Framework of epidemiological principles underlying chemical incidents surveillance plans and training implications for public health practitioners

Surinder S. Bakhshi

Summary
The Department of Health requires District Health Authorities to have plans ready for dealing with chemical incidents to protect public health. The three aspects of a chemical incident are environmental, medical toxicology, and public health advice and information. Public health surveillance plans require generation of a causal hypothesis and assessment of risk. Training provision should emphasize the need for application of epidemiological precepts in drawing up such surveillance plans. The epidemiological principles are systematically outlined with emphasis on their significance.

Keywords: chemical incidents, surveillance, public health role, training

Introduction
There is a growing need for broad knowledge of recognition, investigation and control of chemical health hazards in public health practice. Epidemiological investigations may provide the only relevant information and advice on the effect of chemical incidents on public health. Expertise in the principles and practice of epidemiology is a prerequisite in the training of public health practitioners.

The public health role in chemical incidents, nevertheless, appears to be confusing not only to public health practitioners but also to outside agencies that would benefit from the practice of that role. The confusion lies in the terms 'advice' and 'information'. How does public health information and advice differ from that available in a database to the organizations coping with emergencies?

Three main areas of expertise are recognized when dealing with a chemical incident and its effect on the population:
(1) technical advice and support for measuring toxic chemicals in the environment (environmental toxicology);
(2) medical advice on symptoms of illness (medical toxicology);
(3) epidemiological advice and assistance (public health).

The UK Department of Health has issued health authorities with specific guidance on their role in making adequate arrangements for providing epidemiological advice and assistance in investigation and assessment of risk to health following chemical incidents. It recognizes the complexity of the expertise required and advises that health authorities seek contractual advice on environmental and medical toxicology when bringing their surveillance plans into action. The UK Department of Health has also made provision for a centralized unit to co-ordinate work on response to chemical incidents and surveillance of health effects attributed to chemicals in the environment within the context of current local and regional arrangements for the public health response to chemical incidents.

Relevance of communicable disease control to chemical incident management
Public health is experienced in dealing with infectious disease where the problems are easily classified and managed with familiar and well-established procedures for epidemiological evaluation, outbreak control and population protection. The situation, however, can be very different with a problem for which no infectious or genetic cause is evident. With the demise of the Medical Officer of Health, following the reorganization of health services in 1974, the training of public health practitioners has lacked familiarity with basic knowledge of environmental hazards, related clinical features and technical laboratory procedures, which means that public health practitioners will need to work closely with outside agencies that can provide such expertise.

Chemical incidents are either (1) effect-oriented – those coming to attention because of concern about unusual distribution of clinical symptoms in a locality but lacking an apparent cause; or (2) agent-oriented – those arising from potential exposure events, mainly transport and storage.
accidents, fires and accidental introduction of chemicals in soil, air and water.

As ill health is always present in communities, agent-oriented incidents will inevitably become linked to perceived or real illness patterns, even though the link may, in reality, be non-existent or at best very tenuous. Public concern or alarm necessitates that any relationship between environmental conditions and clinical symptom patterns is evaluated. 7

Defining a public health surveillance system for chemical hazardous substances

Goal
The goal of a surveillance programme is to reduce the morbidity and mortality resulting from chemical incidents. The surveillance system is predicated on the ability of public health practitioners to assess and prevent acute adverse health effects.

Objectives
The objectives are to assess and prevent acute adverse health effects as follows:
(1) describe the illness experienced by the population from the release of a chemical;
(2) identify the risk factors associated with the illness from the release of the chemical;
(3) define the extent of the effect on health of the release of the chemical;
(4) reduce subsequent illness associated with the release of the chemical.

Methods
The unique public health role is to establish surveillance systems that focus on public health (disease occurrence), rather than upon the environmental impact of chemical emergencies (environmental exposure). 8 Although the two topics are closely linked and investigation of environmental illness requires consideration of the level of exposure, the point of entry for the public health practitioner is principally by the recognition of disease occurrence or potential health threats which come to attention.

The essence of such surveillance is preparedness to respond to an incident so as to identify, investigate and evaluate the various toxic risks in the community with a view to taking measures to reduce or eliminate these risks. It is critical that any proposed surveillance system can be implemented without delay when a chemical is accidentally released, or has the potential to be released, in the environment and threatens the health of the general public.

Hence the surveillance systems adopt a framework of epidemiological concepts and techniques whereby investigations may be pursued whatever the nature of the disease. Epidemiological studies find associations between exposure (cause) and disease (effect) to provide invaluable tools in the investigation of disease incidents. Public health is usually required to take action before the incriminating aetiological agent is identified. Analysis can show strength of association between exposure and symptoms and can elucidate dose-response; these are important tools sufficient to initiate response to an emergency. The identification of the causal agent must often await the end of an emergency, to show one's actions were in accordance with subsequent facts. 9

This paper defines the organizational and methodological provisions for a state of preparedness by public health practitioners to respond to a chemical incident. It focuses on investigation of disease occurrence rather than on assessment of environmental exposure. The latter will be expected to be simultaneously investigated by an environmental agency with which a health authority will have a contractual relationship. Implications for training become clear once the public health role becomes defined. An incident is defined as an unexpected hazard from a chemical involving a small or large number of individuals. One or more of these individuals may suffer from an illness that might be due to such an event.

Epidemiological principles

The procedures by which chemically caused disease can be evaluated and controlled follow the same basic epidemiological principles as are used in the investigation of infectious disease. A framework of epidemiological techniques is applied to any environmental health investigation, whatever the nature of the disease.

In any incident, only observational studies are possible at the outset, as the investigator has no control over the study population. The approach to observational epidemiology is placed into two basic designs: descriptive and analytical. As with epidemiological inquiries of any kind, the enquiry procedure entails an initial phase of descriptive epidemiology, followed, if circumstances require, by the design and performance of analytical epidemiological investigations. Once the adverse exposure factor is established by the epidemiological findings, public health intervention is initiated (Table 1).

As surveillance is principally a hypothesis-generating rather than a hypothesis-testing activity, the data are used to provide descriptive statistics of factors associated with acute adverse health effects resulting from chemical substance release. These analyses include, but are not limited to, frequency distributions and cross tabulations of specific variables. The associated morbidity and mortality analyses depend on the number of chemicals released. Individual chemicals are treated as independent variables - univariate analysis. The individual chemicals are then grouped into broad categories to explore if the risk of morbidity or mortality caused by exposure to multiple chemicals is different from the risk caused by exposure...
Table 1 Development of epidemiological field investigation

<table>
<thead>
<tr>
<th>Descriptive epidemiology</th>
<th>Analytical epidemiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define illness</td>
<td>State hypothesis to test</td>
</tr>
<tr>
<td>Consider biological hypotheses and significance</td>
<td>Choose study approach</td>
</tr>
<tr>
<td>Define population at risk</td>
<td>Design study</td>
</tr>
<tr>
<td>Measure disease excess</td>
<td>Sample size</td>
</tr>
<tr>
<td>Establish surveillance</td>
<td>Information on illness</td>
</tr>
<tr>
<td></td>
<td>Exposure comparability</td>
</tr>
<tr>
<td></td>
<td>comparing variables</td>
</tr>
<tr>
<td></td>
<td>ethics</td>
</tr>
<tr>
<td></td>
<td>resources</td>
</tr>
<tr>
<td></td>
<td>quality control</td>
</tr>
<tr>
<td></td>
<td>Perform study and analyse results</td>
</tr>
</tbody>
</table>

Descriptive epidemiology

Descriptive epidemiology is the study of the amount and distribution (for example, what, who, how much, when and where) of a disease in a population. It investigates the general distribution of the disease as it exists in the community. It is the starting point of any epidemiological study. It describes the population of interest and measures person, place and time characteristics against the potential health problems, that is, the amount and distribution of the disease in a population.

There is no control over the study population or the event and the investigator must draw conclusions from observations as the event unfolds. It is an exploratory approach to generate a hypothesis and assess risk.

Preliminary evaluation

The following information is obtained (see Forms 1, 2 and 3 – Figs 1–3):
(1) determine the appropriate geographic area and nature of the outbreak or exposure and define population at risk;
(2) determine demographic and injury details, define illness and produce case definition based on the most commonly recurring symptoms;
(3) determine an appropriate denominator (e.g. population of a community, number of children in school) and calculate occurrence rates.

Formulation of hypothesis

The hypothesis to be tested will be based on the answer to the following two questions:
(1) Do persons with a certain exposure experience more or less symptoms than persons without the exposure?
(2) Do people with a specific symptom have more exposure to a factor of interest than persons without that symptom?
If an association between specified effects on health and a direct or indirect exposure to a chemical is suggested, then a suitable hypothesis can be formulated and tested with analytical studies.

Initial response to reports of a disease outbreak: description of the problem

The surveillance system consists of the following.

Reporting of an event

Public health departments are contacted as soon as possible after an event. Reports of an incident, such as telephone calls, written reports or news items, come from a variety of sources including general practitioners, hospitals, the public or the media. Information is collected on the index case or cases from the person or persons reporting the incident. It includes the name of the person reporting the incident, characteristics of the suspected symptoms and the persons directly affected by the incident.
Case definition of a reported event

(1) An uncontrolled, illegal release or threatened release of one or more hazardous substances.

(2) The quantity of the hazardous substances which are released, or are threatened to be released, need or would need to be removed, cleaned up, or neutralized.

(3) Threatened release of a hazardous substance that can lead to action (e.g. evacuation) that can potentially affect the health of the public.

Definition of the illness

Without a clear idea of what constitutes a case of illness, it may be virtually impossible to develop useful epidemiological data.

In developing case definition two aspects are of initial importance. First, the definition should be, preferably, in objective terms, using data derived from clinical and laboratory findings; second, the illness definition should not include items related to an aetiological hypothesis which could be later subject to epidemiological investigation. It would be impossible, for example, to test the relationship of illness occurrence to a particular toxic exposure if the fact of the exposure were inherent in the case definition.

The case definition may be particularly important when the public health concern is focused on a wide spectrum of diverse diseases possibly arising from the same environmental exposure source.

Defining population at risk

Once a case definition has been established, it is important to define the population at risk. This is the population group or groups in which the disease could potentially occur. When the specific causal factor is known, the population at risk is limited to the segment of the population of the area exposed to the agent. In comparing disease occurrence in groups with and without exposure to the causal factor, the definition of population at risk should be based on general descriptive characteristics of a population, not including any specific environmental hazard exposure. Although it is necessary to define a ‘population at risk’ in such situations, so that epidemiological analyses can be performed, it is important to recognize the arbitrary nature of the definition and the uncertainty of their relationship to an actual environmental exposure.

Data collection

Both environmental and health data are collected. Environmental data will be needed to identify the substance or substances involved in the release.

Data management

Data entry, data transfers and updating information are computerized. Epi Info\textsuperscript{10} word processing, data base, and statistical system for epidemiology on computers is now accepted as the standard format for transference of data, data collection, management and analysis.

Data analysis

Quantifying excess occurrence is the next step. A preliminary evaluation is conducted by gathering information on the first few cases to make a quick estimate of the likelihood that a significant excess has occurred and whether the incident needs further investigation. The estimate can be made by taking the following steps:

(1) determining the appropriate geographical area and time period;

(2) determining an appropriate denominator and calculating occurrence rates;

(3) comparing the occurrence rate with an appropriate reference population.

Observed rates of disease occurrence are estimated once the disease and the population at risk have been defined and the number of cases and the number of people in the population at risk are known. Observed rates are then compared with expected rates as a ratio between the two rates – risk ratio or relative ratio. A ratio that does not differ significantly from 1.0 means that the rates being compared are unlikely to be different
### CHEMICAL INCIDENTS SURVEILLANCE PLANS

**Individual:**

<table>
<thead>
<tr>
<th>NAME: (last) (first) (initial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec: MALE FEMALE (circle one)</td>
</tr>
<tr>
<td>Birth date</td>
</tr>
<tr>
<td>Place</td>
</tr>
</tbody>
</table>

**Occupation:**

<table>
<thead>
<tr>
<th>Address: (street) No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Town: Region: Postal Code:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of onset of symptoms:</th>
<th>Date of diagnosis:</th>
<th>Date of death:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Diagnosis (or symptom complex):</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Laboratory test results:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Comments:</th>
</tr>
</thead>
</table>

**REPORTED BY:**

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date of report:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td></td>
</tr>
</tbody>
</table>

---

**Exposure potential and dose load**

In deciding if an etiological hypothesis warrants investigation, one must consider whether the exposure is merely potential or actual and if it is significant enough to cause disease. Many exposures are possible in any one situation, but there is real concern only for those which result in a sufficiently high dose to affect sensitive individuals in the exposed population. The relationship between potential exposure and actual dose is important in proceeding with an investigation.

**Establishing case surveillance**

Once the facts of the illness are established, case reporting is assessed on a continuous basis. Data collection focuses on rapid, complete case identification. Tabulations of case distribution are made according to time and place of case occurrence and according to demographic features of cases. Charts and maps of case distribution are helpful aids.

**Analytical stage**

Estimating risk and studying causative factors of disease in a population once a hypothesis has been formulated is the next stage in epidemiological investigation. Though most chemical incidents need no further investigation beyond estimating risk, a second phase of data analysis may be needed to obtain greater detail regarding the characteristics of the persons affected, and the features of their illness and testing the hypothesis generated.

Epidemiological procedures are described in their logical conceptual sequence. In a real incident, the various components of an epidemiological inquiry may well come into play at once, or in a different sequence.

**Risk assessment**

Risk assessment is a population concept. Epidemiological methods are used to assess the risks to health that result from exposure to noxious agents.

1. **Population considerations.** As the chemicals frequently involved in incidents are mixtures or their breakdown products, the symptoms experienced by individuals, who are or who have already been exposed, are very often non-specific in character. Chemical agents usually have multiple organ systems effects and depending on the route, duration, amount and concentration of the exposure, the onset and duration of symptoms will vary widely. Risk assessment is the characterization of potential adverse health effects on human exposure to environmental hazards.

2. **Epidemiological considerations.** In a risk assessment process involving toxic substances there is no substitute for details on the condition of those exposed and the circumstances surrounding the incident. Epidemiological data are the most convincing evidence of human risk.

The essence of epidemiological data analysis is comparison. To
assess the significance of an epidemiological data association, one must establish a reference level with which to compare the exposure of interest. Epidemiological comparison between rates and proportions offers important information about the magnitude of risk.

Underlying much epidemiological data analysis is the generic 2 x 2 (four-fold) table, where both the disease and the chemical exposure under investigation are dichotomized. In these estimates, the best single value estimate of the effect in question is called a point estimate. Although the point estimate indicates the magnitude of the comparison, it does not take into account the degree of random variability in the observations. A range of values is used to estimate the effect of this variability. This range is the 95 per cent confidence interval and the process of calculating it is the interval estimation.

Risk calculations are applied only to independent causal factors and specifically exclude factors that are non-causally associated with the illness simply because of their association with a factor which is itself causally associated with the condition. Only those factors causally associated with an illness will influence its prognosis.

The most important form in which the result of epidemiological enquiries is expressed is a rate. When the numerator expresses events that are related to disease, the term is synonymous with the concept of risk. A rate summarizes quantitatively the chance that an individual in that population will experience the event in question. It is a probability statement of the risk of an event in an individual in the population.

A rate allows the risk of an event under one set of circumstances to be compared with the risk under different circumstances. The most important form in which the magnitude of a suspected causal factor can be expressed is relative risk - the ratio of one outcome to another.11

In other words, it is a measure of the likelihood of occurrence of the target event in those exposed and not exposed to the agent of interest. Relative risk assessment works well in concepts of association in which we wish to examine the effect of a particular risk factor on the subsequent occurrence of illness. However, the concept does not apply to case-control studies, where we assemble a group of people with the disease (cases) and an appropriate set of people without disease (controls). What we cannot calculate from these data is an actual risk of getting a disease. We can, however, work out the probability of a person being exposed and calculate the odds of doing so. Relative odds ratio can be calculated as for relative risk.12

**Testing the disease hypothesis**

A number of epidemiological study designs exist to test a hypothesis developed following an acute chemical incident. The development of hypothesis and testing of this hypothesis is required to draw conclusions regarding disease aetiology from a formal analytical study. For any particular situation, several aetiological possibilities may exist. Selection of a hypothesis to be tested may be obvious, but it may be much more difficult where clinical features or other observations do not clearly implicate a particular factor.

The cross-sectional approach is ideally suited to the epidemiological study of an acute incident. Case-control and cohort studies are retrospective in nature and their study designs differ fundamentally in approaching questions of causation from opposite ends of the cause-effect spectrum.

**Cross-sectional study**

Cross-sectional or prevalence studies of exposed vs non-exposed populations provide information on disease frequency (prevalence), estimates of exposures, measurements of personal characteristics and biological effects at a given time. The study can be performed even on a large population, and provides a rapid estimate of the extent of the problem. All persons in a given population are included without regard to exposure or disease. Cases (disease prevalence) are identified in the population, and compared with the remainder of the population (controls). Exposure data are collected simultaneously with disease data. The fundamental difference between the longitudinal and cross-sectional design is that in the latter the time sequence between exposure and disease cannot be inferred. Its use in acute incidents, however, allows a rapid completion time, which is of critical importance for our purpose. The study is relatively easy to set up. It is also possible to study large groups at low cost if the cross-sectional approach is modified to use the total population as the unit of measurement rather than the individual. The method estimates the extent of the problem (prevalence) during an acute onset.

**Case-control study**

Case-control studies start at the disease end and compare frequencies of exposure among cases and non-cases. Case-control studies provide powerful and accurate estimates of risk ratios and can be economical in both cost and study duration.

**Cohort study**

Cohort studies start from the exposure end and assess cause-effect relationships by comparing frequencies of disease within exposed and non-exposed populations. These studies have the advantage of making direct measurements of disease risk because they count illness occurrences in defined populations and so can calculate actual population-based illness rates.

**Post-case surveillance outcome**

Description of intervention epidemiology is beyond the scope of this paper. The outcome can be briefly described as removing or modifying the suspected cause of the disease problem and studying disease reduction, proposing further studies, or no further action being indicated as no significant disease excess is documented.
Discussion

Under the 1973 NHS Reorganisation Act, environmental health functions were separated and became a local authority responsibility. Local authorities were required to appoint public health practitioners working within the NHS as their medical advisers on environmental health. The new relationships were not clearly defined, and most local authorities soon stopped regarding their medical advisers as their principle source of guidance on such matters. 13

The committee of enquiry into the future development of the public health function, in its report in 1988, recommended abolishing the position of Medical Officer for Environmental Health (MOEH) as it straddled uncomfortably between health and local authorities and had proved unsatisfactory in practice. The committee, however, did not provide specific recommendations to clarify the role of Consultant in Communicable Disease Control (CCDC) – successor to the MOEH – in environmental health matters. 14

Although the statutory responsibility for monitoring pollutants and establishing facilities for coping with chemical incidents lies outside the remit of public health practice, it is the public health practitioners who are responsible for advice when health is at risk owing to environmental accidents.

The promotion in recent years of public health responsibility in the management of acute chemical incidents has led to uncertainty and confusion about the role of public health and how it is distinct from that of other participants in this sphere. Such confusion has important implications in training. It is obvious what the public health responsibility is not. Medical preparedness is the responsibility of the emergency services. Whereas the emergency services have learnt to cope efficiently and effectively with acute incidents, there is a gap in public health preparedness to provide a continuing assessment of the impact on the exposed community as a result of a chemical accident and the resulting action to preserve the health of the community. Familiarity with knowledge of environmental hazards, related clinical features and technical laboratory procedures is no longer central to the training and expertise of public health practitioners.

The initial response to an incident is to set up telephone hot lines to assure the public – a public relations exercise on behalf of a health authority – which is not a scientific or professional contribution to a chemical incident. The next usual response is to undertake a retrospective study, days or weeks after the incident has taken place, which makes little contribution to the continuous preservation of health in the management of an incident in its acute phase. The latter is a responsibility of the unique public health role in providing interventions based on epidemiological studies, but – and it is the crux of the issue – this needs to be part of the integral management of the acute incidents. Obviously, public health interventions need to commence when the events occur and continue as the latter unfold.

Chemical incidents pose problems additional to those faced during non-chemical emergencies. A toxic gas release may drift over several kilometres. Its prompt control would demand co-ordinated work of several authorities and emergency organizations. Public health practitioners will provide the only site or control room based source of health advice for the incident team.

Assessment of health risk to the public in a chemical incident requires public health skills. The public health practitioners have a central role in planning for and managing chemical emergencies, and in dealing with the urgency and alarm of community concern. 15 Improving training in the management of, and planning for chemical emergencies is a high priority in public health. 16

The prime public health task is to be prepared to respond immediately to a chemical incident and the ability to provide epidemiological analyses as events progress. It is not the purpose of the initial response to provide answers to questions of causation.

Although this paper describes epidemiological procedures in their logical, conceptual sequence, it should be noted that, in real life, the various components of an epidemiological enquiry may well come into play at once, or in a different sequence. What is important is that epidemiological reasoning is kept clearly in mind. Fortunately, the observational descriptive and analytical cross-sectional approach described is relatively inexpensive, quick and easy to carry out, and can be used on large populations to rapidly estimate the extent of the problem. It allows for timely response and effective interventions to preserve public health.

Conclusion

Getting the public health contribution recognized as an integral part of the emergency response team is only slowly being appreciated. The key to success of public health action lies in ready access to a systematic flow of environmental information and toxicological health data. In return, public health practitioners should be prepared to supply timely and needed information and advice on adverse health effects to the public service providers and the community services.

Acknowledgements

I would like to thank Dr Jeremy Hawker (Regional Epidemiologist, CDSC, West Midlands) and Dr Sarah Walters (Senior Lecturer, Institute of Public and Environmental Health, University of Birmingham), for helpful comments on the draft paper. I also wish to thank Shaukat Ali, Donna McEvoy and Amanda James for secretarial assistance.

Further reading

World Health Organization environmental health criteria 27:

References


Accepted on 22 April 1997