OECD OCDE

OECD EXPERT GROUP MEETING: BASINGSTOKE 2000

APPROACHES FOR ESTABLISHING LINKS BETWEEN DRINKING WATER AND INFECTIOUS DISEASE

9-11 JULY 2000

WATER TRAINING INTERNATIONAL CONFERENCE CENTER
TADLEY COURT, BASINGSTOKE, UNITED KINGDOM

PROGRAMME
ABSTRACTS
LIST OF PARTICIPANTS

dwi

guardians of drinking water quality

DRINKING WATER INSPECTORATE

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PROGRAMME

Sunday, 9 July 2000

18:00 ***Registration***

19:00 ***Informal cocktail/dinner*** (Water Training International Conference Center, Tadley Court)

Monday, 10 July 2000

9:00 ***Welcome and Opening Remarks***
David HARPER – Department of Health, United Kingdom

9:30 PLENARY SESSION 1: SURVEILLANCE OF WATERBORNE DISEASE
Chair: Pierre PAYMENT – Université du Quebec, Canada

Principles and Components of Surveillance Systems

9:30 Paul HUNTER – Chester Public Health Laboratory Service, United Kingdom

Surveillance at Local Level

10:00 Catherine QUIGLEY – CCDC North Cheshire and Wirral Health Authorities, United Kingdom
10:20 James Jerry GIBSON – Department of Health and Environmental Control, United States

10:40 *Coffee Break*

Surveillance at National Level

11:00 Deborah LEVY – Centers for Disease Control and Prevention, United States
11:20 Rosalind STANWELL-SMITH – PHLS Communicable Disease Surveillance Centre, United Kingdom
11:40 Yvonne ANDERSSON – Swedish Institute for Infectious Disease Control, Sweden

Surveillance at International Level

12:00 Chris BARTLETT – PHLS Communicable Disease Surveillance Centre, United Kingdom

12:20 **Discussion**

13:00 *Lunch*

14:15 PLENARY SESSION 2: OUTBREAK INVESTIGATION
Chair: Will ROBERTSON – Health Canada, Environmental Health Directorate, Canada

A Systems Approach to Outbreak Investigation

14:15 Paul HUNTER – Chester Public Health Laboratory Service, United Kingdom

Outbreak Detection (including use of neural networks)

14:45 Kit FAIRLEY – Monash Medical School, Australia

Epidemiological Investigations

15:05 Deborah LEVY – Centers for Disease Control and Prevention, United States
15:25 Catherine QUIGLEY – CCDC North Cheshire and Wirral Health Authorities, United Kingdom

Environmental Investigations

15:45 Kim R. FOX – Environmental Protection Agency, United States

16:15 *Afternoon Tea*

Clinical/Microbiological Investigations Including Strain Typing

16:45 Carl-Henrik VON BONSDORFF – Haartman Institute, Finland
17:05 Gordon NICHOLS – PHLS Communicable Disease Surveillance Centre, United Kingdom

Geographical Information Systems

17:25 To be announced.

17:40 **Discussion**

18:30 **Close**

Tuesday, 11 July 2000

9:00 PLENARY SESSION 3: USE OF WATER QUALITY, TREATMENT AND DISTRIBUTION DATA TO ASSESS HUMAN HEALTH RISK
Chair: Al DUFOUR – Environmental Protection Agency, United States

Progress report on the WHO/OECD guidance document "Improving Microbiological Safety of Drinking Water"

9:00 Mario SNOZZI –Federal Institute for Environmental Science and Technology, Switzerland
Elettra RONCHI – Organisation for Economic Co-operation and Development

Review of Outbreaks

9:30 Gunther CRAUN – Gunther F. Craun and Associates, United States
10:00 Mike WAITE – Drinking Water Inspectorate, United Kingdom

Water Industry Data Resources

10:30 Alan THOMPSON – Lyonnaise des Eaux, France

11:00 **Discussion**

11:15 *Coffee*

11:45 **PLENARY SESSION 4: EPIDEMIOLOGICAL APPROACHES TO ASSESSING ENDEMIC WATERBORNE DISEASE BURDEN**
Chair: Jamie BARTRAM – World Health Organization

Using Existing Surveillance-based Data

11:45 Gordon NICHOLS – PHLS Communicable Disease Surveillance Centre, United Kingdom

Time Series Analysis

12:05 Pascal BEAUDEAU – Laboratoire d'Etudes et d'Analyses, France

Case Control Studies

12:25 Kit FAIRLEY – Monash Medical School, Australia

12:45 *Lunch*

Prospective Epidemiological Studies

14:00 Denis ZMIROU – Grenoble University, France

Prospective Studies in Developing Countries

14:20 Christine MOE – UNC School of Public Health, United States

Seroepidemiological Studies

14:40 Floyd FROST – Lovelace Clinic Foundation, United States

Intervention Studies

15:00 Pierre PAYMENT – Université du Quebec, Canada

15:20 **Discussions**

16:00 *Afternoon Tea*

16:30 **PLENARY SESSION 5: INTERNATIONAL POLICY CONSIDERATIONS**
Chair – Yasumoto MAGARA – Department of Urban Environmental Engineering
Hokkaido University, Japan

18:30 **Close**

ABSTRACTS

PRINCIPLES AND COMPONENTS OF SURVEILLANCE SYSTEMS

Paul R. Hunter
Public Health Laboratory, Countess of Chester Health Park, United Kingdom

Surveillance is central to public health medicine and has a long history. Without appropriate surveillance systems public health specialists cannot identify threats to public health, identify the burden of disease in communities, plan health care or know the impact of their prevention activities. However, good surveillance systems can be costly and time consuming; they are only justified if their outcomes serve an appropriate public health need.

When designing a surveillance system, the first step is to clearly state the aim of the system. It needs to be clear from the outset what the goals of the system are and what the benefits to society will be. This is, in my view, the most important step and one that is all too often ignored.

Once the goal is agreed, the next stage is to identify the target population, what information is to be collected, how it is to be collected, how the information is to be analysed, and how the information is to be used. Within these areas of interest are several key issues:

> How to define the target population? What case definition to use? From whom will the data be collected? How much data will be collected? How and when will the data be transmitted to some central collection point? How will the data be validated and grouped? How will the data be analysed? To whom will the information derived from any analyses be transmitted and how will the information be presented and distributed?

A key issue of any surveillance system these days will be the protection of patient confidentiality.

Finally this presentation will consider key factors in the success of surveillance systems such as sensitivity and timeliness.

SURVEILLANCE AT LOCAL LEVEL

Catherine Quigley
Cheshire & Wirral Communicable Disease Unit, Chester Public Health Laboratory
Countess of Chester Health Park, United Kingdom

The principles that should underpin local surveillance are: 1) the data should be useful for local action and 2) locally used data should feed into regional and national surveillance.

In the United Kingdom, local surveillance is the responsibility of Consultants in Communicable Disease Control (CsCDC) on behalf of Health Authorities. The two main components are statutory notifications of certain infectious diseases and reporting of laboratory isolates. The statutory notification system has several drawbacks – the definition of "food poisoning", which includes waterborne disease, is particularly problematic. Reporting of laboratory isolates is voluntary and despite limitations, this system meets criteria of simplicity, acceptability and specificity. However, timeliness could be improved by further development of electronic communication systems between laboratories and CCDCs.

Local surveillance in the United Kingdom is good at monitoring trends and identifying outbreaks of waterborne illness. Its success in leading to prevention of sporadic cases is less evident. Investigation of sporadic cases of gastrointestinal disease is variable and needs further debate. Methods of collecting more detailed information include postal questionnaires and visits by Environmental Health Officers (EHOs). It is generally agreed that detailed investigation of sporadic cases is not the best use of scarce resources. However the Cheshire & Wirral Communicable Disease Unit (CDU) has found that collection of specific information in a standardised format has proved useful for sporadic cases of cryptosporidiosis. The introduction of legislation requiring regular sampling of water supplies for cryptosporidial oocysts may have implications for local surveillance of waterborne disease.

SURVEILLANCE AT THE STATE AND LOCAL LEVEL IN THE UNITED STATES

James J. Gibson
South Carolina Department of Health and Environmental Control, United States

Surveillance for communicable diseases in the United States is the responsibility of the state and city-county public health agencies, which have the sole authority to enforce most public health actions. Federal agencies such as the CDC receive de-identified health data and serve as technical consultants to the local level. In all states reporting of state-specified acute diseases is required by statute of health providers and clinical labs; physicians report cases by mail or phone to local authorities, and labs report directly to states. While public health responses originate locally, capacity for surveillance data analysis and recognition of disease clusters resides primarily at the state level. Local agencies investigate clusters but most do not have the resources to investigate sporadic cases of common conditions such as Salmonella or Giardia infection. The system has several limitations in its ability to recognise clusters originating from waterborne transmission, and in fact waterborne outbreaks are rarely identified. These include limited ability to analyse surveillance data in smaller agencies, variability in requirements and completeness of reporting among states, delays of weeks in reports from labs, and fragmentation of the system resulting from mistrust between state and local agencies. The limited availability of methods to diagnose viral causes of gastro-enteritis is also a problem. Many outbreaks are caused by recreational use of contaminated waters. Several agencies now use surveillance for gastro-enteritis in hospital emergency departments, or demand for antimotility drugs, for early warning of outbreaks.

US NATIONAL SURVEILLANCE FOR WATERBORNE DISEASE OUTBREAKS

Deborah A. Levy
Centers for Disease Control and Prevention, Division of Parasitic Diseases, United States

Beginning in 1971, the Centers for Disease Control and Prevention (CDC), the US Environmental Protection Agency, and the Council of State and Territorial Epidemiologists have maintained a collaborative surveillance system of the occurrences and causes of waterborne disease outbreaks (WBDOs). The surveillance system includes data regarding outbreaks associated with drinking water and recreational water. State, territorial, and local public health agencies have primary responsibility for detecting and investigating WBDOs and voluntarily reporting them to CDC on a standard form; CDC annually requests these reports form states and territories, and the data are compiled and published every two years. The unit of analysis for the WBDO surveillance system is an outbreak, not an individual case of a particular disease. At least two persons must have experienced a similar illness after either ingestion of drinking water or exposure to water used for recreational purposes. Exceptions to the two-person requirement include single cases of laboratory-confirmed primary amoebic meningoencephalitis and single cases of chemical poisonings if water-quality data indicate contamination by the chemical. The likelihood that individual cases of illness will be detected, epidemiologically linked, and associated with water varies considerably among locales and is dependent on may factors. Recognition of WBDOs is dependent on the characteristics of the outbreak. Information from this surveillance system is used to characterise the epidemiology of waterborne disease in the United States, and data regarding the types of water systems and deficiencies associated with the outbreaks are used to evaluate the adequacy of current regulations for water treatment and monitoring of water quality.

NATIONAL SURVEILLANCE OF WATER-RELATED INFECTION

Rosalind Stanwell-Smith
PHLS Communicable Disease Surveillance Centre, United Kingdom

The historical importance of water related disease still underpins water surveillance, but it may have delayed the innovative approaches needed for our era, with emerging pathogens such as Cryptosporidium spp., Campylobacter spp, and viruses. Attributing cause remains a challenge, with many outbreaks classified as having only a probable rather than a definite association with an implicated water source. Important issues for national surveillance include: surveillance specifically tailored to water, taking account of the associated uncertainties and the lower priority often accorded at the reporting level.

- Multi-disciplinary approach, to ensure input from all the skills and knowledge bases involved.
- Risk assessment, including appraisal of public health risk and identifying critical points in the development of outbreaks and accidental contamination.
- Regular collation of evidence and prompt national reports.
- Research into water behaviour such as drinking patterns and increasing consumption of bottled waters - including differences by age, sex and socio-economic group.
- Travel related waterborne disease, both within countries and abroad.
- Water quality “in transit” (aircraft, ships etc) and associated disease.
- Effects of chronic exposure and the role of host immunity.
- The implications of climate change.

National water surveillance in the United Kingdom is still predominantly outbreak driven. Building on the established regular reports on outbreaks, the next step will be development of more comprehensive surveillance, to provide more understanding of clusters and sporadic cases.

SURVEILLANCE OF WATERBORNE DISEASES AT NATIONAL LEVEL

Yvonne Andersson
Swedish Institute for Infectious Disease Control, Sweden

A more up-to-date system for reporting outbreaks of waterborne diseases was launched in Sweden in 1980, and included epidemiological investigations of large outbreaks. The effectiveness of the new reporting system has increased the number of reported outbreaks. During the period 1980-1999, 116 outbreaks of waterborne diseases were reported in total and afflicted about 58 700 people. The timely discovery of an outbreak and the source of it normally involves a long series of events and contacts with different authorities. The strength of the Swedish reporting system is the close co-operation between different bodies.

The mandatory systems of surveillance of notifiable diseases and reporting from the laboratories seldom reveal a waterborne outbreak. Most Swedish outbreaks have in fact been recognised by the increased numbers of sick people and not through the surveillance system.

The real number of sick persons often differs considerably from the number of primarily reported cases. To be able to take the appropriate action, knowledge of the problems must be obtained and therefore the surveillance of waterborne-disease outbreaks and accidental pollution is necessary. The reporting of outbreaks of waterborne disease in Sweden is not mandatory, but the Environmental and Public Health Board or the County Medical Officer will report an outbreak investigation to the National Food Administration and/or the Swedish Institute for Infectious Disease Control. Our experience in Sweden is that increased information on the local and county levels can increase the number of reports and also the degree of attention given when waterborne outbreaks occur. The surveillance system for waterborne outbreaks could be made more efficient by the mandatory reporting of such outbreaks.

SURVEILLANCE AT INTERNATIONAL LEVEL

Chris Bartlett
PHLS Communicable Disease Surveillance Centre, United Kingdom

Collaborations in communicable disease surveillance amongst EU countries have developed remarkably in the last five years. The Maastricht Treaty provided the political will to underpin these activities. In 1993 an inventory was drawn up of all existing surveillance collaborations involving the Member States. A critical appraisal by experts from each country identified gaps, overlaps and variation in quality, particularly in terms of standardisation of methods, timeliness and use of the information to inform public health action. The heads of institutes with responsibility for national surveillance in each of the Member States have met regularly since then to assist in the strategic development of surveillance. A series of disease-specific networks have been established, each with an operational protocol setting out the agreed case definitions, standard methods and the ways in which the information will be used to inform others including those with a responsibility for developing policy; two such networks will be described, both of which enable surveillance of water-related infections.

Several other projects are strengthening surveillance within the European Union including: a weekly electronic bulletin (http://www.eurosurv.org); Euro Surveillance, a monthly surveillance bulletin; electronic communications systems development; EPIET, a training programme for service epidemiologists. These developments are funded by the European Commission and are designed to be complementary to the longer-standing WHO collaborations. High quality and timely information is being provided on a steadily increasing spectrum of infectious diseases in the European Union, leading to improved prevention of communicable diseases.

A SYSTEMS APPROACH TO OUTBREAK INVESTIGATION

Paul R. Hunter
Public Health Laboratory, Countess of Chester Health Park, United Kingdom

This presentation introduces the session covering the investigation of outbreaks of potentially waterborne disease. It will be argued that the most effective investigations are those that follow a logical systematic approach. Effective outbreak investigation also relies on effective multidisciplinary teams. These teams will be composed of public health doctors, epidemiologists, medical microbiologists, environmental health officers, water engineers and press officers. The stages in the investigation of outbreaks are as follows:

- Preparation and planning.
- Detection of the outbreak.
- Confirmation that it is an outbreak (and not a pseudo-outbreak).
- Description of the outbreak.
- Generation of a hypothesis as to the cause of the outbreak.
- Implementation of provisional control measures.
- Testing the hypothesis (by epidemiological, microbiological and environmental investigations).
- Reviewing control measures.
- Learning the lessons.

Despite the linear model that has been presented here, good outbreak investigations are much more iterative with lessons learnt in one outbreak informing preparation for subsequent outbreak.

OUTBREAK DETECTION (INCLUDING USE OF NEURAL NETWORKS)

Kit Fairley
Monash Medical School, Alfred Hospital, Australia

The use of artificial neural networks in outbreak detection is still in its infancy, though they have been used in other fields for similar purposes (e.g. tornado prediction, electricity need for cities). There are several ways they might prove useful:

- Analysing time-series and other data to predict "expected" numbers of disease cases, given sufficient numbers of previous data points. Where the observed numbers are sufficiently different from predicted, a possible outbreak would be flagged.
- Detecting spatial patterns of disease distribution corresponding to a known potential outbreak source, such as a water distribution network.
- 'Data mining' to find previously undetected relationships between environmental or other "predictive" factors and increases in disease incidence, allowing prediction of outbreaks.

None of these has so far been applied in practice, but studies are under way. The potential uses of artificial neural networks have suffered some exaggeration, partly because they come from the world of artificial intelligence. Although sometimes described as capable of "learning from experience", the commonest forms of neural network are actually more like non-linear regression algorithms, using novel means for exploring the weight space that describes the relationship between "independent" and "dependent" variables. By being non-linear, they offer some real advantages over other statistical techniques. Once trained, they execute very quickly, allowing their use in "real-time" environments.

THEORETICAL ASPECTS OF EPIDEMIOLOGIC INVESTIGATIONS

Deborah A. Levy
Centers for Disease Control and Prevention, Division of Parasitic Diseases, United States

Epidemiological investigations of infectious disease outbreaks should include several basic steps. Some of these steps are performed sequentially while others are performed simultaneously. The epidemiologist must first establish the existence of an epidemic and confirm the diagnosis. An operational definition of a case is developed and the cases are oriented by characteristics of time (development of an epidemic curve and calculation of an incubation period), place (geographic location), and person (age, gender, race and ethnicity, and occupation). A preliminary hypothesis as to causation is formulated and a systematic study is designed to test the hypothesis. Appropriate control and prevention measures are applied based on the results of the study and a written report is prepared.

EPIDEMIOLOGICAL INVESTIGATION – THE PRACTICAL ISSUES

Catherine Quigley
Cheshire & Wirral Communicable Disease Unit, Chester Public Health Laboratory
Countess of Chester Health Park, United Kingdom

Epidemiological investigation of an outbreak thought to be related to contaminated drinking water may involve several areas with large numbers of people exposed. Co-ordination of the investigation is therefore vital. The resources required to undertake epidemiological investigation include access to relevant information about the population exposed and the water supply to the population, computer software with maps and statistical packages, staff for interviews and for data entry and access to expert statistical advice.

In the United Kingdom, the definition of the population at risk usually relates to residence in a local authority or a health authority. An appropriate case definition should be agreed at an early stage and should take account of travel into and out of the area affected. Maps of water supply zones should be provided by the water utility and if water from different treatment works is blended, information should be included on the percentage from each treatment centre to each zone.

The decision to proceed to an analytical study needs careful consideration. Important factors that may influence the results of a case control study are: a) levels of immunity in the population at risk and b) the bias that may be introduced by media coverage and/or the introduction of advice to boil water. If a case control study is undertaken, avoidance of biases (selection, recall and interviewer) is very important. In the United Kingdom, controls are usually selected from Health Authority lists of people registered with General Practitioners. Interviews may be conducted by telephone, face to face or by means of a postal questionnaire. The questionnaire should include questions about the amount of water consumed and exposures to other risk factors, e.g. swimming pools, pets, farm animals and food.

ENGINEERING ASPECTS OF WATERBORNE DISEASE INVESTIGATIONS

Kim R. Fox
Environmental Protection Agency, Water Supply and Water Resources Division, United States

As part of a disease outbreak investigation involving drinking water, an engineering investigation may be necessary to determine how or why the pathogen of concern was able to get to the consumer. In many of the US outbreaks, the survival of the pathogen was dependent on multiple problems within the source water collection system, treatment facilities, or distribution and storage system. In at least one of the major outbreaks in the United States, drinking water was implicated, but no evidence or problems were discovered within the water system itself. The engineering investigation is different from a sanitary survey in that the investigation is to identify weaknesses that may have existed in the past that allowed pathogens to survive. Many of the outbreaks were investigated by re-evaluating historical operational data to identify the weaknesses or lapses in the systems that may have happened. This "late" investigation means that conditions that existed during the outbreak may or may not be present during the investigation. Sampling of water for the etiological agent may or may not be successful in that many of these investigations happen after the outbreak has subsided. In some outbreaks, "old" water was collected from stagnant zones in the distribution system and from ice that was made during the outbreak. This presentation will discuss several techniques that can be used to investigate outbreaks relying on past investigations as examples.

DETECTION AND IDENTIFICATION OF NLV CALICIVIRUSES IN WATERBORNE EPIDEMICS

Carl-Henrik von Bonsdorff
Haartman Institute, Department of Virology, Helsinki University, Finland

Human caliciviruses, and in particular Norwalk-like viruses (NLV), cause large food and waterborne epidemics, but are also easily spread through direct contact. They are apparently the most abundant human viruses that are secreted into and contaminate the environment. Their detection and identification is based on amplification of a stretch of the viral genome by the sensitive PCR-method. The PCR-product is identified by NLV-specific probes. Further isolate characterization is achieved by amplicon sequencing. In case of caliciviruses, a 65 base sequence within the amplicon seems sufficient for initial strain identification.

We have concentrated the virus from 1000 ml water samples by the method described by Gilgen et al (Int J Food Microbiol. 37, 189-999, 1997), which is based on binding it to positively charged filters. The eluted virus is further concentrated to 100 µl by a microconcentrator and the sample then submitted to the PCR. The obtained PCR product was sequenced and compared to that of patient samples. By now, we have used the method successfully in four different waterborne epidemics, where we were able to demonstrate a similar NLV both from the water and the patient samples.

Human caliciviruses might well be considered as indicators for monitoring drinking water for (human) stool contamination. We are presently trying to assess the contamination risk of surface water by measuring the amount of these viruses in sewage.

CLINICAL/MICROBIOLOGICAL INVESTIGATION INCLUDING STRAIN TYPING

Gordon Nichols
PHLS Communicable Disease Surveillance Centre, United Kingdom

Cryptosporidium is the main pathogen linked to waterborne disease outbreaks in the United Kingdom and understanding its epidemiology can lead to strategies for reducing disease. Using patient faecal samples from both routine surveillance and outbreaks *Cryptosporidium* oocysts were typed. A sensitive PCR protocol was developed and applied to 2 057 faecal samples from infected humans and 71 livestock animals. Three genotypes were found; *C. parvum* genotypes 1 and 3 were found only in humans and genotype 2 in humans and animals. Using gene sequencing, genotype 3 was indistinguishable from *C. meleagridis* (previously reported in birds). The two main types (genotypes 1 and 2) showed different seasonal and regional distributions, and genotype 1 was more frequently associated with foreign travel. Analysis of outbreaks associated with swimming pools and drinking water suggests that both main genotypes can be involved. Genotype 2 was associated with drinking water outbreaks where circumstantial evidence suggested that the water had been contaminated from animal sources. In outbreaks associated with genotype 1 contamination appears to have derived from sewage. There were consistent types within families, and more sporadic cases were caused by genotype 2 than genotype 1. Mixed infections with two types were more frequently encountered in swimming pool related outbreaks than in drinking water related ones, perhaps indicating that pool water was contaminated from more than one infected individual. Information from this work is transforming our understanding of both the biology and epidemiology of *Cryptosporidium.* As well as altering our understanding of waterborne outbreaks it also provides evidence for the sources of contamination that may be causing sporadic disease.

PROGRESS REPORT ON THE WHO/OECD GUIDANCE DOCUMENT “IMPROVING MICROBIOLOGICAL SAFETY OF DRINKING WATER”

Mario Snozzi
EAWAG, Switzerland

Elettra Ronchi
OECD

The ’98 OECD Interlaken workshop “Molecular Technologies for Safe Drinking Water” produced three main recommendations:

- Development of a guidance document on microbiological testing of drinking water.
- International co-ordination and promotion of molecular methods in the field of drinking water microbiology.
- International co-ordination for improved surveillance and outbreak investigation.

In 1999 a Drafting Group was formed to address the first of the three recommendations, namely the preparation of a guidance document on *Improving Microbiological Safety of Drinking Water.*

The guidance document is a co-operative effort between the WHO and the OECD. An outline for this document was discussed at a meeting at OECD Headquarters, 9-10 December 1999. At this meeting it was decided that the document would take a holistic approach in addressing the problem of safe drinking water and the needs for effective information management.

Management of drinking water has to be extended to include the whole system. Testing of water quality starts with source water, to be followed by evaluation of the efficiency of the available treatments for pathogen removal and ultimately by end product testing. Proper performance control strategies have to be installed at each step of the system.

The document addresses selection of methods giving an overview of both conventional and molecular methods that might most appropriately achieve the best results at each step of the system; and discusses their relative sensitivity, selectivity and robustness, including economic considerations. The document also provides detailed information on treatment processes, methods to assess distribution system integrity as well as methods for outbreak investigations. Case studies are included in all chapters.

The final chapter gives a visionary summary and reinforces two important messages:

1) New, improved methods are needed to ensure drinking water safety.
2) Research in biotechnology may offer significant solutions to satisfy these needs.

REVIEW OF THE CAUSES OF WATERBORNE OUTBREAKS IN THE UNITED STATES 1991-1998

Gunther F. Craun
Gunther F. Craun & Associates, United States

Since 1991, 109 waterborne outbreaks have been reported in public water systems. In community systems, the most important deficiency was contamination of the distribution system; 36% of 47 reported outbreaks were associated with contamination from cross-connections, backsiphonage, corrosion, inadequately protected storage facilities, and construction, or repairs in the distribution system. The remaining outbreaks in community systems were associated with inadequately treated groundwater (22%) or surface water (17%), chemical feed deficiencies (11%), and miscellaneous or undetermined causes (14%). In non-community water systems, 63% of 62 reported outbreaks occurred in groundwater systems that were inadequately treated. The remaining outbreaks were associated with distribution system deficiencies (13%), unfiltered surface water (2%), and miscellaneous or undetermined causes (22%). Water quality information was available from samples collected during the investigation of 74 outbreaks and from routine surveillance records for 45 systems that reported an outbreak. Coliform bacteria were detected during the investigation of 44 (88%) outbreaks caused by bacterial and unidentified agents but only 5 (26%) outbreaks caused by *Giardia* and *Cryptosporidium*. Coliforms were found during one outbreak of hepatitis A but not in either of two outbreaks caused by small round structured viruses. Although coliforms were found during the investigation of 12 (46%) community and 38 (83%) non-community system outbreaks, only 5 (22%) community and 2 (9%) non-community systems had violated the Environmental Protection Agency's coliform limits in the 12-month period before the outbreak. Thus, meeting EPA coliform requirements may not provide a good indication of a system's potential for an outbreak.

WATERBORNE CRYPTOSPORIDIOSIS IN ENGLAND AND WALES

Mike Waite
Drinking Water Inspectorate, United Kingdom

An outline of the role of the Drinking Water Inspectorate in waterborne Cryptosporidiosis and a brief review of outbreaks investigated between 1990 and 2000. A detailed account of the investigation of specific outbreaks in South Devon and legislative consequences.

WATER INDUSTRY DATA RESOURCES

Alan Thompson
Lyonnaise des Eaux, France

The paper will address the use of analytical data within the water industry, particularly the interpretation of such data by external bodies.

It will then move on to suggest the role that water industry data will play in the future and in particular the initiatives being taken by Lyonnaise des Eaux.

USING EXISTING SURVEILLANCE-BASED DATA

Gordon Nichols
PHLS Communicable Disease Surveillance Centre, United Kingdom

A hypothesis suggests that excess gastrointestinal illness within the community may result from pathogenic organisms in drinking water. Waterborne outbreaks associated with *Giardia* have been uncommon, but between 1983 and 1997 there were 80 outbreaks of *Cryptosporidium* infection in England and Wales, of which 35 were associated with water consumption, and 25 (3 455 cases representing 7% of all cases) with drinking water. There have been 18 outbreaks associated with swimming pools since 1990. Outbreaks were also associated with farm visits. National examination of routine surveillance data on over 60 000 Cryptosporidium cases and over 60 000 Giardia patients reported before the end of 1999 found that with both organisms around a third of all cases occurred within local clusters. A large increase in Cryptosporidium cases nationally occurred at the same time as a large waterborne outbreak in the Torbay area of Devon and was probably caused by people being infected while on holiday in this resort. Cryptosporidiosis is more common in the spring and early autumn and giardiasis is more common in the late summer. Recent travel abroad was a risk factor in 4% of all *Cryptosporidium* cases and around 40% of *Giardia* cases, and travel plays a role in the autumn rise in cases with both. The relatively common detection of waterborne outbreaks in the United Kingdom results from a number of key features, including the routine detection of pathogens by laboratories, routine reporting to a national surveillance system and local monitoring of cases by consultants in communicable disease control. The rapid response to local increases in cases and careful integration of epidemiological, microbiological and reference investigations contributes to a good local system for establishing the cause of an outbreak, controlling it and reporting it nationally.

TIME SERIES TO ASSESS ENDEMIC WATERBORNE DISEASE BURDEN

Pascal Beaudeau
Laboratoire d'Etudes et d'Analyses, France

The increasing use of on-line measurements for assessing and monitoring drinking water quality and the increasing facilities for storage and analysis of computerized data have facilitated the use of time-series studies to assess the waterborne disease burden. This paper focuses on some specifics of carrying out such studies in that field.

The available indicators of health effects and exposure to pathogens are both indirect indicators. Sanitary indicators are restricted to short-term effects of some waterborne diseases, i.e. acute gastro-enteritis symptoms. Current water quality indicators (e.g. increased turbidity or lack of free chlorine content) are not specific for pathogens nor even for faecal pollution but simply indicate a probability of pathogen occurrence, due to temporal events such as contamination of raw water after rain events or as weakness of the treatment.

Therefore, before model fitting, special attention has to be paid to the choice of the step of time and to the design of the indicators in order to fit as closely as possible the nature and the dynamics of infection. If well driven, this stage will not only be of great help in discussing the biological plausibility of the results but also in the validation of the model. Several examples will illustrate this point.

In order to avoid false positive correlation due to confusing effects, seasonal variations have to be filtered out of target variables (sanitary variables), as well as trend and auto-correlation. Only high frequency events are taken into account in the calculation of the relative attributable risk. This leads to an underestimated assessment of the risk and may also result in false negative outcomes.

The advantages of time studies are (i) their low economical cost and (ii) the improvement of risk management, i.e. of dialogue between public health staff and water suppliers by using processing control parameters as exposure surrogates.

CASE CONTROL STUDIES FOR ASSESSING ENDEMIC WATERBORNE DISEASE BURDEN

Kit Fairley
CRC for Water Quality and Treatment, Department of Epidemiology and Preventive Medicine
Monash Medical School, Alfred Hospital, Australia

This session will place the role of "case control studies" in perspective with other epidemiological approaches to define the contribution of drinking water to endemic waterborne disease. It will not deal with epidemic disease. Case control studies have two major limitations when used to assess endemic waterborne disease. The first is that they only look at one disease (e.g. cases of cryptosporidiosis) and therefore can only assess a small fraction of all potential disease. The second is that because of the inherent biases associated with this study design, it is important not to attempt to look for an odds ratio of less than 2. In designing these studies it is important to minimise any biases that may occur, particularly those surrounding the reporting of drinking water consumption. Their optimal use is therefore in conjunction with large randomised controlled trials that do not have the statistical power to address these pathogens. This was the case with the Water Quality Study, recently completed in Australia. Therefore a case control study of cryptosporidiosis is being undertaken to address this separate concern.

THE "EMIRA" PROJECT : A PROSPECTIVE EPIDEMIOLOGICAL STUDY

Denis Zmirou
Grenoble University, France

Design. The "EMIRA" study (**E**pidemiology and **MI**crobial **R**isk **A**ssessment) was carried out between October 1998 and June 1999 in the French Alps. It combined a daily epidemiological follow-up of acute digestive morbidity among a panel of volunteers (with weekly telephone calls to retrieve health data registered daily by one referent person in each household), and a microbiological surveillance of drinking water. Volunteers were recruited among communities supplied by 4 public water systems, with different degrees of raw water vulnerability (one "pristine" groundwater, one surface water, and two vulnerable ground watersheds); all complied with microbial (bacterial) quality criteria. Except in the first group (untreated), water was only disinfected by chlorine. Bacterial analyses were performed on monthly samples of raw and/or tap water in each group to control compliance of drinking water to microbial quality regulations. Protozoans (*Giardia and Cryptosporidium*) were analyzed by immunofluorescence assay. Virological quality of water was assessed using RT-PCR for detection of enterovirus, rotavirus and astrovirus. In addition to routine analyses, samples of tap water were stored (at 4°C) every day by a local sentinel, in order to be analysed in case of an outbreak.

Results. At the end of the study period, 712 cases of acute digestive conditions had occurred to 544 volunteers (176 households, 92 492 person-days), including 46 gastro-enteritis. Twenty-four raw water samples and 44 tap water samples had been collected. Protozoans and enteric viruses markers were common in tap water, despite absence of bacterial indicators: out of 20 positive samples with parasites or viruses markers, 18 were free of bacterial indicators. A statistical analysis adapted to this longitudinal design is underway to compare incidence rates of digestive morbidity according to microbial exposure. Provisional results do not show an effect of viruses markers, but an association with protozoans, including during an epidemic episode with *cryptosporidia* in tap water: the odds ratio of acute digestive conditions is 1.32 [95% CI: 1.1-1.5] for concentrations over 20 oocysts/100L (OR=1.15 [0.9-1.4] between 10 and 20 oocysts/100L), compared to absence of measurable oocysts. Detailed results will be presented at the expert meeting and discussed in the light of other prospective epidemiological studies.

PROSPECTIVE EPIDEMIOLOGICAL STUDIES OF WATERBORNE DISEASE IN DEVELOPING COUNTRIES

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Studies of endemic waterborne disease in developing countries are complex due to many characteristics of communities in developing countries: 1) water sources are often highly contaminated and used with little or no treatment; 2) transport and storage of water in the home may result in degradation of water quality; 3) faecal pathogens are transmitted by multiple routes due to poor sanitation and food hygiene; 4) in many areas, both inadequate water quality and water quantity contribute to waterborne disease; 5) traditional bacterial indicators of microbiological water quality may not be appropriate for tropical source waters. Epidemiological studies of waterborne disease in developing countries have reported a wide range of health outcomes associated with improved water quality and quantity. Many studies suffer from methodological problems. Exposure assessment based on type of water source or poor techniques to measure water quality contribute to exposure misclassification. A prospective cohort study in the Philippines demonstrated the value of good water microbiology and a threshold effect of water quality on diarrhoea. Children who consumed moderately contaminated source water had only marginally higher rates of diarrhoea compared to children who drank uncontaminated water, but children who drank highly contaminated source water (>1000 *E. coli* /100 ml) had significantly higher rates of diarrhoea. Studies in urban Bangladesh reported higher risk of diarrhoea in children consuming piped water with low to moderate concentrations of *E. coli*. Intervention studies in Bolivia and Bangladesh have shown that point-of-use water treatment and safe storage reduced paediatric diarrhoea disease by 44% to 46%.

WATERBORNE INFECTIONS VERSUS WATERBORNE DISEASE: CAN WE UNDERSTAND RISK FACTORS FOR DISEASE WITHOUT UNDERSTANDING RISK FACTORS FOR INFECTION?

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We have conducted serological surveys for antibody response to two *Cryptosporidium* antigens in seven countries, including the United States. Most of these serosurveys were done using blood donors or people who contributed sera for other tests. Results from these serosuveys suggest that: 1) *Cryptosporidium* infections are common and widely distributed geographically; 2) differences in serological response from three paired-city studies suggest that drinking water is an important risk factor for infection; 3) serological response increases with age. Our analysis of sera from a cross-section of residents of seven cities who participated in the NHANES III survey in 1989-90 suggests that: 1) there is a strong geographical variation in serological response to these antigens; 2) serological responses increase with increasing age; 3) the relationships between risk factors and serological response were most apparent for the 1949 age group, suggesting that children are not the optimal group for serological studies; 4) the pattern of risk factors predictive of the intensity of serological response is consistent with person-to-person spread infection; 5) high quality surface sources may predict lower risks of infection. Understanding the relationship between exposure and infection is essential to understand the relationship between exposures and illness. The wide distribution and common occurrence of *Cryptosporidium* infections may influence susceptibility to cryptosporidiosis.

INTERVENTION STUDIES

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Intervention studies have rarely been used to evaluate the level of endemic waterborne illness in a population. Their use has often been limited to monitor the effect on health of a new or improved water supply or to demonstrate the effectiveness of various sanitation procedures. In developing countries, intervention studies have provided data on the reduction of various diseases in the population and the value of water treatment to reduce waterborne diseases. However, these results are often confounded by other factors linked to the overall sanitation and cultural habits of the populations studied: the part played by the water route is inter-linked with these other factors and any interpretation made needs to be carefully validated.

As water quality improves, it becomes more and more difficult to design and implement intervention studies that will not be subject to criticisms and that do not require very large cohorts. Following the example of the Payment studies in Canada, the Australians and the Americans have attempted to repeat these intervention prospective studies. The results of first of several ongoing American studies confirm the Canadian studies while the Australians, in a preliminary report, have reported no health effect due to unfiltered clean surface waters. Several issues need to be addressed and will be discussed: bias, blindness, temporality, plausibility, coherence, strength of association, etc.