has been used for a long time and is the compound that we see most frequently in surface water and shallow groundwater, and other groundwaters at times as well. The fact is if we don't see atrazine, we will often see some of the breakdown products, which are as much of a concern as the parent compound. We did a study two years ago looking at surface water and drinking water supplies in the spring (when these things were being applied to the fields) and asked the farmers to sample after a runoff event when there was maximum turbidity in order to get a worse case scenario. We found in those situations we might have concentration levels up to a few tens of parts per billion. There is certainly potential for some of these getting into the water at levels above the MCL. For example, the MCL for atrazine is three parts per billion. We may see some levels significantly above that. It is useful to keep in mind that EPA has also set some health advisory levels. For longer term consumption of water, you could consume atrazine, according to the EPA, up to 100 parts per billion. So, being in excess of three parts per billion may not be a call for panic, but is a cause for concern.

There are various other herbicides such as 2-4-D, glyphosate, and alachlor which are now covered under the Safe Drinking Water Act. There are some new compounds with sulfur-ureas, things like Accent and Classic. In addition products like Pursuit, Septor, and Broadstrike are being widely used. These are used at lower levels, reducing the amount of active ingredient that is applied--sometimes ounces per acre instead of pounds per acre like atrazine and Lasso. Unfortunately, from an analytical laboratory standpoint, these things are very difficult to deal with because they often require individual analytical methods using high pressure liquid chromatographic methods instead of a gas chromatograph method where all five can be measured. I may have to run six different methods in order to detect those compounds, so it complicates the picture from a laboratory standpoint.

There are various other kinds of substances that might be present such as the radioactive chemicals. Uranium and radium have been of concern, not because someone spilled them out on the road somewhere, but because they are the natural components of the rocks and the aquifers where our water often comes from. There may be some medical, industrial, or nuclear power isotopes in there as well. We do a lot of monitoring around the nuclear power plant up at Palo. They don't seem to have much that is released into the water. In Iowa we can do gross alpha and gross beta screening tests very easily to conclude whether they are there or not. If you have to do more, if you need to know what kind of rating is there, then it gets more complicated and more expensive. The only problem we have had in the state to this point has been the Jordan aquifer. Primarily because of radium levels that are slightly above the 5 pci/L MCL that EPA has set. There are a few water supplies that need to be concerned about that. We thought for a while that EPA was going to increase that MCL to 20 pci/L which would resolve the problem in Iowa, but it looks like they're going to keep the current standard.

The other future focus here, EPA is looking at setting an MCL for radon. They suggest a level of 300 pci/L. Some of our studies indicate that if they set it at that level, roughly 50% of our groundwater in the state will be in violation. Radon is a gas and it comes out of the water as it's being treated. Of the Iowa supplies that we looked at, about 28% may exceed that 300 pci/L standard. We might have to do some kind of additional treatment in order to get rid of the radon. Radon is really not a problem from drinking the water but because it is in the air. We breathe the air and it may cause lung cancer.

There are a variety of other organic and inorganic chemicals we need to be concerned with. There are solvents that we see pretty frequently, called BTEX (Benzene, Toluene, Ethylbenzene, Xylene), which are a group of simple aromatics that are major components of gasoline. Our motor vehicles that we love so dearly may be causing health problems as a result of the distribution of gasoline. It's interesting to go to some of the conferences on underground storage tanks, where instead of talking about parts per billion in the water, they talk about feet products exploding on the ground water. There are other compounds like tetrachloroethylene, a common dry cleaning solvent that we see pretty frequently in the water. Trichloroethylene, a similar compound, was a problem in Des Moines for a number of years. You may remember various industrial chemicals, polycyclic aromatic hydrocarbons, contaminating some of our water supplies because of the old coal gasification plants that are scattered around the state. And then there are various heavy metals as well such as lead and mercury. Lead is an interesting case because of the source: solder joints and the leaded brass that are in the plumbing fixtures in our homes. Asbestos fibers are now regulated in the Safe Drinking Water Act at seven million fibers per liter in excess of 10 microns. There is a transmission electron microscopy test we do for those fibers. Iowa hasn't been enforcing it too rigorously. There are a lot of asbestos cement fibers used out there and they are shedding fibers if the water is corrosive. We've not found anything that exceeds that level which is actually pretty high in terms of an analytical standpoint. That long of a fiber we don't see very often.

My talk has been very general about the various classes of things we might see in the water. EPA put together a brochure on drinking water regulations and health advisories. It's an almost endless list of all the kinds of compounds, pesticides, industrial chemicals, and other things. It gives some specific information on the drinking water EPA has set, some of the health advisories for various times of consumption; 1 day, 10 day, longer term; for a child, for the adult. Those of you who are interested in more specifics about some of these individual compounds may find this to be an interesting reference.

The state of Iowa's drinking water: Recent surveys

Donald Paulin, Iowa Department of Natural Resources

Mr. Paulin has been Deputy Director of the Iowa Department of Natural Resources since December, 1991. He previously served as Administrative Assistant to the Governor. Elected to the Iowa House of Representatives in 1983, he served as Minority Leader and on the Natural Resource, Energy and Environmental Protection Committee, and Judiciary Committee. He was on interim and subcommittees that developed the groundwater bill, REAP, and the leaking underground storage tank bill. Mr. Paulin is an Advisory Board member for the Leopold Center for Sustainable Agriculture and the Center for Health Effects of Environmental Contamination, and serves on the Governor's Environmental Agriculture Committee and other committees. He is a Navy veteran of the Korean War.

Iowa's drinking water is at, or nearing, a crossroads, or a "fork in the stream," for several reasons. The governmental and private entities who are suppliers of drinking water are doing more monitoring for pesticides, synthetic organic chemicals and volatile organic chemicals. As results from this monitoring are reviewed we are gaining a better understanding of the problems. The crossroads we are at is one where past data show water supplies are providing safe water, but new monitoring, new requirements, and more potential for contamination mean that suppliers of drinking water have challenges, including additional costs, that they, their customers, and we, the state, must meet. As the problems and opportunities come into better focus, we will need to develop and address solutions and improve our approach.

I'd like to give you a little background on public water supplies in Iowa. A public water supply is a system that provides water for human consumption and has at least 15 service connections or regularly serves at least 25 individuals daily for at least 60 days of the year. There are three categories of public water supplies: Community, which serves a year-round residential population; Non-transient non-community, which serves the same people at least 4 hours per day, 4 days per week, and 26 days per year (i.e.: industry providing drinking water); and Transient non-community, which is not a community nor non-transient non-community water supply (i.e.: truck stop, rest stops). Within the broad title of public water suppliers, there are many privately owned entities. Public water supplies serve 83% of Iowa's population. Of the 2.8 million residents in the 1990 Census, water supplies regulated by the DNR serve 2.3 million people. The remaining 17% of the population is served by private water supplies. Private water supplies do not have enforceable drinking water standards but do have enforceable construction standards. These construction standards are administered by counties.

Iowa now has 1,936 public water supplies; there are 1,157 community systems, 152 non-transient non-community, and 627 transient non-community. Of the 1,157 community systems, only 42 (4%) use surface water while 1,115 (96%) use groundwater as the source of their drinking water. However, the population served by groundwater is about 66% (1,511,427). Surface water systems provide 34% (789,799) of the population served by public water supplies. The number of public water supplies is declining. In the last 8 years, the number of total public water supplies has decreased from 2,134 to 1,936. Within these numbers, community water supplies have decreased by 0.2%, or is virtually the same; non-transients have declined by 12.6%, and transient non-community systems have decreased by 21.7%. These figures are probably consistent with trends, generally in our rural areas. Darrell McAllister of DNR's Water Quality Bureau attributes the decline to the increasing regulations of the water supply program, the enforcement of these regulations, and the ability of larger water supplies to absorb smaller systems.

While the number of water supplies is a factor in protecting the drinking water, the size or the number of people served by each water supply is a critical factor. Although in some ways unfortunate, it is a fact of life that the larger water supplies are in a much better position to not only handle the cost of required improvements and monitoring, but to keep up-to-date on the increasing regulatory requirements. They may have the expertise on staff that smaller supplies must depend on DNR for. Eighty-eight percent of Iowa's systems serve less than 2,500 people. Water supplies serving less than 500 people make up 57% of public water supplies. Water supplies serving between 500 and 2,500 people make up 31% of the systems. Although comprising the vast majority of the water supplies, these systems do not serve a majority of the population.

It will probably come as no surprise to hear that many water supplies serving populations of less than 2,500 are questioning the need for all the monitoring required in the regulations. While Iowa does not provide financial support for required analysis, many other states do provide assistance, although they are starting to reevaluate this assistance as the costs and responsibilities increase.

Faced with the very real threat of EPA taking over the Iowa program, in April of this year the Iowa General Assembly recognized the need to maintain primacy of Iowa's drinking water program. In 1986 there were 23 regulated contaminants, but that number will increase to 87 in 1995. Legislators realized that the drinking water program needed additional resources. The legislative solution to this problem was to create a water quality protection fund to assure that fees collected each year from construction and operation permits would be used to administer and support the regulated industry. The legislature also dictated the amount of money to be raised from user fees, and appropriated $404,000 from the General Fund for this purpose. Federal funds are also received, although in a small, declining amount.

DNR is in the process of taking comments on proposed rules to implement the new fee schedule. The seventh and final hearing on the proposed rules occurred today in Clinton. If adopted, the proposed rules will require the smaller water supplies to contribute a large portion of the fees. DNR and the Local Government Environmental Resource Council recommended that they be charged 86% of the fees. As indicated earlier, the small water supplies make up a large part of the work load of DNR. Although this user fee is commensurate with the efforts that will need to be expended, it is probable that some citizens on smaller systems will object to paying more per customer than those on larger systems.

Public water supplies have different monitoring requirements based on the category they are in. For example, transient non-community systems only monitor for coliform bacteria and nitrate. Community systems and non-transient non-community systems have about the same monitoring requirements except that the non-transient non-community systems are not required to monitor for corrosivity, total trihalomethanes, radionuclides and gross beta.

Now that we have discussed the number and categories of systems, let's talk about quality. All systems monitor for coliform bacteria. More systems monitor for bacteria in the summer due to the seasonal nature of bacteria in some systems, such as campgrounds and parks. DNR sends each system a letter when they exceed the coliform bacteria limit. This letter also provides the water supply information on the additional monitoring and details of the public notification they must make.

From September 1993 to September 1994 about 200 letters of violation were sent to public water supplies. Some water supplies may have received more than one letter of violation. Forty-seven of the letters notified the water supply of an acute bacterial violation. Most of these bacterial violations occurred in September of 1993, which was expected since the 100 year flood, at least in much of the state, had just occurred.

The number of water supplies exceeding the nitrate MCL has gradually declined since 1985, when 58 water supplies were in violation. In 1993, 37 water supplies exceeded the MCL. So far in 1994, 38 water supplies have exceeded the standard. Since 1989, the average number of water supplies exceeding the MCL is 39. This is about 2% of the total number of public water supplies. The total population served by the water supplies exceeding the MCL in 1993 was about 15,000 people. In 1990, Iowa City exceeded the MCL for nitrate and about 75,000 people were potentially affected. In 1991, Des Moines exceeded the MCL and over 250,000 people were potentially affected. Remedial actions were taken in both cases.

Since 1986, 9 systems have exceeded the fluoride MCL. Three have been resolved and six water supplies, affecting 1200 persons, are presently in violation for fluoride. These are located in Polk, Dallas and Guthrie counties. Two systems, in Cerro Gordo and Boone counties, affecting 90 persons, presently exceed the arsenic MCL.

Recently, water supplies have monitored for lead and copper. We found that the number of systems that exceeded the lead action level was 119, and 135 systems exceeded the copper action level. These numbers surprised us, and also overloaded our capacity to handle all of the communications from the small water supplies, the press, legislators, and others on this complex rule.

Water suppliers have begun to monitor for pesticides, SOCs and VOCs contained in phase 2 and 5 of EPA's regulations. Approximately 1,170 systems are required to do this monitoring. Of the monitoring that has been done and reported, 2,300 samples have detected SOC or VOC at various levels. Twenty-six water supplies have exceeded the MCL for one or more of the contaminants. DNR estimates that the population affected by these contaminants is about 65,700 people.

You may have heard or read the report "*Tap Water Blues*" that was released by the Environmental Working Group. This report, while containing some good information and recommendations, appeared to indicate that water supplies in Iowa and surrounding states were providing unsafe drinking water. In fact the report stated that "14.1 million people routinely drink water contaminated with the five major agricultural herbicides." A more correct statement would have been that the water in question was raw water, or water prior to treatment. From the data provided to DNR by water supplies in the last 20 months, we know that water supplies are detecting these herbicides but there have only been three samples that have exceeded the MCL or Long Term Health Advisory for the 5 pesticides mentioned in the report. These samples were taken from two community systems. Unfortunately, the report did not use the best available information on the quality of water provided at the faucet. However, the report provides good recommendations for protecting source waters and providing incentives for the reduced usage of pesticides.

I hope this summary of Iowa's drinking water supplies provides you with information you can use to further your discussion on the future of Iowa's drinking water.

Innovative water treatment: Today

Ed Moreno, Iowa City Water Division

Ed Moreno is Water Superintendent for Iowa City and has been with the Iowa City Water Division for 7 years. Previously, he worked as a treatment plant operator at the University of Iowa Water Plant and was an environmental specialist and field office supervisor for the Iowa Department of Natural Resources. He holds a master's degree in civil and environmental engineering from the University of Iowa.

Iowa City water is always making news and there are a lot of reasons for that. In the face of all the complaints and all the jokes, what we're striving for is having great water for Iowa City and that is what we're going to achieve. Iowa City has a $50 million renovation project to construct a new water treatment plant and do major upgrades on our distribution system. In doing so we plan to accomplish the transformation of water quality in Iowa City. Through our investigations, we've encountered many water quality issues that are common to Iowa. I will touch on those in addition to some other issues that are occurring around the state.

There is a cartoon by a former resident of Iowa City, Berke Breathed. It shows Opus and a little friend sitting on the fountain in downtown Iowa City. They're lamenting what they're going to miss about Iowa City. They're talking about Barbara's Bakery, the Library, and hanging out at the Pentacrest. At the very end they say, "I'll miss everything about Iowa City except the water. The water tastes like Spic-n-Span." This is the legacy of Iowa City water. I want to give you an idea of why that is. It all starts with our source water, the Iowa River. The issues that we face- the taste and odor problems, the contamination --are mostly related to our primary source, the Iowa River. The Coralville Lake dam is operated by the Corps of Engineers and their mission (criteria for operating) is related to flood control, flow augmentation, recreation, and wildlife--somewhere in there is water quality. They change the flow coming down the Iowa River 3-4 miles upstream from the intake of the Iowa City Water Plant. These changes have a great impact on what happens at our plant. The Corps saved us in 1993, so I'm not disrespecting what they do. Fortunately, we were the focus for their operation during 1993 and they were able to make sure we did not go under like the Des Moines Water Treatment Plant.

In the 1993 flood, water went over the spillway by about 4.5 feet. We see changes in flows coming down the Iowa River ranging from a low of 55 ft^3 / second to a high during the flood of 26,500 ft^3 / second. With that comes drastic changes in water quality.

Samples taken following a heavy precipitation event in our watershed area show the turbidity we sometimes have to deal with. We've seen turbidity range from a low of 2-3 in the winter to a high of 10,000 after a precipitation event. What you can't see is that in one of the vials is also 210 parts per billion of atrazine and elevated levels of nitrate. We have quite a bit of contaminants at certain times in the Iowa River.

The Iowa City Water Plant is right in the heart of the University of Iowa campus. The water plant has always been located at this location, in the heart of campus since 1882. It was privately owned until 1961 at which time the city purchased it and embarked on a very aggressive construction project to upgrade the plant. The Iowa City Water Plant is designed to remove dirt, bacteria, viruses, protozoans and protozoan cysts from the water. Our treatment process it is not designed for lime softening or anything advanced beyond that. We have a computer control system in our plant that allows us to automatically control what is going on in the plant. In addition, we have manual controls out in the plant in case we have problems with our computer system. We have filters that are vintage 1909 and they're still in operation--processing approximately one-quarter to one-third of the water produced daily by Iowa City. The rest is produced out of the new part of the plant. Part of our treatment process allows us to bring deep well water from the Jordan aquifer into the end of the water treatment plant--we utilize it sporadically; sometimes for demand purposes, more often for contaminant purposes. If there are high levels of contaminants in the river, such as nitrate or pesticides or there are problems with treating the organics, we will turn on this deep well and bring in Jordan water, which is really high in solids, but has none of the other contaminants.

Iowa City has a unique system, three underground storage tanks--2 million gallons per tank. Each tank has its own pumping station and independent yet dependent computer controls. Our high service is also computer controlled. The high service pumps have 500 horse power, 200 horse power, and 350 horse power motors. They're operating off a pressure set point that is controlled by our computer system that modulates a butterfly valve. The system is like a hub with spokes on it. Water goes out with pressure ranging from 110-120 psi. The tanks, their computer system, and their pumps maintain a pressure set point throughout the city. In January of 1993, we had a mechanical malfunction which caused flooding in this entire area. Imagine getting a call at 4:00 a.m., coming in and finding these pumps' motors under 5 feet of water--it was a nightmare. They're in a recessed area so we had to bring a crane in, pluck each one out, send it out to be cleaned and dried, and then put it back in. We did all this within 24 hours. Iowa City's water treatment plant in 1972 was believed to be one of the first to have a totally computerized system. The 1972 computer system was a series of relay cabinets that went half way across this room. It had a disk that had less than 16K of memory, and a graphics panel that looked like something out of the old *Star Trek* series. When I came to Iowa City it was still in place and operating some of the plant. One of the first projects we undertook was to gut it and utilize some of the wiring to put in new sensors, then replace the computer with two programmable logic controllers. We interfaced them with a software package that gave us graphics. The operator can now be in the control room, go through the screens and know exactly what is going on in the plant. Currently, we have three modes of operation: The first is totally automatic, where the computer system is programmed to run filters, pressure set some of these modulating butterfly valves on the high service. The second mode is one we call semi-remote, or remote control, where the operator can push a button in the control room, and something will happen out in the plant. The third mode is manual.

The plant has a very basic wet chemistry lab where we do our QA/QC for the plant, deriving samples, which are done on a minimum of four hour increments. We measure where we are and make adjustments from those measurements--we use chlorine, turbidity, nitrates, pH's, and total dissolved solids. Currently, we are allowed to discharge solids directly into the Iowa River; we discharge thousands of pounds of solids each day back into the Iowa River. Two percent of the water treatment plants in Iowa are at the complexity or the rate we are--grade IV surface water treatment plant. In order to do that you need some highly skilled people operating the plant. We are very proud of our staff and the level of education that they have.

I'm going to talk about some of the recent press to give you an idea of the issues that brought us to our decision to proceed with the planning for a new water treatment plant. We normally experience a couple fish kills each year when there are thousands and thousands of fish coming down the river. Back in 1988 and 1989 there was a major drought during which time the water quality of the river was not too bad. There was a lot of algae and stagnation, but contaminants like herbicides, pesticides, and nitrate were very low. However, when it did start to rain we started to see things like foam on the river. People were calling and asking what it was. A lot of organics came down with source precipitation at that time. We had problems treating the water. What we found were higher levels of organically bound iron manganese that we had never seen before. During that time the treated water was going out at good turbidity levels. However, we were not removing the iron manganese in the plant and it reacted with the chlorine in our distribution system. It was oxidized and created this incredible yellowish color, you couldn't tell if you had flushed the toilet or not. In addition, we were utilizing chlorine at levels upwards of 1,200 pounds a day, which comes to about 25 parts per million. Ordinarily we see something less then eight. It was a very difficult time for us. The precipitation event caused an influx of nitrate larger than we had ever seen, something in the order of 65 parts per million as nitrate. For us, the solution to pollution is dilution with the deep wells, but we were unable to meet the demands needed to keep contaminants of nitrate low enough. We went over the limit for 3 days in 1990. It was a very tense time because the high risk group for nitrates is infants under the age of 6 months. At that time there was some literature identifying pregnant mothers as also being at risk. We got a lot of bad press and a lot of heat for that. What also occurred during that time was a major shift in the regulations of the public notification requirements. We had 72 hours to go to the video and the television stations. We had 14 days to go to the newspapers. We had 25 days to send an individual letter to each and every customer to let them know what we had done and what the health implications were. Inside the local newspapers there were charts showing the daily nitrogen levels and the standard of 45 parts per million nitrate. As you may recall, Des Moines also went over the limit during this period of time. There was some media confusion because they were measuring it as nitrogen which had a limit of 10. I recall being in Des Moines and hearing a radio personality saying, "You think we got it bad, look at Iowa City--they're four times higher than we are."

Another key factor was the Safe Drinking Water Act amendment of 1986, which indicated that the game was going to be drastically and very quickly changing. It became apparent to us that we needed to do some major planning for Iowa City. In 1990 we decided to create what we call the Comprehensive Water Facility Plant. Our first step was to interview consultants and choose one who we felt had the flexibility and base knowledge to help us create a plan that allowed us to look at all of the issues in place as well as those we knew were going to be coming. Another thing we did was to form what we called a "technical advisory group." This group consisted of individuals throughout Iowa City: professional people, academicians, soil conservationists, the Culligan Man, local plumbers, and industrial representatives. We asked them to give us some direction. These were issues ranging from water conservation, water use rates and regional water issues, to water quality standards. The Advisory Group discussed and prioritized these issues. The basis of our charge is in the following three statements: 1) Iowa City drinking water should meet all of the existing and predicted water quality standards; 2) The water treatment plant should produce water that is aesthetically pleasing and environmentally acceptable to the general consumer; and 3) water officials should project what we need to do improvement-wise 20 to 40 years into the future. Built into these three items were water conservation, regional water and other issues. We began evaluating the existing water treatment plant to see what was possible, and started to look at water resources in and around Iowa City. We identified a previously unknown aquifer in southern Johnson County, in addition to sources we were already using like the Iowa River, the Jordan aquifer, and the Silurian aquifer. It was very valuable for us to go down and explore the Silurian. We were able to get some bore holes in and found that the water is not there in the quantities we need so we changed our direction of search--we're up north of Iowa City now. We are looking at a site that is approximately 230 acres of land. On that site we'll have our sources and build a new water treatment plant. We are fortunate to have some alluvial sand on the site which would be our primary source. Our intention is to get away from the river as much as possible and utilize sources that are much better. Water is like a recipe and if you're a good cook you start with good ingredients. If you're a really good cook you've got good mixers and bowls. That's what we're intending to do. We don't want to put salt in when we think it should be sugar and we want to have some really nice bowls and instruments to allow us to produce the highest quality water we can.

Our preferred site is on the corner of Interstate 80 and North Dubuque Street. On this site is a quarry where they are mining the sand--they have an alluvial aquifer. There are also some private homes and agricultural activities in the area. We will no longer be allowed to discharge solids into the Iowa River, we will have sludge lagoons. We have done the preliminary investigations to allow us to have horizontal collector buoys. We will be obtaining alluvial water from this site. We're real excited about that. It will be a much more stable water source as far as what's coming in. We're going to be putting a horizontal collector well in a couple of areas on the site, and we're going to install two Silurian pumps. In addition, there is another area we call the peninsula where there is a good alluvial fan that we intend to put two horizonal collector wells in, in addition to two more Silurian wells. We will bring that water into a water treatment plant that will perform lime softening followed by activated carbon filtration. Initially we'll probably go out with prechlorination. With every surface water plant that is designed there's always the future ozone section. Our plant is designed with the future ozone area so that if we see the need in the future to switch to ozonation, the hydraulics will already be accounted for, and we'll just have to bring in the equipment. We'll have a pilot plant in the new plant to continue our studies of issues such as that. We're intending to construct three major feeder lines that will distribute the water differently throughout the city. Right now if you're in Iowa City and you're on the far west side you'll wake up in the morning and find your water just trickling out. We are going to construct 24 inch feeder mains going to those areas, connecting very close to the remote storage tanks. We're also going to connect onto an existing Dubuque Street line that is not too far from the plant. We propose changing the existing water treatment plant to a water pumping station.

One of the bigger issues is related to wellhead protection--water rights. Who owns the water? Who can get the water? How do you protect people from being impacted from well interference by an entity as large as Iowa City, which is looking for water in aquifers that are already heavily used? Another issue is related to public involvement and public notification. We have created a position in the Water Division for a public information and education coordinator, who will address those issues head on. We hope to incorporate valuable information coming from those issues into our future plans. We are in a prime position to make changes. With respect to the well protection and well interference issues we've put together a team of representatives from the USGS, the Iowa Geological Survey Bureau, the Johnson County Health Department, as well as our consultant. We are working on a plan to do some pump testing on the Silurian and we'll share that information with everyone. We've had many meetings and I think that we're in a position now where we can fully get the data and distribute it in a way that will empower the individuals who are concerned to come forward and work with us. We're really excited about that.

Issues related to the recent *Cryptosporidium* and disinfection byproducts problems bring up the issue of balancing risk. You've got acute risk and you've got chronic risk. In the water industry we're aware of the balancing act that we must do. We're struggling quite a bit with our ability to communicate that. That's why these conferences are very important and I'm very pleased to be here; to listen and to learn. Another issue is watershed management. We're currently looking at obtaining the entire site and protecting it, because we have a limited ability to control and manage the entire watershed and the many accesses to it. There are a lot of activities going on in Johnson County to assist with that and we will be participating. I guarantee that the consumer in Iowa City is not waiting for us to put this plan in action. They are buying their point-of-use devices right now. We will also participate with the watershed management team and their ideas. We will be proceeding with our water treatment plant. We are going to be on different schedules, but I think we all have a similar mission. I think we're all starting to acknowledge that.

Let me point out some other things that are going on around the state. Des Moines has constructed a nitrate removal facility. It's unique, they say it's the largest in the world, and that's one way to address that contaminant. We're looking at diluting it. Also, we've embarked on a watershed management project. We're going to be getting a lot of attention here. We're participating with groups in Minnesota and in Iowa to look at protecting the Raccoon River watershed. Keokuk is looking at Aquifer Storage Recovery (ASR), which involves taking treated water and injecting it into the aquifer in the ground to store it and bring it back later. You can run your plant in a certain capacity and then bring it back without having to expand later. Lou Licht in Iowa City is working with poplar trees and their ability to absorb contaminants that are running off into the streams. He'll be working with our project a lot. There are a lot of other issues which I'll touch on. Rural water is a very interesting issue, and the primacy issue and the state's ability to regulate drinking water is a concern for all of us. I'm going to participate in public hearings to give Iowa City's viewpoint on it. Just the ability to control our destiny through instate people is very important. The issue that CHEEC is working on--contaminants and what are their impacts on health? I think a real key issue is looking at staffing for the future--the staff that we're going to need to fulfill these kind of plans. We better have somebody there to run things, and they better be on top of it. They better know some chemistry and have a very broad, extensive background. I think Kirkwood Community College is great for starting that process, we'll see if we can continue to nurture future generations.

Agricultural sources: Livestock confinement

Stewart Melvin, Iowa State University

Dr. Melvin is Professor and Extension Agricultural Engineer in the Department of Agricultural and Biosystems Engineering at Iowa State University. His research and extension programs have focused on soil, water and agricultural waste management problems. He has over twenty years experience in adult education in his areas of expertise, as well as an active research program in agricultural water quality, water table management for drainage and irrigation, soil compaction and conservation tillage and environmental control of animal production systems. Dr. Melvin has consulted in Latin America, Western and Eastern Europe on agricultural effects on water quality. He holds a Ph.D. degree in Agricultural Engineering from Iowa State University.

Livestock production in Iowa and the Midwest has changed significantly in recent years. Compared to animal agriculture in the 1950's and 1960's, today's animal production systems are larger, more specialized and more dependent on purchased feed supplies. Many of the potential environmental quality problems connected with animal production operations have been associated with excesses generated at or on animal production sites. Excess manure at animal production and manure storage facilities, as well as runoff and leachate from manure application sites, represent major problem areas for environmental concerns. Manure excesses have become more of a problem because of readily available commercial fertilizers, large concentration of production units, reduced availability of labor, narrow profit margins and higher priced land.

The amount of animal manure that is retained on land or that reaches groundwater or surface water is not well documented. However, it is safe to say that only a small proportion of animal generated manure is not retained on land on most animal production operations. It is incorrect to use the amount of manure generated by animals as an indicator of actual water pollution. Manure generation is only an indicator of the total potential pollution. Modern manure management systems can be designed to meet strict discharge guidelines.

Pollution Characteristics of Animal Manures

The major water pollutants arising from animal manures are oxygen-demanding matter (primarily organic matter), plant nutrients and infectious agents. Color and odor are potential pollutants of secondary importance. Organic matter serves as an energy source for aerobic bacteria when it enters a receiving stream. Increased bacterial metabolism resulting from a discharge of organic waste into a stream increases the oxygen depletion rate. If the rate of oxygen depletion exceeds the re-aeration rate of the stream, oxygen depletion occurs. Decreased or depleted oxygen levels can result in fish kills and anaerobic conditions in the stream or other water body.

Animal manures contain high concentrations of plant nutrients. These nutrients are beneficial when recycled properly to land. At the same time, nutrients from manure have the potential to increase nutrient concentrations in water bodies if wastes are discharged to water bodies. Nitrogen and phosphorous are the plant nutrients of primary concern. The increased nutrient loading on streams can stimulate the growth of aquatic plants which may have significant impacts on the acceptable water quality of that stream or lake. In addition, high manure loading rates can apply high levels of nitrogen which can, in turn, increase shallow groundwater nitrate concentrations.

Disease transmission of waterborne organisms of animal origin is another potential water pollution hazard resulting from animal production. Several diseases can be transmitted from animal to animal and from animal to man. Modern manure management systems have to take this possibility into account. Prevention of improperly treated manure laden runoff water is the main defense in prevention of disease transmission.

Another pollutant commonly associated with outdoor and unconfined animal production is increased sediment in surface water. Animal traffic in pastures, near and along stream banks, and on open feedlots can result in increased erosion in areas with animal production systems. Sediment is normally associated with cropland erosion, but in watersheds with significant permanent surface cover and high water quality areas there is a potential impact of sediments resulting from animal production systems. Properly designed and operated feedlot runoff control systems and good pasture management can significantly reduce the problem.

Surface Water Concerns

Open Feedlot Runoff

Fish kills in Kansas streams in the early and mid-1960's resulting from runoff from large feedlots was a startling reminder of the pollution potential of resources out of place. Miner, et.al. (1) published early information on the characteristics of the waste stream. They reported that the pollutant potential of open feedlot runoff was highly variable, but in most cases was much higher in pollutant load than raw municipal sewage. Pollutant strength was affected by differences in lot surface conditions, antecedent moisture and temperature, rainfall intensity and season. Highest pollutant strength was found with a low intensity rainfall event, with moist conditions preceding the storm, and during warm weather.

Feedlot surfaces have much lower infiltration capacity than comparable cropland. As a result, storm runoff is initiated on feedlot surfaces before runoff is produced on surrounding soils. If feedlot runoff is allowed to discharge into streams during a low flow period, drastic surface water problems can be expected. For this reason, solids settling and detention of liquid feedlot runoff is recommended for control of surface water pollution.

Runoff control systems must be custom designed to individual feedlots because of variations in species, topography, soil types, climatic conditions, and feedlot management options. However, there are components common to most control systems. An upper diversion channel is required if site conditions are such that surface runoff from outside the feedlot would run into the feedlot area. Feedlot runoff water carries high solids loads. To allow removal of settleable soils from the runoff stream, a settling area is recommended. For feedlots over 1,000 animal units in size, state and federal permit requirements normally require a runoff holding basin. The minimum size of a runoff basin is the runoff volume of a 25 year-24 hour storm. If disposal of wastewater is not convenient soon after each storm, larger storage systems are required.

There is a potential for small feedlots to present water quality problems, particularly if they are located close to a receiving stream or lake. If natural conditions do not allow for settling and infiltration prior to discharge, organic and nutrient loads can be delivered to streams. Small feedlots have been considered as both point and non-point pollution sources. From 1972 until 1987 small feedlots in Iowa were required to have operation permits if they were located close to water bodies. However, in 1987, such feedlots were excluded from operation permit requirements unless notified by the state agency that a permit was required.

Vegetative filters have been proposed to treat runoff from small feedlots as an alternative to impoundment and land application. Dickey and Vanderholm (2) developed design criteria for vegetative filters to treat feedlot runoff. They found that overland flow systems where wastewater was distributed across the filter in a uniformly thin sheet was much more effective than systems using grass waterways or channelized flow. Properly designed and operated filter strips were found to reduce pollutant concentrations by 80% and reduce mass loads by 95%.

Recent interest has been shown in the use of artificial wetlands to treat wastewaters from animal production operations. USDA-SCS is now evaluating several artificial wetland sites in the U.S. to determine the applicability for use in water pollution control.

Waste Storage Sites

Manure can be sorted in solid, semi-solid, and liquid forms in structures made from earth, wood, concrete, steel, and other materials. The surface water pollution potential from manure storage sites can result from discharge of leachate or runoff from manure storage sites or from accidental discharge resulting from structural failure. Leachate or runoff from manure storage has high organic loads and can have significant surface water impact on receiving streams.

Accidental discharge from storage into surface waters is rare but if it does occur significant stream or lake problems can be expected. Liquid manures represent an additional threat since failure of storage or plumbing systems may result in large volumes of high organic load material reaching a watercourse. Structural integrity is important especially with above ground storage systems.

Manure Application Sites

Most manure is ultimately applied to land to obtain final treatment and utilization. Manure application to land can have both positive and negative environmental impacts. Manure properly applied to land can result in higher organic matter near the soil surface and better soil tilth. Infiltration is increased and soil erosion is reduced as a result of both organic mulch and a more stable soil structure on manured soils. When manure is surface applied to areas subject to high surface runoff, there is a potential to lose nitrogen and phosphorus in the surface runoff. Several research projects have been conducted to determine the runoff potential of manure applied under various soil and climatic conditions. Most studies indicate that losses of nutrients in runoff are extremely variable from year to year.

Even though data are variable regarding water pollution resulting from surface spreading of manure in the winter, it is often recommended to restrict manure applications on frozen soils. Annual nutrient loads to streams has been estimated by Rouse and Melvin (3). Incorporation of manure is a practice that has minimized the runoff potential of both N and P. Surface water pollution problems can be reduced significantly by incorporating manures.

Range and Pasture Impacts

In most cases, unconfined animal production is both environmentally sound and compatible with a high quality environment. However, such production can cause changes in vegetative cover and soil physical properties that may result in increased rainfall runoff and pollutant transport to contiguous surface waters. Often the only water quality parameter that can be definitively discerned is elevated counts of indicator bacteria. Increased levels of inorganic and organic sediments may result from high impact or areas where poor management and site conditions exist. Streambank protection may be needed in critical areas, especially in cold water streams where streambank vegetation is critical for a quality aquatic habitat. High use areas, shade, feeding areas, artificial waters, and salt licks should be kept away from watercourses. Good management techniques also include tailoring stocking rates to maintain adequate ground cover for both inorganic and organic sediment control.

GROUNDWATER POLLUTION POTENTIAL

Groundwater pollution potential from animal production operations is of concern at the production site as well as where manure is applied on pasture or cropland.

Feedlots

Research in several states has shown that a compacted layer forms below the surface of active feedlots that provides a relatively impervious layer for air and water transfer. This layer reduces the water infiltration rate and restricts the leaching of salts, nitrates and ammonium into the soil and underlying groundwater. Reducing conditions in this zone promote denitrification and protect against nitrate leaching. Because of this layer, feedlot cleaning should not disrupt the manure/soil interface, but should only scrape or harvest the material off the surface above the layer.

Manure Storage Systems

Bacterial cells, anaerobic slime, and fine organic matter act as sealants in most soils to restrict leachate into shallow groundwater for manure storage structures. Most research has shown that there is initial leakage in permeable conditions, but permeability decreases with time after initial manure storage.

It is still recommended to select deep fine-textured soils from earthen storage systems. Unless these conditions exist, self sealing of manure cannot be expected under natural conditions.

Earthen and formed waste storage structures built in shallow soil above fractured limestone present potential problems from manure storage structures. Care should be given to design of any manure storage system in such conditions.

Land Application Sites

Application of manure to land can have many soil and crop management benefits. Proper application rates and methods can allow efficient recycling of nutrients back to land. In this manner, resources are used wisely and efficiently. However, over application of manure or of manure and commercial fertilizers can create potential shallow groundwater problems.

Nitrogen leaching is generally a problem with high application rates. In some cases, soluble organics and ammonia can be found in shallow groundwater below high rate manure application sites. Phosphorus overloading on soils will result in high phosphorus concentrations in subsurface drainage.

Composition and mineralization rates of manures must be taken into account in order to optimize manure applications to land. The amount of nitrogen in the ammonia plus ammonium form in the manure will dictate the application loss potential as well as the amount of nitrogen in the manure that is eventually available to a crop.

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Plenary Keynote Address

David Osterberg, Iowa House of Representatives

Mr. Osterberg is a former member of the Iowa House of Representatives, serving the people of District 43. During his five terms in the House, he was heavily involved in environmental issues, and was a main player in the passage of the landmark Groundwater Protection Act in 1987. Mr. Osterberg is on the Board of Directors of the newly formed Iowa Environmental Council. He is an adjunct Professor in the Department of Geography at the University of Iowa, where he teaches courses on water quality technology and policy issues. Mr. Osterberg holds masters degrees in agricultural economics, water resources management, and economics from the University of Wisconsin-Madison.

I'm going to talk about the economics and politics of safe drinking water, recent reports that have come out on the quality of water in the United States, and what's going on with the Safe Drinking Water Act that's in Congress now.

We're going to hear a lot about "*Tap Water Blues*," a report just released by the Environmental Working Group. People don't argue about the data but about whether five different herbicides can be treated as one risk. A report like this makes causes. This report implies that many children are somehow in danger. It brought to the fore an older report that ran in Kansas in June [1994]. A Kansas City engineering firm said 19 million people, served by 667 water systems, are drinking water contaminated by the weed killers cyanazine and metolachlor. They don't mention the fact that alachlor and atrazine were also present. They are very widely used herbicides. It concludes that there isn't much to be gained in the efforts to get them out of the water. The study agrees, for the most part, with "*Tap Water Blues*" on what the problem might be. There are herbicides in surface water in Iowa.

There are other reports that didn't get the attention that these two did. "*Danger on Tap*", released in April, 1994, by the Sierra Club, and the Natural Resources Defenses Council (NRDC). The Izaak Walton League, which is not thought of as being the radical fringe of the environmental movement, had a report issued about *Cryptosporidium* being in surface water systems in the Midwest. They used the Milwaukee situation as the takeoff point, and how the people of that city were affected by some kind of flu-like symptoms in 1993. Even though it's not scientifically documented, readers will remember that the report said that 300,000 people were affected. The report talked about a hundred deaths, it doesn't mention the condition of these people before the *Cryptosporidium* problem or whether they might have lived longer if they hadn't drank contaminated water.

Another report came out in September, 1993, from the NRDC called "*Think Before You Drink.*" It stated that millions of Americans are unnecessarily exposed to health destroying microorganisms and toxic chemicals in drinking water. It emphasized the problem with chlorination byproducts, the trihalomethanes (THMs). The chlorine is used in the treatment process for a very good purpose - to destroy pathogens. This report refers to another report on disinfection byproducts by Robert Morris, Medical College of Wisconsin, which appears in the *American Journal of Public Health,* and reported risk factors of 1/100,000 for THMs, which is many times greater than the standard risk factor of 1/1,000,000.

All of these reports indicate there are many things to worry about: herbicides, *Cryptosporidium*, and the byproducts of chlorine, all of which are found in large quantities in the United States, especially the Midwest. Why are we seeing all of these reports at once? The reason is because the Safe Drinking Water Act is up for reconsideration.

The original Safe Drinking Water Act of 1974 came out during the environmental movement of the 1970's - the 1969 Clean Water Act, Clean Air Act, and the Safe Drinking Water Act. It regulated how local water systems protect citizens' health. 1986 was the last time Congress revisited the Safe Drinking Water Act and they made some huge changes, adding to the original list of twenty-three substances by mandating testing of eighty-three contaminants by 1989. The 1986 rewrite of the Safe Drinking Water Act is supposed to have been in effect until April 1991, when it was going to be re-authorized. It has been stuck in Congress since then.

There are three reasons the Safe Drinking Water Act is stuck in Congress: 1) unfunded environmental mandates--the federal government sets the standards but it doesn't provide any money, 2) property rights--how much the government can regulate what you do with your property and whether the government should reimburse you for telling you what you can do with your property (sometimes called takings), and 3) comparative risk assessment--compare risks and go after the ones that are the most important. Should we spend a lot of money getting radon out of water, when the biggest problem with radon is from airborne exposures? Radon in your basement may be a much greater problem than the radon in your water. Why spend a lot of money getting radon out of the water?

The Safe Drinking Water Act states that people should test their basements to see if a radon problem exists.

Those who argue about risk say things like, "Cigarettes cause 200,000 deaths a year in America. Why are we spending any time [money] on pesticides, we should do nothing on pesticides until we take care of the problems associated with smoking." That's what environmental groups fear is the way risk assessment is being used. To give you an example, a Senator speaking on the Safe Drinking Water Act amendment before the Senate said, "Mr. President, I would like to offer an observation regarding the amendment by Mr. Johnson on risk assessment which has been included in this bill. We all know that the issue of risk assessment has captured the attention of the American public and that it has become closer in priority with the larger concept of un-funded federal mandates. Mr. President, during consideration of this legislation a number of senators, including myself, have raised the issue of unfunded federal mandates." Why did property rights and a host of other topics described as the unavoidable mechanisms of the burdensome federal regulation become entangled with environmental protection? This is the senator who talks about unreasonable government involvement.

The Safe Drinking Water Act could not get out of Congress because of those three issues. The only environmental law that came out this fall was the Desert Protection Act. Even when industry and environmental groups agree on something (such as Superfund) it can still get stuck in legislation. The reason for the large number of reports and articles on the environment is politics. Americans do not want to have herbicides or trihalomethanes in their drinking water. They don't want to think about *Cryptosporidium* or any of the other microorganisms that might cause sickness.

Mandates are a question of money. When the federal government decides to pass a law, do they have the obligation to pay for it, or not? It's not a simple question. The citizens that the federal government are trying to protect are the same citizens that are your customers at a local utility. Does that mean the federal government can't do anything about these citizens and will depend on the utility personnel to protect the citizens? Is the lowest level of government the best? People aren't making those decisions. Economic development criteria always get stuck in how strong an environmental law people want to have. Illinois may feel it has an advantage by not having as stringent water standards as Indiana and therefore is capturing a few Indiana firms that are having trouble complying. You realize that it is not a clear picture. The federal government used to put a lot of money into environmental programs - up to 70-75% of the total cost. That has fallen to 30-35% of the total cost. The question of mandates is one of theories but also one of money. If you come up with more money, people are going to care a lot more about environmental policy. In both versions [House and Senate bills] of the Safe Drinking Water Act there is money to help comply ($500-$600 million).

As an environmentalist, property takings scare me a lot. When you have to pay someone to get them to comply with a regulation, that makes it very hard to pass any kind of environmental legislation. Takings has really captured Washington, D.C. It has almost captured the state of Iowa. We've had two takings laws in the last two sessions of the state legislature, neither passed. As an example, both said if you want to widen a road you have to pay the Texaco gas station taken out because it is in the way (everybody agrees to that). If you put in a new road, like the Avenue of the Saints, move it over two miles, a gas station might not be affected by being moved to accommodate the road, but is affected because all the traffic moves over. Is that takings? Will we be able to build anymore roads if we make that decision? Takings is an issue that is keeping things bogged down in the House and Senate.

In the last state legislative session, the question of the state government having primacy over the Safe Drinking Water Act was a big deal. The Iowa DNR is not overstaffed, as some would have you believe. From one of their publications they give the ratio of NPDES permits per FTE for Iowa and neighboring states. This is the Clean Water Act. A person in Minnesota can handle 25 NPDES permits, in Wisconsin they can handle a few more, Kansas is around 40-50, Alaska-60, S. Dakota-60. Iowa is administering around 125 per staff person. The DNR describes this as being efficient. They are only efficient if they are doing the job well. Another question on whether the Iowa DNR is understaffed was raised in a front page article of the *Des Moines Register*. The article said Iowa has the smallest staff inspecting hog waste disposal facilities. It reported that 2.75 persons deal with hog lots and the problems they might be causing. Iowa produces forty-five percent of all hogs in America. The Minnesota DNR has a staff of 10 in this area and they have a third the hogs that we do. I think we're not getting the job done. Understaffing means that very dedicated people are being overburdened, they can't get their jobs done. That is one of the issues that led to the Safe Drinking Water Act. A person can work very hard, but after a while they won't be able to do their job as well.

The federal government was thinking about taking the primacy right away from Iowa because we had too few people doing the job. When we try to get more people we have several choices: make a state appropriation or make the water systems pay more for the technical support they are already getting from the state. In 1992-1993 the legislature came up with the idea of putting fees in a separate fund to go back and disperse safe services to local governments. The local governments were getting the services of the DNR personnel. We worked on it but could get nowhere. One reason was the governor, several years before, had taken a bunch of dedicated fees and put them in the general fund. No one had faith that any money put in a special fund would be used only for the purpose intended. Once that trust was violated, it was very difficult to try to establish any new funds.

The other reason was because it would cost 40 cents per Iowan per year to do all of this. This was thought to be an outrageous amount of money. If this is too much money then how are you ever going to have any services provided by the state government? Obviously, if you're running for office, you've got to say, "I never raised any fees and I'll never raise any fees." I think there is a change in government that has been going on. We see where takings, comparative risk assessment, and environmental mandates have really changed environmental policy in Washington, D.C. and also in the state of Iowa.

Is it true that all these studies are an overreaction, that there's nothing wrong? Or is this a wake up call that we'd better do something about our water systems because there are risks? We have pesticides regularly in water supplies, surface water systems, sometimes violating federal standards. You could show that there may be quite a risk. Instead of talking about one in a million, it may go up to one hundred in a million.

Concurrent Sessions -Afternoon

Innovative water treatment: Tomorrow

Richard Valentine, The University of Iowa

Dr. Valentine is an Associate Professor in the Department of Civil and Environmental Engineering at the University of Iowa and a member of the Executive Committee of the Center for Health Effects of Environmental Contamination. His research interests focus on drinking water treatment including chemical oxidation, chlorine-chloramine chemistry, radium and radon sources and removal, and chemical weathering/dissolution kinetics of natural minerals. Professor Valentine has consulted for industry and government on removing and biodegrading toxic substances in water supplies. He holds a Ph.D. in Civil Engineering (Sanitary - Environmental Engineering) from the University of California-Berkeley.

I'm going to talk about water treatment in the future but first you should know something about water treatment today. I will be addressing issues that some people are not familiar with. This talk has a major component directed towards people who are not familiar with water treatment at all. For those who are familiar with drinking water, my talk will integrate where we've been, what we're doing today and where we're going. To give you the big picture, I'll also talk about what's driving the need for changes in drinking water treatment, then touch on some emerging technologies in research areas, trying not to get too technical.

What is drinking water treatment? Basically, it's about as customized a process as you can get. You can divide treatment technology into surface water versus groundwater, although that distinction is becoming less clear. The University of Iowa water treatment plant is a surface water treatment plant. Water is taken into the plant through the intake structure, which has a screen in it that keeps the bodies and other things out. A series of primary settling tanks where chemicals are added is next, and there's a rapid mixer that stirs the water up a bit followed by some settling of particles. Typically you add chemicals to the drinking water. We have micro-softening. There is what is called a solid's contact unit softening device. The water comes in mixed in this central part. There are lime and polymers added, the water goes down, flows upwards, and then it's considered treated water that's clean and clarified. The water is then collected and sent to filters. In the filters are a couple feet of water, which is gravity fed through two feet of sand. The water then gets chlorinated and goes into some type of storage. That's a whirlwind tour of a surface treatment plant. You may or may not have a solids contact unit, which is for softening. You may have some kind of a time or a set rectangular filtration as Iowa City. Forest City has a groundwater plant. They use large pumps. One of their wells is housed in the water plant. Water gets pumped up. They have a device to inject oxygen into the water. It needs to be oxidized to cause it to precipitate. Most groundwater has iron and manganese. In surface water treatment you have open filters, called gravity filters. A groundwater plant uses pressure filters which are cans filled with two feet of sand. There are many of them because they're compartmentalized, the water flow splits and goes through the filters. The Forest City plant is unique because it re-aerates the water when it's done (possibly to remove some gases that get into the water). Most plants, instead of having a pressure aeration, usually have a device with wooden slats in it (looks like a cooling tower); the water comes in, trickles down, then it would go to filtration. Both of these processes have been used for many years. It doesn't mean they're Victorian as I sometimes hear.

What's driving the changes today? Some new regulations are coming out because of the Safe Drinking Water Act. Those of you who are familiar with water treatment, especially the administrative areas, know that this is going to influence how you do business. It's going to influence the cost a lot. There are a number of rules that are being promulgated and will be finalized in the future. Furthermore, these rules may change. These regulations are staged, and will be implemented over several years. One of the rules that's driving fundamental changes in drinking water treatment is the disinfection byproducts rule (DBP), which addresses a problem discovered in 1974. If you chlorinate drinking water, you produce a variety of organic compounds that are halogenated and suspected carcinogens. The first one discovered was chloroform. Since then a whole list of halogenated compounds, such as bromine, have been identified. Chlorine can oxidize bromide ions and form compounds like bromoform. There are also inorganic disinfection byproducts. They're not associated with all types of disinfectants. Trihalomethanes are regulated now, but haloacetic acids will be regulated very soon. The different stages of the rules require adding to the list of these products and call for the lowering of maximum contaminant levels (MCLs). The DBP rule will be establishing MCLs for organic and inorganic byproducts. That means you won't be allowed to add more than so many milligrams per liter or micrograms per liter of something to the water.

This rule also targets total organic carbon, a natural organic matter. A cup of tea would not pass this regulation, there's too much total organic carbon in it. It's not the total organic carbon they're worried about, it's the fact that the chlorine and other disinfectants react with the natural organic matter. One strategy for controlling these disinfection byproducts is to reduce the amount of natural organic matter. The other is to minimize input of chlorine by using the maximum residual disinfect level (MRDL). If you have a problem meeting a residual in your distribution system, you cannot just crank up the chlorine. The disinfection byproduct rule is trying to minimize chemical disinfection addition, on the other hand, the surface water treatment rule wants to maximize biological integrity of the water. So one rule works against the other. This may have some bearing on how you do business.

Basically, there will be criteria for percent removals of *Giardia*, *Cryptosporidium*, and enteroviruses; things that are not easy to kill. Your plant will be evaluated in terms of the processes you have; certain processes will remove these pathogens. The effectiveness of almost any treatment process largely depends on the concept of concentration times time (CT). Disinfection effectiveness is a product of the concentration you use versus the time you're allowed to contact that disinfectant. You can use less disinfectant for more time or have less time and more disinfectant. It's a tradeoff. Also, there are regulations earmarked to address turbidity. It's not only an aesthetic issue. Just because the water looks clean doesn't mean that it meets the criteria for dealing with potential problems like *Cryptosporidium.*

Radon is an inorganic contaminant that is of particular concern in Iowa. EPA is on the verge of regulating radon in drinking water. Ingesting radon in the drinking water is not the issue. The problem is that water is a means of transport for radon to get into your home and become an airborne problem, where it could affect a lot of people. I'm doing research that shows that in some cities radon could be produced in a distribution system. EPA's regulating this--we want to keep it to 300 pci/L at the point of entry to the distribution system. Some towns that have groundwater have radium in the water. Radium is the source of radon. Imagine being the mayor of a town with one city block that can't meet some regulation. What's going to happen when you try to tell EPA, "look it's not going to fly." EPA is going to say "We have a block in violation, so we have a problem." They're going to go to the legislature, the governor and get it shut down. Another problem is arsenic. Twenty percent of the groundwater supplies in Iowa have arsenic concentrations that may exceed 2 mcg/L. Arsenic is a suspected carcinogen; it causes skin cancer and there is evidence that it causes other cancers at very low exposure levels.

Synthetic organic contaminant rules address volatile organic compounds (VOCs). These are mainly isolated chemicals associated with incorrect disposal of dry cleaning solvents and gasoline leakage, and are not widespread problems in terms of drinking water. There are a number of ways of handling this. I'm focusing more on processes or problems that are widespread internationally. Synthetic organic chemicals are generally thought of as primarily pesticides and herbicides. The issue of pesticides is potentially a problem. You've got it in surface water and some in groundwater, but what does it mean? That's really the big issue. I'm not here to address health effects, I'm here to discuss what you could do about it. If it is a problem, you've got to decide it's a problem.

There are a few other rules, such as the lead and copper rule. Lead and copper is a major problem in some cities. This is important because even if you don't have the problem you will be forced to change your drinking water treatment. The rule that probably has the biggest impact of all of them is called the Information Collection Rule, which requires that you monitor for parameters. The basic idea is to make cities collect information in order to evaluate the adequacy of existing regulations then use this information as a guide for establishing new regulations. It's using positive and negative feedback. This signifies changes in the future because there will be a database. Collecting information is going to be a big deal and it's very costly.

There is some research on treatment technology and future approaches. Innovations on conventional processes are probably as far as things will get for most people and involve optimizing processes for total organic carbon removal. For example, EPA will specify optimizing softening to remove organic carbon. It's like optimizing engine performance so you can cook on your car. These coagulation processes are being governed by criteria on total organic carbon removal. There are several other things that are being researched, new kinds of filter media, a new line of exchange materials, and new treatment chemicals. A lot of it's based on a better understanding of conventional processes.

Plant personnel need to be better educated (through continuing education) and probably a lot better paid. The human element is very important - as you have more stringent criteria in water treatment, these processes become more sophisticated and more difficult to control. People may feel that they've got certain processes installed, but it doesn't matter if they're not working right because personnel aren't trained to operate them.

Some technology is of a more concrete nature. You're going to see the use of alternative disinfectants. The two most important alternatives to free chlorine are ozone and chloramine. Ozone is not a panacea. Ozone is derived from oxygen and decomposes to oxygen, but it also reacts with natural organic matter to form things that we're still not sure of. More disinfection byproducts. The potential problem with ozone has only recently been realized and that is the production of bromine. When you have bromide present, ozone will oxidize it to form bromine which reacts to form brominated organic disinfection byproducts like brominated THM's - bromoform, dibromomethane. Commonly, a more important problem is the formation of bromate. Bromate is the inorganic material. Everywhere in the United States the bromate MCL (10 micrograms per liter) would be lower if it could be measured lower. So we need technology to measure bromine at lower levels.

Chloramine (a well established technology in the U.S.) combines chlorine and ammonia to form a secondary disinfectant with the water treatment systems. Chloramine will be used at a number of places for disinfectant in the distribution systems. Ozone is only good for in-plant treatment. There are other alternative disinfectants: chlorine dioxide - it's effective and generated on site, but it also has problems with the formation of chloride to inorganic disinfection products that are suspected health concerns.

There are technologies available now that are not widely used, for a number of good reasons. There are different approaches to using activated carbon, such as granular activated carbon (GAC) and powder activated carbon (PAC), which are totally different. GAC is used in a fixed bed, just like sand filters, to activate carbon. You have different criteria in terms of the amount of water you can treat per unit volume of carbon. Activated carbon is very good at absorbing a number of contaminants, generally the larger ones like pesticides. It also reacts by removing natural organic matter, which is good because when you chlorinate water, you'll have fewer disinfection byproducts formed, right? That's true except that natural organic matter competes for sites on the carbon and makes predicting when to replace the carbon difficult. There are a lot of questions that have to do with how long the carbon should be used and when to replace it.

A phenomenon called chromatographic effect occurs when one contaminant displaces another. This is well documented with data from utilities in Louisiana treating Mississippi River water. During certain periods of time you may have 100 micrograms per liter of benzene coming in and you might have 1,000 micrograms leaving. It complicates the problem because what had accumulated on carbon can be diluted or washed off. How do you regulate this? Get a sample every 20 minutes? That's why EPA has not yet mandated the use of activated carbon. In the end it may be advocated in some situations. For example, pesticides: the practical limitations are well understood, but there's not much you can do about it. Some of the problems with synthetic recovery may be solved with synthetic absorbent resonance. Some materials may be a lot more efficient than GAC but they may also be a lot more costly, so there's a tradeoff. The problem with GAC is when you take it off line, what do you do with it? If you've really got a contamination problem, you may have to haul it to a hazardous waste landfill. There are issues about efficiency and regeneration. You don't want to use carbon that's already contaminated. How do you get that material off? Utilization of natural organic matter may be the primary benefit of some of these synthetic absorbing methods. For example, activated carbon is naturally occurring in coconut shells.

Another innovation comes with the use of powder activated carbon, which is commonly used now. Granular carbon is about the size of a small grain of sand and is powerful. By making the particles smaller, you've increased its efficiency of use, but you're limited in that you can't make the carbon column out of it. It's like trying to get water to go through flour, it's not going to work.

Contacting PAC with water could be a good avenue to research - using membranes and upfloat filters. You have a membrane--a plastic film like saran wrap--water will go to the center and will flow through it like a filter. The membrane has very small holes the size of molecules. What you're doing is forcing the water through the membrane and leaving behind the stuff you don't want. Most of you are familiar with the term "reverse-osmosis". It's the most stringent of these processes. It's able to remove salts like NaCl, which are very small molecules and it's used for desalination. The problem is, it's very expensive and very high pressure. Right now the water industry is looking at things like manual filtration; membranes with bigger holes that can only stop big molecules like pesticides and some natural organic material. For example, in one study 98.5% of the alachlor in a water sample was filtered. However, if you have ethylene dibromide, a small molecule, none of it's removed. Membrane technology is a big area.

There are also membrane phase contact processes that involve the passage of water containing a contaminant. People are familiar with Gore-Tex, which is teflon-based. Water vapor passes through Gore-Tex, but water does not. Gore-Tex is used to remove some of these volatile organic materials. Another area is the Danz oxidation process, which involves the addition of chemicals to produce what we call free radicals. These are very powerful reactants capable of oxidizing many things in carbon dioxide bonds. These systems have been used for hazardous waste treatment. An example is Peroxone, which is ozone plus hydrogen peroxide. Other processes involve ultraviolet light. An area that is going to be important in the future is biological treatment. This process may be required in the ozonate. In ozonate water, natural organic matter becomes food for bacteria, so you have regrowth problems. The idea is to grow bacteria on sand or activated carbon. How do you do that? You don't just chlorinate or disinfect beforehand. You pass water through these materials that have reactive biofilm that you can bend. There may be some pesticides that could be completely removed in this process. It deserves more research. In biological filtration there are some processes for nitrate removal. One is air stripping using compartmentalized tanks, which may be particularly good for small cities. Basically, you pump water into a tank, it's subdivided into different sections, the water flows from one to the other, and you bubble air through the bottom. There are package units right now that you can buy that are not that expensive. That's one reason EPA's going to regulate radon: the solution is cheap, relatively speaking. That's cost effectiveness.

Another treatment option is aquifer storage and recovery. You may see more of this technique used by larger cities. You treat water and then store it in an underground aquifer. There are natural biological processes occurring and a lot of disinfection byproducts may disappear.

In summary, unless you have well trained people it doesn't matter what treatment technology you use. You're going to see technological innovations being used. The most sophisticated plant I know of is in a Saudi Arabian city where they understand the value of water. There's no problem convincing the government whether people have to spend money on it. Most of Saudi Arabia uses deep ancient groundwater that makes even our filthiest water look great. It has lots of salts and other substances in it. The process they have uses a pellet system to soften water in a way that you don't get a waste stream to contain the water. The waste treatment from this is a dry powder. The groundwater comes up, it's softened, and it goes through membrane filters. If you have a small plant, you could have one or two of these. It's a big plant, it's about 20 million gallons a day. Imagine a room that is 100 feet across and 100 feet deep and it's solid beads. Imagine also, pumps and noise like you wouldn't believe. These things operate at several hundred pounds of pressure, you've got to pump the water to do that. One thing about the membrane stream is that you can't recover all of the water. The best you can do is maybe 75%, the other 25% has to go to waste. They don't do that there--it goes to a distillation plant and it gets distilled, it's too valuable to go to waste. The whole thing looks like one big petro-chemical plant. What do you think their water costs? Just about the same as their gasoline. It's not a coincidence, you pump it out of the ground like oil, you process it like oil, so why shouldn't it cost the same? Everything is subsidized there, but they're treating water like oil and they're pricing oil like it's water.

What's missing from this scenario on intervention are riparian zones and aqua retreats, which is watershed protection. Keep it out of the water, keep the water as clean as you can. I think in the end we're going to have a combination of all these things going on at once.

Underground storage tanks

LaDon Jones, Iowa State University

Dr. Jones is an Associate Professor in the Environmental Engineering group in the Department of Civil and Construction Engineering at Iowa State University. He teaches and does research in the areas of groundwater flow and transport, and soil and groundwater remediation, with an emphasis on flow and transport in glacial till, and the remediation of sites contaminated by leaking underground storage tanks. He holds a Ph.D. in environmental engineering from UCLA.

My talk is about the current process for attacking underground storage tank problems, including how to determine a safe amelioration, and what success we've had in cleaning these things up. What is the objective of the clean up program? Why do we care about underground storage tanks?

Originally, the objective was to reduce the risks. Risk is found from actual free product. It is obvious when gasoline is in drinking water as free product, it's floating there. The two main concerns are vapor. The first vapor concern is contamination in the air where nearby basements present possible explosion hazards. The second concern is related to water supplies. A lot of the regulations are based on drinking water.

Let's talk about the problems that exist with a leaking tank. What can happen during a gasoline spill? Gasoline is a fluid and if it's in a field, it will be held up in the soil through capillary action just like water would be. If there's enough gasoline it will vibrate as free product down to the watertable, and since gasoline is lighter than water, it will float on the watertable. It's shocking to see a well pump out pure gasoline. It will form a free product layer floating on top of the water.

One of the difficulties is that, just like water will be held in the soil with a certain amount of debris, there will be residual free product, little bits of pure gasoline in the pore space that will not float. When soil is held in the vadose zone where water and air are, there is visual free product that will not collect water. If water runs through this soil, the free product will be trapped in the pores and will not move. It will slowly dissolve and some of it will be absorbed into the soil. Looking at the watertable, gasoline is not very soluble in water but parts of it are a little soluble. The groundwater going by here will pick up some of these dissolved components and contaminated flow will then occur in the groundwater.

A lot of wells in Iowa are shallow and the watertable fluctuates. If there is a free product layer, it can get trapped underneath the watertable and it doesn't want to move when it is trapped there. With residual free product, one of the problems is getting the dissolved contaminants out when groundwater is pumped. The contaminants will dissolve very slowly into the groundwater, so free product will be there for a very long time. If residual free product is dissolved in the groundwater, it may also be adsorbed onto the soil. In Iowa, one way to get rid of the free product is wait a couple of years. As the watertable moves up and down and distributes the contamination, no apparent free product occurs. It turns out that it is really a difficult problem to clean up. Just cleaning up the groundwater alone doesn't do it; cleaning up the residual product is necessary. Even if the groundwater can be cleaned up, the residual free product recharges and continues to feed it. Because of the residual saturation, even if free product is pumped, which in some cases it is, 20-30% might be left over. Theoretically, 50% might be more reasonable.

Let's talk about the extent of the problem in Iowa. There are somewhere around 5,000 registered underground storage tank sites in Iowa. A site clean up report is the first step. Almost 1,000 sites have completed clean up reports. That means some monitoring wells have been drilled to determine how bad the problem is at a particular site. To give you an idea, Des Moines itself has more than 300 sites, Council Bluffs has over 200 sites.

The money used to pay for the clean up comes from the Iowa Remediation Fund, which is funded through a one cent per gallon gasoline tax. The legislature decided that given the cost of clean up, many small gas stations and small businesses couldn't afford it. This program has been in existence since October 1990. Also, an insurance fund was set up where the gas station owners pay a premium. The old tank needs to be pulled, problems identified, and new tank and monitoring devices need to be installed. The remediation fund will pay for any problems occurring before October, 1990. From that point in time, the insurance fund will pay for clean ups. Of the 4900 sites, there are 3400 insurance fund eligible sites. It is estimated that 40% of those will be classified as high risk, or sites requiring remediation for cleaning up the groundwater. The current estimated average cost per clean up is $277,000, some will cost more. The way the remediation fund works is through a co-payment system. The owner will pay $77,000 and the fund will pay $200,000. The numbers are calculated based on average costs. So far the cumulative cost to deal with the underground storage tank program in Iowa is estimated at $60,000,000 for site assessment and $280,000,000 for remediation, for a total of

$340,000,000.

What is currently available, unless the legislature changes the tax rate, is about $184,000,000. They also bought bonds. So the allocation of the $184,000,000 is about $60,000,000 for assessment, $110,000,000 for remediation and $14,000,000 for other associated costs. So money for addressing 1400 sites right now doesn't exist. Looking at those average costs, about 550 of those 1400 eligible sites can actually be dealt with. What's to be done? Recently, a priority system has been established, where small businesses are going to get the money first. A small business is defined as having a net worth of less than $400,000, and having two or less sites. If DNR requires just monitoring a site every quarter, in the past the fund would pay for that. The fund will no longer pay for that, so the owners potentially have to pick up the costs. DNR also said that in some cases, owners don't have to use groundwater professionals. The tank owners are required to monitor but can collect the samples themselves and get the results and hang on to them. They don't have to send them in and show they have complied.

The Iowa Department of Natural Resources Underground Storage Tank unit sets the regulations. The insurance fund is a different issue. If DNR sets certain requirements, they have to be met. The question concerning most owners is whether they will pay for them and whether they are eligible for the fund. A situation may occur where DNR requires an owner to put in five more monitoring wells at a site and the insurance fund says wells aren't needed and the fund will not pay for them. What do you do?

There are several steps to address underground storage tank problems in Iowa. The first step is the "high clean up report", and can be thought of as a site assessment or Phase I. It involves going to a contaminated site and determining how big a problem exists, how much soil is contaminated, how much groundwater is contaminated, is there free product, is it a problem to society? It involves going out with a drill rig, taking some soil samples, sending them in, putting in a groundwater monitoring well to see if the groundwater is clean, and determining the potential for movement using a hydraulic computation path to see how fast the groundwater might move to that site. Also, studying the watertable -- how deep is the groundwater, which way is the groundwater going? Are there potential receptors that are impacted nearby? DNR determines how far and where nearby receptors are. Is there any surface water within 1000 feet, are there conduits on the site, utility lines, water lines? Contamination can potentially get into these conduits and move outside. Are there any groundwater wells, basically water supply wells within 1000 feet? Are there drinking water wells that might be impacted?

DNR uses 1000 feet as the limit for groundwater wells. There might be a well another 200 feet away from this limit and it's still a concern. Drilling produces a well log, and gives an indication of the kind of soil material- clay or silt. A reading is taken from a vapor monitor, a sample of what kind of vapor, high carbon vapor, and soil samples are taken to show the groundwater levels around it.

A graph is produced showing the soil contamination. For example, a map will show where a gasoline station and the old tanks are. The data might show soil borings. For example, at monitoring well 8, the soil sample showed a total petroleum hydrocarbon level of 3900. The soil regulation says 100 ppm is unacceptable. The data are taken and interpolated using software. The next step is trying to figure out where the site of soil contamination is greater than 100 ppm, the level at which clean up is necessary. If all samples come back less than 100 ppm, no soil problem exists -- at least the regulations say that. If it is 50 ppm, that can still potentially contaminate groundwater.

Something very similar is done for groundwater contamination. You can monitor wells for benzene dissolved in the groundwater. It is typical to have high contamination around the tank and then it drops off. The standard for benzene in drinking water is 5 ppb.

When the assessment is done, there are three possible results: no further action (soil contamination is less than 100 ppm), low risk, and high risk. High risk means a site remediation is necessary. There are a number of check points DNR uses, any of which can make it high risk.

For example, if soil is contaminated at a rate of 100 mg/kg based on the soil sample of total petroleum hydrocarbons, and drinking water lines are nearby, it is a high risk site. To get out of high risk, moving the water line and putting a new water line in will be sufficient. If contaminated soil rated at 100 mg/kg is within 1000 ft of an active water supply valve, that is also a potential high risk. Low risk can be justified. For example, if the water supply is upgrading at a site or if it is a spring 400 ft deep, it is very possible that the site is never going to be impacted. Soils rated at 100 mg/kg at seasonal high water level have a protected water source. That protected groundwater source is due to hydraulic conductivity. If there is a fill location where there are no drinking water supply wells nearby, and there are no potential hazards to think about, yet there is a high hydraulic conductivity, it is a high risk site. If it is above 5 ppb at a protected groundwater source, even if there are no sources nearby that will be impacted, clean up may still be necessary.

If a high risk situation is identified, a corrective action recommendation must be created. Enough information to determine how to clean it up may still not be present. There is no way to have all the information. Or, the site may be low risk. Depending on where gasoline stations are located, in the city on a street corner or on a country road, impacts the classification of risk. I have mentioned that no action may be required, but I have never seen that. For example, a high risk site has been determined and something needs to be done. Determining the practical technologies for trying to clean up the site is the priority. One of the difficulties in Iowa is a lot of the sites are located in areas of glacial till or loess, shallow, relatively low permeability soils, and often the actual layer of contaminated groundwater is only 3-4 feet thick. It is a pretty thin saturated thickness and is difficult to pump. The practical technology used is to pump out the contaminated groundwaters. Possibly soil venting, air stripping bioremediation, etc. are used as well. We can talk about what the limitations of each of these are.

Here is an example: groundwater is down here with contaminated soil. Visual free product and vapors are present. Clean up is important because it is a potential long-term contamination source for the groundwater. Soil venting is a simple idea. A well is sunk in the ground and instead of pumping water, air is pumped through the soil. A vacuum pump is installed and air is pumped through the system, which volatilizes the air, so air is pulled to the surface. Pumping air will volatilize the contaminants, which would rather be in the air phase than the free product phase or water phase, so they will come out. If there is moisture and if air is pulled through, the dissolved content is increased. Biological remediation occurs at the same time. At a real site, it is difficult to distinguish between the two.

These technologies have some limitations. Many things work quite well with pumping air through the soil. One difficulty is tills are arbitrarily high so it is difficult to pump water through the soil. Also, if there is free product in the soil, it partitions between the air and the free product based on the concentration of the benzene in the free product. There is an equilibrium. When pumping air through here viable free product develops. The bottleneck occurs when so much air is pulled that there is perfectly clean air coming in, yet it still takes time for things to fall through, it still is driven by equilibrium. If poor air distribution exists there is a mass limitation, things can happen only so fast. Putting in more wells and moving more air after a certain point will not speed up remediation. Another thing to watch for is pulling a vacuum and pulling the watertable up. If care is not taken, the watertable will rise and groundwater is pumped. Groundwater is not good for the pumps. Another limiting factor is the radial hydraulics. A well is pumping air through and moving approximately radial. What happens to the velocity of the air as it gets farther and farther away from the well? It continually goes down, so close in is effective, but further out, a soil venting system is limited. Going out so far has no measurable effect. Plus, if contamination is out here the venting will be slower and slower. If another well is put in further out, what happens in the middle between them? A dead spot develops. The point is, regardless, there are going to be areas where there are no effects. There is no way around that to some degree, only so many wells can be installed.

Another possible technology is air stripping. If a venting system is working fairly well, what can be done to address contamination below the groundwater table? A well can be placed below the watertable and air is injected. Air displaces the water in the well and air is blown into the soil. The air is going to find the path of least resistance. This technology has a lot of potential positive applications. If there is residual contamination, free product, and an air stripping system beneath the watertable, it can result in the addition of dissolved oxygen into the groundwater to enhance bioremediation.

When these technologies came out, they seemed to be the solution to every problem. However, I am not aware of much of this being done in Iowa. If there are only 3-4 feet of water, it is pretty difficult, because it's not certain where the air is going to go. At an uncontaminated test site at one of the monitoring wells, we injected air into glacial till with only 3-4' of water above the well, an injection pressure of 10 psi was used. When the system was turned on, it didn't look like there was any air moving: it was displacing the water and then it had to displace the water that was in the core. So the first time it's turned on, there's an air entry pressure. The injection pressure needed depends on the height of the water displaced plus the air entry pressure. Once the system got going, about 10 psi and about 1-1/2 cfm was achieved. Trying the test again after the system recovered achieved immediate flow. Fractures had opened up; the test is going on.

Another thing being looked at is measuring dissolved oxygen. At the till sites horizontal fracturing occurs at a pretty good rate; the problem is being unable to control where it goes. It doesn't change that much. A compressor is heating the air some before injection. When it frosts, a pretty nice ice layer develops that will restrict air. Usually it can be of assistance when used with a soil venting system. When it works well, a lot of volatilization occurs. If buildings are nearby and a soil venting system is not installed to capture the volatilized gases, you may get contaminated basements. To my knowledge, there has been very little application in the field, or the loess, or in areas of low permeability in Iowa to see how well this system works over the long term. If the hydraulics can be controlled, the mass transfer limitations are known, but it's uncertain.

The most common system for cleaning up is pump and treat. Groundwater is being pumped in this system. The regulations assume we know how to do it. They say go clean it up. The limitation to pump and treat is that in a lot of sites, there is only 4-6' of water. Down here is groundwater, but contamination is not down there much. There are limitations - if the pollution has been spreading for 20 years, only so much water can be pumped out of the site, and there is no way it can be recovered in two years. As mentioned, residual free product is going to dissolve into the groundwater. Laboratory experiments have taken some sand, filled it with gasoline, graded it down to gravity and then water was run through the sand trying to get the gasoline out. After 104 volumes, only 12% of the gasoline had been removed, the rest of it was still sitting in the sand. It was found that if air blew through there, the air vented out, around 90% of the gas was vented out. But there is a limitation on how much water is pumped. It's not possible to pump that much water at a till site. Even if wells are in every 10', it will be pumped dry. And the problem of mass transfer limitations on any residual free product that is in the aqueous state, not to mention adsorption. How do we model this? What is the source coefficient? Besides that, it's more of a problem of looking at a path system. Let's say it's unlikely to be able to really get it out. Just keeping it from moving is a goal, so a barrier is installed. A big well is put in, and water pumped out just to make sure that it doesn't get around the barrier. This system is going to be in here for 30 years. An effort to minimize the costs are important.

Based on those issues and realizing there is not enough information, the DNR may say to put in a corrective action design report (CADR). This means some type of remediation must be done at the site to make it low risk. Sometimes that may not be a problem. If the site is high risk because of a drinking water well nearby, it may be cheapest to close the well and not use it for drinking anymore. The other choice is to do an active clean up. The corrective action needs to be on that report. The proposed treatment system used to clean it up and the monitoring used to determine the effects of the contamination movement all need to be in the report. This would be funded by the remediation fund. The next step is to get pre-proposals from consultants who do CADRs. Often a situation occurs where three consultants submit CADRs and one of the CADRs is selected. The owner selects someone else to do it. The consultants don't get paid for doing a proposal. This leads to an interesting situation and one of the things that I think is a problem with the remediation fund.

The people operating the remediation fund are insurance people. The former chair of the UST Board is the person who is the head of the insurance division in Iowa. The people on the Board and the people making decisions on CADRs don't have any technical training on clean up. Their current philosophy is that a soil venting system always has to be used. Pilot tests are not needed, just over-designing all of the soil venting systems will be adequate. The philosophy is that looking at drilling logs will indicate the decay there. There is some range of pay for each till site and it is evaluated from the upper limit and over designed from there. The range of error of permeability can be a factor of 10, possibly more, so over-design could be 100 times more than needed. Over-design is impossible if its unknown where to start. Plus if blowers are used, the pump curve needs to be decided. That's not good engineering. That's like trying to build a house and the price of the wood is unknown. My philosophy is that we have to do it right. Conducting venting pilot tests where air is pulled, measuring the vacuum and finding the radius of influence, the vacuum humidity and the amount of air pulled is the proper way to do it. Then a venting system can be designed for that particular site.

Another problem is there are not enough pilot data, yet a venting system or a pumping system is installed and there is no check on the hydraulics. So this system is in, it's been running and it's not cleaning up the site. It's not even impacting the site. There has been no check on whether the site is covered by the installed system, whether the hydraulics are controlled. My philosophy is the only thing that can be done at these sites is pump water and pump air. Enough is never known to determine how the residual contamination is doing across the entire site. The only thing to do is make sure the hydraulics cover the site. If this is the plume and a venting system is put in, enough information ought to be collected to make sure the venting system is pulling air to the entire area. But this is usually not the case. The system gets turned on, reports get sent to DNR, and DNR goes back to the owners saying to do something different.

Designers of the remediation system don't always understand what information is needed for a good engineering system. Ignorance is a major problem with the remediation program. How long have these sites been needing clean up--5 years? It's a process that's just getting started. There may be 50 sites in the entire state of Iowa to have active remediation. It hasn't been a long time, and there are not sites that have been remediated to closure. There is no follow-up on effectiveness. A system is put in, turned on, but no money is used to go back and measure to see if the pump and treatment system is capturing the flow--is the venting system covering the entire contaminated area or is there a need to go and put in another venting well? Is another pumping well necessary? There is no applied research. I tried to get some money to go out and do air stripping to determine what will work and what won't work, what has potential, and time management successes so far. Sometimes the regulatory personnel seem to have a lack of understanding of hydraulics. Knowing what to test for is important before the problem can be solved. What is needed are feasibility studies before a system can be designed. The CADR procedures have a little bit of field testing and then come up with a solution that is going to work. In five years this site is going to be cleaned up. Soil venting tests and pumping tests should be required, a lot of pump and treatment systems have been designed and put in without ever having a pump test done, and they wonder why only 1/10 of the water shows up that was predicted. Air stripping pilot tests need more planned research and development. Right now there is very little money, if any, being spent on research and development to determine what is happening. There has been very little follow-up to determine if the sites we now have in operation are working. It would be interesting to go back to the 50 sites and determine what has been done in the last five years. Has 50% of the contamination been removed, 25%, are we getting anywhere in cleaning this up?

I will say the UST fund has had some successes, the biggest success is source removal. Go in and pull out these leaking underground storage tanks. If it turns out that a site is never actively cleaned up, eliminating the source will be the biggest thing done because a lot of these sites are going to clean up by themselves naturally, but it's going to be very long term. The other big success includes prevention. Regulations are in place that require new tanks be double-lined and have leak protection so the problem is not recreated. The big question is whether it is feasible. Is it known today that if a high risk site is given $500,000 for clean up, can it really be cleaned up for that amount of money? Can the benzene level get down to 5 ppb? The alternative is that if the goal is not met, money is not given. There has to be a risk involved. At this point it's unknown whether 5 ppb benzene can be cleaned up. Are most of these tank sites really a risk? The regulatory people are starting to think about this because there is limited money. Should these sites be cleaned up, are the sites really a risk to drinking water? That's being discussed, and there is some prioritization of high risk, low risk, and so on. Some of these issues are going to be addressed in the future. The fact is, currently there is not enough money in the program to clean up the sites that exist. So there is already some prioritization. The DNR is sending letters saying to do something about sites. Just because the underground storage tank fund is not fully funded, sites still require action.

Another interesting thing is the law. For example, the DNR sends a letter saying to clean this up and the owner refuses. What are the ramifications? So far, there don't appear to be any. I just saw a letter where a gas station owner had to put in a treatment system, and the DNR wanted him to turn it on. He said, "No, the guy across the street hasn't turned his on and I'm not turning mine on". So the DNR fuel regulator said well, what can we do about this? The letter said apparently nothing can be done about it. The DNR cannot make him turn the treatment system on. Why should a treatment system be on? When should this site be cleaned up even if there is no health risk? Will it be able to be sold? There is also the liability issue. Even if it's decided there is actually not a risk to anybody's drinking water, it causes it to devalue the property if it goes up for sale.

What is safe drinking water? Health risks

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If we lived in an ideal world, safe drinking water would be water that had zero health risks. But it is not an ideal world and there will be some minimal health risks from drinking water. In Iowa, the agricultural segment is a concern by contributing to water and health problems through manure, irrigation, livestock, and waste management. For urban dwellers, chemical production plants discharging into rivers is a concern. All this is part of the water cycle and human activities contribute extensively to this cycle. In this day and age precipitation contains nitrogen oxides and sulfur oxide emissions from industrial plants. These could combine with precipitation producing acid rain. In underground systems bedrock aquifers filter the water. Well water generally has fewer contaminants than surface water, in part due to this filtering ability. Certain water sources are going to have more contaminants in them than others. These contaminants can lead to health problems and that's what I want to talk about today.

There has been a surveillance program in the United States for waterborne disease outbreaks since 1971, which is maintained by the Centers for Disease Control. Its purpose is to collect data and periodically report on the occurrences and causes of waterborne disease outbreaks. When the surveillance program was set up there had to be some basic definitions. One was defining a waterborne disease outbreak. Right now the definition says that at least two persons must have experienced a similar illness after ingestion of the same water. It also can be a single case if it can be laboratory confirmed. For example, amoebic meningeal encephalitis (this is a disease of the brain caused by a protozoan infection) or a documented case of chemical poisoning (such as having excessive amounts of chloride in drinking water: someone ingests this and dies from chloride poisoning) could both fall into to the category of documented single occurrences. Another part of the process is gathering data from the individuals involved in these outbreaks. There must be evidence that implicates water as the source of the illness. Establishing cause and effect is necessary.

There are three major types of water systems: community, non-community, and individual. Community water systems are defined as public or investor owned systems that serve large or small communities, subdivisions, or mobile home parks with at least 15 surface connections or 25 year round residents. These types of community water systems serve 91% of the U.S. population. Non-community water systems serve institutions and industries, camps, parks, hotels, or businesses that may be classified as public. Seventy percent of the 200,000 water systems in the United States are non-community water systems but these systems serve a small percentage of the total population. The other major group is individual-Iowa has many of these. These are usually wells or springs serving one or more residences located outside populated areas.

The most recent data from this surveillance system (1991 and 1992) identified 34 outbreaks of waterborne disease in the United States, 23 involving acute gastrointestinal illness. Identifying the etiologic agent was not possible in most of these cases. The disease is usually manifested by some type of diarrhea. In other cases *Giardia* and *Cryptosporidium* were the agents (both are protozoans). *Cryptosporidium* was the agent that got into Milwaukee's water supply in 1993. In this instance it caused 360,000 to 370,000 cases of waterborne disease over a two week period. Hepatitis A, a virus, had one outbreak. Shigellosis, an acute bacterial disease, had one case. There were a couple of cases involving chemicals. One was an excess of nitrate and the other an excess of chlorine in the drinking water. Overall, these 34 outbreaks affected about 17,500 individuals. One fatality was associated with the chloride outbreak (acute chloride intoxication).

One of the major deficiencies identified with these outbreaks was a problem with the treatment process. Breakdown in the treatment was responsible in 50% of the cases. The second most common deficiency occurred when untreated groundwater supplies became contaminated. The third most common problem was associated with the distribution system deficiencies. These accounted for 15%. It was unknown what the deficiency was in 6% percent of the 34 outbreaks. There were no deficiencies associated with untreated surface water. By law, there should be no untreated surface water in this country. Of the 34 outbreaks associated with water intended for drinking, the etiologic agent was unknown. In 68% of the cases it was parasitic (*Giardia* and *Cryptosporidium* cases), 21% chemical, 6% bacterial, 3% viral, 3% unknown. Viruses, bacteria, and parasites are the common organisms causing disease. With that knowledge the cause of infection in the drinking water supplies can be established. The main purpose of water treatment is to remove organisms and keep the number of cases of disease down to a minimum.

Sixty-eight percent of the outbreaks are from non-community water supplies. For community water systems it's 24%, and individual is 9%. The most common deficiency, treatment, affects 50% of the outbreaks. For the water sources, 77% of the outbreaks involved a well, 18% surface supply, the remaining 6% were springs.

Over the past twenty years of collecting data on waterborne outbreaks, the major problem has been acute gastrointestinal illness where the etiologic agent has not been determined. Where it has been determined, it's been parasitic, bacterial, viral, or chemical. There was an increase through the 1970's and early 1980's. This may be an artifact of increased familiarity with the surveillance system and more effective reporting. Since then there has been a decline, but the surveillance people admit there's probably a lot of under-reporting that goes on in the system. Not every outbreak occurring in the United States is being documented. Some useful information has come from this system. Identifying the outbreak of *Cryptosporidium* was one. *Cryptosporidium* was a new type of parasitic organism that was affecting drinking waters in the United States. This information is useful in modifying and improving treatment systems and will help to solve the problems of waterborne disease outbreaks.

The percentage of outbreaks may also be a reporting deficit. There are probably many people, even in Iowa, having problems with individual wells that never make it into the surveillance percentages. Looking back over the past 63 years, from 1920 to 1983, at water systems deficiencies causing outbreaks of disease, data cover about 415,000 cases. 225,000 had inadequate or interrupted treatment as the primary problem. About 83,000 and 82,000 cases have been contaminated untreated groundwater and distribution problems.

There are bacterial, viral, and parasitic diseases. Some parasitic diseases are not a problem in the United States but may be problems around the world. Two of these are Balantidial dysentery and Ascariasis. These can be a major problem in third world countries. The United States still sees some episodes of *Salmonella* infection, leptospirosis, diarrhea related to *e.coli*, and shigellosis (one episode in 1991 and 1992). Cholera is a huge problem worldwide, but it's not a big problem in the United States. Of the viral diseases Hepatitis A continues to be a problem (one episode also in 1991 and 1992). On the parasitic side, giardiasis and cryptosporidiosis can be a problem.

Are there problems with drinking water supplies worldwide? Yes. For example, providing safe drinking water is a major problem in the Rwandan refugee camps. The disease there is dysentery, an acute gastrointestinal disease that is leading to death. It's fortunate this country does not have that problem. The reason is because drinking water is treated to remove these organisms. Another reason is the healthy habit of keeping latrines separated from drinking water sources. I heard second hand from someone who had just been to Rwanda working in one of these camps that they are trying to do this. But with one million people concentrated into a very small geographic area it's not easy to undertake. They were trying to convince people not to drink the water near the latrines. The refugees were drinking water that was contaminated by their own feces. The public health personnel were trying to teach the people to dig pits for latrines in one area, set up water stations to wash hands, and then prevent the spread of any disease to areas where food might be distributed. It was hoped this would cut down on the hand to hand transmission route.

One of the reasons to be concerned with water treatment is the huge number of people that are exposed to different types of treatment techniques. One of the most common treatments for disinfection is chlorine. In 1982, 171 million people in this country were drinking chlorinated drinking water. Conventional plants that coagulate, sedimentate, and filtrate water supplied 108 million people. If major problems with these types of treatment techniques occur, even if it's a low risk of disease, it could account for a lot of cases because of the huge amount of people being served by these types of water supplies. That's why people who are in the water business are cautious about the quality of the water provided to the public. They want it to be the best it can be because when the numbers are gathered together across the country, millions of people are exposed to materials that are in the drinking water. What is heard today are not the infectious diseases that are being prevented but the huge improvements in the quality of the drinking water, and our sewage systems.

At the beginning of the century infectious disease was the number one cause of death in this country. It no longer is. Today the leading causes of death are chronic diseases. Number one in the country is heart disease; number two is cancer. Early in the next century cancer is going to surpass heart disease because this country does a good job teaching people to measure blood pressure, to stop smoking, and to keep track of cholesterol levels. Those are the three major risk factors for heart disease and it is declining quite impressively, whereas cancer is increasing.

Where drinking water contaminants are concerned, there is usually a low level concentration. People get really concerned about this and I think they should. How big the concern should be is relative and depends upon the contaminant. Sometimes the concern is heavy metals. An example is chromium, which is carcinogenic but is considered mainly an exposure for people in occupations that handle it. Whether it would be considered a carcinogen or not looking just at drinking water is unknown. Lead can be found in drinking water. It's not usually a naturally occurring substance; in most instances it comes from the distribution system where lead soldering is used to hold together the copper pipes bringing water through to the faucet. There is a remedy. Lead-free solder is used. If a house is 30, 40, or 50 years old, there's a likelihood that lead-based solder was used. Sometimes that's not a problem because the insides of the pipes may be caked over, so there's not much water actually coming into contact with the lead. But it can lead to lead levels in the drinking water. Mercury and arsenic are other substances possibly found in drinking water. These are all heavy metals and they can all cause serious diseases.

Let's look at lead poisoning as an example. If lead levels are high enough in children a radiograph can identify deposits of lead where the bone is growing at the epiphyseal plates. In adults it's more likely to manifest itself in peripheral neuropathy, such as the inability to extend a hand or foot (called wrist or foot drop). Children in particular, or adults that have high levels of lead, can have a lot of gastrointestinal pain called intestinal colic. They could have problems with kidney function - a disease called renal tubular acidosis or Fanconi's Syndrome. It can lead to low red blood cell count and anemia with resulting lethargy; oxygen is not getting to tissues. One of the major concerns with children is the development of an encephalopathy. Lead lines can also develop right along the gingiva after exposure to high doses of lead. The major sources of lead in the population among adults are occupational, not drinking water. In children a likely source of lead has been interior and exterior lead based paint. Lead based paints aren't used anymore but there are homes that were built 30-50 years ago that were painted with that type of paint. Little children, usually between 1-3 years of age, put anything they can pick up their mouths, like paint flaking off a wall. Intermediate sources in the past were dust in the household, interior paint removal, automobiles, industrial sources, low doses in food, ambient air, and drinking water. Even today drinking water is a source of low lead exposure. For the last decade there's been a big program in this country trying to reduce lead levels. A report from the National Health and Nutrition Examination Survey that was conducted from 1988 to 1991 just came out. When these surveys are done, a random sample of the population is selected as representative of the entire U.S. population. Some of the initial data found from 1976 to 1980, that persons 1 to 74 years of age had blood lead levels decline almost 80%. This was determined by getting blood samples and measuring how much lead was in the blood. That decline can be attributed to using lead-free gasoline and not using lead solder for canning. In the past a canned good from the grocery store was probably put together with a lead-based solder. Through regulations that has been stopped.

There are also non-organic substances in drinking water. Fluoride can occur naturally or it can be added artificially to the water. Adding it is done primarily to reduce dental caries and has been shown to be highly effective. In high levels it is a toxic. One fatality due to acute fluoride intoxication was documented in 1991-1992. That level is much higher than the one part per million used in fluoridating drinking water.

In Iowa, nitrate becomes a particular concern because one source of nitrate in our drinking water is fertilizers applied to farmland. The disease of most concern regarding nitrate primarily affects infants. Methemoglobinemia prevents red blood cells from transporting oxygen. There have been some reports that nitrate could be related to cancer; stomach cancers particularly. Ingested nitrate is broken down by bacteria in the oral cavity and stomach into nitrite. Nitrite can be further transformed into nitrosamines, which are known to be carcinogenic. The theory is that high levels of nitrate in the drinking water could lead to an increase in cancers. The problem is this link has not been established in human populations. The Center for Health Effects of Environmental Contamination is working with the National Cancer Institute on a study to determine if nitrate could be associated with non-Hodgkins lymphoma, another disease that is found at higher rates in rural populations in the United States.

Radioactive substances can be found in some drinking water sources. In Iowa if a community water supply is served by a deep well tapping the Jordan aquifer it probably has some levels of $radium_{226}$ that are measurable in the drinking water. The concern is that it eventually breaks down into radon gas which can get into homes. This is a big concern across the country. Surveys done in Iowa indicate that 70% of the homes exceed the 4 pci/L guideline advisory level supported by the Environmental Protection Agency. Most of the gas, 95% or more, is coming from cracks in a home's foundation. It comes from the breakdown of minute quantities of uranium in the soil. Breathing in radon gas and $radium_{226}$ is a lung cancer concern- these are radioactive compounds and radon gas is an alpha emitter. An alpha emitter means it travels a short distance, it can cause damage to the epithelium that lines the bronchi of the lung. Most of the exposure data do not come from drinking water or even from residential radon gas. Most of the information has come from uranium miners. Monitoring the air and having miners wear badges that detect uranium exposure is the main source of data collection. Cumulative exposure data estimates are calculated and the population is tracked to see how much lung cancer develops- an association has been seen between lung cancer and radon. Radiation is also associated with a wide variety of other diseases, such as leukemia. One of the biggest sources of information on this has been from atomic bomb survivors in Hiroshima and Nagasaki. Data about radiation comes from occupational groups or people who have been in the wrong place at the wrong time. There was a workforce group of women after WWI that painted radium onto the hour and minute hands of watches. Radium was a substance that would luminesce in the dark. The women had to bring their paint brushes to a very fine point in order to do the hour and minute hands of the watch. This was done by wetting the paint brush with the radioactive compound with their tongue. Following them years later, the women developed osteogenic sarcoma of the lower jaw, in close vicinity to where their body had come in contact with the radioactive substance.

In drinking water the major organic substances of concern are disinfection byproducts, particularly the trihalomethanes. There continues to be a concern whether trihalomethanes could be related to an increased risk of certain types of cancer, including bladder, colon, and rectal cancer. The data don't show a clear association, but there have been several studies that report a slight increased risk in people who have been drinking chlorinated water over a long period of time, perhaps 30-50 years. As a result of this, researchers are investigating other ways to disinfect drinking water without using chlorine. Alternative methods are generally more expensive. The public is going to have to decide whether the cost is worth the benefit. If they feel it is then we should go ahead with it. In a world with a limited number of dollars, should dollars be put into further protection of drinking water or should dollars be put into some other programs where the potential benefit will be far greater?

I want to end up today with an overview of other potential drinking water contaminants. Dry cleaning compounds such as trichloroethylene (TCE) could show up in drinking water. TCE is a central nervous system depressant and it's thought to be a potential carcinogen for people exposed continuously over a long period of time. Benzene is another central nervous system depressive organic substance found in drinking water. Most of the health effects information comes from occupations dealing with large amounts of benzene. A known carcinogen, benzene affects the red and white blood cells and can lead to a leukemia. Carbon tetrachloride can show up in drinking water--usually in very low levels. It is a central nervous system depressant, thought to be a human carcinogen, and can affect liver and kidney function. Most of the health information comes from people in occupational settings dealing with carbon tetrachloride.

Finally, in Iowa and other states, pesticides can show up in the drinking water. There are concerns about a wide variety of health effects from exposure to pesticides. Current problems that may be related to pesticides include cancer, immunologic dysfunction, kidney disease, neurotoxicity, neurologic disease, and the reproductive and developmental effects on small children. There's very little data showing a clear cut association between exposure to pesticides and health effects in human populations. Much of these data come from the mid-1980's from a statewide public water supply contaminant survey conducted in Iowa. The most commonly found compounds were the trihalomethanes- chloroform, bromodichloromethane, dibromochloromethane, and bromoform. They were found in over half of the samples. Chloroform is the most common analyte detected. The majority of the 849 public water supplies are chlorinating and there's a good likelihood that some chloroform will be in drinking water as a treatment byproduct. Atrazine showed up in more than 10% of the water samples and Bladex showed up in about 5%. Volatile organic compounds were also found, as well as some other pesticides (alachlor and Dual) but these showed up less frequently. Chloroform with a mean of about 19 parts per billion has been identified, atrazine about one part per billion, and Bladex about one part per billion as well.

In terms of pesticides and health effects, I don't think the place to look is in drinking water--the exposure is very low level. The people who are going to be at highest risk are those actually mixing, loading, and applying pesticides. We are currently conducting a study called the Agricultural Health Study that involves the states of North Carolina and Iowa. A cohort of people is being established that will be followed through their lifetime to better determine what the chronic health threats of pesticides are. Enrollment started in December 1994. To date 15,000 people have been enrolled in Iowa and questionnaires have been sent to them. One of the questions asks about current protective equipment used when handling pesticides in Iowa, compared to ten years ago. There have been improvements over the ten year period--higher use of hats, goggles, and chemical resistant gloves; 80% now as opposed to 50% then. It is good news because this probably means the level of exposure has been reduced. It is also encouraging that the percentage of people that have never used protective equipment is below 5% compared to over 20% ten years ago.

A recent report published in the *Journal of American Medical Association* looked at the actual causes of death in the United States in 1990. In a single year, there are about 2 million deaths. The authors wanted to know how many of these deaths had an identifiable cause. After looking at the data and reviewing the literature it was estimated the cause would be known for about 50% of these deaths (more than one million). Tobacco, in particular cigarette smoking, causes 400,000 deaths in a single year in the US. Diet and activity patterns account for 300,000 deaths; alcohol abuse--another 100,000 deaths. Drinking water makes the list under microbial agents and toxic agents; even here the role of drinking water is very minor. The most common disease in this category lists pneumonia as the cause of death. That's due to some respiratory route of transmission, not from drinking water. The toxic agents are occupational settings associated with poisonings. Residential radon is believed to be responsible for about 14,000 deaths per year. Further down the list are firearms, sexual behavior, motor vehicle accidents, and use of illicit drugs. Nowhere on the list is drinking water. Drinking water quality is not listed as a major cause of death today. We have a system in place that protects drinking water. It's not perfect, but efforts continue to perfect it- that's encouraging. I wish we had those types of programs in place where tobacco, diet and activity patterns, and alcohol occur because a huge dent on mortality in this country could be made.

Community issues

Larry Curtis, City of Ames

Mr. Curtis has been Mayor of the city of Ames, Iowa, since January, 1990. He served on the Ames City Council from 1978-90. He is a member of the law firm of Singer, Pasley, Holm, Timmons, Mathison, and Curtis, and is an adjunct Professor in Business Law in the College of Business at Iowa State University. He serves on the Finance, Administration and Intergovernmental Relations Steering Committee of the National League of Cities and is Past President of the Iowa League of Municipalities Board of Directors. Mr. Curtis is a Vietnam veteran, serving with the First Air Calvary Artillery Division. He holds a bachelor's degree in mechanical engineering from Iowa State University, and MBA and Juris Doctorate degrees from the University of Iowa.

I have been involved in local government as an elected official for a fair amount of time. The city of Ames provides full service utilities, including water, sewer, and electricity, and runs a continuous operation solid waste disposal facility and waste recovery facility. The recovery facility is one of the few operating in the United States on a daily basis. Ames was the first city in the United States to have such a facility. In my experience as a councilperson, now as mayor, the one service the city provides that has changed most drastically is the delivery of water.

Sixteen to eighteen years ago, when I started my public service as a city council representative, I remember discussing and listening to a presentation the water treatment division gave addressing standards that were parts per million. It wasn't too many years later that the standards dealt with measurements in the parts per billion range. Now it's parts per trillion. Visualizing a trillionth of anything is difficult, whether it be a trillion dollars or a trillion whatever. As a result of this, water treatment has become a very complex issue to understand, especially for an elected official at the local level.

I do not serve full-time in the position of mayor. Ames has a city manager with a full-time staff, and much of the service is voluntary. To address these issues and make policy decisions, to gradually make choices becomes very challenging. Ames needs to address three main areas in the delivery of water. First, the city has to provide a quantity of water. Second, the water needs to be provided on a quality basis. The public asks questions about it, and water has to be delivered safe and high quality. The third element that Ames is just starting to see the sensitivity of is the cost.

Five years ago, the average family in Ames consumed about 800 cubic feet of water per month at a cost of $12. The sewer charge is twice that at this point in time, so water delivery is a reasonably good deal. This year, when the budget goes into its final stages, the average water cost will double for the average family. Not because of more use, but because it costs more to provide the same amount of quality. That is not a large sum of money for most people, $12-25. Most property owners probably don't even realize it. However, the trend of increasing costs is a concern to elected officials. Where is this going to end and what are the costs associated with developing and providing this basic service? It is fundamental that this service must be provided. The cost increase is coming from many different fronts.

The costs of testing for contaminants has become expensive. Ames water service conducts more than 100 analytical tests to insure the water meets minimum standards and is safe to drink. Those tests are not cheap. The increased sensitivity and new proposed standards will require even more testing. It's clear where the cost is going-up. Asking what can be done to minimize the impact of the data needed and required is a good start for municipalities. Water is not something that consumers will quit using. Water can't be turned off like other types of consumer goods can.

The issue of primacy last year was a fundamental concern for the state of Iowa as well as for local communities. Ames felt primacy was a service situation for the community and so we will be very supportive of maintaining it. What the price will be is the issue that people at the laboratory level should be concerned about. Project costs will be passed to the user. That cost is a significant amount of money - about $300,000-$500,000. It's not easy to tell consumers water rates will double in the upcoming year. The reaction has been to call me at home, and ask me why rates have doubled, not to call the statehouse. The process of increasing rates can be complex and it's not well understood by the customer.

Today, the issue of quality has become a fairly significant one from the standpoint of awareness. There are many technical people in Ames who are very knowledgeable about water resources. Many deal with it on an everyday basis and provide technical assistance to others as well. It is not easy to slide by in that type of environment. The reality is there is always an issue Ames seems to be addressing.

Quantity has been a challenge for Ames. A drought in the late 1970's put a strain on the water production system. The system is well-oriented; water is pumped out of wells located throughout the community. They are not in one concentrated area, but spread out. During the drought, keeping up with demand became a problem. A conservation program was needed and instituted at that time. It was a model that is workable for future conservation efforts. Essentially it is an economic model. Water was not rationed from the standpoint of telling consumers it couldn't be used. Instead, if it was used, the user would pay more for it. This approach had an amazing effect! The consumer psychology is a very dynamic environment. If people know their excess use or more than normal use is going to cost them a fairly severe penalty, they suddenly behave differently. The penalty imposed was to charge seven times the normal rate after the consumer had reached their historically based average water usage. It was amazing to see the decrease in consumption. To not conserve would have essentially led to the wells running dry. If that had happened, the options and ability to manage the supply and demand problems would have been severely restricted.

Quantity is something to be dealt with by expanding available resources. The well fields capacity has doubled. Those are decisions we make as we have the capital to do it. Assurance for the water system is vitally important. Ames can now produce and treat roughly 12 million gallons per day, which is twice the actual daily consumption. That is a fairly comfortable margin. It is not without its costs, though. It is the process which best provides future security for the community, at least for the next 30-40 years.

One of the future challenges will be backflow prevention, which is a great way to protect the integrity of water systems and make sure that contamination sources don't occur unexpectedly. Regulations in the near future may be mandated for backflow prevention. This may be a difficult problem in dealing with each individual consumer. Costs and the imposition that are related to these mandates are going to be a challenge.

If there is one term learned very quickly as an elected local official, it's the word 'mandate'. It seems everyone likes to give them but nobody likes to have them. Mandates are a fact of life. Everyone has to live with them. What Ames tries to do is anticipate mandates, and then deal with them on an up front basis. Recognizing mandates as a benefit for the community is the approach. Backflow prevention is one of those mandates that has proven to be a challenge. How will this be accomplished in a rational, logical, cost-effective basis? The idea is to bring it to fruition in such a way that will help everybody from the standpoint of basic service.

Conservation can be done on an economic level. In the future conservation may become a greater emphasis in terms of supply for Ames. But what will be effective for the overall water system? Based on economics, it worked for Ames, but at a national level, that may not be the best or only solution.

Another important issue is watershed protection. Ames had a very significant flood last year. It was a devastating event. Clearly the experience Des Moines had with losing their water production capacity for a period of time scared many people from the standpoint of how easily it happened. Watersheds are important in any system that requires planning. Protecting well fields and all parts of the water system from external sources is part of the planning and preparedness.

The issues of mandates in the future will probably be the biggest challenge. It will be difficult trying to answer the consumer who may not understand all the mandates. Faced with some of those fundamental issues delivery of water will continue to be a challenge.

Advanced concepts in methane fermentation

Richard Dague, Iowa State University

Dr. Dague is a Professor of Environmental Engineering, Department of Civil and Construction Engineering at Iowa State University, and was Departmental Chair from 1985-90. Previously he was Professor and Chair of the Department of Civil and Environmental Engineering at the University of Iowa. Professor Dague has published over 60 journal and proceedings papers. His research interests include anaerobic treatment of biotechnology byproducts, food and livestock wastes; anaerobic conversion of municipal solid wastes; and physical, chemical and biological remediation of groundwater and contaminated sites. Professor Dague holds a Ph.D. degree in environmental health engineering from the University of Kansas, and degrees in civil engineering and sanitary engineering from Iowa State University.

Anaerobic digesters have been used heavily for domestic waste water sludge stabilization. Anaerobic lagoons first were used in 1942 in Australia. Beginning in the 1950's, anaerobic lagoon use became more widespread, particularly for slaughterhouse waste. IBP and many other slaughterhouse operations over the years have used anaerobic lagoons as a pre-treatment process, or perhaps before discharge into a city sewer. Those two processes are called low-rate processing. There are also high-rate processes: anaerobic contact, anaerobic filters, and so on down the line. There are eight high-rate anaerobic methanogenic processes. High-rate means the hydraulic holding time is separated from the solids holding time. The liquid fraction is passed through the reactor very rapidly, but the solids are held.

Why is there so much interest in this? The solids are the biomass, or the organisms. Holding them in the reactor and passing the liquid backwards is desirable. The focus of the development has been processing liquid in a large pyrate while separating the solids and holding them--an anaerobic contact process. The anaerobic contact process was developed in the early 1950's for application of slaughterhouse waste in Austin and Albert Lee, Minnesota. In those cases the waste came into a tank where it was mixed and heated to 35 degrees Celsius (95 Fahrenheit). The liquid flowed into another tank which is a settler or clarifier and the solids were recycled back into the reactor. That's how the liquid holding time was separated from the solids holding time. Quite a few of these reactors have been built.

Another process is the anaerobic filter. This reactor is filled with highly porous material. Early on, these filters were filled with stone. Later, plastic media that provided higher porosity and easier control were used.

Another process, which dates back to the late 1800's, is called the trickling filter, also an anaerobic process. In trickling filters, the liquid trickles through the rock and the biomass and organisms grow on it. It is anaerobic and produces methane so it is similar to the others, but the flow is generally upward.

In an anaerobic digester, there's a volume in and the same volume out . They're completely mixed and have long detention times. The other processes are short-12-24 hours holding time of the liquid- whereas the solids are held by these other methods. The solids are held in the pores of the media, or between the media. They're trapped, allowing liquid to pass, but the solids can't. The microorganisms are held in the reactor and the liquid is released. That's what is meant by separating the solids (the biomass) from the liquid.

There has been work done on anaerobic filters that are hybrids, in which part of the media is taken out of the bottom, where the filter is. That is the upflow, but half of it's filled with media and the other half (the bottom) isn't. In the Upflow Anaerobic Sludge Blanket (UASB) process, a granular sludge develops, the flow goes up through the blanket and the material is converted very rapidly to methane and carbon dioxide. The liquid was going out the top, the flow going up, and the gas going out the top. It's a widely used technology throughout the world and gaining momentum here in the United States. (Two other processes are the fluidized bed and the horizontal flow adaptive reactor.)

A process we've been working on at Iowa State is the Temperature Phased Anaerobic Process. This method uses a temperature (thermophilic) of 55°C, and then it's brought back down to 35°, which is effective in killing pathogens. In the United States there are new regulations on sludge application to land called the 503 Regulations. Many of the sludges will not meet the pathogen requirement because the digesters are operating at 35°C (95°F). Using temperature phasing of 55°C then down to 35°C will meet the pathogen requirement. Research is ongoing in that particular area.

Another process worth mentioning is the Anaerobic Sequencing Batch Reactor, or ASBR. A patent was received on this process in 1993. Its application to many liquid industrial wastes is promising. A pilot plant operating in Cedar Rapids is using this process. It has been applied extensively in laboratory studies on slime waste. A full scale plant being built in Colorado will also use this method.

One of our laboratory units has a 12 liter liquid volume. The biomass is settled, and anaerobic microorganisms, primarily panogenic bacteria called acetogenic bacteria, convert the waste into methane. The upper portion is effluent. Mixing is shut off and granules develop and settle in about ten minutes. A relatively clear super-maten develops on top. This is a batch process with a one day detention time; one-sixth of it is wasted out six times a day. It is fed back into the substrate, whether it's hog waste or industrial waste, and then it's reacted, and then shut off. This happens about every four to six hours for hog waste. Whenever the building is flushed, it's decanted and flushed once a day into the reactor.

There are little particles that don't settle and it looks a little murky. Next, part of it is decanted out. Where do these particles go? They'll be wasted down the sewer then fed some more and the process is repeated. There are some big particles that settle very rapidly; these are going to stay in the reactor, and that's an important aspect of this process. It selects for granules, or granulated sludge. The UASB shown earlier selects for granules in a little different way. It's an upflow reactor, and with gas being produced there are certain particles that rise because of the production of carbon dioxide and methane. The light particles tend to rise faster and leave; those that are heavy tend to stay so this process selects for granules. What is left is mature.

This research is also looking at ways to enhance granulation, to speed it up so these granules develop. The granules are a complex mixture of organics and inorganics, calcium, and ammonium phosphate. They are not artificial. One of the problems faced when a plant like that in Cedar Rapids is built is getting it up to speed as fast as possible. Waiting a year for it to go on line is a long time. Speeding up the process is vitally important, for obvious reasons.

This is the only anaerobic technology, higher technology, that's batch fed. All the rest are continuous flow. In this system there is a starvation period; in the continuous flow system, the substrate concentration is always up at a higher level because it's being fed all the time. The batch fed goes feast-famine, feast-famine. Significant advantages are gained from that. Much of this is the same- settling, decanting, feeding and reacting; settle, decant, feed, react-- continually going through the process. The solids settle to the bottom. It's taken off the top, and a decanter on the top- similar to a floating cover- decants it. The cover goes right down and when it's full, goes back up. A flexible membrane cover can also be used on top of this. This has some very important implications for the reaction and performance of the system. The substrate goes up, then comes down. That's where the feast and the famine comes into play. When there is a higher substrate concentration the kinetics are very rapid, the speed of the reactions is very fast-there's a high driving force. Each one of these is a sequence, in this case there is a six hour sequences, four of them per day. At one end is the starvation mode.

There are about fifty-one different species of methanogens that have been identified in this process. Individual as well as groups of methanogens have different abilities to pull waste concentrations down to the lower levels, some of them can grow at 20 mg per liter, others grow at 5, 4, down to the lower levels. By starving them, a little bit of a competitive advantage is given to the organisms that can grow at low substrate levels. Over time the organisms that can grow best are selected for low substrate levels.

Research on a series of sequencing batches of different sizes and shapes compared tall ones to short ones and how well each selected for granules. The surface of a granule is extremely porous and has many places for microorganisms to grow. By magnifying the granule surface 4,000 times, the different species of microorganisms and caverns can be seen. In methanogenic processes there are three major groups of microorganisms involved. The first group carries out the reactions of hydrolysis. They'll take particles or large macromolecules and break them down into simpler molecules. The second group is called acetogens. They take the more complex molecules and break them down into acetic acid, hydrogen and methanol. The methanogens can only use about three different substrates, one is acetic acid.

Acetic acid is in vinegar, hydrogen, and methanol. It doesn't matter whether cow manure or pig manure is used, methanogens can only use those substrates. A methanogen will crowd close to acetogen because the acetogen is putting out acetic acid, which is the substrate methanogen has been selected for. It will grow right there. The granules end up being much more methanogenically active. The specific methanogenic activity of these substances is much higher than other types of biomass solids from the old conventional anaerobic digesters. They're hardly comparable in terms of rates. Some settling velocities are very hard to measure because of the rapid settling. At concentrations of solids in the reactor ten to fifteen thousand milligrams per liter-the settling velocities are five or six centimeters per minute. That is about two inches per minute. It settles pretty fast. A short settling cycle is important so the decanting and feeding process can start over.

The substrate concentration affects what we call COD or Chemical Oxygen Demand. Over a six hour cycle, COD comes up, then goes rapidly back down again, so it's being slug fed, then batch fed. Again, it goes into the feast, and then comes rapidly back down again within six hours. In fact it's almost back down within three to four hours, so it's getting into the famine at that point. Studies show there is little difference between continuous mixing versus intermittent mixing.

In anaerobic processes, stabilization of wastes is attained by producing carbon dioxide and methane. Methane is a high energy product which can heat a stove or a house. When methane is produced, oxygen debt is avoided. A debt is paid when methane is burned, compared to aerobic systems where oxygen is blown in and converted to carbon dioxide and water, resulting in the production of humongous piles of sludge. In these systems energy is lost in the form of methane. The microorganisms grow relatively slowly, because they lose a lot of energy. From the microorganisms perspective, methanogens lose energy because they're producing methane. The slow reproduction of microorganisms has been interpreted as being slow in reactions--but they're not. The speed organic material is converted to methane and thereby stabilized is faster than most aerobic organisms. The gas production is not constant, it's up and down. In a larger system multiple tanks are used and fed differently, at different times, which levels out the gas production.

In the past it's been thought the anaerobic processes could not and would not work in treating dilute waste unless the substrate concentration was one thousand milligrams per liter or more. We have been treating waste at one thousand, eight hundred, six hundred and four hundred mg/L using a sequencing batch reactor and getting ninety percent removal at temperatures of 35°, 25°, 20° and 15°. An activated sludge system is not going to be used if those rates are continued. During the starvation phase the microorganisms or methanogens are looking around for something to eat. The substrate is very low. Those methanogens that can grow at low substrate concentration end up finding it, and they're able to grow. Over time the sequence selects for organisms that can grow at very low substrate concentrations. This substrate only had 200 BOD (biochemical oxygen demand), and 87 to 90 percent removal occurred even at 15°C, which is almost ambient temperature.

Processes for applications in warm climates are being researched, as are treatments of low strength waste. In temperature phasing, waste is boosted to 55°C and then lowered to 35°. This was found to be a very efficient treatment, which was discovered partly by accident. A student was studying thermophilic and mesophilic biofilters in a side by side comparison. Near the end of the experiments the thermophilic reactors were very highly loaded; their efficiency had gone down quite a bit because of the high organic load. Before these experiments were shut down, the thermophilic filter was run through the mesophilic filter, which resulted in an almost complete removal over the entire substrate. A follow up experiment looked at thermophilic biofilters discharging into mesophilic biofilters. The thermophilic reactors are different sizes and are shorter than the mesophilic reactors. These are biofilters, 5/8" diameter, very porous with plastic media. The experiment took place in a 35°C constant temperature; the loadings over the total system were in order from 2 grams up to 16. A smaller system was set up with different sized thermophilic units connected to the mesophilics, which gave a matrix of loadings. This experiment showed strong removal can occur with this design.

When COD loading is both thermophilic and mesophilic, the system can operate all the way up to 16 and 18 grams per liter per day. A total systems removal in the 91 to 98 percent category can be accomplished--almost complete removal of the substrate. The city of Cedar Rapids hopes to evaluate some of these technologies through the Biotechnology Byproducts Consortium. One company located in that city is installing a thermophilic-mesophilic unit as a pilot project. Another unit will be put in ahead of the existing one to evaluate the high temperature treatment. The removal of COD in the thermophilic unit is not real high, it's only about 30%. The main purpose of the thermophilic unit is to get extremely high reaction rates in order to enhance the conversion of waste into acids for the methanogens.

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