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# Terminal report*

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# REPORT

## First IUPAC Workshop on Safety in Chemical Production

### I. Principles of safety assessment and risk reduction.

1. The International Union of Pure and Applied Chemistry was formed in 1919.It is a voluntary non-governmental association of organizations and has 43 National Adhering Organizations (NAO).It has links with 177 Company Associates in over 20 countries.Chemical Industry throughout the world is closely involved in the work of IUPAC through its committee on Chemistry and Industry (COCI).

2. In his welcome address,D.Wyrch,chairman COCI, IUPAC, mentioned that this was the first workshop on safety in chemical production organized by IUPAC.He mentioned that Industry and Universities were equally represented in the workshop.There were also a few representatives from the government and a fair representation from the developing countries.

3. Mr.J.P.Geanin.President IUPAC,emphasized the importance of technology as a global issue and refered to the international program on Global Changes.In the ultimate analysis most human activities have some impact,including impact on environment.Safety in chemical production is an important ascpect and risks have to be reduced to the lowest possible level.He stressed the importance of the educational aspects in ensuring safety.Mr.E.Keller, Minister of Basel Government, welcomed all the participants and highlighted the importance of the interactions between the chemical industry and the community.

4. The first day, Monday September 10, was dedicated to the presentation of light papers dealing with:

-principles of safety assessment and risk reduction
-safety measures
-risk issues

5. The papers attempted a survey of latest experience in the field of risk management in the chemical industry, as well as in the related industries, such as petrochemistry and crude oil processing.

The origin of the hazard problem which arises not only in the manufacture of chemicals, but also in their transport, storage and usage is the inherent hazard potential hidden within a substance.

Hazard can exist almost anywhere and the avoidance of accidents and their injurious consequences can only be achieved by taking steps to minimise the risk.

Risk management combines the probability of occurence of an injurious event with its consequences and uses the resultant parameters as an aid in the optimization of the use of resources to reduce the probability of the event.

6. There are four principal steps in the process of dealing with risks:

a. Identifying the dangers to people (individual risk or group risk), or to the environment.
b. Quantifying the extent of these dangers.
c. Determination of the acceptability of the risk.
d. Risk reduction measures.

In evaluating hazards it is obvious to consider hazardous properties of chemical substances.such as: thermal stability,flammability dispersability,explosivity,toxicity (including ecotoxicity).

7. The hazard potential of a substance does not make it hazardous per se.For a hazardous situation to occur a triggering mechanism must also be present.

The flammability triangle has been used for many years to show that the essentials to ingnition and continued combustion consist of the presence of:

-fuel (vapour)

-air (oxygen)

-source of ignition

In using the fire triangle to show the necessity of fighting fires,or preventing occurence of fires,two sides of the triangle are to be dealt with.In fire prevention,ignition temperature or source is important but in fire extinguishing nothing can be done unless there is removal of (or reduction of ) fuel and/or air.

8. In contrast to stationary combustion (burning).for an explosion.an independent propagation of the reaction zone (flame) through the free volume with the reactive mixture is essential.

In this context the combustion properties of a chemical substance are very important,properties such as:flash point,explosion limits and burning index B.Z. (explosion velocity).

Hazard identification starts from basic safety data of the materials:flammability,explosibility and toxicity.Data characterizing these properties are established through tests.

9. Hazard identification consists also of establishing the various ways in which a chemical process can reach a dangerous state. Therefore, proper hazard identification must be based on knowledge of the properties of the materials, process flowsheets, process parameters and plant design characteristics.

Identification of hazard should be analysed not only in normal operation, but especially in deviations caused by disturbances, interruptions in the energy supply, raw materials and should also include start-up, shut-down and maintenance procedures.

10. Once the hazard is identified, the next step in risk assessment is to quantify the risk associated with each hazard. Certainly, this is one of the most difficult steps.

In principle, this can be accomplished by determining two parameters:

-the annual frquencies of an event

-the corresponding severity of the accident

The product of these two parameters for any hazard is a measure of the annual risk:

| [Risk] = | [Frequency] * | [Severity] |
|---|---|---|
| (expected loss/year) | (expected no. of events per year) | (average loss per event) |

Risk quantification by means of the expression above needs a calssification of previous emergency accidents in order to establish the corresponding annual losses and, therefore, to estimate the average annual losses (or severity) for each event separately and to pre-establish the frequency of emergency, that is of the probable number of accidents.

Such estimation can be done only on the basis of existing data stored during the operation years of plants,making the object of the study on similar plants.

11. In order to reduce the risk two main approaches are possible:reduction of severity and reduction of probability.Both are equivalent only from an insurance point of view,but from a technical point of view the two dimensions of risk are quite different.

Often the level of concern that a company has for some types of accidents is greater for other types of accidents.For example,a company may be willing to spend resources to reduce the high-consequence accidents (low frequency-high severity) while they may not be willing to spend more to prevent nuisance type accidents (high frequency-low severity) even if the absolute risk associated with the two types of accidents is the same.

Many technical safety measures aim also at reducing the consequences but without reducing or eliminating the cause or potential in explosion protection.This type of consequence reduction often requires constant attention and maintenance in order to keep it effective.

12. In the presentation on appraisal, perception, tolerence standardship of chemical production risks, importance of integration of the scientific and educational aspects with the societal factors was emphasized.Often,factors relating to human exposure were not adequately dealt with in risk assessment.Risk was defined as a compound estimate of likelyhood and

severity of harm and delineated three separate modes of analysis and action:

a. Risk Assessment (description of the likelyhood and severity of threat)

b. Risk Appraisal (evaluation of the personal or societal burden + costs - benefits for protection)

c. Risk Response

There was need to educate the workers and the general public and share information. Industry and the Community need not and should not work at cross purposes, if there was a mutual appreciation of respective roles. There was need to assure the society that while it was unfeasible to have a zero risk chemical process, all the possible precautions had been taken and it was worthwhile to take the residual risk, however small in magnitude it may be. Social justification of chemical production must concentrate on minimising risks to the lowest feasible levels "so as to ascertain the societal benefits".

A number of recent initiatives had been taken for creating community awareness of risks associated with chemical processes like the National Industry Programme in USA on Community Awareness and Emergency Responses (CAER).

There were also international programmes for developing Awareness for Emergency Preparedness like that developed by UNEP. The emphasis should be on sharing information on risks with at least the Proximate Community and create understanding so that there is agreed resolution of technologically controversial issues.

## II. Detailed Case Studies

13. Second day,Tuesday,September 11,was dedicated to detailed case studies,including visits to modern chemical plants,in 16 small groups with mentors from industry covering the following subjects: hydrobromic acid treatment of a diethyl malonate derivative (1),catalytic hydrogenation (2),nitration (3),marine-blue (4),nitration of 2 methyl-5,6-nitro 1,3-benzoxazol (5),catalytic hydrogenation of 2,4-dinitrochlorobenzene (6),dimerization of orthonitrotoluene (7),sulphonation of nitro-aromatic compound (8),multipurpose grinding (9),explosion protection in a grinding unit (10), explosion protection of a spray drier in combination with a fluid bed drier (11),fluid bed drier in pharmaceutical production (12),waste water drains (13),risk analysis of a high rack warehouse (14),chemical exhaust-air cleaning unit (15) and occupational hygiene (16).

The main problems and issues discussed in these groups were: Zurich - Hazard analysis;handling of a strong acid,hydrogen and catalyst;thermal stability of an exothermic reaction,reaction mixture;explosion prevention and limitation in the case of multipurpose grinding,fluid bed drier in pharmaceutical production; spray drier in combination with a fluid bed drier and occupational hygiene.These were very important for all the participants.

The UNIDO delegates actively contributed to these discussions by constructive comments relating to the problems faced in their respective countries.

14. The object of the study in group 14 was the application of "Zurich Hazard Analysis" in a rack

warehouse belonging to SANDOZ with a high degree of mechanization and automation for the storage of chemical raw materials,intermediates and finished product.

The SANDOZ Central Warehouse located near Muttenz has the following overall dimensions:length 150m,width 127m,height 32m,interior space 480.000cu.m.with a total storaging capacity of 49,000 pallets and has been operational since 1971.All conveying equipment of the system is controlled by a Siemens R30 process control computer.which also continuously updates the inventory.After the product data is entered by a page printer,the pallets are translated to the receiving compartments.All further removal and transport of the goods to and from their place of storage is fully automated.

The Zurich method of hazard analysis has been successfully used over many years for any application. It starts by systematically identifying the hazards their triggering mechanism and their associated effects.This information is entered in the hazard catalogue (hazard identification and hazard assessment) where the hazards are consecutively numbered.The hazard catalogue is typically completed by assessing each hazard as to its comparative probability of occurence and its comparative severity.

Hazard catalogue provides the following six hazard cause levels:A.Frequent: B.Moderate: C.Occasional: D.Remote: E. Unlikely and F.Impossible.

The risk profile serves as an important tool in risk assessment management where the sought protection level and then the consecutively numbered hazards can be entered.

There are four hazard effect categories used by Zurich Hazard Analysis,namely: I-Catastrophic: II-Critical: III-Marginal and IV-Negligible.

These data available,risk reduction can be initiated.The risk reduction catalogue lists the measures teken and follows clear priorities given by the risk profile while the sequence is guided by long established system safety considerations adopted by the specialists of many Western countries.

The bookeeping of the corrective actions is done by means of a risk reduction catalogue where all actions taken and their respective improvements achieved are kept visible.

15. Health Protection in Chemical Industry (Group 16)

This case study highlighted the scope of Industrial Hygiene beginning with the recognition of health problems created within the chemical industry. The frequent causes of these problems are:a-chemical: b-physical energy,noise+vibration:c-biological and ergonomic.All these stresses have to be evaluated in terms of their danger to life and health as well as their effect on body functions.

The second aspect of the scope of industrial hygiene related to evaluation of the "work atmosphere" in terms of short-term and long-term health effects.Finally,industrial hygene also included development of corrective measures to eliminate occupational health problems.

The case study highlighted the importance of air sampling for exposure control in a plant,manufacturing dye intermediates.Three different methods of sampling are possible.viz. (a) Air Monitoring, (b) Biological Monitoring and (c) Medical Monitoring.The term "exposure limit" was first included in the Work Environment Convention adopted by ILO in 1977.The concept of Maximum Allowable Concentrations (MAK) was discussed in detail particularly in the context of Threshold Limit Values (TLV) and the obectives of monitoring strategy.These objectives were first to determine the compliance status at the start of the monitoring programme and the second to regularly check changes in exposure conditions.These objectives are achieved by using Occupational Exposure Analysis (OE - Analysis) and the Occupational Exposure Monitoring (OE - Monitoring) programme.The former is implemented by:

a.Chemical Inventory Preparation

b.Hazard Assessment

c.Complain Assessment

d.Prescription of Measurement Protocol OEC (Occupational Exposure Concentration) Determination.

The monitoring procedure in SANDOZ was discussed in detail.In all cases of using a new Hazardous Substances where OEC > 1 MAK,corrective action was to be taken before using the substance.Where OEC >=0.25 follow-up measurement was taken to ensure that corrective action was taken to bring OEC < 0.25 MAK.

In the plant itself which was nearly 40 years old,it was noted that there were four problem areas where air monitoring was done,viz. (I) solvent distribution area:(II) sample taking from Reaction Vessel:(III) sample taking from the two pressure filters.The equipment used in air monitoring were shown and their use discussed in detail.The need for discipline in using such equipments was emphasized.

## III. Panel Discussions

The program of day 3,Wednesday,September 12 was devoted to the evaluation of present day Safety Education in Universities, Engineering schools as well as Industries in various countries of the world,with a special focus on the situation in the developing countries,during the panel discussions on these issues. Under the guidance of experts from Universities and Industries,different alternatives in structuring programmes on Safety in Universities as well as industries were presented.

This was followed by panel discussions of nine different issues covered by the workshop:Safety education in Universities (1),Safety education in Industry (2),Future priorities in IUPAC activities on Safety in chemical production (3),Powder explosion protection (4),Static electricity (5),Thermal analysis (6),Industrial hygiene (7),Hazard analysis (8) and Inertisation (9).Case studies presented in panels 4 to 9 were distributed in advance to all participants of IUPAC - Workshop Safety.These case studies can be used as illustrations while conducting courses in safety.

### 17. Panel 1. Safety Education at the University

Until a few years ago there was a gap between the perception of Safety by Universities and by the Industry.In fact,there was hardly any instruction material available.The University curriculum was already overloaded and the faculty also did not have any particular expertise on the subject.

In the matter of safety education the interpretation of safety should not be too narrow.It would be desirable to include technical,legal and ethical aspects in the syllabus.There should be a realisation that engineers would be legally responsible in the future for accidents.Since special courses in Chemical Safety may have little student appeal,it may be necessary to combine safety and environment protection as a discipline.What was necessary above all was to ensure student motivation.

Chemical Industry should unequivocally support safety education programs at the Universities,since accidents are "cheaper" to avoid than to "face" (the consequences) and also because Safety and Environment Protection are achievable by the same means.

18. Panel 2. Safety Education in Industry

As there are many differences in culture, legislation, social-economic economic conditions from country to country, it would be very useful to promote training at national level and also to promote international understanding on safety policy.

The training methodology must be such as to evoke interest through demonstrations and there should be constant re-analysis of the needs and the methods so as to take care of new developments in technology and legislative requirements.

The panel recognized the usefulness of obtaining papers on framework for safety world wide.

19. Panel 3. Future Priorities in IUPAC Activities on Safety in Chemical Production

The Panel suggested the following line of action:

a. Next workshop on the subject to be held in Japan or USA. Subsequently, such workshop could also be held in a developing country. The workshop would focus on:

-automation

-computer assistance

-hygiene factors

-waste water/air treatment

-storage of chemicals

Decision in this regard would be taken by the end of September 1990 by the Committee on Chemical Industry of IUPAC.

b. Framing of IUPAC guidelines for model lectures in universities and for industry, on safety requirement in chemical production, without restricting entrepreneurial freedom.

c. Creation of Centers for Safety Education in collaboration with UNIDO and other appropriate International Agencies.

d. Workshop on Safety in Production of Biotechnology (which would be further discussed in September 1990).

20. Panel 4. Powder Explosion Protection

The case study for this panel showed how hazard assessment can be applied to determine whether a dust explosion hazard exists in a given industrial plant.

A distinction has to be made between:

-preventive measures which exclude possibilities of occurence of explosion by prevention or by limiting the formation of explosive atmospheres,and

-design measures which will limit the effects of explosions by specific devices.

Explosion protection by design measures is always required whenever the goal of avoiding explosions through the application of preventive measures cannot be reached with an adequate safety margin.

The gap in knowledge existing now between industry and university regarding powder explosion protection must be reduced.

21.Panel 5. Static Electricity

This panel perceives a gap between theory and practical applications and felt that the case studies should serve as an aid for the assimilation of guidelines and measures which should be applied to prevent ignition hazards due to static electricity industry.All the cases presented were based on real incidents that occured in production facilities.

In connection with static electricity many participants felt that technical information on the subject was necessary not only for chemical engineers but also for other specialities.viz. mechanical engineers, civil engineers, electrical engineers.

22.Panel 6. Thermal Analysis

The case study deals with technical and safety Study of synthesis,highly exothermic in mass phase which is stable only within a very limited temperature.It analyses thermal stability of the reaction,heat transfer and reaction optimization in batch/semi-batch conditions.The panel emphasized the need to use thermal data for safety and optimization of process conditions.

23.Panel 7. Industrial Hygiene

In the overall context of safety,occupational hygiene is a science of utmost importanece but it is not sufficiently developed.Occupational hygiene is the discipline of anticipating,recognizing,evaluating and controlling health hazards in the working environment with the objectives of protecting worker's health and well-being and safeguarding the community at large.

The role of occupational hygiene in the process of risk assessment and in the field of risk management is determining and essential in the chemical industry because the majority of the hazards are of chemical nature and concern the problems specific to that science.

Three methods come into consideration for the evaluation of risk assessment in Occupational Hygiene:

a.Ambient monitoring - to evaluate ambient exposure and health risk compared to our appropriate reference.

b.Biological monitoring - represents the measurement of work place agents,or their metabolism in tissues,expired air or in any combination.

c.Health surveillance - means periodical medico-physiological examination of exposed workers,with the objective of protecting health and preventing occupationally related desease.

The panel felt the need for joint effort and multi-disciplinary approach.For this purpose these should be support for International efforts already taken up by other organizations like EEC.WHO.ILO etc..

24.Panel 8. Hazard Analysis

This case study is intended to provide an introduction for selecting a worst-case accident for determining the different steps resulting from an accident,to develop simple models and to make a first order estimate on possible dangerous consequences.There was a consensus about the need for IUPAC to transfer knowledge from developed countries to developing countries in safety hazard analysis and also in safety education.There was also need for integration of Hazard Analysis into teaching programmes.High prority is to be given to teaching methodology followed by presentation of real cases and computer modelling.There should be special courses for specialists,some of them being conducted by participating experts.It was also felt that Technical Managers should be periodically required to deal with existing safety problems by using safety control techniques.

25.Panel 9. Inertisation

The explosion risks which are linked to the utilization of flammable solvents and explosive dusts made the subject of this panel discussions.One of the most effective protection measures is the so called Inertisation,which means the displacement of oxygen (or air) by inert gas so as to make an explosion impossible to happen.

The goal of inertisation is to get a high degree of safety in production without using a large quantity of inert gas.Application of this technique requires theoretical knowledge about fluids mechanics.combustion and gas-dusty mixtures properties and of course,some practical experience.

Even though this safety measure is widely used in industrial practice there do not exist appropriate courses at technical Universities.

## IV. Safety Issues in Developing Countries

26. Safety issues in Developing countries

The Chairman of the Final Panel discussions also invited the UNIDO consultant from India who had circualted a paper on Safety Framework in Developing Countries to highlight the perceptions of the developing countries.It was emphasized in this presentation that while an appropriate Legislative System,based on the felt need of the country could be framed and suitable administrative framework integrated with such a legislative system,the need to build up the required institutional expertise for effectively controlling hazards posed considerable difficulties. Therefore,the developing countries required facilities for adequately creating and building up such safety expertise to meet the challenges of new technologies.

In this context the following suggestions were made for IUPAC to consider:

1. A system should be created for Information Storage and Exchange,relating to chemical accidents, safety technology and equipments.

2. Institutionalise Hazard Analysis/Safety Training arrangements,particularly for Small and Medium Industry Managers,on regional basis through collaboration with UNIDO.

3. Frame guidelines for Safety, including Safety in Transfer of Technology arrangements.

4. Evolve mutual industry assistance network channelised through individual IUPAC associated companies in developing countries.

5. Hold more workshops on various aspects of Safety in Chemical Production.

## V. Views of UNIDO Participants

27. Views of UNIDO Participants

UNIDO had nominated eight participants from eight developing countries. These countries were China, Indonesia, Philippines, Thailand, Zimbabwe, Egypt, Columbia and Mexico. All these participants felt that the workshop was extremely relevant and had provided them with a good insight with respect to risk analysis techniques and safety issues in the Chemical Industry. Some of the participants felt that it would also have been interesting if problems faced by the developing countries could have been covered in the workshop, so that the need for cooperation between developed and developing countries could be fully appreciated. It was also urged that more case studies relating to actual accidents in the Chemical Industry could have been discussed.

All these participants emphasized the need to improve safety conditions in the Chemical Industry in their respective countries and unequivocally urged the need for IUPAC/UNIDO to take interest in this regard. For this purpose, the following suggestions were made by them:

a. UNIDO/IUPAC should assist developing countries to improve safety in Chemical Production, particularly by improving the expertise in these countries for Risk Analysis and Hazard Control.

b. This assistance could be in the form of a Global Project or through the Regional Network System, as developed in the case of the RENPAP project, with programmes on Safety relating to training and exchange of Information.

Particular stress was laid on creation of an Information System to facilitate storage and exchange of information relating to accidents, safety equipments, methodologies and techniques of risk assessment and the educational facilities available in Technical Institutes and Universities in this regard. Many participants expressed willingness to act as nodal points, particularly within their region and offered organizational and other input support, either in kind or in local currency.

## VI. Conclusions

1. The first IUPAC Workshop on Safety in Chemical Production reflected a high level of excellence in scientific, technical and educational aspects involved.

2. The workshop focussed on the present status of Hazard Analysis and safety in Chemical Industry through (a) presentation by experts both from the Industry and the University, (b) analysis of case studies and (c) panel discussions.

3. The workshop provided a good forum for exchange of knowledge between University and Industry and helped in bridging the gulf between theory and practice.

4. It highlighted the fact that there was considerable room for further developing expertise and knowledge on safety in Chemical Industry, particularly with reference to the needs of developing countries.

5. In view of the position emerging as mentioned above, there was consensus that conclusions reached require to be followed up with another workshop on safety, the details of which would be finalised by COCI in September 1990 in Paris.