ANNEX I. List of Participants in the WHO Consultation on

"HAZARD PREVENTION AND CONTROL IN THE WORK ENVIRONMENT: *AIRBORNE DUST*"

World Health Organization, Geneva

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ANNEX II. Knowledge Gaps and Recommendations for Future Research

II.1 Background

Dust control has been the subject of wide-ranging research since the early 1900s, and there is an extensive literature in the form of books, manuals, journal articles and, more recently, electronic media such as CD-ROMs and the World-Wide-Web (see Chapter 11). Much of the available literature is scattered, appearing very often in engineering journals, rarely read by occupational hygienists.

Meanwhile occupational hygiene literature often emphasizes exposure assessment and health effects, at the expense of prevention and control issues. One reason is that practitioners who develop innovative solutions to control problems often receive no incentive from their employers and little career advantage in publishing them. Partly as a result of this (it has been argued), the range of technical control options currently available to us is rooted in science which comes from the 1950s and earlier! But since this time, occupational hygiene itself has moved to the point where a structured multidisciplinary and broad-based approach to dust control problems can be identified, covering strategic, technical and managerial issues.

With the preceding in mind, participants in the WHO Consultation (July 1998) proposed some guiding principles and new approaches for future research in this field. The following aspects should be emphasized:

- Control at the source, through adequate design of equipment and work processes; consideration of control measures as an integral part of any system, and not as an afterthought.

- Design of controls with the worker in mind (man-machine interface), having work practices, maintenance, hazard communication, education and training as essential considerations. (If maintenance is ergonomically difficult, control performance will deteriorate.)
- Design of control measures which are economically feasible and which also aim at conserving raw materials and other natural resources.

- Design of controls for low/no maintenance.

- Replacement of “end of pipe” solutions by source control, of expensive solutions by low-cost solutions, and of isolated solutions by an integrated approach to control.

Research on control measures needs to be interdisciplinary and should integrate all substance, machine and human aspects, also taking into account possible environmental impacts. There is a need for a holistic approach whenever considering hazard prevention and control.

II.2 Research topics

A. Control strategy and development

1. Quantitative models relating exposure to process parameters. Research in this area will help evaluate the reliability and economics of process changes under consideration to improve control, as well as provide guidance on the collection of the information necessary for field studies on exposure.

2. Economics and control strategies. What are the different engineering alternatives for minimizing hazards and what are the costs? How do we compare the economics of prevention to the economics of control?

3. Use of video exposure monitoring, computational fluid dynamics and other tools to investigate the behaviour of control systems. Use of visualization techniques to establish adequate work practices, to educate workers and to modify any unsafe behaviour.

4. Following from number 3., improvement of generic approaches to process-specific and engineering controls for a variety of common exposure scenarios, such as powder weighing and coating.

B. Exposure minimization

1. Fundamentals of dust generation by solids. How physical form of solid (granules, flakes,

slurries, powder, size distribution etc.) affects aerosol generation, and how this can be applied at, for example, conveyor transfer points, in de-dusting treatments, and in more effective use of sprays. What throughput of material gives the least dust per kg of throughput?

2. Performance of seals and fittings on process equipment to minimize leakage

3. Application of Process Safety Management review techniques to the control of worker exposure. (In reviewing the design of equipment to prevent catastrophic losses, elaborate review processes have been devised. Perhaps, the same sort of review can be devised for contaminant generation so that designers are encouraged to think about process choices which affect generation rates and occupational exposure. Before process changes are made, occupational safety and health professionals need to know how to conduct a hazard assessment which is predictive of exposure and how to conduct a technical options analysis so that process options are selected which truly minimize workers' exposure.)

4. Evaluation, with prospective studies, of the effect of hazard prevention and minimization efforts upon worker's exposure and cost. These are principally pre- and post-control implementation studies.

5. Relationships between process disruption and exposure.

C. Control measures development

1 Application of Computational Fluid Dynamics (CFD) to the design of local exhaust ventilation systems. This could be used as a part of an effort to develop mathematical models of workplaces, to predict the effect of workplace changes upon exposure. CFD models should be developed for various scenarios in the laboratory and then "field calibrated" for actual processes. Limitations of this analytical technique must also be identified and addressed.

2 The use of microprocessor-based process controllers that, in principle, could incorporate sensors and basic decision-making for the operation of ventilation systems and other controls.

3 Recirculation. Evaluation of the safety and health implications of air cleaner performance.

4 Resource Conservation. Evaluate the benefits (conservation of energy, environment, economics) of various engineering control technologies. This must address the economics of resource conservation.

D. Management issues

1 Research into the effectiveness of various management systems at improving use of control measures, systems and procedures; including, for example, performance indicators for plant managers, incentive schemes for staff, and integration of workplace environment measures into product quality schemes.

2. Development of training programmes for occupational hygienists to provide an adequate level of understanding on managerial processes, aims and constraints.

3 Work by professional bodies and occupational hygiene educators with other educators to integrate occupational hygiene and safety into other curricula, in fields such as management, chemical and production engineering, emphasising removal of hazard at source by design.

E. Respirator issues

1. Relationship between anthropometric measurements and respirator fit should be more fully investigated, over the full range of ethnic types.

2. Development of respirators that perform better under workplace conditions, so that they reproduce there the performance they achieve in the laboratory.

II.3 Communication and professional incentives

1. Professional societies should encourage publication of control solutions and case studies by:

(1)giving strong incentive through their continuing professional development schemes to the publication of control solutions and case studies by their members, and,

(2) seeking industrial sponsorship for periodic awards for control solutions by occupational hygienists.

2. Occupational hygiene journals should commission reviews of developments in prevention and control methods, their application and management, so that what is available becomes more widely known.

3. Educational institutions should collaborate with trade and industry associations in presenting seminars and short courses on prevention and control issues.

ANNEX III. The Production Process as Hazard Source for Control Purposes[9]

III.1. Process

A systematic approach to control solutions requires a classification of processes or activities from which hazards may arise. The classification herein proposed is derived from *a descriptive analysis of the structure of a production process* - a design analysis which provides answers basically to the following questions: what has to be produced? by which method?

The material flow of the production process is used, as a point of reference, to investigate the possibility that another method, hopefully less hazardous, can be used to achieve the same production results (Kroonenberg and Siers, 1983; Eekels, 1987; Swuste et al., 1993). According to design analysis, a production process comprises three levels, namely production function, production principle and production form, which are interrelated and organized hierarchically (Table III-1).

Table III-1 Design analysis

what:	PRODUCTION FUNCTION
	core activity
how:	PRODUCTION PRINCIPLE
	general process
	energy source

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fax: +31 15 262 2235; e-mail: Paul.Swuste@wtm.tudelft.nl operational control methods

by use of: PRODUCTION FORM

detailed design, machines

preventive measures

The *production function* is the highest level and divides the production process into its core activities.

The *production principle,* the second in order, specifies the general process (e.g. bulk feed through pipes vs. sacks opened and poured into the process), motive power (energy source) and operational control methods by which the function is, or can be achieved.

The motive power relates to the energy source utilized. The operational control methods determine the distance of the worker from the exposure source, and can be classified as: direct manual, direct mechanically driven, and indirect (remote controlled or automated method). For the manual and mechanically driven operations, the worker is close to the machine or equipment. The remote controlled and automated operations increase the distance between the machine and the operator, but not for maintenance workers.

The lowest level is represented by the *production form, which* determines how the production principle is carried out; it describes the materials, tools and machines in use and the eventual measures applied to prevent accidents or exposure.

The concept of production functions is closely related to the classification introduced in 1936 in the chemical industry, dividing a production process into the so-called unit operations, as is shown in Table III-2 (Badger and McCabe, 1936). The assumption behind unit operations is that, although the number of individual processes is great, each one can be broken down into a series of steps which appear in process after process.

Table III-2 Unit operations

material receipt
material storage
transport and feed
processing
packaging
waste disposal

These operations have common techniques and are based on the same scientific principles. The concept of unit operations is not restricted to the chemical industry, but has been used in industry in general. A classification according to unit operations is helpful and is incorporated in the proposed classification of production processes (Shreve, 1956; Blackadder and Nedderman, 1971; Geankoplis, 1978; Hovinga and Deurloo, 1984; Ghosh and Mallik, 1986).

III.2 Production Functions

In the following sections, the manufacture of products is subdivided into three production functions: processing operations, materials handling and supporting operations. Waste disposal is an operation which contains elements of materials handling and of processing and is linked with both.

Processing operations

Processing includes all activities where materials change their form, state, composition or assembly. It takes place through a whole range of scales from micrograms to tonnes, in unit, batch and mass/bulk production and in departments ranging from laboratories through workshops, canteens, building sites to production departments and automated chemical reactors. A broad classification of sub-functions (Hovinga and Deurloo, 1984; Moore and Kibbey, 1982), is hereby presented, under four headings:

- shaping: changing of shape and/or state with no volume change;
- separating: changing of shape or composition with reduction in volume or division into several parts;
- combining: uniting or coalescing into one body or one substance with increase of mass; and
- surface treatment: influencing the micro-geometric shape and quality of the surface layer.

Handling of materials

Handling of materials - which covers transport, storage and packaging, as well as the processes of feeding materials into, and removing products from, manufacturing processes (Bolz and Hagemann, 1958; Caenegem, 1979), can be sub-divided as follows:

- transport: continuous and discontinuous;
- feeding/emptying: the interface between transport and processing; and
- loading and unloading, storage and packaging: sub-divided according to the physical form of the product.

Supporting operations (e.g. repair and maintenance)

Supporting operations consist of *repair, maintenance*, *replacement* and adjustment, *setting and cleaning.* Under each of these types of operations, alternative means of achieving the same result (or production function) can be grouped together, thus allowing, in principle, a choice to be made between the different alternatives, on the basis of the associated hazards and of the ease with which they could be controlled.

Combining the classifications of hazards and processes provides the basic tool for embarking on risk management.

III.3 From Hazard to Process

For example, in a few branches of industry in the Netherlands, agreements with a view to reducing occupational hazards have been made between social partners. Toxic substances, as well as noise and physical workload, play an important role in these agreements. In general, the approach taken for reducing the emission or exposure to toxic substances has been *substance-oriented.* Therefore, the possibilities of replacing toxic substances with less toxic ones, or of reducing the transmission, or of reducing the exposure, are well documented. For some of these solutions, like local exhaust ventilation systems or personal protective equipment, much commercial information is available. Various formats of material safety data sheets have also been introduced for toxic substances.

However, other *source-oriented* control measures, like adaptations and alterations of production lines, machines and installations, have not yet been sufficiently worked out and have been only briefly mentioned both in the literature and in agreements between stakeholders.

Problems related to occupational accidents or exposure to occupational hazards become manifest at the level of the production form. But the accident or exposure scenarios are determined by the production principle. Expertise in the fields of safety science or occupational hygiene is specifically focused on the production principle. This expertise, possibly complemented with quantitative exposure assessment results, allows the assessment of the types of hazards and the magnitude of the risks related to a certain production principle. In this way, a translation can be made from a given occupational hazard, or to be more precise from an accident or an exposure scenario, to various process indicators.

The above description provides a generic description of the design analysis, particularly in terms of occupational hygiene hazards. An added difficulty arises with new designs when there is no previous experience to indicate the type of associated potential hazards, and of safety hazards likely to arise in unusual situations. In order to find ways of overcoming this problem, an experimental study was undertaken, involving a combination of the design analysis and a safety analysis technique entitled HAZOP (hazard and operability) study. A HAZOP study is a proven and well established technique in the chemical industry for identifying possible process deviations. The technique is applied during plant design or during the design of complex installations, and consists of a systematic search for deviations that may have harmful consequences.

In general, the technique is used during the detailed engineering design of a process or installation, when process flow diagrams (PFD), piping and instrumentation diagrams (P&ID) and operation manuals are prepared. Process flow diagrams depict the major process equipment together with the principal process flows and process controls involved. Normal operating temperatures and pressures, as well as mass flows and compositions of the main flows are indicated. The piping and instrumentation diagram is a schematic representation of all equipment, piping and instrumentation of a plant; this is a basic working document in engineering and construction and serves as the principal reference when operation manuals are prepared.

During the detailed engineering phase, changes in the design are possible, but are limited to possibilities that do not alter the choices made during the phase of the basic engineering design of the process or installation. The results of a HAZOP study usually lead to the introduction of extra devices such as valves, reference points, or other control devices.

In a survey in the Dutch steel industry, a HAZOP study was applied to an installation of steel works, using the basic material flow instead of PFDs and P&IDs (Swuste et al., 1997a). In contrast to classical HAZOP studies, the safety analysis was not used directly to generate design adaptations, but to determine possible accident scenarios. These accident scenarios were evaluated and validated from subsequent incident records. The results of the study showed a high predictive value for the accident scenarios and also identified and indicated directions in which the results of the study could be improved.

The HAZOP technique focuses on the disturbed process flow, and has been proven useful in the generation of accident scenarios. This technique is suitable when studying highly automated and complex installations, such as steel works, where operations are remote-controlled, hence workers do not come into the vicinity of hazard sources during normal conditions (the undisturbed process flow). However, if the process flow is somehow disturbed (e.g., workers have to investigate a failure in the process), the source-worker distance may be appreciably reduced thus introducing safety and occupational risks. Although this study was limited to foreseeing safety hazards (accidents), the same methodology could be used in relation to health hazards, e.g. exposure to toxic materials.

III.4. From Hazards via Process to Solutions

When accident and exposure scenarios per production principle are formulated using the results from the design analysis, the analysis (as used in the described projects) also guides the search for solutions.

The research in the building industry gives an example of solutions following from systematic variations in either production functions or production principles (Swuste et al., 1997b). Here, too, expertise from the fields of safety science and occupational hygiene is used to indicate the consequences of each variation in terms of accident and exposure scenarios, leading to a mutual comparison of different solutions to the same problem.

The comparison of solutions can also include other criteria, such as the costs of the solution, maintenance requirements, training needs for workers, and other criteria, which influence the acceptance of the solution by the different parties within companies. In the study in the building industry, the production principle contains the greatest possibilities of variation leading to solutions.

Changing or eliminating production functions can have even more far reaching consequences. When a certain production function is eliminated, all hazards and risks associated with it automatically disappear. However, there are limited opportunities to change production functions in existing installations or processes.

During the design of an installation, a production line or a plant, the possibilities for modifying the production functions are much more extensive. Both the production function and the production principle are generic descriptions of a production process and can, by their nature, be applied during the phase of basic engineering design, in contrast to the production form (which greatly resembles the stage of PFDs and P&IDs). Basic engineering design is a phase where the design analysis, in combination with expertise from the safety science and occupational hygiene fields and the principles found in the HAZOP technique, can potentially bypass initial support on the expected accident and exposure scenarios and propose different solutions and design variations to eliminate or control them. Instead of applying these techniques during detailed engineering design when change is costly, the consequences of a given design, in terms of accident and exposure scenarios can be predicted in advance during basic engineering design and dealt with long before the actual construction starts.

During a survey in the rubber manufacturing industry, the design analysis was applied to an existing process and technology and showed itself able to subdivide different production processes into comparable parts (Kromhout et al., 1994; Swuste et al., 1993). This division is a necessary step in a study design, which is extended over a whole branch of industry and where the variation in production processes is extensive and dependent on the type of product produced. In the rubber manufacturing industry, the design analysis was not used to generate solutions for observed occupational hazards. The survey was focused on an inventory of existing solutions and control measures. The state of the art of control measures was determined and the effectiveness of these control measures was established. The control measures concerned were local exhaust ventilation, the replacement of powdered and toxic raw materials and the use of personal protective equipment.

The results of this survey were not encouraging. The almost complete absence of source-related solutions, the low efficiency of the solutions applied and the restricted replacement of powdered, toxic raw materials showed a rather ill developed risk management approach in this branch of industry. In a follow-up survey, five years after the original survey, the state of the art on control measures was determined again (Swuste and Kromhout, 1996). The results were more encouraging. A growing number of source-related solutions had been introduced in the companies. To a great extent this was the result of increasing pressure from the Ministry of Social Affairs and Employment and the Factory Inspectorate after the first survey, finally leading to an industrial agreement on working conditions and prevention of occupational hazards between social partners in the rubber manufacturing industry.

The two surveys in the rubber manufacturing industry showed the need for support to companies in the generation of possible solutions and control measures. Solutions are mostly chosen on the basis of available, commercial information, or on the basis of information supplied by a branch organization of the Factory Inspectorate. There is a clear need for information on solutions that have stood the test of experience. This need is not restricted to the rubber manufacturing industry. Recent initiatives have been taken to expand the 'company memory' on prevention to a national and even an international level, using solution databanks. These initiatives have been supported by developments in legal requirements. To ensure the success of these databanks, which potentially can become 'the state of the art of prevention', a classification not only of production processes, but also of hazard generation and solutions needs to be applied to the structure of this databank. These classifications provide the basis for a navigation system by which a user of the databank is guided to preferred solutions. The principles for these classifications have been partly worked out in projects conducted for the Ministry of Social Affairs and Employment of the Netherlands (Swuste et al., 1997c), the European Commission (Hale et al., 1994) and the construction industry.

References for Annex III

Badger W, McCabe W (1936). *Elements of Chemical Engineering*, 2nd edition. Mc-Graw-Hill Book Company, Inc. New York .

Blackadder D, Nedderman R (1971). *A Handbook of Unit Operations*. Academic Press, London.

Bolz H, Hagemann G (1958). *Materials Handling Handbook.* The Ronald Press Company, New York.

Caenegem R van (1979). *Grote Winkler Prins Encyclopedie.* Elsevier, Amsterdam.

Eekels J (1987). *Ontwerpmethodologie: mogelijkheden en grenzen*. (Design methods: possibilities and limits). Technische Universiteit Delft.

Geankoplis G (1978). *Transport processes and unit operations.* Allyn and Bacon, Inc., Boston.

Ghosh A, Mallik AK (1986). *Manufacturing Science.* Ellis Horwood Limited, Chichester.

Hale A, Swuste P, Tijmensen B, Pantry S (1994). *Collection and Dissemination of Information on Solutions for Improving Conditions at the Workplace*. Report European Union, DG V/F/2. Delft University of Technology, The Netherlands.

Hovinga H, Deurloo A (1984). *Vervaardigingstechnieken* (Manufacturing techniques). Diktaat vakgroep Werktuigbouwkunde, Technische Universiteit Delft.

Kroonenberg H van den, Siers F (1983). *Methodisch Ontwerpen* (Design methods). Vakgroep Ontwerp- en Constructieleer, Technische Universiteit Twente, Enschede.

Kromhout H, Swuste P, Boleij J (1994). Empirical modelling of chemical exposure in the rubber manufacturing industry. *Annals of Occupational Hygiene* **38**(1):3-22.

Moore H, Kibbey D (1982). *Manufacturing*. Grid Publication, Columbus, Ohio.

Shreve R (1956). *The Chemical Process Industry*. McGraw-Hill Books Inc., New York.

Swuste P, Kromhout H, Drown D (1993). Prevention and control of chemical exposures in the rubber manufacturing industry in The Netherlands. *Annals of Occupational Hygiene* **37:**117-134.

Swuste P, Kromhout H (1996). Improving working conditions in the rubber manufacturing industry in The Netherlands. *Occupational Hygiene* **3:**341-349.

Swuste P, Goossens L, Bakker F, Schrover J (1997a). Evaluation of accident scenarios in a Dutch steel works, using a hazard and operability study. *Safety Science* **26** (1/2):63-74.

Swuste P, Drimmelen D van, Burdorf A (1997b). Application of design analysis to solution generation: hand-arm vibrations in foundation pile head removal in the construction industry. *Safety Science* **27**(2/3) 85-98.

Swuste P, Hale A, Zimmerman G (1997c). Sharing workplace solutions by solution data banks. *Safety Science* **26**(1/2):95-104.

ANNEX IV. Case Studies

IV.1 Objective

The collection of case studies has two objectives, namely:

- to motivate occupational health professionals to search for solutions, by applying available knowledge on dust control to actual problems at the workplace level; and

- to disseminate useful experience on control solutions, thus promoting exchanges of experiences in this important field.

A *format* for case studies is proposed in this annex. Format is important because it systematises the collection of information. It also serves as a checklist of aspects involved in planning, implementing and evaluating a control system, from the decision-making process, to workers' perception and participation, to technical issues and cost benefit.

Two *examples of case studies* are also presented in this annex. (These examples were prepared before the formulation of this annex; therefore, they do not follow the proposed format.) The aim is to trigger the preparation of such case studies to be collected and eventually disseminated by WHO, duly acknowledged, in a future series of booklets. Solutions not considered "sophisticated" enough to be published in the specialized literature, but efficient, are particularly welcome.

It is hoped that this Annex may encourage dissemination of solutions by ingenious and dedicated occupational hygienists throughout the world, who often design simple cost-effective solutions for dust control, and do not always get deserved recognition. Whenever the environmental impact is important, which is often the case, the examples prepared may also be proposed to the UNEP Cleaner Production Data Base.

IV.2 Recommended Format for Case Studies

A. Workplace Characteristics:

A.1 Name and Address (Optional)

A.2 Type: (e.g., foundry, pesticide packing, rubber manufacturing, and construction)

A.3 Products:

A.4 Number of Workers:

B. Operation: e.g., shakeout, cast cleaning, bag filling, sawing, etc.

B.1 Description:

B.2 Source Characteristics

B.2.1 Dust Source:

B.2.2 Mechanisms of Dust Production and/or Dissemination: break-up of larger pieces, dust fall and air currents, bad work practices, etc.

C. Description of Adopted Control Measures, by Category:

For example:

- *changing the process to achieve the same result by other means***:** e.g., buying material already in the desired size to avoid sawing at this workplace.
- *work practices***:** see Section 3.1 for an example.
- *ventilation:* e.g., a semi-enclosed work station with local exhaust (down-draft) was installed ...
- *wet methods:*

and so on.

D. Implementation of Measures

D.1 Decision-making process:

Action triggered by: (for example) workers' complaints, medical reports, labour inspection.

Team involved:

Establishment of Priorities:

D.2 Main difficulties encountered:

Cost:

Specialists with know-how on dust control:

Availability of control equipment:

E. Evaluation of the Efficiency of Measures

E.1 Environmental Evaluations (measurements)

Before:

After: upon installation, and later (e.g., after 6 months). (The sustainability of a programme is important, and this is rare to find). Such measurements should be carried out at the same point, with the same instrumentation and procedure.

E.2 Workers' Perception

Although very subjective, inquiries on the workers' perception of improvements may give valuable insight on the control strategy.

E.3 Medical and Personnel Service Feed-back

Effects on Health conditions:

Effects on Absenteeism:

F. Cost-benefit Analysis

Number of workers protected:

Initial investments:

Operational costs:

Savings in raw material, materials recovered, etc.:

Decrease in health expenditures:

Decrease in environmental costs:

Visible effects on productivity:

IV.3 Examples of Case Studies

IV.3.1 Example from the Literature

This is an example from a publication by the British Occupational Hygiene Society (BOHS, 1996) of a summarized case study for the purpose of providing ideas for persons with similar problems.

Keeping it Simple (BOHS, 1996)

The importance of looking at every stage in the processes carried out in the workplace cannot be overemphasized. Even when you think the job is done and dusted, there could be hazards that need to be addressed.

THE PROBLEM

A ceramics producer kept its dust well under control during the actual production process, but the problem arose when disposing of the empty bags, which had contained harmful raw materials. These bags were just thrown on the ground, where the operators stood on them, rolled them up, and threw them away. And the result - clouds of dust billowed into the air, affecting the operators and coating the working area, which ultimately had to be cleaned.

THE SOLUTION

Because the hoppers where the dust was mixed already had dust extraction systems fitted, the company adapted the canopy, attaching a polythene bag to a flanged hole. The empty dust bags were then rolled up above the hopper and pushed through the hole, directly into the polythene bag.

THE COST

Negligible! All that this method required was for a hole to be cut in the existing canopy, and the purchase of a supply of polythene bags. Nothing could be simpler!

THE BENEFITS

No more escaped dust to pose health risks to operators or mess up the working environment. A simple solution to the problem means no need to fit special exhaust ventilation.

A dust-free environment means a happier and more productive workforce - and at negligible cost!

IV.3.2 Dust Control Measures for a Small Tungsten Mine[10]

IV.3.2.1 Introduction

In tungsten ore mining, large amounts of dust are generated in the process of tunnel and stope drilling, blasting, and mucking operations. The silica content of dust may be over 70%.

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[10] Principal investigator: Prof. Shao Qiang and Eng. Shi Jin, Institute of Environmental Health & Engineering, Chinese Academy of Preventive Medicine, Beijing

In the mine studied here as an example, production increased rapidly in the past, especially in the years 1956-1958, due to the introduction of dry pneumatic drills and mechanization to replace the old manual methods. However, due to the lack of the necessary dust control measures, dust concentrations at workplaces were as high as several hundred mg/m^3, which resulted in a disastrous incidence in the rate of silicosis among workers (the prevalence of silicosis in the tungsten mine was over 50% in 1956).

Several years later most of the workers involved died. Disasters of this sort focused the attention of the government, managers of mines, workers and institutions responsible for occupational health and safety to cooperate in investigating effective methods for controlling dust in mines. Comprehensive measures for controlling dust were put into place in every mine in 1958.

This is the case of a small tungsten mine where comprehensive dust control measures have been applied with good management since 1959, as described below. Dust concentrations at workplaces were decreased from the original several hundreds mg/m^3 to around 2 mg/m^3 (which is the hygienic standard of dust containing silica at a workplace). Over 80% of the dust concentrations at workplaces were less than

2 mg/m^3. After 1960, there were no new cases of silicosis among new workers performing dusty jobs.

IV.3.2.2 Control Measures

During drilling

In the process of tunnel and stope drilling, wet drilling was adopted, including the following.

- The rock wall was washed with a water jet (or spray) as cleanly as possible, in order to remove the dust which settled on the wall during blasting (Figure IV-1[11]).

[11] *Figures are placed at the end of this Annex.*

- Wet type pneumatic drills were used instead of dry pneumatic drills. Much less dust was produced during rock drilling when water was applied through the hollow drill steel to the cutting bit, so that the point of dust production was constantly flooded. In the early stage, the dry drills were converted to wet by the machine shop of the mine itself; which sometimes produced uncertain results. Today there are different kinds of well-designed wet drills on the market which are equipped with air-water locked valves to guarantee that water is applied first through the hollow drill steel to the cutting bit during operation, with water pressure kept 0.1~0.2MPa below compressed air pressure in practice.

During blasting

In order to confine and minimize the dust produced in the blasting process, the following measures were adopted.

- A plugging water bag was added between the explosive and plugging sand in the drilling hole (Figure IV-2 and Figure IV-3);

- There were water spray facilities, composed of several nozzles, 10-30 m from the working surface; these could produce water spray curtains (Figure IV-4) during blasting. The sprays were controlled manually or automatically, and lasted for 15~30 minutes after blasting.

- The dust-laden air could be removed immediately after blasting by a local exhaust ventilation system, as mentioned below.

- After blasting, the rock wall was washed, as mentioned above.

During mucking operations

In this process the broken rock or ore was loaded into cars for removal, or was transferred to chutes by means of a muck shifter or other mechanical means. Implemented measures included the following.

Generous use of water. This was the main dust control measure in this process, but incomplete wetting limited the efficiency. As the rock was handled, new, unwetted surfaces were constantly being formed and dry dust escaped. Continuous application of water to the muck pile was therefore necessary.

Equipping the muck drifter with *spray nozzles*, which could spray water during shovelling and loading operations by means of an automatic controlled valve.

General dilution ventilation, which was applied to take care of the residual dust still airborne in spite of the local exhaust ventilation system.

Comments on ventilation

The specific methods described above were effective in reducing dustiness, but rarely accomplished full control. Ventilation was required to take care of the residual dust. As well as the general mine ventilation, local ventilation systems could be used, consisting of an axial fan and a connecting pipe line, including a scrubber if necessary. The scrubbers had efficiencies of 80-95%. Three arrangements were generally available and the most appropriate could be selected according to the requirements.

Blow type (Figure IV-5) - Fresh air was drawn from the main tunnel by the fan, conveyed by the pipeline (made of rubber, steel or reinforced plastic), and blown out at a point about 10 m from the working face. The air velocity at the working site had to be not less than 0.25 m/s. If the air quality in the main tunnel was not good enough, a scrubber was added before the fan.

Exhaust type (Figure IV-6) - Contaminated air from the working site was drawn through the exhaust pipeline, located about 5 m from the working face, and discharged into the returning air tunnel at a point about 10 m downstream of the working face tunnel. If the discharged exhaust air might pollute another inlet air source, the exhaust air had to be treated by a scrubber before discharge.

Combined type (Figure IV-7) - Whenever the distance of the working face tunnel was greater than 200 m, a combined type was needed. The arrangement of blow pipe line and exhaust pipe line of the combined type local exhaust ventilation system is shown in Figure IV-7.

IV.3.2.3 Effectiveness of Single and Comprehensive Dust Control Measures

Effectiveness of single and comprehensive dust control measures are shown respectively in Tables IV-1 and IV-2.

IV.3.2.4 Complementary Measures

Respirators: Workers insisted on wearing dust respirators during working hours; this was helpful and safer especially when there were weak points in dust control measures of which workers were not aware.

Supervision: Dust concentrations at the work sites were periodically tested by the health and safety department, in order to detect any failures or weak points in dust control.

Health education: Health education of the manager and workers was very important, so that they were made aware of the severe effects of dust exposure and therefore implemented or collaborated with the dust control measures.

Table IV-1 - Examples of Single Dust Control Measures

Process	*Dust control measure*	*Dust concentration before control measure* *mg/m³*	*Dust concentration after control measure*	*Efficiency* *%*
Rock drilling	Using wet drill	368	3.6	99
Blasting	Water spray and ventilation	122	5.2	96
Mucking	Wetting with water perfectly and continuously	66	4.9	92
Cleaning the tunnel wall	Washing down with water perfectly	11	1.5	87
Cleaning the air from the main tunnel	Using scrubber	6	1.1	81

Table IV-2 - Effectiveness of Comprehensive Dust Control Measures

Process	*Dust control measures*	*Dust concentration after applying dust control measures* *mg/m³*	*Remarks*
Rock drilling	wet pneumatic drills	1.5 (average of 12 samples)	2 drills working simultaneously
Rock drilling	washing down wall perfectly		
Rock drilling	blow type local fan ventilation		air velocity at working area 0.35-0.54 m/s
Mucking	wetting the muck pile perfectly and continuously	1.5 (average of 8 samples)	
Mucking	washing down the wall perfectly		
Mucking	applying blow type local fan ventilation		air velocity at working area 0.35-0.54 m/s

FIGURES

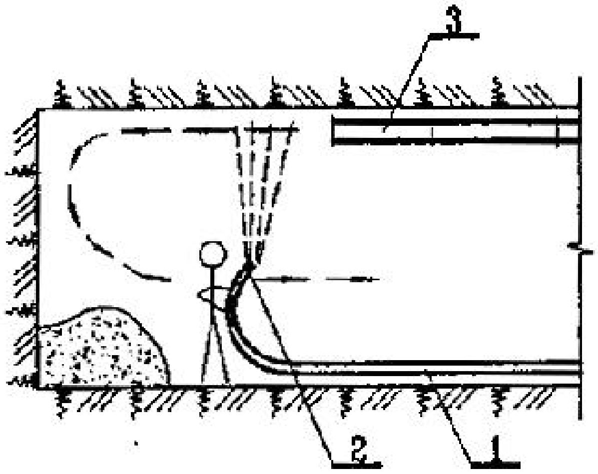

Figure IV-1 Washing down the wall with water jet:

1. Water pipe line 2. Flat type jet nozzle 3. Ventilation pipe line

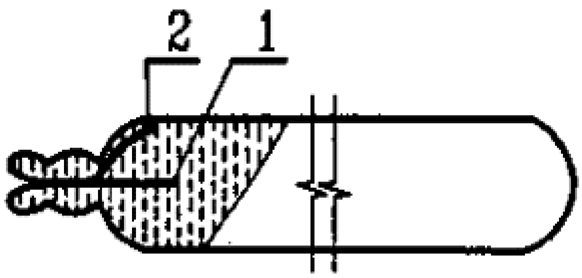

Figure IV-2 Structure of water bag:

1. Position ***before*** filled with water; 2. ***after***

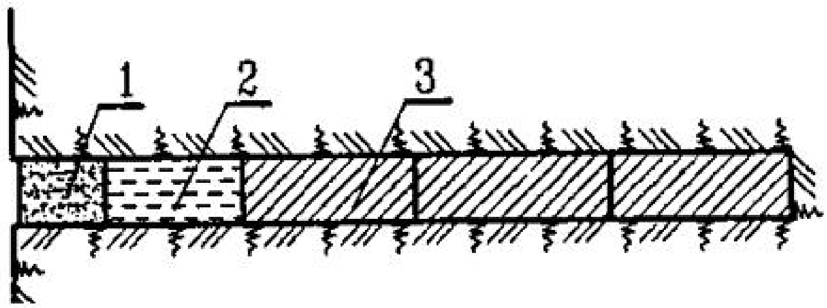

Figure IV-3 - Water bag in drill hole:

1. Plugging sand; 2. Water bag; 3. Explosive

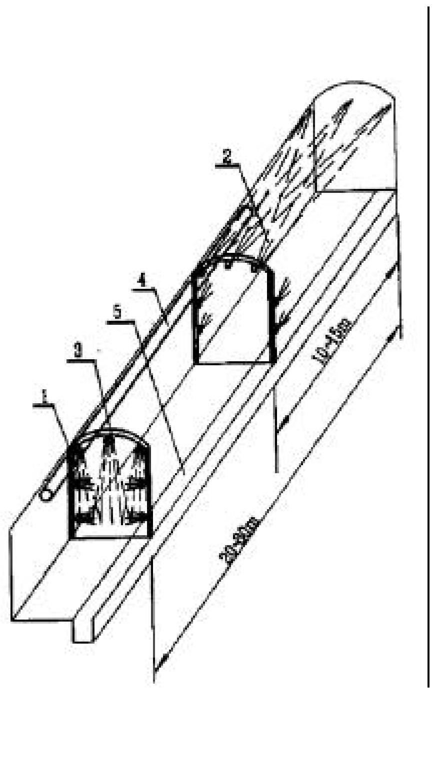

Figure IV-4   Water spray curtain for blasting:

1. Water spray curtain; 2. Forward water spray curtain; 3. Water pipe line;

4. Exhaust ventilation pipe line; 5. Trench for waste water

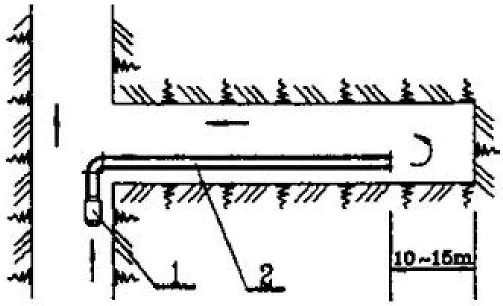

Figure IV-5   Blow type local fan ventilation system: 1. Fan; 2. Ventilation pipe line

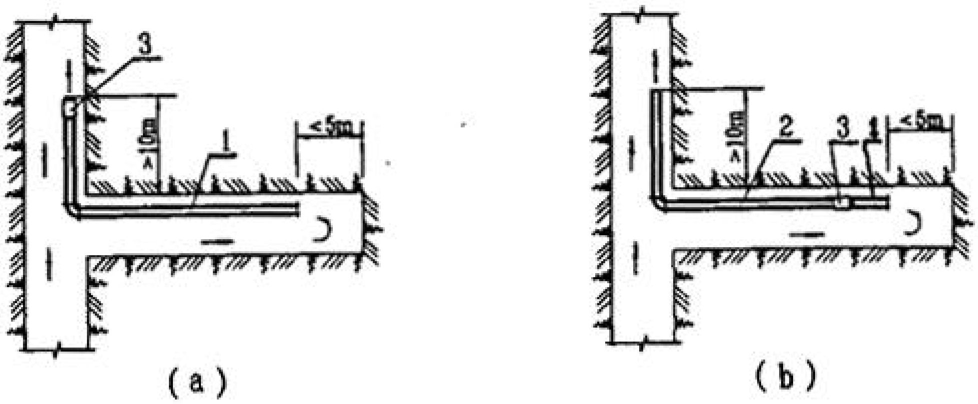

Figure IV-6   Exhaust type of local fan ventilation system:

(a) Using steel pipe line   (b) Using rubber pipe line

1. Steel pipe line 2. Rubber pipe line 3. Fan

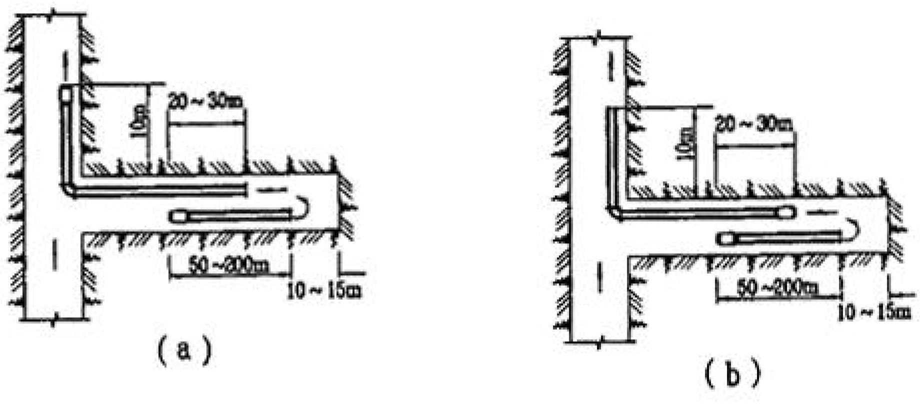

Figure IV-7 Combined type of local fan ventilation system

(a) Using steel pipe line (b) Using rubber pipe line

Reference for Annex IV

BOHS (1996) *The Manager's Guide to Control of Hazardous Substances, with 21 Case Studies*, General Guide No.1, British Occupational Hygiene Society, Derby DE1 1LT, UK