CHEMICAL ACCIDENTS

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1. INTRODUCTION

Today we live in a world where nobody can be safe from environmental disasters. After Tsernobyl and Bhopal, waiting for the climate change and looking at the threats of environmental pollution - who can be an outsider? The western world is so dependent on high risk technology, that chemical disasters are probable and one can speak about risk-societies.

Enormous volumes of hazardous materials are transported every day and several thousand million tons of hazardous materials are in storage sites throughout the world. Accidents with chemicals do happen, and not only in the industrialized world but also in developing countries. Besides acute releases of a chemical substance to the environment, like in Bhopal, also mass intoxications caused by contaminated food (pesticide intoxications, toxic oil syndrome in Spain) have occurred. Sometimes a health hazard may arise, by exposure of human beings to contaminated water or food, several years after the release of poisonous chemical to the environment has occurred.

1.1. Hazardous materials dumping

Large quantities of hazardous waste are produced in western countries especially. Waste disposal is often expensive and may pose a health or environmental hazard, and because of this a new kind of trade has been taking place between some western industrialized nations and certain developing countries. Toxic waste, chemicals and radioactive materials, shipped out from the West, are being dumped on African soil. According to reports 3800 tons of hazardous waste were found stored at a site in Koko, Nigeria and several thousand tons of hazardous materials have been dumped in other African countries. Often this trade is silent, dumping sites are not known, and serious health effects may happen before any preventive measures have been taken to reduce exposure of the people living near the dumping sites.

1.2. Pesticides cause accidents

Pesticides are used in large quantities in most developing countries in agriculture and for vector control purposes. In Tanzania, for instance, pesticide use increased from 2623 tons in 1970 to 12 000 tons in 1983. This increase in the use of pesticides causes new environmental health hazards. For instance, in Zanzibar, Tanzania, the investigation of the areas in which waste chemicals were stored revealed the existence of large quantities of pesticides. In many places the stores were in bad condition, and the waste chemicals were an imminent threat to the public health and the environment.

The acute health effects of pesticides are reported by D.N. Maeda and A. Tarimo from the Tropical Pesticide Research Institute, Arusha, Tanzania. They have investigated the pesticide poisoning cases in the Arusha region and they report that there is a gradual yearly increase in the number of poisoning cases. Some cases are suicides and others are homicides, but there are also poisoning cases due to occupational and environmental exposure. Pesticide residues have contaminated food and feeding stuffs. Seeds for planting purposes, treated with large quantities of toxic pesticides have caused several lethal poisonings among hungry people who have eaten poisonous seeds.

Looking at the history of the various cases of poisoning the writers sum up the pesticide health problems: "Indiscriminate dumping of pesticides in our country, ignorance and lack of proper knowledge of the toxic hazards of various pesticides, failure to educate the farmers on how to make safe and best use of these chemicals, lack of proper protection from pesticide spray-mist, carelessness in handling toxic materials, insufficient labelling of pesticides, lack of legislation and pesticide control boards, and lastly, lack of proper pesticide disposal procedures. These are the major contributing factors towards increasing misuse of pesticides in Tanzania".

2. SPECIAL FEATURES OF CHEMICAL DISASTERS

Chemical disasters can be classified in three types from the point of view how they are brought to light. The first type is an accidental release, fire or explosion that evokes acute health hazard to the people who exist in that area. Chronic health risks may appear later. The most serious example of this kind of accident was the disaster in Bhopal, which caused death of several thousand people and acute respiratory, eye and skin diseases to human beings who existed in the neighborhood of the chemical plant. Many of those people suffer today from a chronic pulmonary disease caused by inhalation of methyl isocyanate gas.

Sometimes a leak of chemicals to the environment takes place so slowly, that it is not observed immediately but can be suspected on the basis of impurities that are found in the environment, for instance in drinking water, air or soil. In this second type of disaster the possibility of health hazard arises and experience in toxicology and environmental medicine and hygiene is needed to find out the appropriate manner of proceeding. It is usually necessary to take hygienic samples from the environment for chemical analysis, investigate the level of exposure of the people, and examine the possible health effects of the exposure by an epidemiological study. This kind of disaster can happen at the hazardous materials dumping sites.

The third way in which a chemical disaster may be brought to light is when several human beings or animals become ill. The illness can be an acute poisoning or a chronic disease, like a cancer. Epidemiological investigations are needed to evaluate the problem. An example of this kind of disaster was the toxic oil syndrome in Spain.

2.1. Acute releases

Numbers of deaths, injuries and evacuations as a result of acute chemical releases in the USA in the year 1986 were estimated in a study made by Dr Binder from CDC. By combining the three largest relevant national data bases, 587 events resulting in public health impacts were identified; 58 resulting in deaths, 496 resulting in injuries and 111 resulting in evacuations. However, these data bases were not comprehensive and the numbers are underestimates. The largest number of deaths in a single event was 14. The number of injuries in the 496 events was 2254. Three of the events resulted in injuries to over 100 persons. Among the most common chemicals in these events were natural gas, chlorine, gasoline, ammonia, sulfuric acid, hydrochloric acid, diesel oil, corrosive liquids, sodium hydroxide and phosphoric acid. 56% of the events were involving a transit vehicle or an activity related to transportation. At least 109 crashes, derailments and vehicúlar overturns were detected.

In Finland a register of accidents (VARO) has been established since the year 1986 at the Finnish Technical Inspection Center. The register collects information concerning pressure tank accidents, explosions, mine accidents and accidents during production, storing and transportation of hazardous chemicals. 91 events were identified during the year 1987. Ten of those events caused injuries; four people died and twelve were injured. Marked environmental damage followed four accidents and in two of them, caused by release of monochlorbenzene and piperylene there was a risk of environmental major accident as a consequence. The types of events were: leakage and release of chemicals in 43%, explosion in 25%, fire in 19% and others in 13%. Only serious accidents are reported to the institute which collects detailed information of those events. Most chemical accidents were caused by propane, petrol, diesel oil, ammonia, chlorine, carbon monoxide and by different acids and bases.

Acute chemical releases and major accidents happen every year all over the world, but chemical disasters which cause death and injuries in large scale are fortunately not very common. The worst this kind of disasters has obviously been the Bhopal disaster in 1984, when methylisocyanate gas release from a pesticide plant caused death of thousands and injuries to 200 000 people. During that disaster 500 people died before reaching any medical aid. About 6000 people had serious respiratory, circulatory and central nervous symptoms and about 2000 of those died in a week after the accident. Ten thousand patients had serious respiratory and eye symptoms and about a hundred thousand patients were seeking some kind of medical aid in 24 hours after the accident. Several thousands of the patients have suffered from long term respiratory effects caused by exposure during the disaster.

The immediate symptoms after exposure to methyl-isocyanate in Bhopal were respiratory, eye and skin irritation and circulatory collapse. To the respiratory symptoms included irritation of upper airways, pulmonary oedema either immediately after exposure or after a latent period. About 40% of pulmonary oedema patients who got corticosteroid therapy had a relapse in 3-4 days after the therapy had finished. The patients had many kinds of pulmonary complications, like pneumothorax, infections etc. A part of the patients have got chronic obstructive pulmonary disease and bronchial hyperreactivity as a consequence of the acute exposure.

2.2. Slow releases

A chemical disaster can result also from slowly occurring or repeated releases of a chemical to the environment. An example of this kind of event in Finland is presented here. It will hopefully not be a disaster, in quantity of casualties, but in any case it is a serious environmental accident. The event happened in a county named "Kärkölä" in Southern Finland. The county has an industrialized population centre of "Järvelä" with 2000 inhabitants. The inhabitants of the population centre and its surrounding area receive their drinking water from a water intake plant in Järvelä.

In the population centre there is an industrial facility including a sawmill, which is located over an important groundwater area. Part of the groundwater at the water intake plant is derived from that area. The company had used from the 1930s until 1984, 7-10 tonnes per year of a fungicide containing 2,4,5-tri-, 2,3,4,6,-tetra- and pentachlorophenol in the ratio of 24%, 72% and 4%, respectively.

In the year 1987 it was noticed that the groundwater as well as water of the water intake plant were contaminated by chlorophenol. The water intake plant was closed, and detailed investigations were carried out to investigate the contamination of soil and water. Remarkable levels of chlorophenol (56 000 - 190 000 ug/l) are found in the groundwater in the area of the sawmill and elsewhere. The population of the community was exposed to chlorophenol by drinking water and by eating fish which was caught from a nearby, contaminated lake. The time at which the public water system had become contaminated is unknown, and it is possible that the contaminants have been present in the groundwater for years, even decades.

The content of chlorophenol in urine of the exposed community population was still elevated 2 months after closing the water intake plant, compared to a non exposed control group. A study on cancer incidence among the community population was carried out by the Finish Cancer Registry, because chlorophenol is suspected to cause cancer. The total age-standardized cancer incidence was below that of the whole country, and it was at the level of the neighbouring counties in Kärkölä. The incidence of non-Hodgkin lymphomas of men in Kärkola county was remarkably high compared to the whole country and to neighboring counties. A case control study of non-Hodgkin lymphomas among men is being carried out but not yet completed. The results of that study may reveal if the contamination of soil and groundwater has been a probable cause of the higher non-Hodgkin lymphoma incidence among the men in Kärkola.

2.3. Epidemics

The epidemics or mass poisonings caused by chemicals are often difficult problems. The disaster is brought to light typically not as a chemical problem, but as an epidemic of a disease without obvious aetiology. It may take a long time, like in Minamata bay in Japan, before the causative factor has been identified.

One of the most serious episodes of this type recently occurred in Spain. It was in May 1981 when an outbreak of a previously unknown syndrome began to appear in the working-class suburbs of Madrid. Over 20 000 persons were ultimately involved. By June 1982, 315 patients had died (around 16 deaths per 1000 cases). Initially, the clinical features included interstitial pneumonitis, diverse skin rashes, lymphadenopathies, intense eosinophilia, and gastrointestinal symptoms. Nearly one-fourth of those who survived the acute phase required later hospitalization for neuromuscular alterations ranging from simple myalgia to mixed polyneuropathy, to progressive paralytic neuromuscular illness. Scleroderma-like changes of the skin were also observed in the late stage, along with pulmonary hypertension and Raynaud's phenomenon. This sort of combination of symptoms and illness progression as well as the occurrence pattern of the syndrome, appear unique. One month after the occurrence of the first cases the illness was found to be associated with the consumption of inexpensive denatured rape oil, sold in unlabeled plastic containers and usually acquired from itinerant salesmen.

Epidemiological methods were helpful in investigation of the epidemic. The key factor in the source identification of the origin of "toxic oil syndrome" was the description of case occurrence in relation to the most evident determinants, such as residence (working-class suburbs but not the middle-class centre of Madrid being affected); social class (the highest incidence occurring among lower social strata); type of community affected (multiple hospital admissions and readmissions from families, but no contagion in hospitals, barracks and schools); age (no cases reported among children under six months of age; etc.

Following this descriptive analysis, case referent studies proved to be very useful. The first and simplest one was performed in the Nino Jesus Hospital, Madrid. All of the 345 sick children admitted to the hospital for the syndrome, but only 6% of the children admitted for other reasons, turned out to have consumed the suspected oil. In the province of Avile, case households were compared to size-matched reference households. The oil had been consumed in 100% of the former households versus less than 30% of the reference households. Numerous case reports and case referent studies added support to the suggested association and led to define clarification of the disaster source, if not to the responsible chemical agent.

3. PREPAREDNESS PLANNING FOR CHEMICAL DISASTERS

People need information concerning the existing chemical risks of their environment and to these risks include also the risks of accidents and disasters. It is important to note that, in principle, it is possible to prevent chemical disasters and to be prepared for them, because with a few exceptions they are "man-made". This is a special feature of the chemical disasters and a challenge to the modern society. Prevention and preparedness are warranted by this principle.

A chemical disaster always happens at some specific geographical place at a specific point of time. It is there, at that very community where and when local officials and other people have to meet the accident. Therefore local preparedness planning is necessary, at least in high risk areas. The specific prevention and preparedness activities which are needed vary depending upon the local situations, but the planning process itself can be done everywhere according to a similar method.

In Finland mapping of chemical accident hazards is the responsibility of fire and rescue service, which has the general management responsibility in rescue operations. At the local level it is the municipal fire service which has been statutorily assigned to investigate and report known local chemical hazards and to prepare contingency plans for them. Emergency response planning is the responsibility of municipal environmental health units. In the best case the planning, and exercises testing the plans, have been carried out jointly with all the sectors involved: the fire service, the police, health services, local industries, local radio station, and supportive services such as toxicological, meteorological and technical advisors. The focal point of information gathering, alarming and maintaining communications is the regional alert centre which can be reached by any telephone by dialing "000". Nevertheless, at this moment the level of preparedness in Finland can be rated high only in some industrial communities.

The environmental health sector is responsible for health hazard assessments of disasters in Finland. The situation in the case of slow releases of chemicals or epidemics may be ill defined. An active early involvement by means of fact-finding, sample taking and consultation of experts needs to be stressed. In this way one should try to distinguish a true hazard from a likely false alarm. Past experience demonstrates that reluctance and indecision to investigate in the early phases as well as inadequate information to the public, may result in later engagement in a hopeless post-situation analysis and wastage of resources. The role of research institutes is central as a consultation point for local officials in all types of chemical disasters, but especially in slow releases and epidemics where skills in toxicology and environmental epidemiology play a central role.

In USA, where chemical industry is abundant and chemical accidents do happen, a Hazardous Materials Emergency Planning Guide developed jointly by 14 federal agencies exists. It is being published by the National Response Team in compliance with Section 303 (f) of the "Emergency Planning and Community Right to Know Act of 1986", title III of the "Superfund Amendments and Reauthorization Act of 1986" (SARA). This planning guide includes detailed advice to select and organize a planning team in a community. According to the document "Experience shows that plans are not used if they are prepared by only one person or one agency. Emergency response requires trust, coordination, and cooperation among responders who need to know who is responsible for what activities, and who is capable of performing what activities. This knowledge is gained only through personal interaction. Working together in developing and updating plans is a major opportunity for cooperative interaction among responders."

US planning guide contains general information concerning: the planning process, hazard analysis, outline of a hazardous materials emergency plan and keeping the plan up-to-date.

4. THE UNEP - APELL PROCESS

A programme handbook on "Awareness and Preparedness for Emergencies at Local Level (APELL)" was published by the United Nations Environment Programme (UNEP) in 1988. This handbook is intended to assist decision makers an technical personnel in improving community awareness of hazardous installations, and in preparing response plans for unexpected but possible hazardous events. The book contains a ten-step approach to the APELL process for planning for emergency preparedness. The steps are:

(a) Identify the emergency response participants and establish their roles, resources and concerns.
(b) Evaluate the risks and hazards that may result in emergency situations in the community.
(c) Match these tasks to the resources available from the identified participants.
(d) Make the changes necessary to improve existing plans, integrate them into an overall community plan and gain agreement.
(e) Commit the integrated community plan to writing and obtain approvals from local governments.
(f) Educate participating groups about the integrated plan and ensure that all emergency responders are trained.
(g) Establish procedures for periodic testing, review and updating of the plan.
(h) Educate the general community about the integrated plan.

The APELL ten-step approach is a method to promote the emergency preparedness at the local level. The timing of the APELL process will vary from community to community depending upon local circumstances, but it will probably take several years in most of the high risk communities to complete the ten-step process.

5. EMERGENCY RESPONSE IN CHEMICAL DISASTERS ASSESSMENTS DURING A CHEMICAL DISASTER

The role of the assessment is to get rapidly a correct view on what is the situation at the disaster site. All relevant available information has to be collected for the initiation of relevant response activities. A timely and appropriate assessment of a chemical disaster helps to decrease impacts on human health and to the environment. The goals of the assessment are to:

(a) determine the site, type, size and distribution of the release;
(b) identify the chemicals and their reaction products;
(c) define the populations at risk;
(d) conduct a quick toxicological evaluation;
(e) identify appropriate treatment regimens;
(f) evaluate emergency medical care and health service capability;
(g) describe morbidity and mortality;
(h) organize shelters for fatalities.

The most important components of the assessment are notification, data collection, and review. Coordination and implementation of medical care and rescue activities are based on the assessment. The initial notification of a chemical accident is made to the local or regional rescue and health authorities. In Finland the notification is given to the regional alert centre, which can be reached by any telephone by dialing "000". The alert centre is located usually at the fire station which the first rescue team leaves in 60 seconds in the case of an accident of fire. The health authorities receive the notification from the regional alert centre immediately if they are not the initial recipients of the notification.

Once notification is received, the local authorities assemble as a team, identify a team leader and begin the assessment and coordination of the response activities. Depending on the type of the disaster the team includes authorities of medical therapy, environmental health and hygiene, police, industry and fire service. The team is in close connection with public information media like local radio, with occupational and industrial health authorities and environmental and (in the case of mass casualties) military officials and with external experts and institutes of toxicology, meteorology and technical fields. Once the team has been established, responsible governmental departments should be notified and the communication between the local and the national levels of the administration organized.

Both the assessment and emergency relief operations are carried out at the site of the disaster, where the leadership of the operations also has to be. National governmental departments may, however, have a key role in that they allocate further resources and e.g. information channels to cope with the disaster when such resources are needed.

(a) Determine the site, type, size and distribution of the release

The exact site (chemical plant, storage site, a site by the route of transportation of a chemical) and type (atmospheric dispersion, leakage, explosion, fire, spill) should be determined. A chemical disaster may involve one or more types of releases and one event may lead to other types of events as consequence. For instance in the Texas City disaster 1947, a fire in a fertilizer-containing ship caused a massive explosion in the ship. Because of that explosion oil storage tanks nearby went up in flames, and so did a chemical plant. A nearby ship, also loaded with explosive fertilizer caught fire next evening and another explosion rocked the city and ignited a sulfur warehouse.

Other characteristics that have to be determined are the size of the release (estimated weight or volumen of chemicals dispersed) and the distribution (dispersion area) of the release. The latter is affected by meteorologic conditions and geographic characteristics. The dispersion of the release can be estimated by a computerized models if such is available.

(b) Identify the chemicals and their reaction products

The chemicals, their quantity and ambient air concentrations need to be assessed and analysed if feasible. The reactivity and physico-chemical properties of the chemicals should be identified. Methods of verification include: contacting officials in charge of manufacture, storage, transport or usage of the chemicals and environmental sampling from air, water, food or soil. In fires and explosions may be formed many unknown by-products and samples should be collected for later analysis.

Identification of chemicals is the prerequisite for the evaluation of their toxic effects, determining medical treatment for injured, providing personnel protective equipment for rescue personnel, follow-up regimens for the exposed, and control measures for environmental clean-up.

An active early involvement by means of fact-finding, sample taking and consultation of experts in identifying of the chemicals needs to be stressed. Uncertainty of the identity of the chemical may lead to serious problems in toxicity evaluation, medical treatment and other activities. During the Bhopal disaster the suspicion of cyanide and phosgene exposure caused confusion on the appropriate treatment of the exposed patients, and the question if cyanide and phosgene exposure caused deaths and injuries in Bhopal remains still open.

(c) Define the populations at risk

Information should be collected about the proximity and size of residential neighbourhoods and of public or commercial buildings. Certain groups of people are especially vulnerable in disasters. To those include children, aged, non ambulatory persons and individuals with chronic diseases. In Bhopal there was a slum region in the neighborhood of the chemical plant. The houses in the region did not give much protection against the gas cloud. A railway station was situated 1.5 kilometres from the plant and a hundred persons found dead there during the disaster. In many cities of developing countries the chemical industry plants are located in the neighborhood of residential regions. So is the situation also in some of those western cities which are built around an industrial facility.

(d) Conduct a quick toxicological evaluation

Impacts of a chemical exposure on human health are determined by the chemical, the exposure routes and amount of exposure. During the ongoing release, inhalation and dermal exposure are the usual exposure routes. During the post-impact phase, dermal exposure through contact with contaminated objects or ingestion of contaminated food or water may be important exposure routes.

The current computerized toxicological data systems and hardware systems, including CD-ROM capabilities, make relevant toxicological information readily accessible and easily transportable. In some cases a back-up laboratory should be contacted.

(e) Identify appropriate treatment regimens

Based upon all relevant toxicological, medical and epidemiological information, a consensus of clinical opinions should be used to identify the most appropriate treatment regimens. This information should be quickly disseminated to emergency medical care providers. Specific treatment regimens for different poisonings are very few and specific antidotes exist only for a couple of poisons. However, if the antidote therapy is possible its use may save lives of many patients.

(f) Evaluate emergency medical care and health service capability

The role of public health and medical officials during a chemical disaster differs dramatically from their routine responsibility. This may cause fear against new operating procedures and because of huge amount of work completed a loss of coordination of required operations may result. Therefore, planning and training of these operations facilitates the provision of appropriate medical care during a chemical disaster.

Evaluation of the availability and quantity of medical care must be conducted. This includes also determination of the status of emergency medical care capability and back-up facilities. After establishing of diagnostic criteria and treatment regimens, also the capability and needs to diagnose and treat exposed persons have to be assessed. The evaluation includes also decontamination of exposed individuals in order to prevent secondary exposures among medical care providers, and decontamination facilities.

(g) Describe morbidity and mortality

Chemical disaster may cause an immediate need to quickly collect information on the incidence, distribution, location, type and severity of disaster-related health effects. It is essential to identify as early as possible a case definition that will be universally and consistently applied.

(h) Organize shelters for injured and fatalities

In many cases of chemical disasters there is increased mortality among the exposed population. Fatalities, especially if not recognized, may lead to contamination of food, drinking water, and impairment of hygienic conditions which then leads to epidemics. Therefore, an important consideration is organizing shelters for those who have died during the chemical disaster, and collection of dead from the disaster area.

6. INFORMATION SOURCES ON CHEMICAL HAZARDS

A specific feature of chemical disasters is a need to rapidly conduct an evaluation of toxicological profiles of chemicals. There are numerous different information sources in the chemical hazard area: specialists in the field, traditional handbooks and machine-readable databases. Computerized databases can be used on-line, and some of those are available on CD-ROM disks. Factual databases such as Hazardine, Hazardous Substances Data bank and ECIN contain original source data, e.g. numeric toxicological details or directions.

There are also bibliographic databases which contain only citation and abstracts referring to journal articles, reports or books. Those may be useful in preparedness planning for chemical disasters. NIOSHTIC, CISDOC, HSLINE and Chemical Safety Newsbase are some of the bibliographic databases with information on chemical hazards. MHIDAS, which is an off-line database, contains information on chemical accidents during last 25 years.

CD-ROM disks are a good alternative for on-line searching. There are a few databases with information on hazards published on CD-ROM such as OSH-ROH, CHEMBANK, CCINFO and GEFAHRBUT CD-ROM. CD-ROM disks are more user-friendly than on-line databases and very suitable for information searching in disasters situations. Combined to a portable microcomputer they can be used even in field operations.

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