Chimia 58 (2004) 37–41

ISSN 0009–4293

Tools and Procedures of the Science Officer in the Management of Hazardous-Material Incidents

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Abstract: A chemical science officer ensures with his know-how, his experience based on continuous improvement and with the help of databases, optimal advice to the operational crew. In the event of incidents with hazardous materials, great attention must be given to self-protection of the operational crew, to the shelter of residents, to the environment and to the prevention of destruction of assets. While minimizing the hazard, the chemical science officer works closely with the officer-in-charge, environmental authorities, police and chemical analysis groups.

Keywords: Chemical hazard · Chemical science officer · Propagation models · Soil contamination

1. Risk Assessment: The Need for Chemical Knowledge

Incidents with all kinds of chemicals such as known and unknown solid-, liquid-, and gaseous substances are called hazardous materials incidents. These incidents lead to negative press whether there is a fire or not. In such cases local or/and regional fire brigades need specific know how from chemical science officers about the chemical resistance of the tools used in dealing with the incident.

1.1. *The Science Officer in the Incident Management Organization*

Well-trained officers-in-charge of the fire brigades are experts in the fire fighting business. They know the correct tactical actions for fire fighting operations. But they have minimum experience and knowledge about the hazards and necessary consequences for operations involving chemicals. In the canton Aargau chemical science officers are summoned for support of the officer-in-charge [1]. Four experts are named for all regional fire brigades. In operation they are executive members of the authorities [2]. Centralized notification authorities summon them on the basis of action plans depending upon the alarm received.

Chemical science officers are assigned to the chemical officer-in-charge to provide advice. Their advice has first priority for the safety of the operational team. They suggest the protection equipment required, how to decontaminate and clean injured people and operational material.

Prevention measures are proposed to limit damage. Cordoning off and evacuation actions are discussed. The operation of the chemical analysis group is coordinated. The chemical science officer proposes specific methods to end and limit the consequences of a spill *e.g.* the treatment of the retained fire fighting water or the contaminated soil (Fig. 1 and 2 [3]).

The chemical science officer has the duty to estimate and report to the environmental department the most significant danger arising from the chemicals to soil, water or

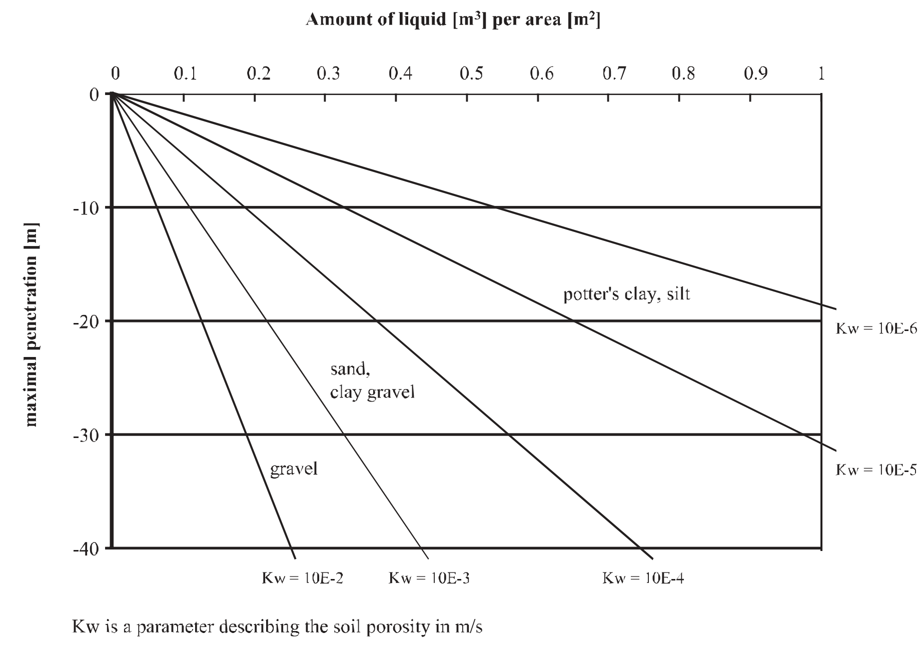

Fig. 1. Depth of liquid in soil [3]; amount of liquid [m^3] per soil [m^2] in relation to enter soil

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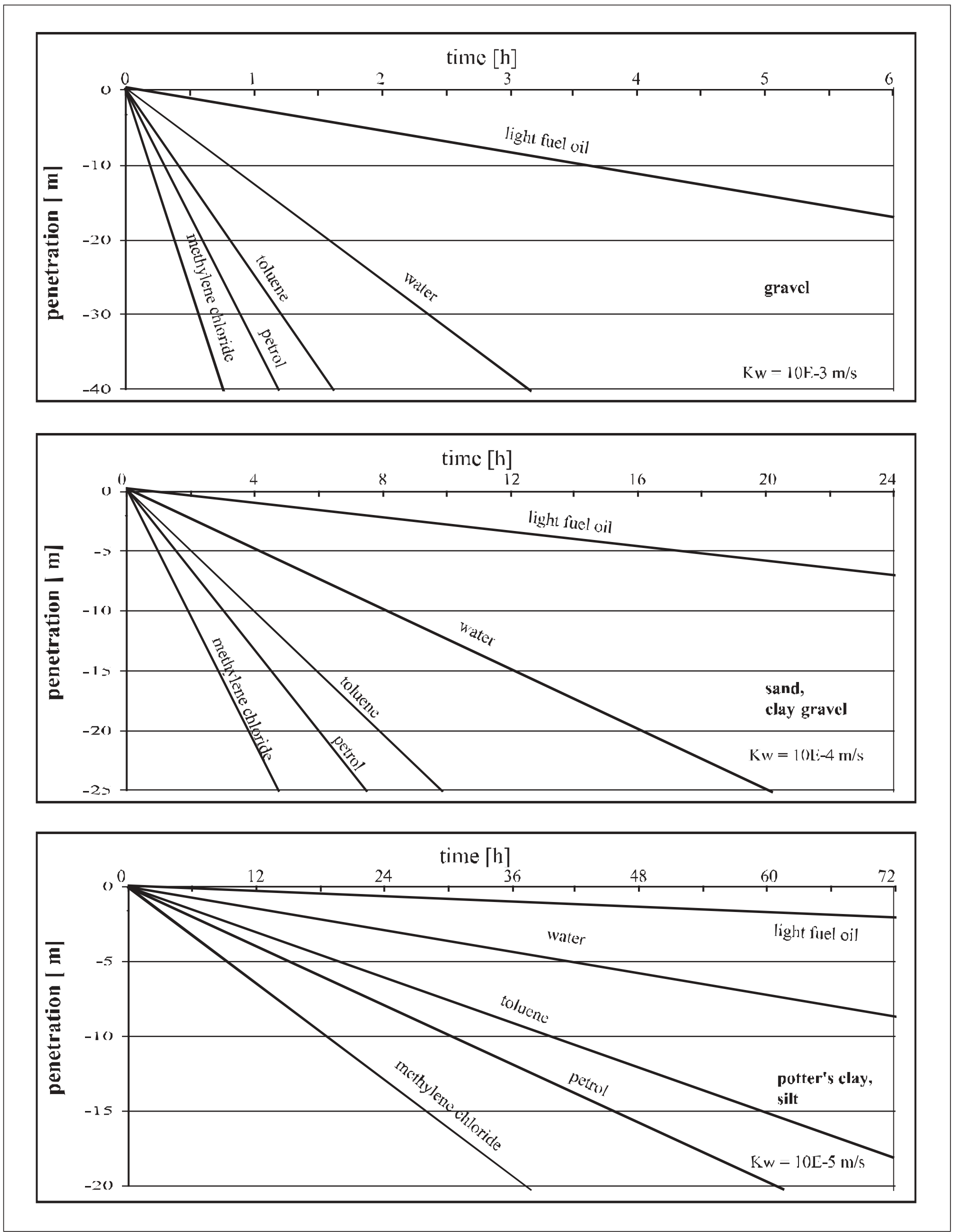

Fig. 2. Depth of liquid in soil as function of time [3]; time [h] in relation to enter soil [m]

air. The goal is to limit the danger to the operational crew, the local residents and to minimize the contamination of the environment. The knowledge of the chemical science officer can also be of importance for the authorities and journalists.

1.2. *Continuous Duty*

At the hectic start of the operation, chemists and engineers without continuous preparedness and education on how to handle chemical spills are of little help as advisers. Education at universities and the expertise on the job in industry is an important basis. However experience in actual hazardous chemical manufacturing sites and the elaboration of realistic incident scenarios are an important mandate for chemical science officers. Knowledge of the location of hazardous goods provides efficient support. Scenarios are developed for the simulation of realistic effects [4]. The speed of spreading gases requires modeling to evaluate the risk followed by timely warning at the right places. For a correct scenario with realistic spreading models the worst case scenario is used for a first impression [5]. Together with the knowledge of the stripping tools of the fire brigades the forecast can be realistic. With ongoing measurements of air and analyzing the weather and wind situation the recommendations can be adapted. The basic chemical knowledge of redox reactions, toxicities and spontaneous reactions of certain chemicals provides enormous support to the operational crew.

Based on results of the analysis group and the information on spreading models at the site of the incident, the risks are re-evaluated to support the operational crew. The 'Model of Effects with Toxic Gases' (MET) [5] is helpful for making decisions. This was originally developed for military use. This booklet is easy to handle and guarantees a quick and realistic evaluation of the endangered area.

For maximum effectiveness chemical science officers are trained in interpreting toxic values by attending conferences and having discussions about real accidents and their solutions.

2. Links and Helpful Tools

The first information tools are the senses. The eyes and nose are not only used for identification of the escaped chemical but also for self protection. The observations of physical conditions near the accident and feedback from the fire fighters about the physical state, viscosity, color, *etc.*, all have to be taken into consideration to assess the danger from the start.

2.1. *Gaining Information at the Site of the Incident*

The best knowledge of the installation can be given by the plant manager and by the people present during the accident. Material Safety Data Sheets, transportation documents, storage lists, risk assessments for authorities, and installation schemes are helpful tools to gain an overview of the possible range of the consequences of an incident. For accidents on the road the direct contact to the responsible shipping agent – and not just to his telephone answering machine – is required. Chemical information services like TUIS or ICE [6] and centers of toxicology are helpful tools. Local authorities provide information about soil, wastewater collection systems, ground water, inhabited areas and other endangered places.

If there is no information available to the contrary, the reaction of the involved chemical with water should be observed. A quick measurement of the pH-value of extinguishing water is helpful to identify the substance. Air measurements with analyzing instruments such as gas-tubes and simultaneous air monitoring sets minimize the time required for identification and reduces the range of possible chemicals. It gives essential information about chemical groups, redox reactions or acid/base behavior to be considered.

2.2. *More Detailed Information*

The information collected on site is compared to book knowledge to provide optimal input for the officer-in-charge.

- Initial information about groups of compounds; also accessible by fire brigades: ERI-Cards [6]
- Useful manuals for initial information:
  - Zürcher Giftgesetz [7]
  - Gefahrengut Ersteinsatz [8]
  - Gefahrengut im Umgang mit Chemikalien [9]

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- Manual for specific information:
  – Handbuch der gefährlichen Güter [10]
- Very detailed information:
  – Gefahrengutschlüssel [11]
- Material Safety Data sheet from the producer

Direct connection to the internet on site becomes more and more necessary. For some useful Web-pages see the list of literature (updated: date of submission).

2.3. *Analysis of Information*

Current weather data and specific measurements have to be analyzed continuously. It is very important to decide where and when the analysis team should measure and which methods should be used. This has to be done in accordance with the advice of chemical science officers. Checklists such as 'Checklist for Chemical Science Officers' (Fig. 3) and a 'Place-Time-Value' chart (Fig. 4) are used to collect and map all information. The chemical science officer needs all this information for a broad assessment of the danger to fire fighters, public, soil, water, and air.

It is best to have a team of two to three chemical science officers to provide consolidated advice to the officer-in-charge. In the hectic of the operation this assures that no important fact is overlooked. The chemical science officers can be located at different places to support the officers-in-charge of different sections.

3. Tips and Tricks from Incidents with Hazardous Materials

The tasks of the chemical science officers can be demonstrated based on real incidents. The variety of different incidents and the elements of surprise should not be underestimated. Aggravating situations like tunnels, bridges, traffic, power lines, congested areas, *etc*. must be borne in mind.

3.1. *Small Damage by Packaged Goods*

Different chemicals and the shipping of packaged goods challenge both laypersons and chemical science officers when it comes to identification of the hazard. First clues for the identification of hazards often are given by the senses eyes, ears, and nose. Additionally transportation papers are helpful unless they are marked 'miscellaneous' or 'not otherwise specified' (NOS).

On a muggy, warm day with light wind from the north-east an incident with a transport of hazardous goods occurred. The transportation paper mentioned 'dicyclopentadien' and 'miscellaneous' as freight. The fire brigade had to treat the spill seriously as dicyclopentadien (UN No. 2048; easy inflammable, from 26 °C spontaneous, very intensive reaction (caused by peroxides), poorly water soluble, extinguish only from far distance).

Odor, color, and the description from the persons who detected the accident and the first information of the fire brigade did not fit to dicyclopentadien. More than 1 h later the trade name of the substance involved was known. The internet search could be run at the site. Finally the chemical was identified as unproblematic synthetic hydrophobic modified acryl polymer (emulsifier). In parallel the Material Safety Data Sheet from the supplier was received.

Suddenly the evaluation of the risk for the wastewater was more important than the initial hazard of an explosion under the prevailing weather conditions. It had to be

Checklist for Chemical Science Officers 1 / 1

❑ Actual status ❑ Person responsible for filling in form:

Results of observations

❑ Involved chemicals: ____
synonyms: ____
❑ Hazard number: __ __ UN number __ __ __ __
❑ ERI-Card number __ __ __ Hommel number __ __ __ __
❑ Key figures: ❑ MAK ❑ limit of olfactory detection
❑ IDLH ____ ❑ LD_{50} ____
❑ Producer/Supplier: ____
❑ User/Contact person:
❑ Type of vessel: ____ Size of vessel: ____
Involved amount: ____ amount of spill: ____
❑ Aggregate: ❑ liquid ❑ solid ❑ gaseous ❑
❑ Main hazard: ❑ explosive ❑ burnable ❑ toxic ❑ corrosive
❑ radioactive ❑ hazardous for water ❑ hazardous for air ❑ ____
❑ Other chemicals involved in incident:
their main hazard: ____
❑ Potential, visible effects on humans, animals and plants:
____
❑ Weather: ____
Wind direction: ____ ____ speed of wind: ____ km/h
❑ Ignition sources nearby (railway, cars, current transmissions): ____
❑ Water bodies in the endangered area (WWTP-dikes):

Consideration of the hazard

❑ Hazard for the emergency team: ____
❑ Hazard for the public: ____
❑ Danger for: ❑ Animals/Plants ❑ Ground water ❑ bottom water
❑ WWTP-dikes ❑ ____ ❑ ____
❑ Risk of asserts: ____

Checklist for Chemical Science Officers 2 / 2

❑ Actual status ❑ Who has to give an answer?: ____

Actions

Actions have to be checked and adjusted continuously!
❑ Barrier necessary:
❑ Measuring of air pollution necessary: ____
❑ Security of task force
❑ available protective equipment adequate
❑ additional hand and face cover necessary
❑ inhalation protection necessary for
❑ Overall protection necessary for ____
❑ Filter mask necessary for ____
❑ Protection of inhabitants
❑ no special actions required
❑ warning for the following areas:
❑ Apply for evacuation of the following areas: ____
❑ **Message** to ❑ police ❑ local authorities ❑ ____
❑ **First Aid** for injured persons based on leaflet
❑ leaflet given to the medical persons/doctor
❑ **Extinguishing agent** for fire safe:
❑ Adequate extinguishing agent: ____
❑ Inadequate extinguishing agent: ____
❑ Adequate **adhesive agent**:
❑ Adequate **neutralisation agent**: ____
❑ **Resistance to chemicals** (x = adequate; O = inadequate):
❑ Pump: ❑ Tubes: ❑ Collectors:
❑ Other material used: ____
❑ **Deactivate Chemical**:
❑ at injured people:
❑ at stuff of fire brigade: ____
❑ used material:
❑ soil: ____
Recommendation actions and disposition of contaminated soil, only admittance of authorities
❑ Interim storage of damaged material: ____
❑ Disposal of damaged material: ____

Fig. 3. Checklists for chemical science officers

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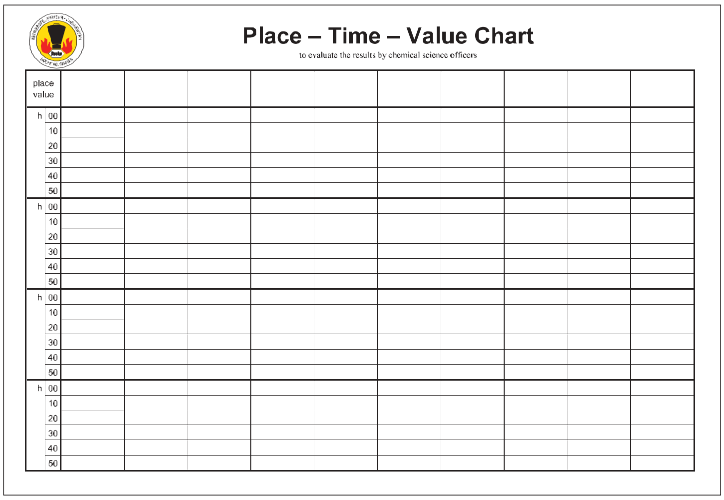

Fig. 4. Place – Time – Value chart

determined where the escaped material would go if it started raining. It was accepted that the small amount of substance could be washed away into the local sewage water system.

3.2. *Decontamination and Zoning*

As the first priority environmentally hazardous substances should be prevented from dispersing. For safe operation, zoning has to be defined [12].

At the exit of the central zone, decontamination will be conducted based on the advice of the chemical science officer. In most cases water with defined additives is adequate. Normally a solution of 1% is prepared for the following:

- tensides for lipophilic substances and hydrocarbons;
- sodium hydrogen carbonate for acids;
- citric acid for bases;
- Sodium thiosulfate for oxidative substances such as chlorine or bromine.

A very good method to stop the decomposition of nitric acid is the reaction with urea (7 kg of urea/1000 l; $H_2N\text{-}CO\text{-}NH_2 + 2\ HNO_3 \rightarrow CO_2 + 2\ N_2 + 3\ H_2O + O_2$).

In some cases polyethylenglycol or Previn® [13] could be used to clean contaminated persons before they are transported for medical treatment.

3.3. *Hazard Potential of Transportation with Liquid Pressurized Gases*

Near a city a tank wagon with 20 t of liquified ammonia derailed. No ammonia leak was detected. The initial shock of the accident wore off. Measurements and actions could be decided and prepared without time pressure. The chemical science officer calculated the spread of ammonia based on 'Technischer Behelf für den Schutz bei C-Ereignissen' (MET) [5]. Tables such 'Maximalen Arbeitsplatzkonzentrationen' (MAK) [14], 'Immediately Dangerous to Life or Health concentrations' (IDLH) [15], 'Emergency Response Planning Guidelines' (ERPG) [16] and 'Temporary Emergency Exposure Limits' (TEEL) [17] are helpful to the operational group.

Definition of Emergency Response Planning Guidelines (ERPGs) [16]:

ERPG-1: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 h without experiencing or developing life-threatening health effects.

Definition of Temporary Emergency Exposure Limits (TEELs) [17]:

TEEL-0: The threshold concentration below which most people will experience no appreciable risk of health effects.

The definitions of TEEL-1 to TEEL-3 are equal to ERPG-1 to ERPG-3. TEEL-values are calculated ERPGs of a variety of functions of toxicities data *e.g.* LD, LC.

Today the ERPG-values [16] are available for basic chemicals but are only rarely used. They have the advantage of giving limits for short-time exposure where the majority of inhabitants could suffer for at least 1 h. They are devised in categories as 'mild transient adverse health effects or perceiving a clearly defined objectionable odor' or 'experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action' or worst 'experiencing or developing life-threatening health effects'.

The extent of the leakage and the underlying soil are the most important factors for the dispersion of harmful substances at the beginning [18]. The weather plays an important role for concentrations in the area surrounding the accident. Sunlight, rain, turbulent wind or calm have great influence on the size of the endangered areas. Stable wind directions at night with grate dispensing and high concentrations are problematic. For commerce reasons a tank-to-tank transfer at night might be better because traffic can be stopped completely.

In case of a release theoretical propagation calculations [5] would have been checked against the results by the chemical analysis group. These results should be filled in a place-time-value chart (Fig. 4) to have a quick overview of the current situation and predictions on how the gas will propagate. The risk for the population during tank-to-tank transfer was assessed by the response team and the police in order to make a decision for a further shut off or an evacuation.

In the chaotic start of an accident, theoretical calculations such as pool evaporation are impossible. Tables were used to evaluate the amount of the spill (Fig. 5 and 6 [19]).

3.4. *The Most Probable Accident Involving Hazardous Goods: Transport of Fuel and Combustibles*

The hectic traffic situations cause accidents again and again. Based on hazardous material transportation statistics, accidents involving hazardous materials are seldom. The probability of accidents with fuel and combustibles is higher.

One morning with fog, low visibility and white frost, a tank truck with fuel (UN 1203) turned over at the inflow to a motorway so that the fuel leaked out of the bottom side. Concerns about the explosion hazard led to a road block of 15 km in both directions. The leak could not be stopped. Most of the fuel ran through a separate sewer water system to a retention basin.

The emission of odor was low because of the weather conditions. More than one chemical analysis group controlled the explosion hazard online by using an alarm value of 20% of the lower explosion limit on different sites. Specific canals and shafts were measured. The possible escape of fuel from a dike received intensive attention. For safety reasons the overrun was coated with adhesive agent.

In a risk analysis and under time pressure it had to be considered whether a transmission line near the accident should be switched off. Based on weather data and the incident it was decided not to switch it off. But it was possible to take this action quickly if necessary.

The highway could be reopened step by step with the cleanup. A flushing of the sewer water system was proposed for the next day.

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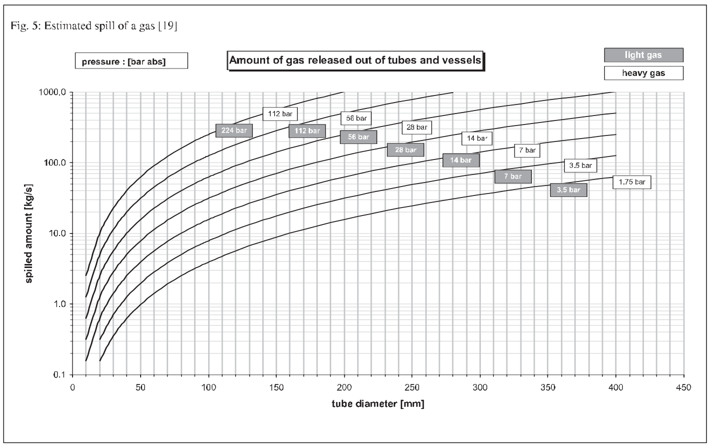

Fig. 5. Estimated spill of a gas [19]

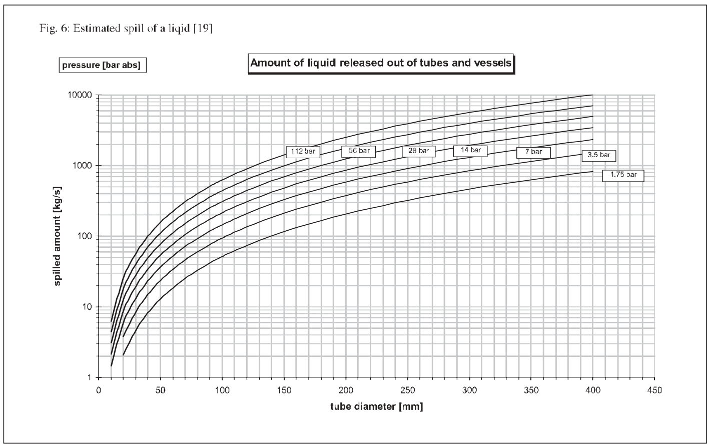

Fig. 6. Estimated spill of a liquid [19]T

The complex deployment required a constructive partnership between the operational crew, police, chemical hazard crew, chemical science officer, authorities, chemical analysis teams, road-maintenance crew and the electric power company. There is a possibility to estimate the amount spilled by using Fig. 6 [19].

3.5. *Chemistry in Farming*

In daily life chemicals are present all the time without being recognized as hazardous. Economic farming depends very often on hazardous chemicals such as fertilizers or pesticides. The knowledge of processes in farming is also important for the chemical science officer. A simple fire of a storage room with fertilizers at a farm can require the presence of a chemical science officer. Support about the physical and toxic properties of nitric gases or about the absorption of the fire water are typical questions chemical science officers have to answer. In order to ensure adequate disposal, he gives advice about the retention of extinguishing water, the handling of residuals, and the handling of nitric gases.

The chemicals added to storage grass in big silos together with high ambient temperature can cause critical conditions. Wet grass with these added chemicals forms nitrous gases. The boiling point of nitrogen dioxide (21 °C) allows a lake to be formed of this hazardous chemical. The nitrogen dioxide has to be vented and absorbed by more than one water gun. The chemical analyzing team has the duty to monitor the disposal and guarantee the MAK limits [14], IDLH [15] or ERPG values [16]. Housing and weather conditions, temperature, humidity, sun shine, wind, *etc*., all have to be considered [20].

4. Conclusions

Chemical substances are common in everyday life. They have to be stored and shipped between different locations. Accidents can happen not only during production, transport, storage but also during application. Therefore it is important to be prepared for such accidents at all times and under all circumstances. Chemical fire brigades with chemical resistant material and the know how of chemical science officers guarantee that the negative effects of incidents with hazardous materials are kept at low level.

Acknowledgements

We would like to thank Dr. W. Jucker, Roche AG, Sisseln, Mr. M. Schmid, Section Environmental in the Building Department of Canton Aargau, Mr. H. Schwab, Swiss National Railways, K. Gimmel 'Emergency management', Lonza AG, Visp, and Mrs. C. Comerci, F. Hoffmann-La Roche, Ltd., for the assistance with this article.

Received: November 19, 2004

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