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POTENTIAL THREAT TO CONVENTIONAL FUMIGATION FROM REGULATORY LEGISLATION IN EUROPEAN COMMUNITIES

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ABSTRACT

The Council of the European Communities has adopted the Council Directive of 15 July 1991 concerning the marketing of plant protection products (91/414/EEC). The main aim of the Directive is to standardize agrochemical registration within the EC in order to establish common standards of health and safety and to enable free circulation of products. The Directive must be implemented by member states within two years, i.e., by 15 July 1993. During the course of this time, uniform principles for evaluating pesticides will be established in a special directive comprising 6 separate Annexes. Requirements for the dossier to be submitted for the authorization of a plant protection product must include much more information than was required previously. Health and safety standards nowadays are much higher, very strict, and the use of many plant protection products or active ingredients will be suspended or limited in coming years. Special care is taken in the use of pesticides for the protection of post-harvest grain and in the use of pesticides at facilities where food is produced, processed, or stored. Fumigation with toxic gases like phosphine, methyl bromide, and hydrogen cyanide is employed commonly in Europe as an efficient practice to control stored-product pests. As of now, there appear to be no real alternatives or substitutes for toxic fumigants. To some extent and under certain circumstances modified atmospheres (MA) are replacing the above mentioned fumigants. According to the mentioned EC Directive, in the near future regulations in members states will affect to some extent the use of fumigants. First of all, great care must be taken to ensure that fumigants are always used wisely and carefully. The latest innovations in stored-product protection will be adopted in regulations (Resolutions of the Council of Europe, Annexes etc.), governing mainly safety improvements and reduction in fumigant dosages. The harmful effects on workers and the environment can be avoided if the application is carried out strictly according to written recommendations using modern techniques of sealing, pressure testing, leak detection, and filtering to avoid pollution of the environment (below the emission limit). The

EC registration Directive will have a great impact on stimulating an intensive search to modify and render safer the use of available conventional fumigants. The basic aim of the Directive is the protection of human health and conservation of the environment.

EUROPEAN COMMUNITIES COUNCIL DIRECTIVE CONCERNING THE PLACING OF PLANT PROTECTION PRODUCTS ON THE MARKET

On 15 July 1991, the European Community adopted the proposal for the Council Directive concerning the marketing of plant protection products (Official Journal of the EC, L 230 1991). Members of the European Community are obliged to comply with the Directive until 15 July 1993, and from that date on, the plant protection product must be authorized according to the Directive. The Directive includes instructions on how to authorize the chemical plant protection products and preparations based on microorganisms and viruses.

The main provisions of the Directive are as follows:

1. A "positive list" of pesticide active ingredients approved for use in the EC will be established, as Annex I of the Directive.
2. Formulations containing these active ingredients will be registered nationally.
3. Mutual recognition by member states of registrations granted by other member states provided that agricultural, plant health, and environmental (including climatic) conditions are comparable.
4. Three-year provisional registration of formulations by member states pending an EC decision on the active ingredient.
5. Re-evaluation of older active ingredients within 12 years (or possibly longer, for some products) during which member states will be allowed to retain the product registrations.
6. Standardized rules on retention of data submitted in support of registration (ten years for the original registration and five years for data submitted thereafter) and on confidentiality of data.
7. Standardized packaging and labeling requirements.
8. Improved information exchange between member states.

The main task of this paper is to deal with the current status of conventional fumigants and their foreseeable future in the light of the new procedure.

The basic text of the Directive consists of 24 articles, and in the near future, in a separate Directive, six Annexes will be established. These six Annexes are as follows:

I Active ingredients authorized for incorporation in plant protection products (i.e. the "positive list").

II Requirements for the dossier to be submitted for inclusion of an active ingredient in Annex I.
III Requirements for the dossier to be submitted for the authorization of a plant protection product.
IV Risk phrases.
V Safety phrases.
VI Uniform principles for the evaluation of plant protection products.

Annex I of the Directive comprises the list of the authorized active substances (the "positive list") that will not pose any unacceptable risk for human or animal health and for the environment when used in accordance with good plant protection practice. The Directive determines exactly the procedures for including active substances in the list of Annex I by 15 July 1993, with the next deadline set for 15 July 2003. Reviews of active substances may be initiated at any time by the Community if there are indications of harmful effects. The list of active ingredients, or the initial listing in Annex I will be in effect for up to 10 years, with renewals granted for a 5-year period. As far as we know, no active ingredients have yet been authorized for inclusion in the EC positive list (J. Sackett, personal communication).

The contents of the application dossier are given in Annex II to the Directive. Dossiers must be compiled and sent to the authorities upon the acceptance and inclusion of the active ingredients in the Annex I. Active ingredients on the market prior to 15 July 1993, but not included in the list of Annex I, will be the subject of a review programme during the period up to 15 July 1993. A member state that receives an application for a new active ingredient must ensure that the applicant send a copy of the dossier complying with Annex I to the other member states and to the EC Commission. At the same time, the member state must submit another dossier on at least one finished product containing the active ingredient concerned.

Physico-chemical, toxicity, and ecotoxicity testing should comply with the methods given in Annex V of the EC Dangerous Substance Directive (Directive 79/831/EEC). The Standing Committee on Plant Health (SCPH) will scrutinize each dossier (documents) and vote on whether to include a particular active ingredient in Annex I. The contents of the application dossier are given in Annex III of the Directive.

National applications can be submitted by the manufacturer, importer, or distributor of the product. It is interesting that member states have no time limit for scrutiny of the dossier but it must be done within a reasonable period.

Conditions for the authorization of a plant protection product by member states are:

1. A new active ingredient must be listed in Annex I
2. The product is effective and safe under conditions of good plant protection practice.

3. The nature and quantity of the active ingredient(s), metabolites, and toxic impurities when appropriate, can be determined by commonly used methods.
4. Physico-chemical properties of the ingredient have been determined and pose no unacceptable hazards.
5. Maximum Residue Levels (MRLs) are agreed and accepted by the member state.

When the product is authorized by one member state, producers can request recognition in the other member states who must authorize the products. If the authorization is refused by the other member states, they must provide a detailed explanation for the rejection, e.g., the plant protection product is inadequate for the local agricultural conditions because the conditions (agricultural, plant health, climatic, environmental) are not comparable with those of the country that originally authorized the product. Member states refusing to recognize authorization or requiring re-testing to support the authorization must notify the EC Commission and justify their action. After each quarter, member states are obligated, within a period of one month, to provide other member states and the EC Commission the following information concerning the authorization or refusal of the plant protection product: trade name(s), code number of the product, type of preparation, name and quantity of each active ingredient in the product, the intended use and directions for use of products, provisionally-established MRLs, and reasons for refusal.

Every year, each Member State is obligated to prepare an annual list of the products authorized in its own country and distribute the list to the other member states and to the EC Commission. The special value is that the Directive acknowledges the importance of continuing research into plant protection products. But, at the same time the SCPH must establish the criteria that will be applied in the research and the development work. After the trial is authorized, research can be done under controlled conditions, especially when the environment is liable to be contaminated by various products containing a microbial active ingredient. This provision does not apply to genetically-modified organisms, that are the subject of Part B of Directive 90/220/EEC currently under discussion.

Functions and responsibilities of the SCPH are determined precisely by the Directive. They are as follows:

1. Assessment of dossiers for positive listing of active ingredients.
2. Review of existing active ingredients in products already on the market.
3. Adjudication of a member state's refusal to mutually recognize a product authorization granted by another member state.
4. Adjudication on the continued emergency use of a product or the national authorization of a product containing active ingredients not listed in Annex I.

5. Preparation of amendments to the Annexes and technical standards and guidelines for implementing the Directive.

The Directive introduced standardized rules on the protection of data submitted to support an active ingredient, and product authorization, as privileged information for a certain period. The EC Commission has made a formal proposal for the adoption of the Council regulation to implement Prior Informed Consent (PIC) procedures for the import and export of certain chemicals including banned or severely restricted pesticides. In the post-1992 European market, the EC is considered a single country with regard to PIC procedures. Under the Commission's proposed regulation, member states would nominate a designated authority to notify third countries of export of chemicals subject to PIC procedures, while the Commission would keep other member states informed of PIC decisions. The Commission would report at regular intervals to the Council and to the European Parliament (Agrow 1991). Three annexes form part of the regulation.

In Annex I there is a list of forbidden chemicals or those strictly limited in use in the member states of the EC. Chemicals subject to PIC procedures and countries participating in the PIC scheme appear in Annex II. Annex III provides necessary information for notification to the EC Commission. In the case of import of chemicals into the EC, the Commission would evaluate, in close conjunction with member states, the risks posed by the chemicals and determine whether imports should be allowed, prohibited, or restricted. According to the new regulation governing the environmental model, the EC Commission is allowed to adopt standards for contamination of the atmosphere, without prior consultation with the EC Ministerial Council, thereby encouraging member governments to accept stricter standards (Agrow World Protection News, No. 139, 1991).

INTERNATIONAL ORGANIZATIONS, ASSOCIATIONS AND PROGRAMMES IN THE FIELD OF PESTICIDE CONTROL

In response to public concern in member states of the EC, a number of international and non-governmental organizations have adapted their programmes to address the issue of safe use of pesticides. The organizations also considered the safety aspects of the use of pesticides in different fields e.g., agriculture, and public health, and this trend continues. However, a scientific approach to the problem of pesticide safety is essential in order to assess the potential risks involved in the chronic exposure of the public to pesticides in the environment or as contaminants in food. Today, the most widespread health problem in the world is probably malnutrition. The FAO (Food and Agriculture Organization of United Nations) estimates that despite the use of pesticides, about 25% of harvested crops are lost because of insects, rodents, birds, and spoilage. Pesticides are needed to curb these

losses and protect plants. In recent years, there has been increasing public concern about the safety of chemicals of all types.

Pesticides are chemicals to which everybody is exposed to a certain degree. Their potential hazards can be assessed scientifically on the basis of considerable available toxicological and human exposure data. Public fear and concern can be reduced by providing reliable scientific information on the need for pesticides and their safe and rational use. Today, numerous international and national organizations are dealing with necessary research and harmonization of regulations on pesticide residues and their safe use. The major organizations are mentioned below.

International organizations

1. *World Health Organization - WHO*

Within the WHO, the evaluation of hazards to humans and the environment from pesticides, the promotion of the safe use of pesticides, training and education, have been included among the tasks of the "International Programme on Chemicals Safety" (IPCS) which is a collaborative programme of several organizations: International Labor Organizations (ILO), United Nations Environment Programme (UNEP), and WHO. Recently, the WHO Regional Office for Europe sponsored the establishment of an International Center for Pesticide Safety in Milan, Italy. The center will provide information, research, training, and laboratory assistance to countries in the European region.

2. *Food and Agriculture Organization of the United Nations - FAO*

Since 1985, when the "International Code of Conduct on the Distribution and Use of Pesticides" was accepted, FAO has supported and encouraged governments with regard to the registration, control, and safe use of pesticides. The FAO prints regularly a comprehensive set of internationally agreed technical guidelines that provide the basis for implementation of the Code provisions. FAO efforts are also supported by many governments, industries, and various non-government organizations. The PIC (prior informed consent) process is built into the Code. One of its main provisions is the notification of all member states of a decision by any state to ban or severely restrict the use of pesticides. Notifications will be processed by a joint FAO/UNEP programme and will include necessary information, e.g., on the reasons for the ban or restriction, supplementary information, and alternative substances.

3. *The United Nations Environment Programme - UNEP*

The "International Register of Potentially Toxic Chemicals" (IRPTC) which is part of UNEP is closely associated with FAO in the PIC procedure in realizing the London Guidelines concerning the exchange of information on

banned or severely restricted chemicals in international trade. The IRPTC will play a significant role in future PIC work by using the IPCS to provide information and advice on human effects of exposure to these chemicals.

4. *International Labor Organization - ILO*

The ILO has adopted recently a "Convention and Recommendation" concerning safety in the use of chemicals at work, while at the same time preparing a Code of Practice intended to guide the member states in drafting national legislation and establishing the infrastructure needed to deal with chemical safety. Upon consultation with the other organizations and within the framework of the IPCS, criteria for the classification of hazardous chemicals, including pesticides, will be prepared.

5. *Non-governmental organizations*

The "International Group of National Associations of Manufacturers of Agricultural Chemicals" (GIFAP) must be mentioned. The GIFAP that enjoys official relations with the WHO prints guidelines to promote safety in the use of pesticides and carries out field studies to evaluate the effectiveness of protective clothing under tropical conditions. Members of the GIFAP have agreed to comply with the relevant provisions of the FAO "International Code of Conduct on the Distribution and Use of Pesticides".

Coordination of Activities

Activities among organizations are coordinated to prevent contradictory activities and disagreements. In this respect the WHO has gained considerable experience and deals successfully with the WHO and FAO experts in the "Joint FAO/WHO Meeting on Pesticide Residues" (JMPR).

Assessment of the risk of pesticides to humans is often based mainly on interpretation of results obtained from animal experiments. The WHO experts believe that care must be taken when interpreting results obtained from experiments on animals in the prediction of possible effects in humans. Predictions are markedly more reliable when human data are available especially when exposure or the actual dose is measurable.

"Control of Pesticide Applications and Residues in Food - A Guide and Directory - 1986", edited by Bengt v Hofsten and George Ekström, Sweden, 1986, contains a very useful guide and directory to international organizations, associations, and programmes in the field of pesticide control, and to national authorities responsible for pesticide control (responsibility, names in English and the national language, address and postal address, telephone, and telefax). The activities, publications, and postal addresses for 8 major inter-governmental organizations and their regional offices or members are given. In addition, 9 international programmes are described fully and their addresses and publications are also mentioned.

CURRENT STATUS OF TOXICOLOGICAL EVALUATION

In the /WHO/IPCS "Recommended Classification of Pesticides by Hazard and Guidelines to Classification" 1992-1993, fumigants have yet to be classified by hazard level (WHO/PCS/ 92.14). At present, their classification states no criteria for concentration in the air as a basis for classification. Most of these compounds are highly hazardous and present-day recommended limits for exposure to gases (health standards) have been adopted by relevant institutions in many countries.

In the Joint FAO/WHO Food Standards Programme Codex Alimentarius, maximum residue limits (MRLs) and acceptable daily intake (ADI) are specified also for fumigants (FAO/WHO,CAC/Vol. XIII. Ed 2, 1986).

Thus, for hydrogen cyanide, the specified ADI is 0.05 mg/kg body weight (bw) (total cyanide, expressed as hydrogen cyanide) and the MRL is 75 mg/kg for food grains and 6 mg/kg for flour. For hydrogen phosphide, the ADI is not necessary because good usage practices should ensure that residues are not present at the time of consumption. For inorganic bromide ADI determined and expressed as total bromide ion from all sources is 1 mg/kg. The MRL in mg/kg is 75 for avocados; 50 for cereal grains and whole meal flour; 30 for citrus fruit, fruit and strawberries; 250 for dates (dried), raisins, sultanas, currants (dried); 20 for fruit, prunes (dried); and 400 for herbs and spices. In the summary of toxicological evaluations prepared by the Joint FAO/WHO Meeting on Pesticide Residues (JMPR), 1991 (UNEP/ILO/WHO. WHO/PCS/92.9), the IPCS specifies toxicological data of pesticides including the fumigants, referring to the ADIs of residues and dates of last admittance of ADIs by JMPR, (dates of the last toxicological assessments of pesticides which are currently applicable). Thus bromomethane (methyl bromide) was evaluated in 1966 and bromide ion value 1 was defined as the ADI (mg/kg bw). The ADI evaluation for bromide ion was likewise made in 1988 when it was defined as 1. The same applied to carbon disulphide in 1965 - no ADI, for carbon tetrachloride in 1965 - no ADI, for chloropicrin in 1965 - no ADI, for dibromethane 1.2 in 1966 - 1 as bromide ion. For ethylene oxide in 1968 - no ADI, for hydrogen cyanide in 1966 - 0.05, for hydrogen phosphide in 1966 - providing that the residues in food are 0, no ADI is required. Dates for the Joint FAO/WHO meetings on Pesticide Residues in 1992 and 1993 year have been fixed (Rome, 21-30 September 1992, and Geneva, 20-29 September 1993) (GIFAP Bulletin, 1992). The list of ingredients scheduled for toxicological and residue evaluation has been determined for the 1992 meeting and the 1993 meeting. Among the compounds recommended for priority attention for residue re-evaluation, by the joint FAO/WHO meetings on pesticide residues one finds bromide ion (inorganic bromide), by request of the Codex Committee on Pesticide Residues, (CCPR 1991), and

bromomethane, by request of the CCPR, 1990 for the 1992 meeting. There were no fumigants on the priority list for toxicological and residue evaluations by the JMPR at the 1993 meeting nor listed under "desirable for residue evaluation at the next possible JMPR". It is obvious that in the very near future there will be no significant changes in recommendations for international maximum residue limits for fumigants used in food protection in the EC. This opinion is supported in part by the regulatory status of methyl bromide in the US. Since 1981, the US Environmental Protection Agency has been reviewing the labeling of methyl bromide for post-harvest and soil fumigation. Conclusions are as follows (Fumigants and Pheromones, 24, 1991):

- Inorganic bromide residues are no longer of toxicological concern.
- Completed studies do not indicate a problem except for mutagenicity.
- Plant metabolism studies show no residue of toxicological concern.
- To date, all data support the continued registration of methyl bromide, and the "Methyl Bromide Industry Panel" with the support of the food industry plans to maintain all labeled uses.

For post-harvest uses, at that time, no protocols had yet been approved.

Also, there are many more studies under review that affect residue chemistry, environmental fate (for example potential ozone depletion), and reentry.

On the basis of ADI and safety coefficient 100, many countries have defined pesticide maximum residue levels in various kinds of food. MRLs are defined on the basis of home produced foodstuffs and imported food, namely of both raw materials and processed food. Here, of course, the nutritional habits of the population in a given country play an important role, this being the main reason for differences that occur in MRLs of pesticides and of fumigants in any particular country.

The following is a list of MRLs for methyl bromide, hydrogen phosphide, and hydrogen cyanide in certain countries of Europe.

France - hydrogen cyanide (mg/kg): 15 for food grains, 5 for rice; inorganic bromide ion (mg/kg): 100 for lettuce, 50 for tomato and dried fruit, 30 for potatoes and other vegetables, 20 for fresh fruit and citrus fruits, 200 for medical herbs and spices etc.; methyl bromide (mg/kg): 0.1 for food grains and their products; phosphine (mg/kg): 0.1 for food grains, 0.01 for all other products.

Germany - hydrogen cyanide (mg/kg): 15 for cereals (rice not included) and spices, 6 for flour other cereal products rice and cacao; inorganic bromide ion (mg/kg): 400 for spices, 50 for food grains and cereal products, legume, cacao, almonds, nuts, oil crops, green coffee, tapioca, tea raw materials, herbs, dried vegetables and fruit, potatoes, 20 for strawberries, 5 for other vegetable foodstuffs; methyl bromide (mg/kg); 0.1

for miscellaneous products; phosphine (mg/kg) : 0.1 for food grains, 0.01 for foodstuffs and fodder.

Croatia - hydrogen cyanide (mg/kg): 6 for food grains, fresh and dried fruit, dried vegetables, mushrooms, spices; inorganic bromide ion (mg/kg): 50 for food grains and processed products; phosphine (mg/kg): 0.1 for food grains, 0.01 for processed products, dried fruit, vegetables, and tea.

CURRENT REGULATORY STATUS OF FUMIGATION IN EC

At the 18 June 1987 meeting attended by experts from Belgium, France, Federal Republic of Germany, Italy, Luxembourg, Holland, Great Britain and Northern Ireland, the representatives of the European Council through the Committee of Ministers adopted Resolutions AP (87)2 and AP (87)3 "On the use of pesticides in premises where food is produced, processed or stored" and on "pesticides used for protection of grain after harvest " as a partial agreement in the field of social and public health (Council of Europe, Resolution AP (87)2 and 3, 1987). The meeting was also attended by representatives of Austria, Denmark, Ireland, and Switzerland - the states that have been participating in public health activities since 1965. The main goal of these resolutions was to achieve greater uniformity and harmony among members of the European Council . At that time, some of the pesticides mentioned in the resolutions were used in all member countries and some only in certain countries. Hereunder are some examples for present-day authorization of fumigants in some European countries.

In France, hydrogen cyanide is not authorized for fumigation of stored-products for human consumption and fodder. Methyl bromide and hydrogen phosphide are authorized for use in agriculture. There is a special, very specific regulation on the use of fumigants that are approved by the state authorities.

In Germany, all three fumigants are authorized for use in agriculture, but under very specific conditions (Reichmuth, 1988; Pflanzenschutzmittel-Verzechnis, 1989/90).

In Croatia, all three fumigants are authorized for use in agriculture under circumstances approved by the state authorities (Pesticidi u poljoprivredi i sumarstvu, 1990).

By contrast, in Hungary, methyl bromide and hydrogen cyanide are not used in agriculture, while phosphine derived from aluminium and magnesium phosphide, may be used only in large-scale farming by skilled and trained personnel (G. Ungvary, personal communication).

Of the fumigants, the above mentioned resolutions approve the use of methyl bromide, hydrogen phosphide, and hydrogen cyanide but classify them as "highly toxic fumigants". The fumigants admitted generally by the member states include hydrogen phosphide and methyl bromide. Hydrogen cyanide has been approved by only some of the European countries.

The text adopted by the Committee of Ministers in Resolution AP (87)2 for the three highly toxic fumigants, as pertains to residues, safety aspects, and environment, is as follows:

Methyl bromide

Residues. The residue resulting from the fumigation of grain with methyl bromide is predominantly inorganic bromide formed by reaction of the fumigant with certain grain constituents, mainly those compounds containing sulphur or nitrogen. An extensive review of the literature on bromide residues in foodstuffs has been published. Some unchanged methyl bromide is present at the end of the fumigation, but this disappears fairly rapidly when the goods are aired, with the rate of loss depending on the temperature and moisture content. The 1979 Joint FAO/WHO Meeting on Pesticide Residues recommended a "guideline level" of 5 mg methyl bromide/kg cereal grains applicable at the point of entry into a country. The JMPR recommendation for cereal food products ready for consumption is 0.01 mg/kg.

Safety aspects. Methyl bromide is an extremely toxic product. Its use should be limited to well-trained and licensed operators wearing full protective equipment. During treatment, access to buildings or other rooms should be strictly controlled. After the appropriate fumigation period, degassing of the building should be carried out with great care, considering also the possible slow release of absorbed methyl bromide from the fumigated products. Access to the building or fumigated spaces should only be allowed after it has been shown that residual methyl bromide concentration in the air is well below limits.

Environment. Fumigation should only be carried out where the distance to other buildings is sufficient to avoid any risk to neighboring people during fumigation and degassing under various atmospheric conditions.

Hydrogen phosphide (phosphine)

Residues. Hydrogen phosphide is highly toxic to human beings (threshold limit value: PH_3 : 0.1 mg/m^3 air (F); 0.3 mg/m^3 air (NL); lethal dose : 2.8 mg/l for short exposure, but because the reaction by which it is produced takes place comparatively slowly, a period of 2-3 hr elapses before a harmful concentration is built up. The time taken for the reaction to proceed to completion depends upon the humidity and temperature. A period of five days is allowed normally and it should never be less than three days. At the end of this time, a small proportion of aluminium phosphide may remain undecomposed but further decomposition takes place when the grain is moved. The "spent" material containing any decomposed aluminium phosphide or magnesium phosphide should be removed from the grain either by sieving out the packets or by aspiration in the case of tablets or pellets. Very little if any reaction takes place between hydrogen phosphide and grain

constituents. The residual phosphide is likely to be negligible.

Safety and environmental information: as for methyl bromide.

Hydrogen cyanide

At one time, hydrogen cyanide was a fumigant of major importance but in recent years it has been superseded by other fumigants and its use is now confined mainly to space fumigation, e.g., flour mills or ships holds. Occasionally, grain for export is treated by adding a proprietary preparation of calcium cyanide.

Residues. The rate is equivalent to about 75 mg HCN/kg grain. Some of this is lost during the exposure period, and further loss occurs when the grain is ventilated after treatment. The residual cyanide content of the grain at the time of importation is likely to be low. For example, cargoes treated with calcium cyanide in the exporting country contained less than 10 mg cyanide/kg when sampled in the UK.

Safety aspect/environment: similar to methyl bromide.

PRESENT-DAY TRENDS IN THE PROTECTION OF STORED AGRICULTURAL PRODUCTS

Present-day trends in the protection of stored agricultural products are directed to an ever increasing adoption of preventative measures and control of pests using non-conventional chemical pesticides. Public concern over the use of pesticides and their residues in the environment and food is growing, and influences directly or indirectly the awareness as to the necessity of limiting their production and application.

Such a situation also applies to the fumigants which, owing to their specific characteristics, relatively simple application, and rapid effects on pests, are very effective pesticides. Certainly some of the fumigants, namely hydrogen phosphide, methyl bromide, and hydrogen cyanide will still be used for many years, provided that special action be taken to apply them in an expert, safe, and highly-controlled manner. All those involved in the chain of production, sale, and application of these fumigants should undertake their duties with great responsibility because only by doing so will these really useful chemical compounds have a good chance of continuing to be manufactured and used for the protection of food. It is of great importance to realize that in food protection, there are growing requests for the application of alternative methods in order to eliminate eventually the application of toxic chemicals. Modern consumers show a growing interest in food free from pesticide residues, a requirement that will be even more conspicuous in the near future. Therefore, modified atmosphere (MA) or controlled atmosphere (CA) technologies having minimal undesirable effects on products and the environment, are now and will be, particularly in the near future, one of the most significant alternative methods for the protection of food.

Storey (1990) considers that the fate of fumigants' use will be determined by three basic guidelines: technical factors, regulatory policies, and cost/benefit/risk relationships. We share his opinion and believe that the future of fumigant application in the EC will also depend on this. Research will be intensified and will generate a new scientific understanding, speedy exchange of information, and recommendations and decisions at the level of the above mentioned world and European organizations, committees, and agencies as regards re-evaluation or new registration of pesticides, including the fumigants .

It is interesting to note that numerous authors have expressed similar opinions over the past few years regarding the future of fumigant application (Bond, 1987, 1990; Rassman, 1988; Reichmuth, 1988, 1990, 1991; van Graver, 1990; Winks, 1990; Quan, 1990; Banks, 1990; Keever, 1991). These authors believe that progress in the development of formulations and methods of application to enable efficient and safe use of fumigants is certainly one of the most significant factors affecting the future application of fumigants in the protection of stored agricultural produce. Nevertheless, as conventional fumigants are toxic and dangerous substances, their application should be subjected to strict inspection, and compliance with the legislature and recommendations of the international and national organizations and authorities, on the basis of which the government or governmental institutions of each particular state establishes its regulations. The governmental regulations define normally the usage of permitted fumigants for certain types of products, the conditions under which the fumigations are permitted, and the conditions to be met by organizations and persons carrying out the complete process of fumigation, including preparatory work, application, exposure, and aeration as have been documented for some regions (AFHB, ACIAR, 1989 ; Korunic, 1992).

Due to ever increasing demands for safe application of fumigants, it is quite certain that fumigation will prove an increasingly expensive measure of protection of stored agricultural products because of additional expenses involved in obtaining improved gas tightness, testing gas tightness, monitoring devices and safety equipment, fumigation education, and because of rising insurance costs for coverage of fumigators and fumigation, as well as considerable increase in the cost of fumigants, their equipment and transport. Prior to deciding on undertaking fumigation, increased attention will be paid to the cost/benefit/risk relationships which, according to Storey (1990), are perhaps the most important interacting combination of factors affecting the future use of fumigants.

ENVIRONMENT AND NEED FOR RESEARCH

Recent scientific data on residues in food, gas residues physically linked to products, development of new measurement techniques for

quantifying very low concentrations and residues (in the region of ppb or even lower), and the establishment of toxicological links with the dysfunction of cells, have led to increasing requests for pesticide testing, examination of their safe application with respect to people and the environment, and prescription of rigorous health standards. All these will affect the future of conventional fumigant application limiting their application, although at present not forbidding their use. Over the past ten years, there has been growing interest in discovering and introducing measures to provide maximum protection for fumigators. Also in some developed countries, intensified investigations have been carried out to reveal the ultimate destination of fumigants released into atmosphere, both during application and during airing. For fumigator protection there has been an urgent need to manufacture and test small, portable, inexpensive devices for measurement of gas concentrations in air for use by all fumigators. The purpose of these devices is to detect and react to gas concentrations in the air at the level affecting health standards, and to measure the time-weighted average exposure and upper limit of concentration (Threshold Limit Values - TLVs). At present such devices exist and some are being used (e.g., Dräger badge, Cititox), thereby rendering the fumigation process considerably safer for the fumigators. In some countries, including those in Europe, there is growing and even acute concern about the environment. Among numerous contaminants of the atmosphere (industrial chemicals and similar pollutants), fumigants are included in the group discussed, and related to by certain regulations aimed at protecting the environment. Particular attention has been paid to three fumigants: methyl bromide, phosphine, and hydrogen cyanide. The institutions concerned with the human environment are constantly seeking for new data on the release of these fumigants into the atmosphere. Though TLVs in the air have been specified for each particular fumigant (albeit for adult workers only and not for children, the aged, or the sick), these institutions, very often government agencies, require, for safety reasons, considerably lower concentration limits in the air than the TLVs prescribed. Such low gas concentrations could be found in the air near fumigated facilities and adjacent buildings. Therefore, it is extremely important to know the dispersion of fumigants and their fate in the atmosphere (degradation and end-products), as well as the impact of very low concentrations of gas on people. This problem of contamination of the environment by fumigants is now, and will be, one of the main factors affecting the policy of further application of fumigants. Therefore, intensive investigations have been made to discover and introduce methods of application capable of preventing most effectively gas leakage from the fumigated area (i.e., improved sealing technique), introducing efficient monitoring systems (i.e., personal monitors) during the whole process of fumigation, and introducing new technologies of airing (e.g., application of gradual airing, suitable scrubbers, and filters for reducing gas emissions).

This problem has been addressed by several researchers in Europe (Waritz and Brown, 1975; Arendt *at al.*, 1979; Castro and Besler, 1981; Reichmuth *et al.*, 1981; Noack and Reichmuth, 1981, 1982; Fritz *et al.*, 1982; Amoore and Hautala, 1983; Reichmuth and Noack, 1983; Pazynich *et al.*, 1984; Jackson *et al.*, 1988; Reichmuth, 1990, 1991). Also many papers have been published outside Europe (Atchbarov *et al.*, 1984; Bond and Dumas, 1987; Bond, 1990; Winks, 1990; Storey, 1990; Banks, 1990; Keever, 1991). Widespread application will probably continue with fumigants that in addition to their properties of pest toxicity, high diffusion and penetration, low reaction with treated products, low noxious residue, simplicity in packing, and easy detection, should also excel in other characteristics such as chemical instability in the atmosphere with a low or practically no noxious effect on the environment (Reichmuth, 1991). In practice, for the storage of agricultural products, the fumigants conforming to the above mentioned characteristics are phosphine, methyl bromide, and to some extent hydrogen cyanide. Mention has already been made that in some cases, they can be replaced by inert gases CO_2 and N (where the fumigated area is sealed effectively, the exposure period is not a limiting factor, and when the residue required is zero).

More than a decade ago, in Germany, Reichmuth *et al.*, (1981) started intensive research on environmental and health aspects of fumigation in stored-product protection. Their aim was to establish the risk of the application and emission of fumigants used in storages. During fumigation and airing, concentrations of gases were measured in the close vicinity of fumigated plants (mills and granaries). It was found that the concentration of phosphine was greater than 0.15 mg/m^3 phosphine (German TLV) only in the area up to 10 m distant from the fumigated storage structure, in cases where fumigation was at normal dosages, even for structures with average levels of gas tightness. Higher concentrations for short periods could be found at greater distances, but only in exceptional cases. Similar results have been obtained for methyl bromide and hydrogen cyanide. An additional problem occurs with the application of methyl bromide, namely the occurrence of methyl chloride and its gradual emission into the atmosphere (i.e., emission problem). The German TLVs have been exceeded at distances greater than 10 m only in rare cases. In the light of recent discoveries, however, in the public health sector in Germany, derived mainly from accidents with chemicals in human surroundings, the value of 0.02 ppm v/v (1/5 of German TLV) has been defined as the critical level of concentration. That is to say that such a low concentration in the air shall not be exceeded in residential areas. The person in charge of fumigation must measure continuously the concentration of gas, and should it rise higher than the critical level, all persons in the area must be evacuated at the expense of the relevant firm. Noxious effects of low concentrations on plants and animals have been investigated simultaneously (Noack and Reichmuth, 1981, 1982). It was found that the critical concentration of phosphine for plants (for lettuce during

the vegetative period, this being a rather sensitive plant) was 3 and 8 mg/m^3, and 20 and 53 ppm v/v, respectively, i.e. considerably higher than the critical level of 0.02 ppm v/v. Pazynich *et al.* (1984) recommended average limits of exposure in urban areas during 24 hours, one month, and one year as 0.004, 0.0015 and 0.001 mg/m^3 phosphine respectively, as critical values. These values have been adopted in the former USSR. These relatively rigorous standards of permissible concentrations of gas in the atmosphere shall also affect greatly further development of fumigation and the application of fumigants in other countries of the EC.

CONCLUSIONS

On 15 July 1991 the European Communities Council adopted the directive concerning the marketing of plant protection products. Members of the EC are bound to comply with the directive by 15 July 1993. The main aim of the directive and its annexes is to standardize agrochemical registration within the EC, in order to establish common standards of health and safety and to afford free circulation of products.

In the post-1992 European Market, the EC is considered a single country. The main resolution and recommendations concerning marketing of plant protection products will be provided by the EC "Commission and Standing Committee on Plant Health" (SCPH). When the plant protection product is authorized in one member state, producers can request recognition by the other member states that must, in most cases authorize the product.

In response to public concern over the use of pesticides and their residues in the environment and food, a number of international and national organizations are now maintaining close cooperation in the field of pesticide control, and have adapted their programs to provide reliable scientific information on the need for pesticides and their safe and rational use. These organizations are dealing with necessary research, and standardization of regulations on pesticide residues and their safe use.

At present, food consumers are showing a growing interest in food free from pesticide residues, a requirement that will be even more exacting in the near future. Therefore, modified atmospheres having minimal undesirable effects on products and the environment will provide one of the most significant alternative methods for food protection. Added expenses for improvement of gas tightness, testing for gas tightness, monitoring devices, safety equipment, fumigator training, insurance coverage, and especially for very strict inspection, and the cost of fumigants and their transport, will all affect the future of conventional fumigation by limiting its application.

Throughout the world and in Europe, there is growing concern for the environment. Among numerous contaminants of the atmosphere, fumigants are also included in the group referred to in regulations aimed at protecting the environment. Different international and national institutions concerned with

the environment are constantly in search of new data on the release of these fumigants into the atmosphere. In Germany, for safety reasons, responsible authorities very often require considerably lower concentration limits for fumigants in the air than the TLVs prescribed.

The problem of contamination of the environment by fumigants is and will be one of the main factors affecting the policy of further application of fumigants. Therefore, intensive investigations have been made to discover and introduce methods of application capable of minimizing gas-leakage from the fumigated area, introducing efficient monitoring systems (i.e., personal monitors) for the entire process of fumigation, and introducing new technologies of airing (e.g., application of gradual airing, application of suitable scrubbers or filters to reduce emission of gas).

The relatively rigorous standards of permissible concentrations of gas in the atmosphere accepted in one member state of the EC, according to the Council directive of 15 July 1991 concerning the marketing of plant protection products, shall affect greatly the further development of fumigation and application of fumigants in other countries of the EC.

Pesticides are chemicals to which everyone is exposed to a certain degree. Their potential hazard can be assessed scientifically on the basis of available toxicological and human exposure data. Fumigants, namely methyl bromide, hydrogen phosphide, and hydrogen cyanide, belong to the group of highly hazardous pesticides and according to present-day development and knowledge, will still be applied in the field of stored-products for many years, provided that special measures be taken to apply them in an expert, safe, and rigorously controlled manner.

Progress in the development of formulations and methods of application and aeration, to enable efficient and safe use of fumigants, is certainly a significant factor that will affect the future use of fumigants in the protection of stored agricultural products.

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