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REPORT ON THE WORK CURRENTLY IN PROGRESS ON ALTERNATIVES TO METHYL BROMIDE

(Submitted by UNIDO)

Foreword

As part of the decisions taken during the 19th Meeting of the Executive Committee of the Multilateral Fund for the implementation of the Montreal Protocol, the Subcommittee on Project Review recommended that UNIDO take the lead in preparing, in collaboration with the other implementing agencies, a brief paper on the work currently in progress on alternatives to methyl bromide.

This report has been prepared in cooperation with UNDP, World Bank and UNEP as well as in contact with the Secretariat of the Multilateral Fund, based on the work of the UNIDO consultants Messrs. Christopher H. Bell and Biswahjit Chakrabarti from UK.

WORK IN PROGRESS ON ALTERNATIVES TO METHYL BROMIDE APART FROM THAT FINANCED BY THE MULTILATERAL FUND

I. INTRODUCTION

1. Properties of Methyl Bromide

Methyl bromide (MB) is a simple alkyl halide with properties that fit into the very narrow band of requirements of physical, chemical and toxicological characteristics needed for a successful fumigant. The discovery in 1991 of the ability of MB to enhance reactions of chlorine with ozone and thus potentially to contribute to global ozone depletion brought this much relied upon pest control agent to the headlines and caused a flurry of political and scientific activity, together with no small measure of controversy. The compound became a listed chemical under the Montreal Protocol in November 1992.

MB has the empirical formula CH_3Br and a relative molar mass of 94.95. Alternative names for MB are bromomethane, monobromomethane, and, more recently, as a result of greater familiarity, the abbreviated MB. Trade names include, Bromofume, Desbrom, Haltox, MBR-2, Metabrom, Methylbrom, Methyl-o-gas, Sobrom 9B, Terr-o-gas 100, Bromogaz, Selfume, Brom-o-sol, and Bromopic. MB is a colourless gas at temperatures above 3.56°C and at low concentrations has no noticeable odour. At high concentrations it is said to have a sickly sweet or musty odour and a burning taste. The lack of odour has disadvantages when MB is used as a fumigant and this has sometimes been overcome by the inclusion of a warning gas, such as chloropicrin or amyl acetate, at concentrations of 2% and 0.3% respectively.

2. The Uses of Methyl Bromide

Methyl bromide has features which make it a versatile and convenient compound for use in many different applications. As a gas it is quite penetrative, reaching pests in soil, commodities and structures which would be difficult to access by most other control measures. It is relatively easy to apply and is active against pests even at low temperatures and gas concentration levels, though there is a broad range of susceptibility among the different groups of organisms requiring control. Exposure times typically range from 2 hours up to 2 days with concentrations ranging from 10 to 150g m^{-3} for commodities and 2-4 days with application rates of 20 to 125g m^{-2} for soils. Exposure periods and concentrations are set within these ranges depending on the material being treated, the target pest, and the local quarantine, contractual or regulatory requirements.

Many of the diverse uses of MB each require only small quantities of the gas annually. Despite their low consumption many of these applications are currently of considerable importance for the particular industries concerned, as well as for national economies, and may involve quarantine legislation (UNEP, 1995). The sheer number of individual uses of MB makes the overall consideration of replacement procedures a complex and very broad topic for research and the implementation of phase out schedules.

3. Global Production and Quantities Used for Treatments

Methyl bromide has been used as a fumigant to control pests and diseases since before the second world war. It was first used to control pests of horticultural produce and pests of stored grain (de Francolini 1935a; 1935b; Shepard and Buzicky, 1939). Later it became established as a treatment for structures (Hill and Border, 1953) and more recently as a fumigant against pests and diseases carried in soil (Kolm, 1962; Kempton and Maw, 1973). Today about 80% of its total usage as a fumigant is on soil. Between 1984 and 1992 the world-wide use of MB increased by 60% to over 70 thousand tonnes per annum, largely as a result of soil treatments in the open. Throughout this period uses other than on soil have tended to remain constant (Annex 1, Table I).

There are six companies reporting production of MB (61,724 metric tons in 1990) in the USA and Western Europe, though production in Asia, China and Eastern Europe is known to be significant. Some estimates of production from these regions are presented in Annex 1 (Table II), together with figures from the rest of the world (Table III) which show the USA to be the major producer. From discussions with the manufacturers there would appear to have been little further increase in production since 1992 (For 1995 market figures see Annex 1, Table IV) and usage figures have continued to see a slight trend towards soil and away from commodities.

4. Alternatives for Methyl Bromide Uses

There is a general consensus that no single alternative exists for the unusually wide range of uses of this important fumigant. The topic of alternatives for uses on soil, on perishable or durable commodities, or in structures or transport, has been extensively reviewed by the Methyl Bromide Technical Options Committee (UNEP, 1995) and further up-dated in a recent book (Bell *et al.*, 1996).

In summary, while there are many methods and materials that offer possibilities for replacement of MB, there is no single alternative available for immediate use by producers, store keepers or pest control supervisors. Alternatives to MB will only develop in response to financial investment in research and development. It is essential that such research on alternatives (chemical, non-chemical and integrated systems) be performed thoroughly under a wide range of practical conditions. This is essential to avoid substitution of MB by fumigation or treatment with other chemicals, or by other methods, which may be more damaging to health and the environment than MB itself. Some research and extension work is being funded by the implementing agencies of the Montreal Protocol (see Annex 2), in response to the agreed phase out schedule, but other bilateral or collaborative projects are in progress as listed below.

II. RESEARCH IN PROGRESS IN DEVELOPING COUNTRIES ON REPLACING METHYL BROMIDE

1. Research in Africa

Several lines of research are in progress to find alternatives to MB, mostly in South Africa (D S Cassidy) and Zimbabwe (P. Wilkinson, D W Blair), for soil uses.

Workers from industry in S. Africa and Zimbabwe have developed systems avoiding the use of MB for treatment of strawberry, cut flower and tobacco (D W Blair) production (UNEP, 1996a). For the latter, the use of soilless media such as pine bark for germination of seedlings in locally produced seed trays which could be sterilised by steaming, is an alternative. For cut flowers and strawberries, a wide variety of nematocides and fungicides have been tried coupled with biologically active organisms and substances such as *Trichoderma spp.*, oxyhumates and other soil amendments. Transfer of this holistic technology in most situations would rely on a mix of cultural procedures and other chemical treatments woven together in an integrated control programme, the details of which would have to be worked out for each cropping system.

In Kenya, Nigeria, and some other countries, many universities are pursuing work on the potential grain protectant qualities of a wide range of pesticidal extracts from African plants is in progress. Besides the classic discovery of pyrethrum many years ago from chrysanthemum family flowers in Kenya, the properties of extracts of the neem plant, originally from India but now widespread in Africa, and promising results from other extracts (e.g. clove oil), have been obtained. The toxicological properties of many plant extracts would require extensive evaluation before registration could be granted in most countries, and this may act as an obstacle to their ready adoption as MB alternatives. Also, the situations in which grain protectants of this nature, or indeed any kind, are used are very different to the set of circumstances leading to the use of fumigants, and so it is probably not appropriate to regard such measures as true MB alternatives.

2. Research in Asia

In Malaysia work is in progress under the government post-harvest research programme on the use of aziradachin (neem kernel extract) for control of stored product pests of cereals. Elsewhere in the S E Asian region programmes are underway on use of alternative fumigants and gases, following on the bilateral programme with ACAIR. IPM strategies have been the subject of case studies in Malaysia, Indonesia, Thailand and Philippines for cropping of hot peppers and cabbages (UNEP, 1996b).

3. Bilateral Research from Australia

The use of well-sealed plastic enclosures for rice and other products, coupled with atmosphere replacement with CO_2 or fumigation with phosphine, has been used with success under the auspices of an ACAIR extension programme, and is a technology already transferred for use in S E Asia (J. van S. Graver).

4. Bilateral Research from Germany

The German Organisation for Technical Cooperation (GTZ) (contact Dr G Laborius) has identified a number of relevant research activities for phasing out MB in their overseas programme for developing countries as follows:

Promotion of sustainable plant protection systems/Jordan

1. Solarization as a means of soil sterilisation using plastic sheeting to cover the soil.
2. Use of metam sodium as a soil fumigant, especially for control of nematodes.
3. Appropriate combination of plant hygiene, crop rotation, healthy seed and solarization, and wall co-ordinated irrigation and fertilization techniques.
4. Trials using "tachigareen" (Isoxazol) for control of soil fungi.

Plant quarantine protection/Syria

1. Use of hydrogen phosphide producing formulations as an alternative method whenever this is technically possible and sufficient time is available.
2. Fumigation trials by using ozone in cereal bag stacks covered with gastight plastic sheeting.
3. Fumigation trials with controlled atmospheres using elevated carbon dioxide (CO_2) concentrations in fumigation chambers.

Project contrôle phytosanitaire/Morocco

1. Nematode control trials in the production of export crops (tomatoes) using tagetes as a trap crop.

Integrated pest management project/Egypt

1. Nematode control trials in vegetable cultivation using tagetes as a trap crop.
2. Trials with nematode-resistant grafting stock
3. Trials with an algal product effective against nematodes.
4. Deep ploughing down to a depth of 1 m.

Pesticide control development project/Jamaica

1. Disposal of obsolete stocks of methyl bromide (3-4 tonnes)

Most of the above projects are at an early stage of development.

5. Bilateral Research from the UK

The UK ODA has launched a programme on sustainable agriculture in developing countries with emphasis on peri-urban regions. Some small bilateral projects have commenced in Africa for improvement of land use. The intention to promote IPM practices in these programme should eventually produce systems which could be adopted in any local region where MB is used.

The Natural Resources Institute (NRI) has an ongoing demonstration project in Egypt testing alternatives for commodity and soil fumigation. Their main approach is to use CO2 and phosphine. A similar project haws been carried out in Kenya (personal communication from Mr R W Taylor, NRI, UK).

6. Research in South and Central America

The work in progress varies from country to country and crop to crop. The major user of MB in the region is Brazil (1990-1994 average of 861 tonnes per annum, UNDP, 1995), mostly for the treatment of tobacco seed beds. Work is in progress on floating hydroponic systems and rearing seedlings on trays in greenhouses, and on the use of methyl isothiocyanate formulations such as dazomet as alternatives. Metam sodium awaits registration in Brazil.

A demonstration project for MB recovery and recycling for the treatment of dessert grapes is under way in Chile, a major grape exporter to the USA (UNEP 1996c). In Costa Rica the water melon trade relies heavily on MB and it is likely that representations will be made to define this use as critical as there does not seem to be an alternative for the local situation (C A Hidalgo). In contrast, cut flowers, representing Columbia's third major export after coffee and bananas, and 10% of the world market, are produced without use of MB.

In Columbia there are about 450 producers and an area of 4,500 hectares of polythene-covered greenhouses are used for flower cultivation, of which over 95% are for export purposes. Colombia is on the north-western corner of South America. The equator passes over the southern region of the country and the floricultural areas are around 2200 metres higher than the sea level,. The climate, as a result, is fairly mild and even throughout the year, with average temperatures ranging from 15°-19°C.

Disease problems are inherent in flower production. However, due to several reasons over a period of 20 years, floriculture developed in Colombia without the use of MB. Apart from considering its use as too dangerous and too costly, there seems to be a valid scientific reason for not using MB in Colombian soil. The soil has a very high organic content of around 18%, this lead to high retention of MB gas for a longer than usual period, resulting in the need for delayed planting because of the inherent danger of phytotoxicity. One farm, where soil organic content is low and nematodes are a problem, could not be cured within the required time-scale and cost by other chemical applications. This farm started using MB from 1994, using 4,150 kg to treat about 11% of their flower beds. Otherwise all soil disinfestations in Colombian flower farms are achieved through IPM, use of steam and use of other formulations such as metam sodium, basamid and telone.

IPM involves making use of all possible resources to reduce and prevent the incidence and effects of a given disease or pest with minimum chemical intervention. Crop sanitation, disease-free plant materials, physical and cultural controls, disease or pest resistant varieties, screening for diseases and record keeping together with design of greenhouses, positioning of insect traps, use of pheromones, strict monitoring of soil nutrients and moisture, etc., are all part of the Colombian floricultural system. The success of the system depends upon a detailed understanding of these aspects. The

Colombian Flower Growers Association (ASOCOLFLORES) distributes to their members a weekly information fact sheet, a monthly newsletter and a journal incorporating technical information four times a year (J C Isaza). The Association also supports periodical meetings among the growers. The successful adoption of IPM programmes in other countries will rely on the creation of a similar infrastructure to disseminate up-to-date information to growers.

III. CONCLUSIONS

It can be deduced from the above that there is relatively little work in progress globally that is specifically directed towards the replacement of methyl bromide uses in developing countries. There are nevertheless a profusion of scenarios available for the reduction and withdrawal of MB. Many of these present plausible ideas. However, although such methods, materials and alternative strategies have potential for the replacement of most MB uses, there is no in-kind alternative available for immediate use. Only if financial and technological support is made available to growers or other user groups will alternative procedures that prove to be effective be accepted readily, and MB uses abandoned. In trying to take a balanced approach, it is essential on one hand that the use of MB is not prolonged beyond the minimum necessary period, but on the other hand an indiscriminate action to withdraw MB could have serious effects on the economy of a state or country and on the social and cultural life of a community. The degree of dependency on MB varies enormously around the world. It is likely that some regions will be able initially to reduce or substitute MB uses quickly, whereas another area may find it economically difficult to replace MB at all. Therefore before the phasing out of MB is considered, the term "alternative" needs to be defined. In essence, an alternative should:

a) be environmentally sound
b) be efficacious and meet all the regulatory requirements
c) not affect quality or shelf-life of produce
d) be cost effective
e) not radically alter current storage/trading practices
f) not degrade socio-economic structure of a region/country

It is imperative that research on alternatives is carried out in the regions where MB is currently used; this is particularly important for the agricultural and horticultural areas of use where climatic conditions and geographical locations may influence the outcome. Ideally, every country, developing or developed should convene an active working group with scientists, methyl bromide users, producers, retailers and Government departments to work together on individual projects to replace MB. The successful completion of each project, bearing in mind the above criteria, would need to be written up as an operational manual or monograph which will provide a problem and country specific set of solutions. In addition, there should be an evaluation of whether the local infrastructure is robust enough to sustain the system which would be required for alternative systems to be put in place. There will be need for assistance in the development of internal capacity building measures to meet local requirements, through research, specific training, and related extension programmes. For developing countries, if indigenous expertise is not apparent, external expertise and provision of funding will have to be made available.

REFERENCES

Bell, C H, Price, N R and Chakrabarti, B (1996) *The Methyl Bromide Issue*. John Wiley and Sons, Ltd, London.

de Francolini J (1935a) *Revue Path. Veg. Ent. Agric. Fr.*, **22**, 1-8.

de Francolini J (1935b) *Revue Path. Veg. Ent. Agric. Fr.*, **22**, 9-12.

Hill E G and Border B S J (1953) *Milling* **121**, pp 488, 490, 492, 494-5.

Kempton R J and Maw G A (1973) *Ann. appl. Biol.*, **74**, 91-98.

Kohn S (1962) *Mushroom Growers Assoc. Bull.*, **152**, 329-333.

Shepard H H and Buzicky A W (1939) *J. econ. Entomol.* **32**, 854-859.

UNDP (1995) Draft Interim Report - Survey of Consumption of Methyl Bromide and Potential Alternatives in English-Speaking Africa, South-East Asia and South America.

UNEP (1995) 1994 Report of Methyl Bromide Technical Options Committee for the 1995 assessment by the UNEP Montreal Protocol on substances that deplete the ozone layer.

UNEP (1996a) Regional Workshop on Methyl Bromide for English Speaking Africa, Harare, September 1995 - Workshop Report. UNEP Industry and Environment.

UNEP (1996b) Regional Workshop on Methyl Bromide for South East Asia and the Pacific, Bangkok, October/November 1995 - Workshop Report. UNEP Industry and Environment.

UNEP (1996c) Regional Workshop on Methyl Bromide: Latin America and the Caribbean region, Bogota, October/November 1995 - Workshop Report. UNEP Industry and Environment.

ANNEX 1 - Figures for Methyl Bromide Production

Table I. Estimated global sales of methyl bromide (tonnes) by use sector

Year	Soil	Post Harvest	Structural	Chemical Intermediates	Total Sales*
1984	30,408	9,001	2,166	3,997	45,572
1985	33,976	7,533	2,257	4,507	48,273
1986	36,090	8,332	2,029	4,004	50,455
1987	41,349	8,708	2,923	2,710	55,690
1988	45,131	8,028	3,647	3,804	60,610
1989	47,542	8,919	3,613	2,496	62,570
1990	51,306	8,411	3,234	3,693	66,644
1991	55,079	10,290	1,817	4,071	71,257
1992	57,407	9,855	2,264	2,648	72,174

Data source: MB Global Coalition (1994)

* Use on perishables not included : 6,537 tonnes estimated in 1992 (UNEP, 1995)

Table II. Production of methyl bromide in the former USSR and Asia based on information given to UNEP (1995)

Year	India	China	USSR	Total
1984	45	45	2,268	2,358
1985	45	45	2,268	2,358
1986	68	45	2,268	2,381
1987	68	45	2,268	2,381
1988	68	113	2,268	2,449
1989	91	136	2,268	2,495
1990	91	136	2,268	2,495

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(Annex 1 contd)

Table III. Sales of methyl bromide by region including chemical feedstock, but excluding China, India and the CIS. Data source: MB Global Coalition (1994)

Year	North America	South America	Europe	North Africa	Rest of Africa	Asia	Australasia	Total Sales
1984	19,659	1,389	11,364	183	1,595	10,687	704	45,572
1985	20,062	1,503	14,414	45	1,975	9,743	531	48,273
1986	20,410	1,774	13,870	380	2,205	11,278	538	50,455
1987	23,004	1,820	15,359	385	1,751	12,816	555	55,690
1988	24,848	2,058	17,478	277	1,582	13,555	812	60,610
1989	26,083	1,701	16,952	618	2,075	14,386	755	62,570
1990	28,101	1,621	19,119	432	1,838	14,605	928	66,644
1991	30,909	2,068	17,447	1,058	2,093	16,843	842	71,260
1992	29,466	2,300	18,521	1,363	1,697	16,944	1,294	71,585

Table IV. Figures (metric tonnes) for the 1995 market (methyl bromide manufacturers)

NORTH AMERICA	31024
ASIA & OCEANIA	19155
EUROPE	17301
AFRICA	4191
S. & CENTRAL AMERICA	3608
TOTAL	**75279**

ANNEX 2.

Actions by the Implementing Agencies of the UN and World Bank in Response to the Methyl Bromide Phase-out Timetable

At the November 1995 meeting of the Parties to the Montreal Protocol in Vienna the following reduction and phase out timetable was agreed:

Developed Countries -	25% reduction by 2001 50% reduction by 2005 Phase out of all but quarantine, preshipment uses by 2010. Critical agricultural uses (yet to be defined) will continue beyond 2010.
Developing countries -	Freeze at the average usage level of 1995-8 in 2002. No phase out date listed.

During these negotiations, the findings and recommendations of the MB Technical Options Committee set up by UNEP were taken into account.

Some member nations have gone ahead of the Montreal Protocol in controlling supply of MB as shown below:

Austria	Phase out by 2000, except for essential uses.
Canada	25% reduction by 1998
Denmark	Phase out main use (tomatoes in glasshouses) by 1996
Denmark and other Nordic countries (Norway, Sweden, Iceland and Finland)	Phase out by 1998, exemption for quarantine and preshipment
European Union	25% reduction by 1998
Indonesia	Phase out by 1997
Japan	Reduction of 5% by 1996 in advance of agreed timetable.
Netherlands	All soil uses phased out since 1992
USA	Phase out import and production by 2001

Three workshops on MB, funded by the Multilateral Fund, were organised by UNEP and governments for the autumn of 1995 in three strategic locations, Harare, Zimbabwe for English speaking Africa; Bangkok, Thailand for S.E. Asia; and Bogota, Columbia for Latin America (UNEP, 1996a, b and c).

HARARE

Presentations were made by scientists and government representatives from Botswana, Egypt, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Namibia, Tanzania, Uganda, Zambia and Zimbabwe. A significant finding that emerged was that there was much uncertainty over the quantities of MB used in African countries and a lack of information on the detailed spectrum of use in individual nations. For countries such as Kenya, Malawi and Zimbabwe most use was on soil (cut flowers, strawberries and tobacco seed beds), but for other countries such as Egypt, Ghana and Tanzania nearly all MB was used against stored product pests on grain and other products.

Conclusions of the workshop - These may be summarised as follows:

1. Three years of field and related studies are likely to be required for the widespread registration of alternative chemicals, whether of synthetic or botanical origin.
2. Demonstration projects would be required to ensure that the "unique and varying conditions found in Africa are given reasonable attention". A list of suitable topics for demonstration projects was identified at the workshop.
3. There was a real constraint in the adoption of alternative technologies because of lack of technical know-how, personnel training and finance.
4. There was widespread concern that alternatives for soil sterilisation were less effective with a narrower range of activity against soil-borne pests and diseases than MB.

BANGKOK

Presentations were made by representatives of Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam. The major use of MB in the region was for commodity fumigation, largely for export purposes. The annual usage in the countries represented was up to 1500 tonnes of MB. However, it was recognised that there was a need for additional information on MB use in the region.

Conclusions and recommendations - The workshop identified the following areas for pilot projects on alternatives:

1. Improving current techniques for grain storage fumigation using CO_2 and phosphine.
2. Development of alternative post-harvest and quarantine treatments for vegetables, fruits and cut flowers.
3. Soil treatment alternatives in the Philippines, Thailand and Malaysia.
4. Ship hold treatments for grain imports and exports.
5. Recycling and improving efficiency of the use of MB.

BOGOTA

Presentations from national representatives to the workshop were received from Argentina, the Bahamas, Bolivia, Brazil, Chile, Columbia, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Mexico, Nicaragua, Panama, Peru, Trinidad and Tobago, Uruguay and Venezuela. The situation varied from country to country and crop to crop. In Costa Rica the water melon trade relied heavily on MB and substitution of an alternative seemed unlikely. In contrast, cut flowers, representing Columbia's third major export after coffee and bananas, were produced without use of MB (see under specific case studies below). A demonstration project for MB recovery and recycling for the treatment of dessert grapes was under way in Chile, a major grape exporter to the USA. For many countries there was a need for more internal capacity building and for lines of communication between governments and industry to be strengthened.

It was concluded that more information was needed about MB uses in the region before many countries could submit proposals for demonstration projects. Some countries identified a number of possible demonstration projects.

OTHER ACTIVITIES

The World Bank Initiative with UNDP has been involved in a wide variety of research projects in partnership with FAO and other bodies centred round an initiative to introduce IPM techniques at the farm level by financing research, training and method evaluation procedures as part of a sustainable agriculture policy. One major programme in Indonesia involved the training of about 800,000 farmers, 1,100 extension workers and 520 pest officers at a cost of approximately 30 million dollars. The World Bank is currently planning to promote the development of MB alternatives within its existing IPM programme.

UNIDO has been involved in technical co-operation projects on pesticides with developing countries for more than two decades, particularly in Asia and the Pacific. Topics such as methyl bromide containment/replacement could easily be linked with UNIDO ongoing and pipeline programmes on pesticides.

Bilateral Demonstration Project (UNDP and CSIRO, Australia) - The use of sheeted bag stacks for holding durable produce under modified atmospheres using technology developed by CSIRO Australia is one line of approach that was already in use in Indonesia and Malaysia. A demonstration of the technique was carried out at Harare, Zimbabwe in September, 1995. The operation involves the laying of a ground sheet before building the stack, and then gluing a canopy sheet to the ground sheet. A negative pressure is then drawn on the enclosure to test for leaks, using a small pump. If more than half the tiny negative pressure is restored within 15 min, the canopy is examined for leaks and resealed as necessary. Carbon dioxide (CO_2) is then applied to the basal aperture used for the pressure test, and displaced air is vented from a small flap in the top of the enclosure until it contains over 80% CO_2. The adoption of this technique in Africa would rely on the availability of suitable materials, including bottled carbon dioxide, and extensive training for stacks to be set up correctly and monitored.