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# EVALUATION OF NON-LETHAL HEALTH EFFECTS AFTER EXPOSURE TO TOXIC GASES

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## 1. Introduction

Accidents with toxic chemicals can cause different kinds of health effects. In the recent past, several methods have been developed to quantify these health effects Up to now attention has mainly been focused on lethality, since in this field the problems encountered are already considerable but also because of the limited knowledge on dose-response relationships for non-lethal health effects However the number of injured due to an accident is important information, not only for emergency response but also for prevention and preparation purposes A more accurate estimate of the number of injured will improve the efficiency and effectiveness of the available medical equipment. Hospitals can be informed at an early stage about the injured (including the severeness and numbers) and regarding the capacity that will probably be required

The consequences of exposure to toxic materials can vary strongly, not only between species (inter-species variation) but also within a certain species (intra-species variation) The nature of the damage depends on the way the substance enters the body and on the quantity the individual has been exposed to As chemical disasters affecting a large number of people will mostly occur with (toxic) gases, this paper focuses on inhalatory exposure.

Non-lethal health effects have been defined as all adverse effects that are not expected to cause death within 48 hours after exposure. The time limit of 48 hours has been introduced by the European Chemical Industry Ecology and Toxicology Centre, ECETOC, as it is considered possible to give a patient with serious problems sufficient treatment within this period [ECETOC, 1991]. Non-lethal health damage includes all health effects except death, varying from slight irritation to irreversible damage.

The term "health effects" refers to the type of health damage ("end-point"). It is not the same as "response", which indicates the part of the exposed population showing the effect under consideration ("effect-incidence"). In the same way, dose-effect relationships are distinguished from dose-response relationships a dose-effect relationship connects the type of health effect to be expected to a certain dose, whereas a dose-response relationship relates effect incidence to dose.

This paper is largely based on a study that is being carried out by TNO, which is commissioned by the Dutch government. As this project will be finished by the end of this year, results can only be given to a limited extent

## 2. Inventory of categorizing methods

### 2.1 Introduction

Only a few attempts are known of a systematic approach of the quantification of non-lethal toxic health effects. In this paper they are reviewed and some remarks are made.

Categorizing methods will be evaluated on the following criteria:
- categories have to describe acute effects (for definition see section 1);
- categories must describe a range of seriousness of effects;
- the categorization must have sufficient resolution, i.e. at least 3 but not more than 6 non-lethal categories;
- categories must be closely connected to medical aid, which means that it must be possible to derive triage criteria from the category descriptions;
- for each category, it must be possible to derive threshold values or (ideally) dose response relationships.

It is important that theoretically derived health effect categories such as reviewed here correspond with the needs of medical aid, since the hospitals receiving the casualties will benefit from a specified description of the health damage. This aspect at the same time is one of the most difficult problems in this field.

Not only will health effect categories be used in triage, but also in forecasting numbers of casualties. Several decision support systems calculate such numbers, thereby offering the medical services information that is used in determining the required medical aid capacity. These calculations can only be performed if there exists a quantitative relationship between exposure (concentration and duration, dose) and health effect.

### 2.2 Existing categorizations

In quite a few publications, descriptions are given of non-lethal health effects. Mostly symptoms (external characteristics) are described. Changes on organ or cellular level are also given. See for instance the descriptions of symptoms of ammonia exposure (from [Caplin, 1941], who is cited by many authors).

General, global categorizations are found with:
[Bridges, ...]
- irritation
- narcotic effects
- delayed adverse effects (sensitization, teratogenic, carcinogenic) [Notten, 1983]
- reversible changes or damage
- very slowly disappearing changes or illness [Gezondheidsraad, 1985]
- physiological effects: reflexes by stimulation of chemosensors
- pathological effects: functional disturbances and/or morphological abnormalities
- immunological effects: disturbances of the immune system
- carcinogenic and mutagenic effects

Table 2.1 Categorization of ammonia symptoms [Caplin, 1941]

| Category | Description |
|---|---|
| Mild | - reddening of the conjunctivae, lips, mouth and tongue with swelling of the eyelids and oedema of the throat |
| Moderate | - distress, increase in pulse and respiration rate<br>- marked swelling of the eyelids with spasm and lacrimation<br>- moderate oedema of the oropharynx with burning of the mucous membranes and resulting in stripping of the epithelium to reveal dark red patches<br>- examination of the chest reveals diminished air entry/moist sounds |
| Severe | - shock, restlessness and obvious distress<br>- rapid pulse of poor volume<br>- cyanosis and great difficulty in breathing<br>- generalized moist sounds in the chest |

By TNO, a categorization with five categories has been developed, based on literature from the 1970's These categories are
- slight irritation,
- severe irritation;
- reversible damage,
- irreversible damage
- death

The measure for lethal effects is the $LC_{50}$, and as a measure for slight irritation the STEL is taken. Values for the other three categories are interpolated by dividing the distance between these $LC_{50}$ and STEL, put on a logarithmic scale, into four equal parts.

Another categorization is given by ECETOC A Task Force of the Scientific Committee of ECETOC has established, after other authors [AIHA, 1988, Illing, 1989, Baxter et al , 1989] three threshold values, resulting in four categories (descriptions see table 2.2)
- detectability,
- discomfort;
- disability,
- death

Table 2.2 Categorization according to ECETOC

| Category | Characteristics |
|---|---|
| Death/permanent incapacity (D4) | Death/permanent incapacity occurring either immediately or soon after exposure or a permanent loss of a necessary faculty (e g blindness) resulting in a serious restriction of normal social or economic activity The possibility of surgical correction (eg corneal grafting) does not affect "permanence". |
| Disability (D3) | External assistance needed because:<br>- persons are disabled by exposure and cannot take action necessary to protect themselves or escape and/or<br>- exposed persons acquire an illness OR a condition of which the outcome or duration can be significantly modified by treatment or nursing care OR a condition with long lasting residual effects including effects on the outcome of an existing or subsequent pregnancy. |
| Discomfort (D2) | Exposed persons may request assistance but their condition, though unpleasant and possibly amenable to symptomatic relief<br>- does not produce disablement,<br>- does not result in permanent or long-lasting effects.<br>- is not modified as regards outcome and duration by treatment or nursing care |
| Detectability (D1) | Exposed persons may make complaints or enquiries or may express anxiety, but exposure (if perceived at all) will be perceived only by smell, taste, sight or by sensations (mild sensory irritation) which does not persist after exposure ceases There are no direct effects of exposure on health |

This categorization also does not meet all criteria The descriptions do relate to acute effects, although reference is made to long term effects ("outcome of pregnancy") The categories do describe a range of effects. There are three non-lethal categories Regarding this number, ECETOC points out that there is in principle an infinite number of possibilities to be chosen, and that each choice is more or less arbitrary, however, this number is supported by earlier publications (the ones mentioned above).

Furthermore ECETOC has tried to design a categorization that corresponds with medical aid practice. Each threshold is supposed to correspond with a toxic effect requiring a certain kind of practical response; according to ECETOC this approach is conceptually related to the triage of accident casualties. Whether this is a proper categorization for such purposes is however not immediately clear. Can a triage physician determine immediately after an accident whether a patient will suffer permanent health impairment? Is a patient unable to escape if he cannot run 100 meters within 15 seconds or if he is completely unable to walk? Is it possible to determine at the triage stage already the result of a specific treatment? These questions show that a categorization that ECETOC has developed may be very well suited for a global level, but that under operational circumstances more specific descriptions are required

The Dutch physician Pieter van der Torn, who is with the Health Service in the Rijnmond Area, has evaluated amongst others the ECETOC categorization, and has developed an adapted version. He argues that to be of use under operational circumstances, a categorization must be based on an estimate of the patient's stability In his own categorization he also takes into account the potential threat of vital functions However, he does not provide a method to determine threshold values or any other quantification.

Each of the categorizations discussed above is useful in its own way but none of them meets all criteria mentioned before The ECETOC descriptions, although they are too abstract for operational purposes, form a suitable starting point for a further operationalization which should give the symptoms that are typical for each of the four categories This categorization corresponds with existing triage categories for mechanical health effects (for instance the division as developed by the Dutch Medical Defence Council), which is beneficial for the uniformity within the emergency response services.

## 2 3 Designing a more practical categorization

The aim of operationalization as mentioned at the end of the former section is to give a more practical description of the phenomena that occur at various exposure levels This requires a concept that supports both the medical response and the operational emergency management. From a medical aid point of view, the categories must offer the possibility to "label" the casualties in a way that has some practical significance to the hospital personnel. The operational emergency management requires that there be a relationship between exposure and the characteristics of the categories, so that it is possible to predict the number of health effects of a specific nature.

On the other hand, the concept itself must be supported by experimental toxicology, which means that the categories developed and especially the parameters that are chosen as measures of a certain type of damage can be evaluated quantitatively Which consequences follow from this boundary condition in terms of parameter choice is not yet clear at the moment; however, it means that a categorization must be judged against the kind (and the amount) of information that is available from toxicology, not only now but also in the future. Although at first sight it may seem a problem to generate sufficient information, in some respects the solution of the problem might be easier than expected. This has to do with the nature of toxicological experiments as they are carried out nowadays.

The aim of the majority of toxicological experiments is to determine one specific parameter, e.g. an $LC_{50}$ or a No Adverse Effect Level. Only those observations are made that are necessary to determine this specific parameter. At the same time, a lot of valuable information is lost because it is simply not recorded. In other words, the efficiency of the use of experimental animals could be improved a lot by designing a more comprehensive observational programme, which immediately would give us a great deal of insight into the non-lethal effects of exposure to toxic chemicals.

At the moment, designing the proper categories is being carried out by TNO in cooperation with the Dutch Poison Control Center (NVIC, Utrecht). This is carried out for a number of groups of similar substances. The route to be followed is that first on a global level the symptoms are assessed to the four ECETOC categories. By adding the consequences for the vital functions of the organism, it is possible to check whether the symptoms that are assessed to one of the categories for each of the substance classes are more or less comparable in seriousness. Next, the proper parameters are chosen for each of the symptoms.

The seriousness of the effects in the four categories can roughly be characterized as follows. Detectability refers to observation by smell, colour of the released material, changing colour of tissues or other materials that have been in contact with the released chemical, and sensory irritation. The latter is measured by the percentage decrease in respiratory rate (a typical parameter is the $RD_{50}$, the concentration at which the respiratory rate has decreased with 50%), whereas the others are quantal ("yes/no") effects. Discomfort and disability contain those effects that at least cause distress, up to severe health impairment. Permanent health impairment and death are endpoints that need no further explanation.

Regarding the substance classification, locally acting substances are distinguished from systemically acting substances. Exposure to a locally acting chemical may result in a decrease of lung function (typical parameters e.g. forced vital capacity (FVC), forced expiratory volume (FEV), etc.), followed by asphyxiation due to glottis or lung edema (swollen tissues causing blocking of (parts of) the respiratory tract).

Systemic agents affect a specific target organ. In table 2.3 a classification system for damage to organs is given, which also contains long term effects of incidental exposure.

In some cases chemicals have a combined local and systemic effect (e.g. acrylonitril, $SO_2$, $CS_2$). No classification has been encountered that deals with this problem in a specific, orderly fashion.

Table 2.3 Classification of health effects from exposure to systemic agents

| | |
|---|---|
| 1 - | enzyme induction or other biochemical change (no pathologic changes; no changes in organ weight); |
| 2 - | enzyme induction and subcellular proliferation or other changes in organelles (no other apparent effects); |
| 3 - | hyperplasia, hypertrophy or atrophy (no changes in organ weights); |
| 4 - | hyperplasia, hypertrophy or atrophy with changes in organ weights; |
| 5 - | reversible cellular changes (cloudy swelling, hydropic or fatty changes); |
| 6 - | necrosis or metaplasia (no apparent decrement of organ function); neuropathy (no apparent behavioral, sensory or physiologic changes); |
| 7 - | necrosis, atrophy, hypertrophy or metaplasia with a detectable decrement of organ function; neuropathy with measurable behavioral, sensory or physiologic changes; |
| 8 - | necrosis, atrophy, hypertrophy or metaplasia with definitive organ dysfunction; neuropathy with gross behavioral, sensory or motoric changes; any decrease in reproductive capacity; any evidence of fetotoxicity. |
| 9 - | pronounced pathologic changes with severe organ dysfunction; any neuropathy with loss of behavioral abilities, motor control or sensory ability; reproductive dysfunction; any teratogenic effect (no maternal toxicity). |
| 10 - | death or pronounced life shortening; any teratogenic effect with maternal toxicity. |

## 3. Conclusions

Non-lethal health effects are an important part of emergency management information, and can be used in the preparative phase as well as in the response phase. Valid data on non-lethal health effects have to be based on a proper categorization, that meets criteria as stated in section 2.1. Only a few existing categorizations can be used as a starting point for further development of this concept.

A categorization that is of more practical use to disaster preparedness and response should take into account the requirements by both the medical response and the emergency management. The correspondence with triage criteria and the possibility to predict numbers of casualties are important in this respect.

To prevent that the categories remain "empty", it is important that they relate in a meaningful way to experimental toxicology. This demonstrates the need to enlarge the observation programme of many toxicological experiments with observations of the consequences of exposure to toxics before death occurs.

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## APPENDIX 1 - SYMPTOMATOLOGY OF SOME CHEMICALS

In this Appendix the symptomatology of a number of chemicals is described. Data are extracted from R.E. Gosselin, R.P. Smith, H.C. Hodge - Clinical Toxicology of Commercial Products, Williams & Wilkins, Baltimore/London, 1991 (5th edition). Comparable compounds have been grouped together.

Ammonia:

1 Vapours cause irritation of eyes and respiratory tract. High concentrations may cause conjunctivitis, laryngitis, tracheitis, and pulmonary edema or pneumonitis. Cough, dyspnea and pleuritic chest pain are common symptoms. A sensation of suffocation may be induced by spasm of the glottis or by laryngeal edema.
2 Contact with skin can cause burns with vesication. If squirted into the eyes, an early rise in intraocular pressure may mimic narrow angle glaucoma. Corneal edema and oval semidilated fixed pupils are typical. Late injuries include obstructive glaucoma, opaque corneal scars, iris atrophy and cataracts.

Aniline, Nitrobenzene:

1-Chloro-2,4-dinitrobenzene,
Dinitrobenzene,
Dinitrotoluene,
Nitrochlorobenzene,
Trinitrobezene,
2,4,6-Trinitrotoluene.

1 Lips, tongue and mucous membranes navy blue to black; skin slate grey, all without signs of cardiac or pulmonary insufficiency.
2 Severe headache, nausea, sometimes vomiting, dryness of throat.
3 Central nervous symptoms: confusion, ataxia, vertigo, tinnitus, weakness, disorientation, lethargy, drowsiness,and finally coma. Convulsions may occur but appear uncommon.
4 Cardiac effects; heart blocks, arrhythmias,and shock.
5 Death, although uncommon, is usually due to cardiovascular collapse and not respiratory paralysis.
6 Urinary signs and symptoms may include painful micturition, haematuria, haemoglobinuria, oliguria, and renal insufficiency.
7 A late acute haemolytic episode should be anticipated at 6 or 8 days after exposure.

<u>Carbon disulfide</u>:

1 Mild to moderate irritation of skin and mucous membranes.
2 Headache.
3 Garlicky breath, nausea, vomiting, diarrhoea, and occasionally abdominal pain.
4 Weak pulse, palpitations.
5 Fatigue, weakness in the legs, unsteady gait, vertigo.
6 Hyperaesthesia, agitation, mania, hallucinations of sight, hearing, taste, and smell in acute, massive vapor exposures and sometimes in ingestion periods.
7 Central nervous depression with respiratory paralysis.
8 Death may occur during coma or after a convulsion.

<u>Carbon monoxide</u>: Reversible with Oxygen.

Nitric Oxyde: Nonreversible with Oxygen

1 No symptoms or shortness of breath during vigorous muscular exercise (0 to 10 % COHb).
2 A mild headache and breathlessness on moderate exertion (10 to 20 % COHb).
3 Throbbing headache, irritability, emotional instability, impaired judgement, defective memory, and rapid fatigue (20 to 30 % COHb).
4 Severe headache, weakness, nausea and vomiting, dizziness, dimness of vision, confusion (30 to 40 % COHb).
5 Increasing confusion, sometimes hallucinations, severe ataxia, accelerated respirations, and collapse with attempts at exertion (40 to 50 % COHb).
6 Syncope or coma, with intermittent convulsions, accelerated respirations, tachycardia with a weak pulse, and a pink or red discoloration of the skin due to presence of COHb (50 to 60 %). This sign, however, is more common at autopsy than in living patients, who may exhibit pallor or cyanosis instead.
7 Increased depth of coma with incontinence of urine and faeces (60 to 70 % COHb).
8 Profound coma with depressed or absent reflexes, a weak thready pulse, shallow and irregular respiration, and complete quiescence (70 to 80 % COHb).
9 Rapid death from respiratory arrest (above 80% COHb).
10 Miscellaneous: COHb (reversible with oxyhemoglobin) changes the oxyhemoglobin curve, metabolic acidosis (low pH, $PCO_2$, and bicarbonate), CNS depression due to cerebral edema and increased intracranial pressure, pulmonary edema, inhibition P450.
11 Watch for late neurological, psychiatric and cardiac complications.

<u>Carbon tetrachloride</u>:(Chlorinated hydrocarbon solvents)

| | |
|---|---|
| n-Butyl Chloride | |
| Chlorobromomethane | Hexachloroethane, |
| Chloroform, | Penthachloroethane, |
| Methylene Bromide, | 1,1,2,2-Tetrabromoethane, |
| Methylene Chloride, | Tetrachloroethane, |
| Methylene Iodide, | Tetrachloroethylene, |
| Acetylene Dichloride, | Trichloroethylene, |
| 1-Bromo-2-chloroethane, | 1,1,2-Trichloroethane, |
| Ethyl Chloride, | 1,1,1-Trichloroethane, |
| Ethylene Dichloride, | Vinyl Chloride, |

1 Prompt nausea, vomiting, and abdominal pain. Sometimes the pain becomes intense enough to mimic an acute surgical complication.
2 Headache, dizziness, confusion, drowsiness, and occasionally convulsions.
3 Visual disturbances, sometimes consisting of a concentric restriction of the colour fields without central scomata (toxic amblyopia).
4 Rapid progression of central nervous depression with deepening coma and death from respiratory arrest or circulatory collapse.
5 Occasionally, sudden death due to ventricular fibrillation. Presumably this event may be heralded by frequent ventricular premature systoles.
6 In massive exposures the above symptoms merge with those outlined below, but central nervous depression may subside without sequelae, or an essentially asymptomatic interval of a few days may precede hepatorenal decompensation.
7 Kidney and/or liver injury, symptomatic or subclinical. Either may occur insidiously after an otherwise unrecognised exposure. The kidney lesion usually produces the more severe disturbance in human carbon tetrachloride poisoning.
8 Oliguria, albuminuria, anuria, gradual weight gain, edema. Death may occur within 1 week in the absence if effective supportive treatment.
9 Anorexia, jaundice, and right upper quadrant pain due to an enlarged and tender liver.

Cyanide:

| | |
|---|---|
| Acetone cyanohydrin | Malonitril |
| Acetonitrile | Phtalonitril |
| Acrylonitril | Propionitrile |
| n-Butyronitrile | Succinonitrile |

Symptomatology:

1 Massive doses may produce, without warning, sudden loss of consciousness and prompt death from respiratory arrest. With smaller but still lethal doses, the illness may be prolonged for 1 or more hours.

2 Upon ingestion, a bitter, acrid, burning taste is sometimes noted, followed by a feeling of constriction or numbness in the throat. Salivation, nausea and vomiting are not unusual. Solutions of sodium and potassium cyanide are corrosive because of their high alkalinity. Other symptoms follow in rapid progression.

3 Anxiety, confusion, vertigo, giddiness, and often a sensation of stiffness in the lower jaw.

4 Hyperpnoea and dyspnea. Respirations become very rapid and then slow and irregular. Inspiration is characteristically short while expiration is greatly prolonged.

5 The odour of bitter almonds may be noted on the breath or vomitus. This characteristic is sometimes a diagnostic help, but as many as 20 to 40% of all persons are said to be congenitally insensitive to the odour of HCN.

6 In the early phases of poisoning, an increase in vasoconstrictor tone causes a rise in blood pressure and reflex slowing of the heart rate. Thereafter the pulse becomes rapid, weak, and sometimes irregular.The victim notes palpitations and a sensation of constriction of the chest. A bright pink coloration of the skin due to high concentrations of oxyhemoglobin in the venous return may be confused with that of carbon monoxide poisoning.

7 Unconsciousness, followed promptly by violent convulsions, epileptiform or tonic, sometimes localized but usually generalized. Opisthotonos and trismus may develop. Involuntary micturition and defecation occur.

8 Paralysis follows the convulsive stage. The skin is covered with sweat. The eyeballs protrude, and the pupils are dilated and unreactive. The mouth is covered with foam, which is sometimes bloodstained, indicative of pulmonary edema. The skin colour may be brick red. Cyanosis is not prominent in spite of weak and irregular gasping. In the unconscious patient, bradycardia and the absence of cyanosis may be the key diagnostic signs.

9 Death from respiratory arrest. As long as the heart beat continues, prompt and vigorous treatment offers some promise of survival.

Dichloropropenes:

Allyl Alcohol
Allyl Bromide
1-Chloro-3-bromopropene-1 (CBP)
3-Chloro-2-methyl-1-propene
1,2-Dibromo-3-chloropropane
1,3-Dichloropropane
Epichlorohydrin
Hexachlorocyclopentadiene
Propargyl Bromide
Propylene Dichloride
Bromobenzene

1 A. Inhalation of high vapor concentrations: gasping, refusal to breath, coughing, substernal pain, and extreme respiratory distress at vapor concentrations over 1500 ppm. Irritation of eyes and upper respiratory mucosa appears promptly after exposure to concentrated vapors. Lacrimation and headache are prominent. Coma may occur rapidly.
B. Inhalation of low vapor concentrations: central nervous depression and moderate irritation of respiratory system. Headache is frequent.
2 Dermal: severe skin irritation with marked inflammatory response of epidermis and underlying tissues.
3 Oral: acute gastrointestinal distress with pulmonary congestion and edemas. Central nervous depression, perhaps even in the absence of impaired oxygen uptake.
4 By any route, possible late injuries to liver, kidneys and heart.
5 After inhalation exposures, malaise, headache, chest and abdominal discomfort and irritability have been reported to persist several weeks and perhaps for several years.

Formaldehyde:

Acetaldehyde
Acrolein
Furfural
Glutaraldehyde
Metaldehyde
Methenamine
Paraformaldehyde

Symptomatology:
1 Irritation of mucous membranes, especially of eyes, nose and upper respiratory tract.
2 With higher concentrations, cough, dysphagia, bronchitis, pneumonia, edema or spasm of the larynx. Pulmonary edema is uncommon.

Hydrogen sulfide:

Sulfur
Carbonyl Sulfide

Low to moderately high vapor concentrations:

1 Irritant actions:
  Eyes: painful conjunctivitis, photophobia, lacrimation, and corneal opacity
  Respiratory tract: rhinitis with anosmia, tracheobronchitis with pain and cough, pulmonary edema with dyspnea, sometimes late bronchopneumonia.
  Skin: direct contact (as a solution) may produce erythema and pain.
2 Gastrointestinal effects: profuse salivation, nausea, vomiting, diarrhoea.
3 Central nervous effects: giddiness, headache, vertigo, amnesia, confusion, and unconsciousness.
4 Miscellaneous: tachypnea, palpitations, tachycardia, arrhythmia, sweating, weakness, and muscle cramps.

Very high vapor pressures:

1 Sudden collapse and unconsciousness, with or without a warning cry.
2 Death from prompt respiratory paralysis, usually with a terminal asphyxial convulsion.
3 After sublethal exposures coma may disappear promptly, but full recovery is usually slow; the patient may have a residual cough, cardiac dilatation, slow pulse, peripheral neuritis, albuminuria, and some degree of amnesia or of psychic disturbance. recovery is eventually complete in most nonfatal cases.

Iodine:

Bromine
Chlorine
Fluorine

1 Inhalation of iodine vapor is very irritating to mucous membranes, and both upper airway and pulmonary effects have been described in laboratory animals.
2 Hypotension, tachycardia, cyanosis, and other signs of shock.
3 Headache, dizziness, delirium, collapse, and stupor.
4 Death may be due to circulatory collapse, asphyxiation from edema of the glottis, aspiration pneumonia, or pulmonary edema.
5 Occasionally haemorrhagic nephritis (with oliguria or anuria) becomes apparent within 1 to 3 days. It is probably a sequel to severe shock and/or intravascular haemolysis.

Methyl bromide:

Methyl Chloride
Methyl Iodide

(Symptoms appear 3 to 12 hours after inhalation of vapor)

1 Dizziness and headache
2 Anorexia, nausea, vomiting, and abdominal pain.
3 Lassitude, profound weakness, slurring of speech, and staggering gait.
4 Transient blurring of vision, diplopia, sometimes strabismus, and even temporary blindness.
5 Mental confusion, mania, tremors, and epileptiform convulsions, perhaps with a Jacksonian-type of progression.
6 Rapid respirations, associated with signs of severe pulmonary edema, cyanosis, pallor and collapse. Pulmonary edema, convulsions, and mental confusion may occur independently of one another.
7 Coma, areflexia and death from respiratory or circulatory collapse.
8 Low-level subacute vapor exposures have produced a syndrome of persistent numbness in the hands and legs, impaired superficial sensation, muscle weakness, unsteadiness of gait and absent or hypoactive distal tendon reflexes.
9 Late sequelae include bronchopneumonia after severe pulmonary lesions, renal failure with anuria due to tubular degeneration, and severe weakness with or without paralysis. These difficulties, however, tend to subside with a few weeks or months, and complete recovery is the rule. Hepatic failure does not occur, but jaundice and other evidence of mild hepatic injury are noted occasionally.

Nitrogen oxides:

Nitrous oxide
Nitric oxide
Nitrogen dioxide
Nitrogen tetroxide
Nitropropane
Nitrogen pentoxide
Phosgene
Thiophosgene
Chlorine
Bromine
Fluorine
Hydrogen Chlorine
Hydrogen Fluorine
Hydrogen Sulfide

Sulfur Dioxide
Ozone
Chlorine Dioxide
Chloropicrin
α-Chloroacetophenone
Propylene Oxide
1-Chloro-1-nitropropane
1,1-Dichloro-1-nitroethane
Cyanic Acid
Nitrogen Trichloride
Phosphine
Acrolein
Ethylene Oxide

1 Usually no symptoms occur at the time of exposure, with the exception of a slight cough and perhaps fatigue and nausea. Exposure to low concentrations may result in impaired pulmonary defence mechanisms (macrophages, cilia) with complications as in no. 10 below.

2 Only very concentrated nitrous fumes produce prompt coughing, choking, headache, nausea, abdominal pain, and dyspnea (tightness and burning pain in the chest).

3 A symptom-free period follows exposure and lasts for 5 to 72 hours.

4 Fatigue, uneasiness, restlessness, cough, hyperpnoea, and dyspnea appear insidiously, as the adult respiratory syndrome gradually develops.

5 Increasingly rapid and shallow respirations, cyanosis, mild or violent coughing with frothy expectoration, and physical signs of pulmonary edema (rales and rhonchi). The vital capacity is rapidly reduced. A serous exudate may develop in the pleural cavity, but its volume is usually small.

6 Anxiety, mental confusion, lethargy, and finally loss of consciousness.

7 A weak, rapid pulse, dilated heart, venous congestion, intense cyanosis, and severe hemoconcentration. Circulatory collapse is secondary to anoxia and hemoconcentration.

8 An asphyxial death due to blockade of gasexchange in the lungs. Death commonly occurs within a few hours after the first evidence of pulmonary edema.

9 Sometimes a second acute phase follows the initial pulmonary reaction after a quiescent period of several weeks. Cough, tachypnea, dyspnea, fever, tachycardia, and cyanosis at this stage are usually due to bronchiolitis obliterans. The relapse may be abrupt and fulminating, leading either to death or a slow convalescence.

10 In nonfatal cases, convalescence may be complicated by infectious bronchitis, bronchiolitis obliterans, pneumonia and general asthenia. Rarely diffuse pulmonary fibrosis may develop.

Xylene:

Benzene
Cumene
Styrene
Terphenyl
Toluene

1 In vapour exposures a transient euphorbia is sometimes observed.
2 Headache, giddiness, vertigo, ataxia and tinnitus.
3 Confusion, stupefaction and coma.
4 Often associated with this coma are tremors, motor restlessness, hypertonus and hyperactive reflexes, but frank convulsions rarely occur except in association with terminal asphyxia.
5 Death from respiratory failure or from sudden ventricular fibrillation.

Attachment 11

**Dear Sir!**

I and my colleagues are extremely sorry that we could not take part in the meeting of CCMSP (NATO Committee on Challenges of Modern Society Project) which occured in October in Belgium.

At the same time beeing greatly interested in maintaining close relations with you and in making a joint report we send our suggestions "The System of Classification and Identification of Emergency Situations when Handling Dangerous Chemicals" for your consideration.

As for suggestions on the other themes we shall send them to you as they will be prepared.

We should be obliged if you would send us the materials of the Belgium meeting and the information whether the suggestions presented to you would be suitable for use in the joint report.

*Yours faithfully*
*Yuri Musiychuk*

# The System of Classification and Identification of Emergency Situations when Handling Dangerous Chemicals /Suggestions/

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## 1.General Introduction

The given document presents the principles of approach to the classification and identification of hazards due to accident release of dangerous chemicals, while producing, transporting and storing. The present concept considers (both in predictive and factual aspects) the following types of hazards connected with handling of chemicals:

- toxic hazard **T**
- fire hazard **F**
- explosion hazard **E**

The mentioned types of hazards are considered in the complex of factors defining the possible scenarios of developing emergency situations and their probable consequences. These factors include physicochemical and toxic properties of chemicals, conditions of forming releases, criteria of estimating probable levels of environment pollution, parameters of fire and explosion hazards, as well as the scale and volume of injured humans and animals and material losses.

As a base of the offered classification approach primarily we used the long-term experience stored by different government supervision bodies of the USSR in respect to providing safety in handling chemicals, as well as certain directive materials adopted in other countries - Directories of the European Economic Community 82 /5O1/ EEC 3, in particular [1,2,3,4]

The offered concept cannot be used for estimating the consequences of accidents in atomic energy units, as well as accidents in chemical enterprises caused by acts of sabotage and military actions.

## 2.The Structure of Predictive Classification Formula of Hazard of Chemical Accidents

Let the notion of hazard index of chemical accidents be as follows.

The hazard index of chemical accidents is a complex parameter representing in its encoding the actual or potential levels of unfavourable consequences for the total environment, human health, integrity of material resources as a result of chemical and related accidents.

It follows from this determination that the offered classification formula should represent a logical set of different parameters designated with the aid of hazard indexes of the appropriate levels.

In general case the predictive classification formula of hazard of chemical accident release can be presented as follows:

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **TFE:** | xxxxx-xx-x. | x/x. | x. | x. | x. | x. | x. | x. | x. | x. | x |

where:

The first three letters outline the kind of danger included in the classification formula.

1-designation of a chemical substance; (For designation the International Classification System - CAS - or any other one more convenient in use may be employed).

2-released volume index dependent upon the portion of released substance mass expressed as a percentage of the established limited storage volumes adopted in the Directories 82/501/EEC (see Tables 1 and2);

3-release hazard index defined by accident conditions and certain critical parameters (temperature and pressure) of a chemical substance (see Tables 3 and 4);

4-toxic hazard index (see Table 5);

5-fire hazard index (see Table 6);

6-explosion hazard index (see Table 7);

7-actual or predictive hazard index of possible atmospheric air contamination (see Table 8);

8-actual or predictive hazard index of possible water contamination (see Table 9);

9-actual or predictive hazard index of possible soil contamination (see Table 10);

10-actual or predictive index of possible injuries of humans and animals, scale of the environment pollution, material losses (see Table 11);

11-actual or predictive index of amount of manpower and means used for eliminating consequences of chemical accidents as well as effectiveness of their use (see Table 12).

The classification hazard index formula is divided into informational and predictive (or actual) parts.

The informational (left) part represents properties of chemical substances, conditions of forming releases, as well as potential toxic, fire and explosion hazards. The predictive (right) part contains the complex of informational and predictive indexes representing the potential hazards for environmental subjects and possible (or actual) unfavourable consequences of chemical accidents which include responses of living bodies to exposure, scale of injuries and material losses. The probable consequences of chemical accidents are estimated with the aid of number of models including mathematical, physical, biological and other concepts of forming exposures and their effects.

In general we can say that to predict consequences of chemical accidents the models of following types may be used:

- mathematical models of forming releases and models for the determination of acoustic exposures and of fragments scattering;

- mathematical and physical models of diffusion of harmful substances in the environmental subjects ("puff" models, Gausse models, thermic models etc) with the determination of the "concentration (dose) - time" relationship;
- models of responses of human and animal bodies to static and dynamic exposures (such as toxic, thermal and acoustic ones) ;
- models of estimation of effectiveness of management and technical decisions and of preventive medical measures as well as rendering the first-aid assistance to the injured.

Let several definitions and notions characterizing the offered parameters be as follows:

Critical temperature - the temperature above which a substance cannot exist in liquid state [5].

Critical pressure - the pressure which keeps possibility of the gaseous phase to be liquified [5].

Pool fire - spilling of an inflammable liquid burning with stable diffused flame [5].

Fire ball - surface burning of clouds of combustible vapours-and-air mixture [5].

Instant release - releasing chemical substances into the environment for less than 1 minute.

Non-stationary release - releasing chemical substances into the environment with variable intensities for extended periods of time.

Stationary release - releasing chemical substances into the environment with constant intensities for extended periods of time (over 20 minutes).

Permissible degree of water body pollution - determines suitability of one object for all the kinds of water use practically without any restrictions [7].

Moderate degree of water body pollution - is indicative of certain hazard for population and public water use in water object. Its use as a source of domestic water supply without reducing the level of chemical contamination by purification can result in appearance of initial signs of intoxication in some portions of population, especially in cases when water contains substances of the 1-st and 2-nd classes of hazard [7].

High degree of water body pollution - is indicative of absolute hazard of domestic water use in a water object. Use of such a water object as a source of public water supply should be prohibited because removal of toxic substances is a difficult problem. Use of such water for drinking can result in manifestation of signs of intoxication and development of delayed effects [7].

Extremely high degree of water body pollution - is indicative of its absolute unsuitability for all the types of water use [7].

Table 1.

**Hazard indexes according to release volume and trotyl (TNT) equivalent [1]**

| N | Characteristics of load | Index value | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1 | Quantity of released substance (% of Seveso level) | < 0.1 | > 0.1 | > 1.0 | > 10.0 | > 100 |
| 2 | Trotyl (TNT) equivalent (tonnes) | < 0.1 | 0.1 - 1.0 | 1.0 - 5.0 | 5.0 - 50.0 | > 50 |

Table 2

**Seveso levels adopted for storage of dangerous chemicals [4]**

| N | Substance category | Maximum mass of substance, tonnes |
|---|---|---|
| 1 | Extremely toxic chemicals | 5 |
| 2 | Chemicals defined as toxic, fire-hazardous or explosive | 10 |
| 3 | Gaseous substances including liquified gases, classified as highly fire-hazardous | 50 |
| 4 | Highly and extremely fire-hazardous chemicals (except substances of item 3) | 5000 |

Notes:
1. Quantities of substances indicated in Table 2 should be considered as maximum allowable in concurrent storing in storehouses of plants, located for less than 500 m from one another.
2. Gradation of storing volumes is specified and may be changed depending on requirements, adopted on the national base or agreed internationally.

Table 3.

**Classification of chemicals according to critical parameters [5]**

| N | Description | Group number |
|---|---|---|
| 1 | Chemicals with critical temperature below the environmental temperature | 1 |
| 2 | Chemicals with critical temperature above and boiling point below the environmental temperature | 2 |
| 3 | Chemicals with critical pressure above the atmospheric pressure and boiling point above the environmental temperature | 3 |
| 4 | Chemicals with exceeding parameters | 4 |

Table 4.

**Characteristics of chemical releases according to classification groups and accident conditions.**

| N | Description | Index value |
|---|---|---|
| 1 | Complete destruction of vessels containing a substance of the 1-st group (instant gas release) | 5 |
| 2 | Puncture of vessels above the level of the 2-nd group liquid substance (instant gas release) | 4 |
| 3 | The same - below the level of the 2-nd group liquid substance (non-stationary gas release) | 3 |
| 4 | The same - above the level of the 3-rd group liquid substance (non-stationary source of gas-aerosol phase) | 3 |
| 5 | The same - below the level of the 3-rd group liquid substance (spill, stationary vapor release into atmosphere, non-stationary release into water bodies) | 2 |
| 6 | Puncture of vessels containing a substance of the 4-th group (spill, stationary vapor and aerosol release into atmosphere, non-stationary release into water bodies) | 1 |

Table 5.

**Chemical toxicity indexes [6]**

| N | Description | Index value | | | |
|---|---|---|---|---|---|
| | | 4 extremely toxic | 3 highly toxic | 3 moderately toxic | 5 low toxic |
| 1 | Average lethal dose when ingesting through eating or drinking, $DL_{50}$, mg/ks | < 15 | 15 - 150 | 151 - 500 | >500 |
| 2 | Average lethal dose when absorbing through skin, $DL_{50}$, mg/kg | < 100 | 100 - 500 | 501 - 2500 | >2500 |
| 3 | Average lethal concentration in air, $CL_{50}$, $mg/m^3$ | < 500 | 500 - 5000 | 5001 - 50000 | >50000 |

Table 6.

**Fire hazard indexes [5]**

| N | Classificaition of chemicals | Flash point °C | Index of probability of ignition at meters=X, m | | | | Index of probability of occurrence of | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 10 | 100 | flash fire | pool fire | fire ball |
| 1 | Combustible liquid | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | Flammable liquid | 40 | 3 | 0 | 0 | 0 | 0 | 5 | 5 |
| 3 | Highly flammable liquid (a) | 13 | 5 | 5 | 1 | 1 | 3 | 5 | 0 |
| 4 | Highly flammable liquid (b) | -45 | 5 | 5 | 5 | 3 | 5 | 5 | 1 |
| 5 | Cryogenic or chilled liquid | < -160 | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| 6 | Liquified flammable gas | -107 | 5 | 5 | 5 | 5 | 5 | 5(0)* | 5 |
| 7 | Compressed flammable gas | - | 5 | 5 | 5 | 5 | 5 | 0 | 5 |

* Liquid phase can be absent.

Table 7.

**Explosion hazard indexes of chemicals/air mixtures [7,8]**

| N | Group designation | Self-ignition point, °C | Index value |
|---|---|---|---|
| 1 | T1 | > 450 | 1 |
| 2 | T2 | 300 - 450 | 2 |
| 3 | T3 | 200 - 300 | 3 |
| 4 | T4 | 135 - 200 | 4 |
| 5 | T5 | 100 - 135 | 5 |
| 6 | T6 | 85 - 100 | 6 |

Table 8.

**Hazard indexes of atmospheric air pollution.**

| Hazard index | Hazard determination | Maximum concentrations range, TLV [9] | Types of injuries (short-term exposure). [10] | Odour by *Stern* scale. [11] |
|---|---|---|---|---|
| 1 | Allowable | 1.0 | No changes | Without odour or weak odour |
| 2 | Moderate | 1.1 - 10.0 | 1. Threshold changes of reflectory actions<br>2. Functional changes within the physiological limits<br>3. Signs of body sensibilization | Weak odour |
| 3 | Dangerous | 11.0 - 100.0 | 1. Increasing responses to specific odours<br>2. Functional changes beyond the physiological limits<br>3. Allergic responses in most sensitive persons<br>4. Increase of non-specific diseases including chronic illnesses | Easily bearable odour |
| 4 | Highly dangerous | 11.0 - 100.0 | 1. Unbearability of odours, irritating action<br>2. Acute toxic injuries of respiratory tract and other organs<br>3. Acute allergic diseases<br>4. Exacerbation of certain types of chronic illnesses (cardio-vascular and respiratory tract diseases in particular)<br>5. Pronounced rises of sickness rates | Strong odour |
| 5 | Extremely dangerous | > 100 | 1. Acute lethal injuries<br>2. Sudden mortality increase among groups of chronic patients with cardio-vascular, respiratory tract and other diseases | Very strong odour |

Table 9.

**Classification of water objects according to pollution degree [7]**

| Pollution degree | Evaluation of the 1-st or 2-nd category water body pollution | | | | | | | Hazard index value |
|---|---|---|---|---|---|---|---|---|
| | Organoleptic | | Toxicological | Sanitary | | | Bacteriological | |
| | Odour, taste, (grades) | Degree of exceeding $TLV_o$ | Degree of exceeding $TLV_t$ | $BOC_{20}$ | | Dissolved oxygen, mg/l | Number of lyctopositive intestinal bacilli in 1 l. | |
| | | | | I | II | | | |
| Permissible | 2 | 1 | 1 | 3 | 6 | 4 | $<1x10^4$ | 0 |
| Moderate | 3 | 4 | 3 | 6 | 8 | 3 | $1x10^4$-$1x10^5$ | 1 |
| High | 4 | 8 | 10 | 8 | 10 | 2 | $1x10^5$-$1x10^6$ | 2 |
| Extremely high | >4 | >8 | >100 | >8 | >10 | 1 | $>1x10^6$ | 3 |

Notes:

1. $TLV_o$ - maximum allowable concentration of substances established according to organoleptic sign of harmfullness;
2. $TLV_t$ - maximum allowable concentration of substances established according to toxicological sign of harmfullness;
3. $BOC_{20}$ - biochemical oxygen consumption

Table 10

**Hazard indexes of chemicals for soils [13]**

| N | Description | Index value | | |
|---|---|---|---|---|
| | | 5 | 3 | 1 |
| 1 | Persistance in soil, months | >12 | 6 - 12 | <6 |
| 2 | Migration | migrates | slightly migrates | no migration |
| 3 | Persistance in plants, months | >3 | 1 - 3 | <1 |
| 4 | Influence on edible value of agricultural products | strong | moderate | no |
| 5 | Toxicity, $LD_{50}$, mg/kg | <200 | 200 - 1000 | >1000 |
| 6 | TLV in soil, mg/kg | <0.2 | 0.2 - 0.5 | >0.5 |

Table 11

**Possible consequences of chemical accidents [1]**

| N | Description | Index values | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1 | Number of victims | - | - | 1 -5 | 5 - 20 | >20 |
| 2 | Number of injured | - | 1 - 10 | 10 - 50 | 50 - 200 | >200 |
| 3 | Wild animals death, tonnes | <0.1 | 0.1 - 1.0 | 1.0 - 2.0 | 2.0 - 10.0 | >10.0 |
| 4 | Domestic animals death, tonnes | 0.1 - 0.5 | 0.5 - 2.0 | 2.0 - 10.0 | 10.0 - 50.0 | >50.0 |
| 5 | Freshwater fish death, tonnes | 0.1 - 0.5 | 0.5 - 5.0 | 5.0 - 20.0 | 20.0 - 100.0 | >100.0 |
| 6 | Sea-water animals death, tonnes | 0.5 - 2.5 | 2.5 - 25.0 | 25.0 - 100.0 | 100.0-500.0 | >500.0 |
| 7 | Area of contaminated soil or water with persistent chemicals which requires decontamination (ha, $km^2$) | - | 1 - 10 ha | 10 - 100 ha | 1.0 - 5.0 $km^2$ | >5.0 $km^2$ |
| 8 | Total cost of losses in social and economical spheres connected with environmental pollution due to chemical accidents (MECU)* | - | 0.015 - 0.15 | 0.15 - 1.5 | 1.5 - 15 | >15 |
| 9 | Number of destructed buildings | - | - | 1 - 10 | 10 - 100 | >100 |
| 10 | Area of building destruction (ha, $km^2$) | - | 1 - 10 ha | 10 - 100 ha | 1.0 - 10.0 $km^2$ | >10.0 $km^2$ |

* million ECU adopted as an conventional currency unit

Table12

**Manpower and means required [1]**

| N | Description | Index values | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 11 | Number of mobilized rescuers (firemen, troops of Ministry of Home Affairs, medical personnel etc.) | 1 - 50 | 50 - 100 | 100 - 1000 | 1000 - 5000 | >5000 |
| 12 | Man-days measure of evacuation | 1 - 10 | 10 - 100 | 100 - 5000 | 5000 - 50000 | >50000 |
| 13 | Number of people staying in case of accident in their dwellings for more than 2 hours or being left without drinking water and electric energy supply for up to 24 hours | 1 - 100 | 100 - 1000 | 1000 - 50000 | 50000-$2x10^5$ | >$2x10^5$ |

## 3. Factual Classification Formula of Hazard Index of Chemical Accidents

The structure of the classification factual formula of the hazard index of a chemical accidents occurred is of the same form as the predictive one, yet there are some differences in their contents.

These differences are connected with the necessity of representing actual (not predictive) data of losses due to an accident.

Keeping practically the informational data fields unchanged the hazard indexes are introduced into the right part of the formula characterizing the real consequences of the accident occurred determined by the same parameters as ones used for the predictive purposes.

To estimate the release volume or the scale of the accident occurred after backslash delimiter in field 2 the correction "a" is introduced which takes into account the effectiveness of manpower and means used to prevent accidents, reduce losses and eliminate consequences.

According to [1] parameter "a" takes the following values:

a=0 - in case when volumes of a released substance could not be decreased;

a=1 - in case of successful actions of emergency teams and use of proper localization and neutralization means which reduced releases significantly;

a=3 - in case of complete preventing possible harmful releases.

In field 3 which defines the release nature the predictive hazard index is substituted for the code representing an actual event (see Table 13).

**Table 13**

**Encoding of hazard manifestation type**

| N | Description | Code |
|---|---|---|
| 1 | Explosion + fire + toxic substances release | 1 |
| 2 | Explosion + toxic substances release | 2 |
| 3 | Explosion | 3 |
| 4 | Fire + toxic substances release | 4 |
| 5 | Fireball | 5 |
| 6 | Toxic combustion gases release with subsequent ignition | 6 |
| 7 | Toxic gases and vapours release | 7 |
| 8 | Liquid spill with subsequent ignition (pool fire) | 8 |
| 9 | Liquid spill of toxic substanses | 9 |

Both for purposes of prediction and estimation of accidents occurred it is necessary to define the field 10 as maximum of the whole set of indexes presented in Table 11. So prerequisites for establishing a single approach to estimate the total hazard index of an accident, are created, which is completely correlated with the regulations of the Directory Matherials 82/501/EEC. In view of the fact that the hazard indexes presented in Table 11 can range from 1 to 5 (depending on the severity of the consequences of an accident) the total hazard indexes can be presented in the following grades (see Table 14).

**Table 14**

**Grades of gravity Scale of chemical accident hazards**

| N | Accident hazard | Index value |
|---|---|---|
| 1 | Slight | 1 |
| 2 | Requiring attention | 2 |
| 3 | Dangerous | 3 |
| 4 | Very dangerous (lage-scale) | 4 |
| 5 | Disastrous | 5 |

## 4. Example of Forming the Classification Formula of Chemical Accident Hazard

As an example let's consider a case of the automobile accident which resulted in breaking a tank with 30 tons of liquid chlorine. In this case 20 tonnes of liquid chlorine were poured on the road forming spill of 5x4 $m^2$ in size. Some portion of liquid chlorine penetrated into river which resulted in poisoning water. At the time of accident wind blew in the direction of the forest and the agricultural farm located at a distance of 200 m from the accident site. A school was situated near the farm where there were 75 persons at the moment of the accident.

Let's form the informational part of the formula.

| Parameter | |
|---|---|
| Designation according to CAS | 7782-50-5 |
| Hazard index by the release volume (see Table 1 and 2) | 4 |
| Hazard index by the release character (see Table 3 and 4) | 2 |
| Toxicity index (see Table 5 and [6]) | 3 |
| Fire hazard index (see Table 6) | 0 |
| Explosion hazard index (see Table 7) | 0 |

Then, taking into account the physico-chemical and toxic properties of chlorine we can assume that the hazard indexes of environmental pollution for appropriate release volume can amount as follows:

| | |
|---|---|
| for atmospheric air (see Table 8) | 5 |
| for surface water bodies and ground water (see Table 9) | 4 |
| for soil (see Table 10) | 3 |

To estimate the possible consequences of such accidents we shall use the block of models defining the diffusion processes of chlorine in atmospheric air and in water bodies with subsequent evaluation affects for human beings, domestic and wild animals, fish, as well as the parameters of destruction and volumes of material expenditures needed to eliminate the consequences.

Let by calculation it is established that due to given chlorine spill a cloud of vapours of high concentrations has been formed which resulted in poisoning of humans and animals and their partial death. To eliminate the consequences of the accident emergency teams were used of more than 100 persons in number. Seventy five persons were evacuated and the total expenditures to eliminate the accident amounted to 1.5 conventional currency units (MECU).

In this case the predictive hazard indexes were as follows (see Table 11 and 12).

| Parameter | Hazard index |
|---|---|
| Number of victims | 3 (1 person) |
| Number of injured (chemically poisoned) | 4 (50 persons) |
| Wild animal death | 3 (1.5 tonnes) |
| Domestic animal death | 3 (5.0 tonnes) |
| Freshwater fish death | 3 (10 tonnes) |
| Sea-water animal death | 0 |
| Area of contaminated zone | 3 (15 hectars) |
| Means used to eliminate the accident | 4 (1.5 conventional currency units, MECU) |
| Area of destruction | 0 |
| Number of mobilized services | 3 (100 persons) |

| | |
|---|---|
| Evacuation measure | 2 (75 persons) |
| Number of persons existing in conditions of emergency situation | 1 (75 persons) |

Thus the predictive classification formula of the hazard of the chemical accident due to chlorine spill takes the following form:

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TUU: | 07782-50-5. | 4/0. | 2. | 3. | 0. | 0. | 5. | 4. | 3. | 4. | 3 |

In that case the first three letters outline the predominating danger kind, which is associated with toxicity. Other factors as fire and explosion hazards are negligible and unclassified. It noted by letter U.

When predicting, for the purpose of aggravating the situation, it is suggested that the effectiveness of measures to reduce the release volumes equals to 0.

In view of that the maximum predictive index accounts for 4, the present accident should be classified as a very dangerous or large-scale one (see Table 14).

Then suggest that a real accident took place in the same circumstances, but due to preventive measures taken the gravity of injuries and damage volumes were essentially reduced. In this case the hazard indexes according to Table 11 will be as follows (parameters in the Table 12 remain unchanged):

| Parameter | Hazard index |
|---|---|
| Number of victims | 1 (0) |
| Number of injured | 2 (5) |
| Wild arlimals death | 0 (0) |
| Domestic animals death | 1 (0.1 tonnes) |
| Freshwater fish death | 1 (0.1 tonnes) |
| Sea-water animals death | 0 (0) |
| Area of contaminated soil and water with chemicals | 2 (5 hectars) |
| Evaluation of damage cost | 2 (0.014 conventional currency units, MECU) |
| Number of destructed buildings | 0 (0) |

Besides let the parameter of the effectiveness of using manpower and means directed to reducing the release volume "a"=2. The code corresponding to dangerous substance spill (9) is introduced into field 3 (see Table 13). Then the classification formula of the actual hazard index of the accident under consideration will be as follows:

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TUU: | 07782-50-5. | 4/2. | 9. | 3. | 0. | 0. | 5. | 4. | 3. | 2. | 3 |

From the analysis of the given formula it follows that in spilling chlorine above 10 % of the permissible level high hazard of chemical contamination of atmospheric air, water bodies and soil is possible. But due to the effective use of emergency teams of more than 100 persons in number it has been possible to essentially reduce the release of the harmfull substance and consequences of the accident which can be characterized as requiring attention (see Table 13).

## 5. Structure Analysis and Construction Rules of Classification Formulas

In the present work we attempted to identify the levels of accident hazards due to release of chemicals into the environmental subjects. Taking into consideration the variety of scenarios of the accident consequences the classification formula is divided into two parts - the informational and predictive (or factual) ones. Use of the second part of the formula in predictive or factual aspects does not change its structural form.

Fields 7-9 in the left section of the predictive part (contamination) illustrates the potential hazard of the particular substance behavior in certain scenarios of the emergency situation as for the environmental subjects (atmospheric air, water of water bodies and soil).

The factual formula presents the indexes of the contamination levels of those environmental subject which have been affected (in the considered example atmospheric air and water bodies).

From the above it follows that the predictive formula should contain the data about the utmost probable consequences typical for a particular chemical accidents with adequate conditions of forming substance release, fire or explosion while the factual formula contains only parameters established during investigation or measurement.

The format of the identificator is divided in 12 fields and contains 36 characters horizontally (line notation) including 10 outer delimeters as a point for main fields and as a colon for the first (number 0) outline information field. In field 2 a backslash is used as an inner delimeter.

Structurally the identificator is represented as follows:

| Information (left) part | | | | | | | Predictive/Actual (right) part | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Outline danger kind | CAS designation | Vol-ume | Hazard | | | | Contamination | | | Losses and used resources | |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| XXX: | xxxxx-xx-x. | x/x. | x. | x. | x. | x. | x. | x. | x. | x. | x |

The missing characters in the designation of a substance (field 1) according to the adopted encoding system CAS are added with null in front. (For example, chlorine - 07782 - 50 - 5, methylizocyanate - 00624 - 83 - 9, nitroglycerin - 00055 - 62 - 0). In field 1 a hyphen is used as an inner delimeter, which corresponds to CAS conventions.

In the absence of the affects and, accordingly, that of the hazard index null is introduced into the corresponding position.

The rezulted presentation of form unification and principles unity of choosing parameters allows this classification formula to be used for the identification purposes of both occurred and predicted accidents. In this case it is possible to organize independent and at the same time internally compatible data bases which allows to analyze on the international level the state of safety when handling dangerous chemical substances and to carry out scientifically valid planning of investigations in this field.

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Attachment 12

Revised 5/21/92

Revised Outline of Final Report

| Contents | Responsibility |
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| I. Introduction/ Background | (MURTOMAA, Finland) |
| II. Health Hazard Assessment | (ALP, Turkey; DEWEGER, Netherlands) |
| III. Decision Support/ Reporting Systems | (ALP/DEWEGER) |
| IV. Health Plan Development | (BAXTER, UK) |
| V. Environmental Health Considerations | (RODGERS, USA) |
| VI. Response Organization/Personnel and Health/Medical Follow-up | (GRAY, USA) |
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| A. Available Data Bases | (MATYUNAS, USA) |
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