IPCS

INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY

REPORT OF THE INFORMAL CONSULTATION ON

AIRCRAFT DISINSECTION

WHO/HQ, GENEVA, 6-10 NOVEMBER 1995

UNEP

**United Nations Environment Programme
Programme des Nations Unies
pour l'Environment**

**International Labour Office
Bureau International du Travail**

**World Health Organization
Organisation mondiale de la Santé**

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ACRONYMS

AIHA:	American Industrial Hygienist Association
CFC:	chlorofluorocarbon
DHI:	dengue haemorrhagic fever
DME:	dimethylether
ECETOC:	European Centre for Ecotoxicology and Toxicology of Chemicals
FAO:	Food and Agriculture Organization of the United Nations
FEV_1:	forced expiratory velocity
GWP:	global warming potential
HC:	hydrocarbon
HCFC:	hydrochlorofluorocarbon
HFC:	hydrofluorocarbon
IARC:	International Agency for Research on Cancer
ICAO:	International Civil Aviation Organization
IGR:	insect growth regulator
IPACT:	International Pharmaceutical Consortium for Toxicity Testing
IPCS:	International Programme on Chemical Safety
IPPC:	International Plant Protection Convention
JE:	Japanese encephalitis
LC_{50}:	lethal concentration for 50% of experimental animals
LD_{50}:	lethal dose for 50% of experimental animals
MCS:	multiple chemical sensitivity
MDI:	metered dose inhalers
NOEL:	No-observed-effect level
ODP:	ozone-depleting potential
OIE:	Office Internationale des Epizooties
OP:	organophosphates
PAFT:	Programme for Alternative Fluorocarbon Toxicity Testing
ppm:	part per million
TWA:	time-weighted average
ULV:	ultra-low volume
WHO:	World Health Organization

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1. INTRODUCTION

An informal consultation was convened at WHO Headquarters from 6-10 November 1995 to address contemporary issues relating to the disinsection of aircraft, and was generously supported by the US Department of Transportation.

The Consultation was opened by Dr W. Kreisel, Executive Director, on behalf of the Director-General. In his opening remarks, Dr Kreisel observed that international air traffic has increased to such an extent that its possible role in the spread of human, veterinary and plant diseases required careful examination. Not only may insect vectors transmit diseases to people in flight but also to people in places served by aircraft. In addition, aircraft may introduce insect vectors to places where they were not previously present.

WHO Expert Committees have had a long interest in the potential transport of disease vectors by aircraft. Their conclusions and recommendations have been published as WHO recommendations to Member States, most recently in 1985. Since then, concern over the chlorofluorocarbon propellants recommended for aerosols to be used for disinsection of aircraft has led to a reconsideration of their use.

A number of countries require disinsection of aircraft prior to landing. Others do not accept this practice, particularly if it is carried out when passengers are on board. Increasingly, the advice of WHO is being sought concerning the risk to human health, both if aircraft are sprayed or are not sprayed. There is also growing concern, over practice of aircraft disinsection, amongst international organizations concerned with air transport and the public.

The Consultation was therefore specifically needed to evaluate the available scientific data and experts were requested to make recommendations to WHO as to:

1) whether disinsection of aircraft is needed;

2) if needed, how should it be implemented;

3) which chemicals (pesticides, solvents and propellants) and which methods can be recommended.

The Consultation would be expected to devote itself to evaluating the needs for aircraft disinsection and assessing the risks to passengers and crew arising from its use. Only valid scientific information would be considered so that the conclusions and recommendations of the consultations would be scientifically justifiable and realistic.

Professor M. Lotti, Padua, Italy, was appointed as Chairman, and Dr A.L. Black, Canberra, Australia Rapporteur. The agenda of the meeting and a list of participants are attached as Annexes 1 and 2.

The Consultation convened in plenary session for comprehensive discussion of aspects relating to aircraft disinsection and divided into three working groups to consider the different aspects in detail.

2. GLOBAL PERSPECTIVE

2.1 <u>Nature and extent of the problem</u>

More than half of the world's population is at risk of infection by vector-borne disease. For any given vector-borne disease, there are countries or regions that are currently endemic for that disease. There are also areas where these diseases do not currently occur, but which are susceptible to introduction or re-introduction of vectors and pathogens. The magnitude of the health problem caused by five major vector-borne diseases is shown in Table 1.

Table 1: Tropical vector-borne diseases of importance in international air travel

DISEASE	NUMBER OF AFFECTED COUNTRIES	POPULATION AT RISK	MORTALITY	MORBIDITY
Malaria	90	2,300 million	1.5 - 2.7 million	300-500 million cases/year
Dengue/DHF	100	2,500 million	25,000	10-25 million/year
Lymphatic filariasis	76	1,100 million	--	100 million infected*
Leishmaniasis	88	350 million	--	12 million/year
Chagas disease	21	100 million	45,000	3 million/year

* 43 million disabled

2.2 <u>International movement of vector-borne diseases</u>

Vectors and pathogens can be transported between nations by air, sea, or land. Pathogens can be transported either in infected humans or in infected vectors. There is abundant evidence that vectors and vector-borne disease agents are transported internationally. Transport is achieved both in cargo and in passenger-carrying craft.

Surveillance programmes at airports and seaports have documented the importation of known or potential mosquito vector species, among them, *Aedes aegypti, Aedes albopictus, Aedes polynesiensis*, *Aedes scapularis*, *Aedes togoi*, *Anopheles gambiae*, *Anopheles albimanus*, *Anopheles barbirostris*, *Anopheles subpictus*, *Culex pipiens*, *Culex quinquefasciatus*, *Culex annulirostris*, *Culex sitiens*, *Culex tritaeniorhynchus*, *Mansonia uniformis*. Other possible insect vectors belonging to the families *Muscidae* and *Reduviidae* have also been intercepted (Craven et al., 1988; Evans et al., 1963; Hughes, 1961; Le Maitre & Chadee, 1983).

Each year cases of vector-borne disease are documented in countries outside the known distribution of the disease. In the USA, for example, about 130 cases of dengue were reported each year between 1986 and 1992 (Rigau-Perez et al., 1994). Similarly, during the 27 years from 1966 to 1992, an average of 1324 cases per year of malaria was reported for that country (Zucker et al., 1995).

In the great majority of instances, these infections were acquired by people while travelling in known endemic regions of the world. In other instances, however, infections are seen in persons with no travel history. In the case of malaria, some of these latter infections may be due to infection through blood transfusion or by needle sharing among intravenous drug users. Still other cases are due to transmission by local vectors (Maldonado et al., 1990, Layton et al., 1995) that have bitten infected travellers or other infected people (such as migrant workers or illegal immigrants). Finally there is some evidence that, at least in the case of malaria, infected vectors may actually be transported by means of aircraft or ships.

3. HUMAN DISEASES AND THEIR VECTORS

3.1 Malaria

Malaria is transmitted by *Anopheles* mosquitoes in some 90 countries, mainly in tropical areas. Millions of deaths from malaria still occur annually, mostly in Africa (WHO, 1994c). Among the four species of human malaria parasites, *Plasmodium falciparum* is the most pathogenic while *Plasmodium vivax* is the most widespread and likely to cause clinical relapses.

Among the countries currently free of endogenous malaria, many remain vulnerable and receptive. Vulnerability is related to the actual number of imported cases. Receptivity refers to the number of new cases of malaria that might originate from a single imported case, considering the vectorial capacity of local anopheline species of malaria vectors (Gilles and Warrell, 1993).

In considering the risks of aircraft carrying infected malaria vectors or human malaria cases to new areas it is convenient to define some of the origins of malaria cases as follows (WHO, 1963):

imported malaria: cases of human infection acquired when the person visited another country;

introduced malaria: cases due to local transmission from an imported case;

airport malaria cases involve passengers on aircraft or people in countries where malaria is not endemic, due to transmission of malaria by infective *Anopheles* mosquitoes brought on aircraft from a malarious area (Isaacson, 1989);

runway malaria cases are those contracted by people who acquire the infection from infective *Anopheles* mosquitoes which bite them at an airport during a stopover in a malarious area (Conlon et al., 1990).

More than 50 recorded cases of airport malaria and runway malaria have been reported during the past two decades (Carnevale, 1995) and it seems likely that many more have occurred without detection.

3.2 Plague

Bubonic plague transmitted by rat fleas has caused many human epidemics throughout history (Pollitzer, 1954; Gratz, 1988). Outbreaks of human plague have occurred recently in India, Myanmar, Madagascar, Mozambique, Tanzania, Peru and the USA (WHO, 1993a; 1994a, 1994b, 1995). Infected rodents with their fleas may be transported to new areas, raising special concerns to prevent the spread of plague from active foci during outbreaks. Moreover, rodent

damage to the structure of aircraft, ships and other vehicles can have dangerous consequences. Therefore, articles 52.60 of the International Health Regulations (WHO, 1983) specify the steps to be taken whenever rats or plague are suspected in international transport. The benefit of disinsection procedures are particularly relevant to guard against fleas surviving on aircraft at such times.

3.3   Arboviral diseases

3.3.1   Dengue and dengue haemorrhagic fever

Dengue and dengue haemmorhagic fever (DHF), as transmitted by the principal mosquito vector *Aedes aegypti*, are present in more than 100 tropical and sub-tropical countries around the globe.

The overall prevalence of dengue is in the millions with estimates of 2.5 thousand million people or two-fifths of the world's inhabitants at risk to the disease in urban centres in Africa, the Americas, Asia, the Mediterranean and Pacific regions. However, there is significantly more dengue and DHF now being reported from rural areas in Asia where water supplies have been improved and the vector(s) mosquitos have been introduced along with the virus.

Since the 1950s when the initial DHF outbreak occurred in Asia there has been a dramatic increase in the number of epidemics. From 1950 to 1970, nine countries experienced outbreaks. In the decade of the 1970s, six more countries were added to the list and in the 15 ensuing years there have been 24 countries which have either experienced DHF cases or epidemics. Today, 41 countries have experienced DHF. It is estimated that the annual incidence is some tens of millions of cases, with approximately 500 000 hospitalizations, 95% of which are children under 15 with an average mortality rate of 5%.

There are several real and potential mosquito vectors of dengue and DHF/DSS, mainly *Aedes* species belonging to two subgenera, i.e., *Stegomyia*, and *Finlaya*. As previously mentioned the principle vector is *Aedes aegypti* which features most prominently among the *Stegomyia*. Secondary vectors within that subgenus include *Aedes albopictus*, *Aedes polynesiensis* and species in the *Aedes scutellaris* complex which have been shown to be effective vectors. Dengue isolations have also been obtained from the forest dwelling *Aedes (Finlaya) niveus* subgroup. It is known that vertical (transvenereal/transovarial) transmission of the virus occurs in nature within certain populations of *Aedes aegypti*.

The distribution of two major species, *Aedes aegypti* and *Aedes albopictus* is illustrated in Figures 1 and 2. Figure 3 indicates the general distribution of dengue covering the period from 1975 to 1995 and Figure 4 the general distribution for yellow fever between 1970 and 1995 in the Americas and Africa.

3.3.2   Yellow fever

Yellow fever continues to occur in significant outbreaks mainly in Africa. More than ten mosquito species can transmit the virus, including *Aedes aegypti*, *Aedes africanus*, *Aedes simpsoni*, *Aedes taylori*. In the Americas, there are at least six real or potential vector species in addition to *Aedes aegypti*, and other container or tree hole breeding species[1] of importance in the

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[1]   *Aedes scapularis, Aedes fluviatilis, Runchomyia frontosus* and *Sabethes chloropterus*.

sylvatic cycle *including, Haemagogus* species, *Aedes leucocelaenus* and Sabethes species. *Aedes albopictus* has been introduced into two countries in which yellow fever occurs, namely, Brazil and Nigeria. *Aedes albopictus* has been shown to be an effective vector of yellow fever in the laboratory (Mitchell et al., 1987).

During the period of 1970-1995, yellow fever has been reportedly present in 41 countries, 25 countries in the Americas experiencing disease outbreaks in sylvatic areas and 16 countries in Africa experiencing both sylvatic/rural and urban epidemics.

Annually the number of reported cases averages 1200, the maximum number reported in a single year being 5340 in 1988. Mortality averages around 30%. The total number of deaths reported for the period is 8500, with a yearly average of 340. The greatest number occurring in 1988 when 1714 deaths were reported. The numbers reported are felt to be greatly underestimated.

3.3.3 Japanese encephalitis

Japanese encephalitis (JE) is considered a serious disease of significant public health priority, particularly in endemo-epidemic areas in a number of Asian countries, because of its high case-fatality rate and grave sequelae with neuropsychiatric disorders (Igarashi, 1992). The disease is spreading and the potential for spread is substantial.

In South-East Asia, JE has its distribution in 14 countries with the largest outbreaks occurring in China. The principal vector mosquito species is the rice paddy breeding *Culex tritaeniorhynchus* which feeds on domestic animals and man. An additional six vectors are *Culex* species[1] as well as *Anopheles barbirostris*, *Anopheles hyrcanus*, *Mansonia uniformis*, and *Mansonia annulifera* species (Vythilingam et al., 1994). Pigs are the principal reservoir hosts or amplifiers of the virus.

From 1971 to 1994, the number of cases of JE in Asia totalled 1 281 427, the annual average being more than 55,000 cases. Mortality ranges from 5 to 10% (Umemai et al., 1985) with a total of 53 244 deaths during the period and an average of 2315 per year. More recent publications are also available (Barzaga, 1989; George et al., 1990; McCallum, 1991; Sharma et al., 1991; Chaudhuri et al., 1992).

3.4 Other vector-borne diseases of humans

With the exception of rodent plague (a disease specifically subject to the International Health Regulations), there has been less concern with ectoparasitic vectors of disease (ticks, lice, mites and fleas), which would be unlikely to board aircraft directly. The control of these insects in the vicinity of airports is undertaken through the management of both the potential animal hosts in the area as well as the health of human staff and employees.

There are other important insect- transmitted human diseases that represent significant global problems. Some, such as lymphatic filariasis, require repeated contact with the infected vector for transmission. Consequently, they represent a very limited potential risk in terms of international spread through air transport.

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[1] *Culex gelidus, Culex bitaeniorhynchus, Culex pseudovishnui, Culex vishnui, Culex fuscocephala* and *Culex quinquefasciatus*.

Figure 1: Actual and potential distribution of *Aedes aegypti*, 1995
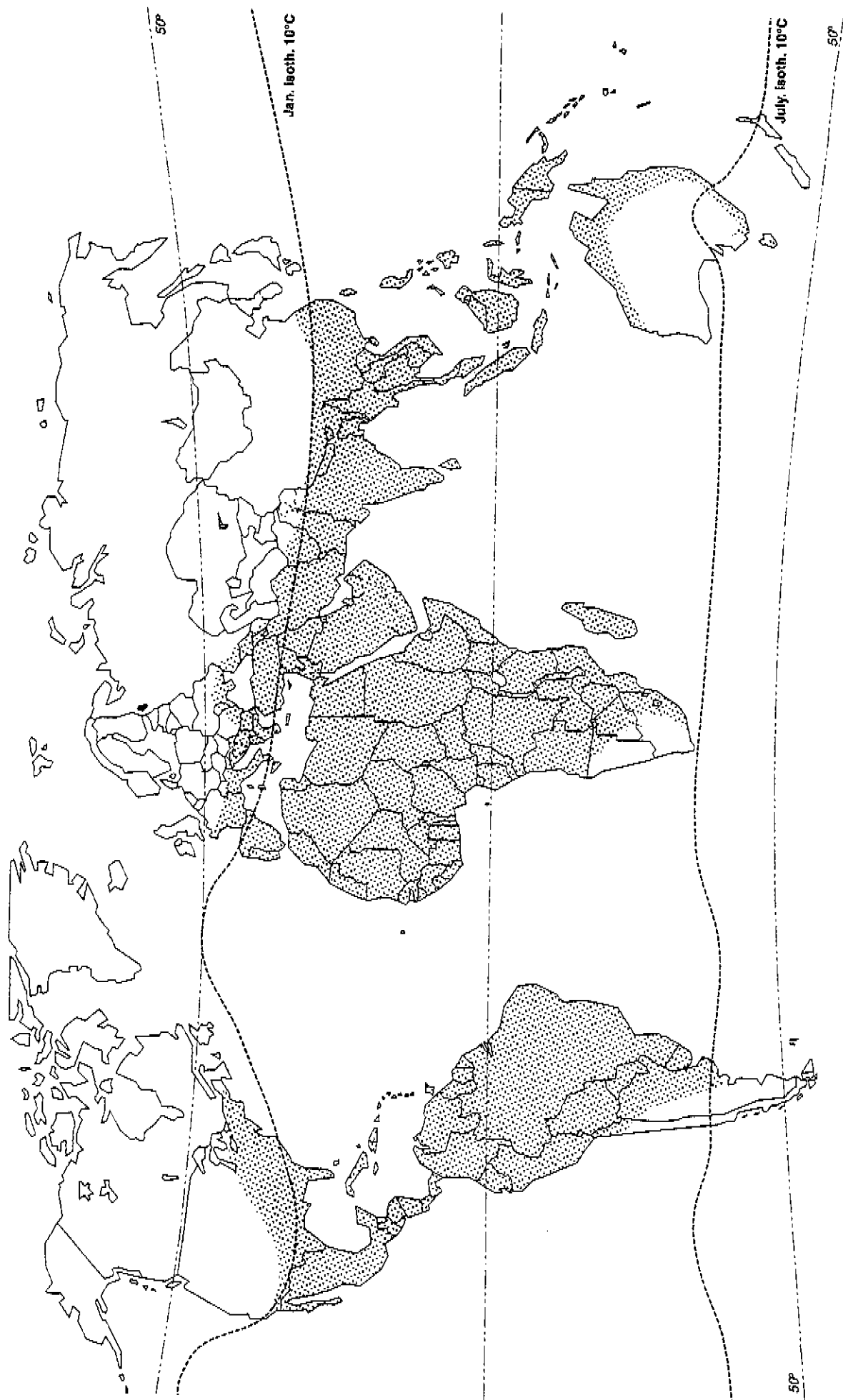
Figure 2: Countries where *Aedes albopictus* is reported to be present, 1995
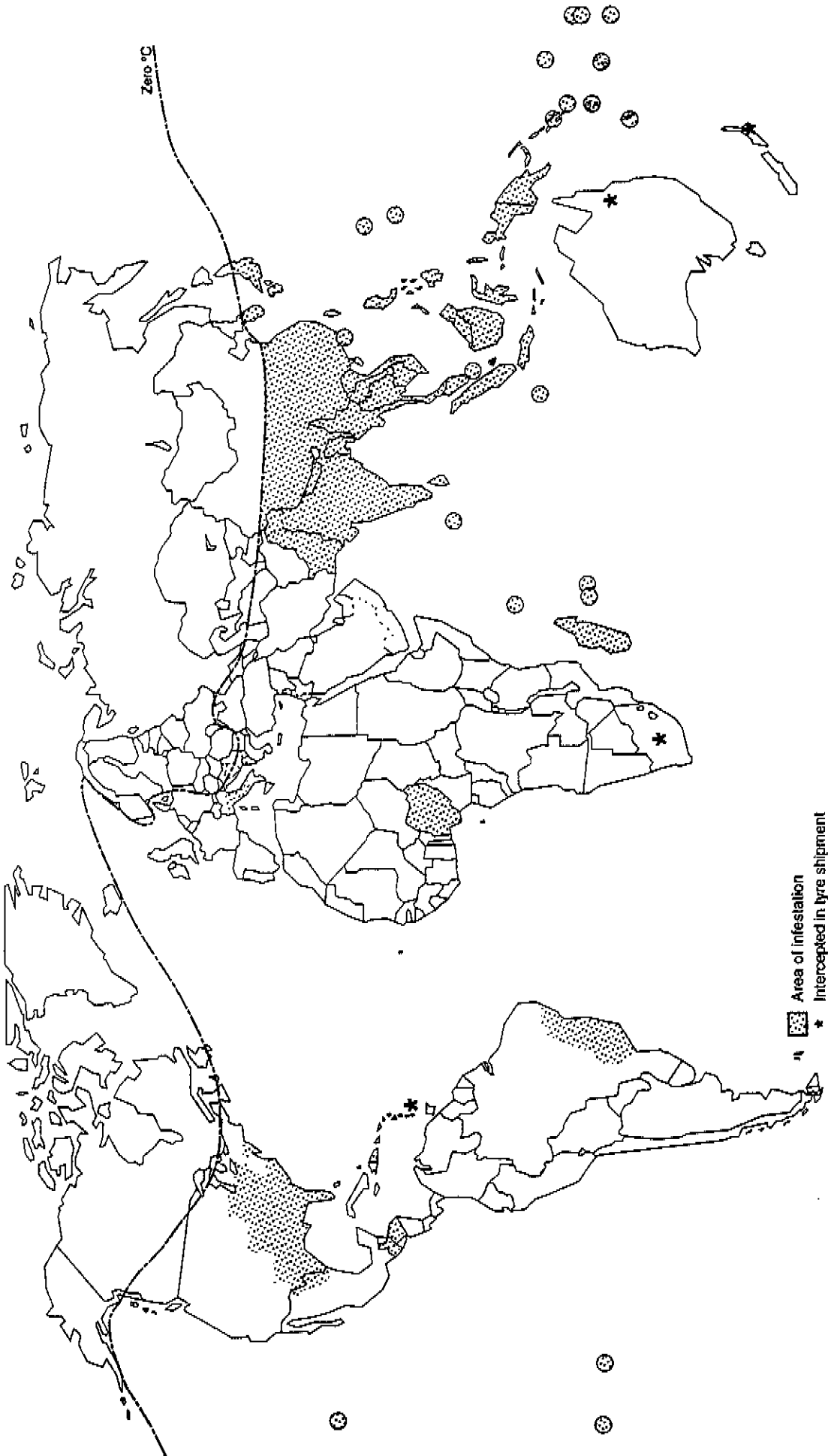
Figure 3: The general distribution of dengue and/or dengue haemorrhagic fever, 1975-1995

* Countries which have experienced DHF outbreaks
△ Imported cases (probable or confirmed)
≠ Unconfirmed

Figure 4: Countries officially reporting cases of yellow fever in the African and American regions during the period of 1970-1995
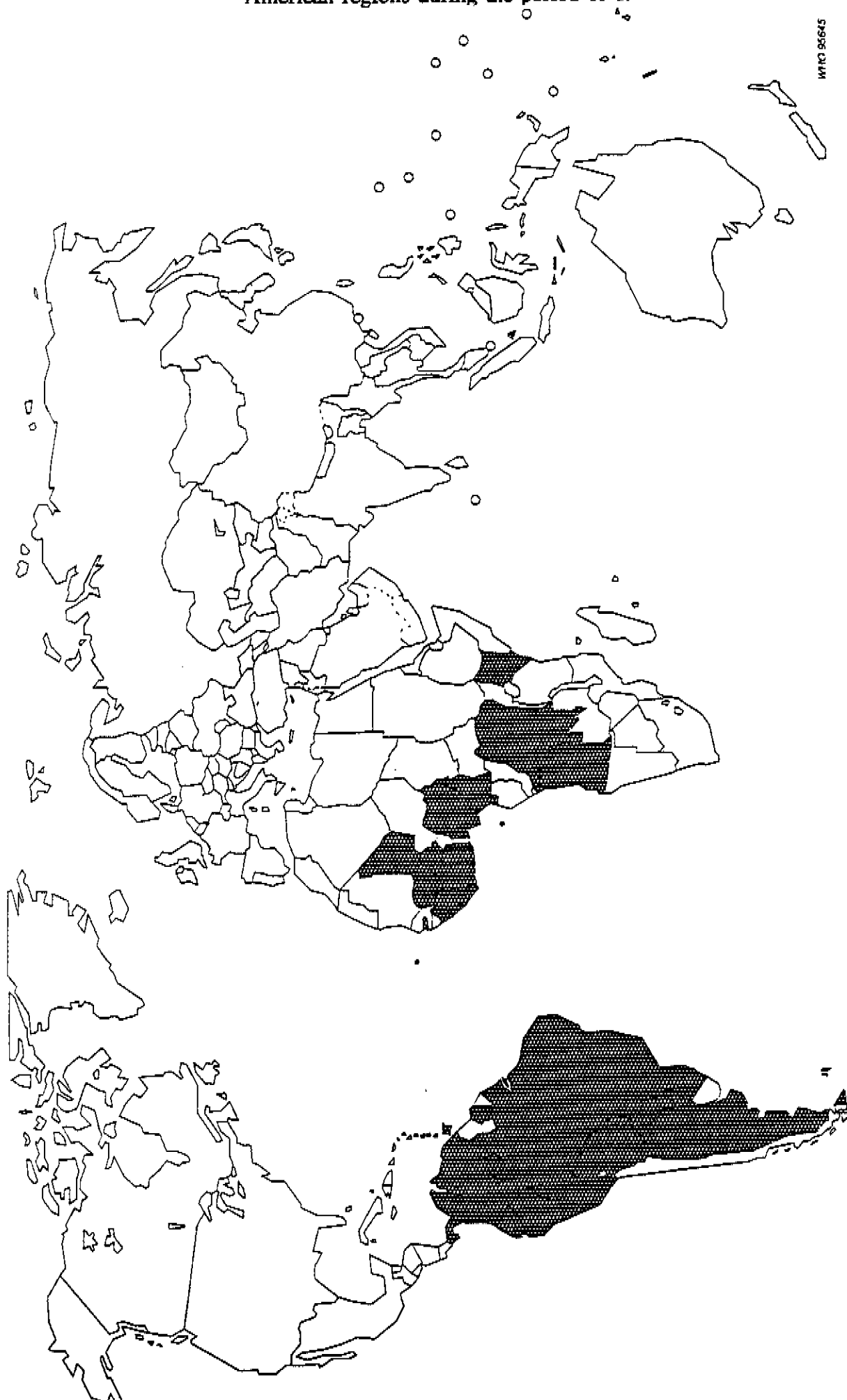
Other human diseases transmitted by insects, such as the leishmaniases, trypanosomiases and onchocerciasis, have received less attention. This is presumably due to their complicated zoonotic host relationships, the narrow biological niches of the vectors involved or the limited potential for rapidly developing epidemics. (Chaniotis et al., 1974; Healing, 1995; WHO, 1989a).

4.   PLANT PESTS AND DISEASES

Insects and other plant pests have been carried across national boundaries for centuries. With the advent of air travel, this movement substantially increased, posing a very serious threat of pest introduction and spread. Although plant quarantine laws were established as early as the sixteenth century, concerned countries recognized that, in order to prevent the introduction and spread of plant pests, they needed to take concerted action at global level. This led to the establishment of the International Plant Protection Convention (IPPC) in 1951 at the FAO Sixth Conference. The contracting parties to the IPPC agreed to take common and effec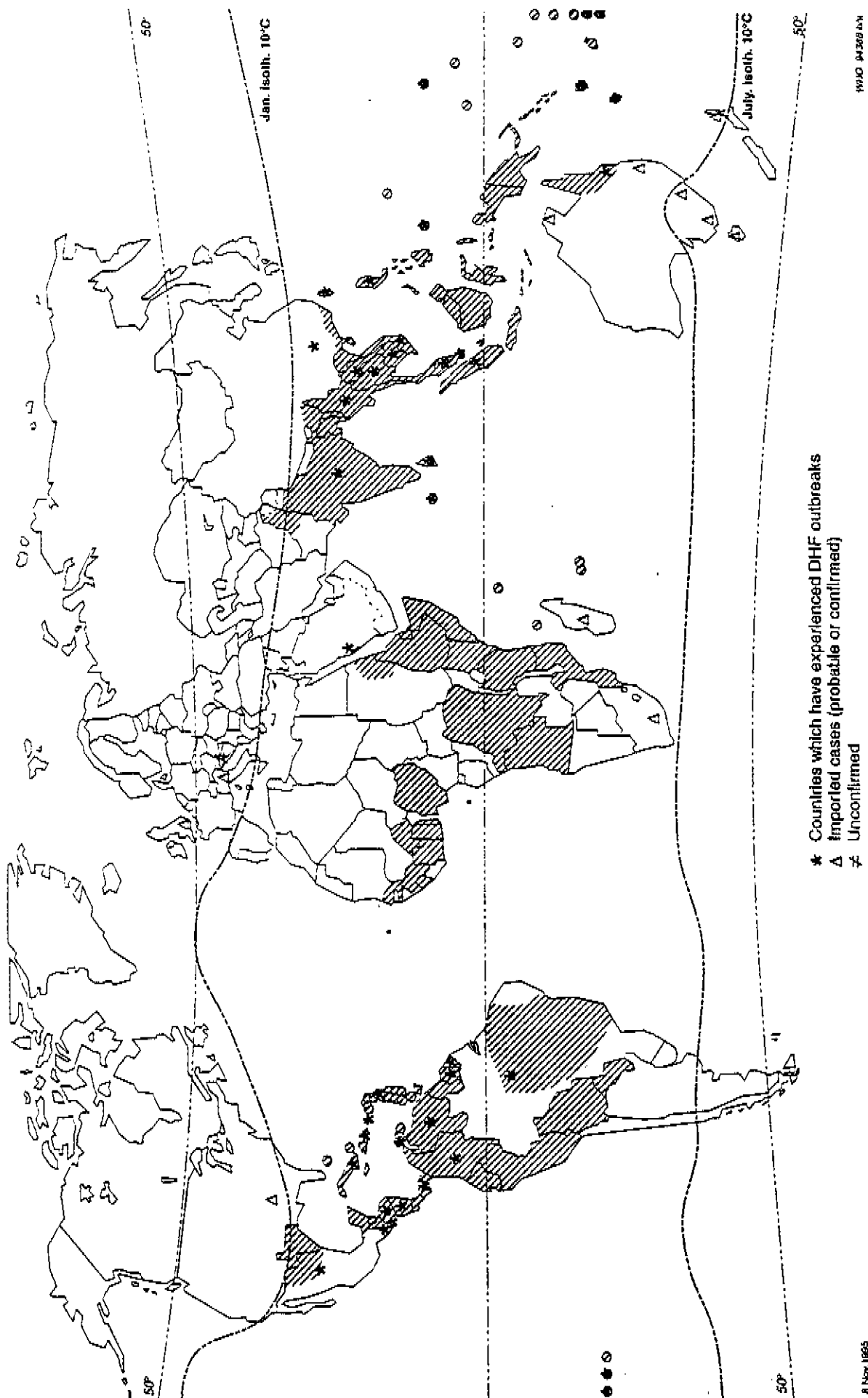tive action to prevent pest introduction and spread and promote their control through the implementation of certain technical and administrative measures.   These include the establishment of an official plant protection organization to discharge the obligations under the IPPC (inspection and treatment of means of conveyance and their cargo and baggage) and the issuance of phytosanitary certificates.

One of the major concerns of the contracting parties of the IPPC is to prevent or delay the establishment of plant pests associated with air travel. It is widely recognized that this pathway poses a particularly dangerous pest introduction risk. The quarantine pest lists published by many countries (i.e. Australia, New Zealand, USA) document thousands of pest interceptions every year at points of entry in aircraft.   FAO and Regional Plant Protection Organizations (RPPOs) regularly publish reports of quarantine pest introductions. These reports include the interception of insect pests and vectors, in air cargo compartments and passenger cabins, which have entered the aircraft while it is being loaded or which have been associated with agricultural articles in cargo or baggage.

It is, therefore, necessary to strengthen surveillance activities at international airports and other points of entry, and effectively to disinsect aircraft and other means of conveyance to eliminate the risk of introducing insects and vectors of plant diseases of quarantine significance.

5.   ANIMAL PESTS AND DISEASES

The comments made about plant pests in the previous section are equally relevant to the insect pests of animals, including vectors of animal diseases.

The introduction of these insects by aircraft can be demonstrated by the introduction of the fly *Musca vitripennis* into the USA by cargo jet from Europe. *Parafilaria bovicola*, Tubangui, a parasitic nematode of cattle causing haemorrhagic filariasis, has been shown to develop to the infective stage in *Musca vitripennis* (Morgan et al., 1985).

There are similar pest/host or vector/pathogen associations for a range of insects considered a threat to animal health e.g. *Culicoides* transmitting blue tongue virus of sheep, *Anopheles* and *Aedes* spp. transmitting Western, Eastern and Venezuelan equine encephalitis, and *Stomoxys calcitrans* harbouring hog cholera.

Many of the insects which have been intercepted on board aircraft are known vectors of animal diseases. The relative importance of hitchhiking insects affecting animal health is dependant on the value of animal husbandry in a Member State's economy.

6.   RELATIVE RISKS OF VARIOUS MODES OF TRANSPORT

The spread of human, veterinary and agricultural vector-borne diseases throughout the world continues to remain a problem of global public health importance. Infectious diseases continue to be the leading cause of human death, in global terms. Several of these important disease threats are transmitted by insect vectors. Effective strategies designed to control and limit the extent of these disease threats must be based on integrated risk assessment principles. Accurate epidemiologic and surveillance activities are one of the cornerstones of such risk-assessment and risk-management practices.

Principles and practices designed to limit the spread or extension of disease must acknowledge both known and defined risks of current patterns of disease as well as the potential risks posed by emerging and re-emerging disease threats.   The former are exemplified by currently observed and reported patterns of malaria transmission and the re-emergence of dengue fever in many parts of the world, while yellow fever and Japanese encephalitis represent potential problems for disease emergence/re-emergence.

There is abundant evidence that international transportation plays an increasingly important role in this process (Wilson et al., 1994). The growth in the volume of movement of goods, passengers and produce has been dramatic. This increase in the amount of international traffic has been accompanied by both an expansion in routing as well as a growth in international agreements designed to facilitate and enhance commerce.

The movement of disease, either by way of the transport of insect vectors or the travel of infected hosts themselves, accompanies international transport. Examples of the deleterious consequences that may follow the introduction or reintroduction of disease vectors across geographic boundaries are well documented. *Aedes albopictus,* an effective vector of dengue fever has been introduced into the Americas, Nigeria, Italy and other areas via surface transport.   Large numbers of travellers and migrants present with clinical illnesses in areas where these diseases are not commonly observed or have been eliminated. Examples include malaria, dengue fever and Chagas' disease.

As noted, there is abundant evidence from some areas of the world which document the transport of insect vectors and other harmful insects across international boundaries by aircraft. There is however a paucity of surveillance and epidemiological information regarding the magnitude of this problem in other modes of transport.   The size and relative risk of the transportation of vectors by other methods of transportation requires   investigation and quantification in order to facilitate the development and implementation of effective control strategies.

Ocean going transportation particularly in terms of containers that may be carried some distances from ports of entry may be important methods of transporting disease vectors internationally. Additionally, the movement of commodities and material over land routes, which may be facilitated by the construction of new roads and highways offers opportunities for increased risk of vector transport. Coordinated, integrated disease and vector control programmes will need to consider the relative risk posed by each of the methods of transportation.

Containers can be a potential means of transporting rodents and insects. There are difficulties in knowing whether containers might be infested. Precautions need to be taken to ensure that infestation does not occur prior to, or at the time of, loading. If containers are opened after arrival without adequate supervision rodents and insects may escape control measures.

The application of vector and rodent control measures to containerized traffic presents particular difficulties. Some containers are destined for clearance at off-airport locations and quarantine measures applied at the airport could be detrimental to the interests of the importer. In any event, as customs authorities would undoubtedly insist on being present at the first opening of a container, there would be a need for coordination between the governmental authorities involved.

To that end, detailed examination and evaluation of the relative importance of insects and vectors transported by ocean-going vessels, trains, road vehicles and containers should be undertaken.   Principles of surveillance and vector control monitoring originally established for airports may provide useful models for other points of entry.

Insect vector control programmes, including disinsection, should be based on assessments of risk that encompass all forms of international transportation.

7.   ESTABLISHMENT AND RE-ESTABLISHMENT OF INSECT PESTS AND VECTORS

Some WHO Member States are concerned about the spread by aircraft, ships, trains, road vehicles and cargo containers of new insect vector or pest species to their country, irrespective of whether or not they are infected specimens.

Past experience has noted that one of the features of a new species being introduced into a suitable environment and becoming established is that it can successfully occupy an available ecological niche (e.g. *Anopheles gambiae* in Brazil and Egypt; *Pieris rapae* in New Zealand; *Aedes albopictus* in the Americas (Soper and Wilson, 1943; WHO, 1955; Hawley, 1988; Moore et al., 1988).

Autochthonous outbreak of vector-borne diseases have often followed a period of consolidation by a newly introduced species of vector (e.g. dengue in Fiji transmitted by *Aedes aegypti*; malaria in Brazil and Egypt transmitted by *Anopheles gambiae*; Dengue in Guam transmitted by *Aedes albopictus* (Haddock et al., 1979).

Some Member States (e.g. Australia, New Zealand and the USA) have well documented knowledge of what insect vector or pest species are arriving, and by which entry pathways such as aircraft, ships, cargo containers, etc. (Manson & Ward, 1968; Richardson, 1979; Keall, 1981). Other states have documented evidence of new insect species which have become established although there may be insufficient evidence of the precise entry pathway (Laird, 1984).

In an attempt to prevent the introduction of new pest species which pose a threat to human, animal and plant health, or to the environment, Member States may take action(s) according to their national import requirements - aircraft disinsection is but one of these.

The vector/pathogen or pest/host association of the insects intercepted on aircraft in the past are well established. Import requirements may be determined by the legislative authority of the Member State with due regard for commitment to international agreements and in accordance with regulations and standards established such as WHO, ICAO, IPPC or OIE.

When Member States have spent considerable sums of money in eradication or control of particular insect vectors or pests they once more consider that they are justified to ensure that a re-establishment of these does not occur.

Another aspect of establishment is that an active pathogen/host involvement producing human disease can occur with hitherto unsuspected vectors. This was demonstrated in Guam when abnormal vector pathogen relationship were involved because of the absence of primary vectors on the island (Ward, 1984).

8. VECTOR CONTROL

The Consultation reviewed Article 83 of International Health Regulations (3rd edition, 1983) and considered the existing provisions fully adequate. It consequently agreed that Member States should limit any routine requirement for disinsection of aircraft cabins and flight decks with an aerosol, while passengers are on board, to aircraft operations originating in, or operating via, territories that they consider to pose a threat to their public health, agriculture or environment.

WHO was requested to intervene at an early stage in order to play a coordinating role in the control of transport of insect vectors which might find suitable conditions to reproduce in areas where they were unknown before. WHO has also been requested to consider taking the most appropriate action to avoid the spread of diseases in areas where they are not yet in existence and to prevent cases of so-called "airport malaria".

As a result of this WHO made a number of recommendations. The first recommendations for aircraft disinsection were published in Annex 6 in the Eleventh Report of the Expert Committee on Insecticides (WHO, 1961) and subsequently in the first edition of the International Health Regulations 1969. Since 1985, it has been found more convenient to publish the recommendations on that subject in the Weekly Epidemiological Record of WHO in order to follow more adequately the development in techniques for aircraft disinsection.

In 1985, the Weekly Epidemiological Record (WHO, 1985b) described specifications for aerosols which included specifications for dispensers, (these specifications are also detailed in Equipment for Vector Control). The content of the WHO Standard Reference Aerosol (SRA) and of some alternative aerosols, disinsecting procedures (disinsecting before take-off "blocks away", disinsection on ground on arrival, residual treatment of aircraft for disinsecting) are also provided.

In an addendum to residual treatment of aircraft for disinsecting (WHO, 1985c), it was pointed out that each time an aircraft has been treated in this way a certificate must be issued by the responsible authority for presentation to appropriate officials.

Further, the Weekly Epidemiological Record (WHO, 1985d) provided details on the procedure for aircraft disinsection by application of a residual insecticide mentioning spray material, equipment and methods and giving an example of a certificate of residual disinsection.

In a subsequent publication (WHO, 1987) WHO indicated that the residual disinsection method would be submitted to the World Health Assembly for approval. In addition, it was stated that at the recommended rate of application intervals between retreatments could be extended to eight weeks, provided that surfaces routinely cleaned were treated on a weekly basis via a "touch-up spray".

8.1   CURRENT PRACTICES

Disinsection methods presently used by airlines fall into two groups:

(1)   spraying before or during flight using aerosols

(2)   residual treatment

1.   <u>Spraying using aerosols</u>

(a)   **"Blocks away" disinsection as recommended by WHO**

This procedure takes place after passengers have boarded, the doors have been closed and prior to take-off.

The aircraft is treated by crew members walking through the cabins discharging approved single shot aerosols at the prescribed dosage.

Passengers should be advised prior to disinsection to close their eyes and/or cover their faces for a few seconds whilst the procedure is carried out if they feel that it may cause them any inconvenience.

To be effective the aircraft air conditioning system must be turned off whilst spraying is carried out and crew must treat all possible insect harborage including toilets, galleys, wardrobes, lockers, etc. Spray cans used must be retained for inspection by the Port Health Authority on arrival.

Holds and the flight deck are sprayed prior to departure - the flight deck prior to boarding by the crew. Cans used are also retained in the aircraft for inspection.

An entry should be made in the aircraft "declaration of health" confirming treatment.

(b)   **Pre-flight and top-of-descent spraying**

Similar to "blocks away" except that the aircraft cabin is sprayed on the ground prior to passengers boarding, using an aerosol containing a residual insecticide.

The timing of this spray allows lockers to be open and minimum inconvenience to passengers.

Pre-flight spraying is followed by a further in-flight spray carried out at "top-of-descent" as the aircraft starts its descent to the arrival airport.

This spray is as for the "blocks away" treatment. Again all cans used must be retained for inspection by Port Health Authorities if required and suitable entries made in the aircraft declaration of health.

The "blocks away" method has been recommended by WHO and is presently used by several airlines. During spraying, overhead racks, lockers and toilets have to be opened and properly sprayed. In practice, treatment is commonly done during taxi-ing when they are closed. Insects located inside are not fully reached and controlled by the spray. To avoid this problem, the Consultation recommended that a

pre-spray be applied with a residual insecticide (permethrin). Doses of this additional treatment are provided in Annex 3 with a full description of the method.

In addition to the "blocks away", the "top-of-descent" method is also acceptable (a full description is given in Annex 4). With this method, spraying of the cabin is done immediately after the aircraft started its descent to destination. At that time, the air recirculating system is shut off and the aerosol remains within the cabin long enough for optimal efficacy. However, for the same reasons, a pre-spray has to be applied as added to the "blocks away" method (same areas sprayed, same insecticide and same dosage).

Empty cans used for pre-spray have to be retained and delivered to Port Health Authorities on arrival as those used for the cabin spray ("blocks away" or "top-of-descent").

"Blocks away" or "top-of-descent" with a pre-spray application are effective and easy to implement. The main inconvenience is related to the presence of passengers in the cabin during the spray. In order to avoid this inconvenience, a new pre-embarkation spray has been developed in Australia and New Zealand. In this case, it is an aerosol mixture of a fast-acting (d-phenothrin) and residual (permethrin) insecticide that is used. Spray is carried out shortly before passenger embarkation with all overhead lockers and toilets opened. All insects on board are controlled. Insects entering after treatment are controlled by the residual efficacy of permethrin. In addition, fewer insects may enter a cabin treated with permethrin because of the strong repellant effect of this insecticide. Air conditioning should be turned off during spraying.

The promising pre-embarkation method will have to be further tested before being recommended by WHO (a description of the proposed method is given in Annex 5). It should be kept in mind that whatever spray method used in cabins, it is emphasized that cargo holds must also be treated.

In the case of a flight with multiple sectors, the pre-embarkation spray would have to be carried out if required, on each sector.

2.   Residual treatment

In this method the internal surfaces, excluding food preparation areas, of the aircraft are regularly sprayed with a residual insecticide to ensure that if an insect gains access to the aircraft and lands on a surface it will receive an effective dose of insecticide.

Treatment must be repeated at intervals not exceeding eight weeks and must use WHO recommended methods and insecticides.

Any treated areas subsequently deep cleaned or refurbished within the second treatment intervals must be retreated to ensure compliance.

A fluorescent dye may be added to the spray to enable ease of identification of treated areas.

Insofar as efficacy, inconvenience to, and safety of passengers with possible predisposition to adverse health reactions is concerned, the residual disinsection method provides the most assurance. It remains efficacious for eight weeks and does not require passengers or crew to be exposed to aerosol sprays. It has the added benefit of lessening the workload of aircraft cabin crew.

Nevertheless, the Consultation recognizes that not all airlines would employ this method for various reasons associated with airline operations and, to a lesser degree, cost considerations. It is for this reason that the Consultation agreed that airlines should be given several options for achieving effective disinsection.

8.2   VECTOR CONTROL IN AND AROUND AIRPORTS

Most airports are sited well outside urban areas and, in tropical regions, are often adjacent to rice fields, irrigated fields or marshes where *Anopheles* vectors of malaria and mosquito vectors of other diseases are common. Most airports cover very large areas and include not only terminal and baggage handling buildings, but kitchens, hangars, garages, store rooms, refuse disposal points and, usually, drainage ditches, some of which may contain polluted water.

Discarded containers of every type, old vehicle and aircraft tyres and even flower pot sources in the terminal building can all serve as larval habitats for *Aedes (stegomyia)* species. Drainage ditches along runways and irrigated areas adjacent to the perimeter may be the source of *Anopheles* and *Culex* mosquitoes. Finally, poorly constructed sewage facilities near dormitories or hotels can be prolific sources of *Culex* vectors and pests.

The International Health Regulations specify the conditions to be maintained in and around airports for the prevention of vector breeding, particularly that of mosquitos and for the prevention of rodent infestations.

Ideally, prevention of vector and rodent breeding should be carried out through environmental measures which will eliminate the larval habitats. However, this is not always the case where extensive marshes or irrigated areas are close to the airport. In such cases the use of chemical or biological pesticides may be necessary to control mosquito breeding.

Rodents are known to be carriers of fleas which are vectors of disease, and in themselves may be carriers of human disease agents.

Where rodent infestation is found in airport buildings or in the grounds of the airport, immediate steps must be taken to control the infestations. The use of rodenticides will almost certainly be necessary to control the infestations. Infestation by even a single rodent on an aircraft and especially by a rat gnawing at a cable can endanger the aircraft and its passengers.

Evidence is available that mosquitoes breeding in airports, both vector and pest species as well as pest insects such as flies and cockroaches, will readily gain access to aircraft and may thus be transported to distant areas. This includes the transport of insects which may be resistant to insecticides.

As noted above, wherever possible, actual or potential breeding sites of vectors and pest insects should be eliminated by environmental methods. This should include the disposal of any containers which may hold rain water and breed potential *Aedes* vectors of dengue and yellow fever, ensuring that all drainage ditches in the airport grounds are kept clean and free from vegetation that can encourage anopheline and culex breeding and that all polluted water drains in which *Culex*, vectors of filariasis and pests can breed are put in underground pipes or channels.

The chemical control of vectors

Under certain circumstances environmental control of mosquitos may not be readily possible. This may be the case with *Anopheles* breeding sites on the airport grounds or in areas around the perimeter of the airport. Salt marshes, mangrove swamps or other areas of slow moving or stagnant water, in the vicinity of airports can be prolific sources of mosquito breeding and their extent or environmental considerations may exclude drainage as a solution. Containers holding water for household use may be common in housing close to the airport and the inhabitants may be unwilling or unable to dispose of them in the absence of piped water supplies and these may have to be treated with low toxicity larvicides. If adult malaria vector species are frequently found in buildings of the airport and breeding sites are difficult to locate, the use of adulticides as indoor residual sprays to areas which it is particularly necessary to protect, may be necessary and this will also be considered below.

Chemical control of malaria vector breeding with larvicides

There are a number of larvicides that can be used in the mainly fresh water habitats that can be found around airports and, occasionally, on the grounds. In some areas larvicidal oils are still used. This is wasteful as most do not disperse well on the surface of the water and have very little persistence of action.

Several organophosphorous compounds will provide effective and persistent control of larvae but in fresh water habitats, especially those from which animals might drink, only those with a very low mammalian toxicity should be used. Generally speaking, in the fresh water habitats in which most anophelines breed, one of the insect growth regulators (IGR) or the biological larvicide, *Bacillus thuringiensis* serotype H-14, should be used.

Table 2: Larvicides for use in non-polluted aquatic habitats

Insecticide	Chemical type	Dosage a.i. (g/ha)
Diflubenzuron	IGR	25-100
Iodofenphos	OP	50-100
Methoprene	IGR	100-1000
Pirimiphos-methyl	OP	50-500
Pyriproxyfen	IGR	(LC_{90}=0.000376 ppm)
Temephos	OP	56-112
Bacillus thuringiensis H-14	microbial insecticide	

Larvicides for use in freshwater containers

As noted above, control of the container breeding *Aedes* species should best be done by eliminating the container larval habitats in which they may breed. If, however, the use of larvicides is decided upon, these should be restricted to those which have an extremely low mammalian toxicity, especially if the water in the containers may be used by humans or animals.

The compounds suitable for use in containers are:

> temephos
> methoprene
> pyriproxyfen
> *B. thuringiensis* H-14

Larvicides for use in polluted water

Frequently it is necessary to apply larvicides for the control of mosquito breeding in septic tanks that are not well sealed or to pit latrines and sewage ditches where *Culex* mosquitos, usually *Culex quinquefasciatus*, breed in this highly polluted water habitat. Many chemical larvicides are quickly broken down in such habitats but experience has shown that the following are suitable:

> chlorpyrifos
> fenitrothion
> fenthion
> *Bacillus sphaericus*

Adulticides

Under certain circumstances larvicidal control may not be practical or possible. In such cases control may have to be aimed at the adult stages.

The use of adulticides for adult mosquito control may take two principal forms, the use of space sprays for temporary but rapid control or the use of indoor residual sprays to effect long persistence of control.

Space sprays can be applied either in the form of thermal fogs consisting of a variable percentage of active ingredient of the insecticide usually with diesel oil as the carrier. While they may effect a high rate of kill, space sprays have little persistence and must be frequently repeated, especially if the insecticide applied has little effect on mosquito larvae. The use of ultra-low-volume (ULV) applications of insecticide concentrates is increasingly common and a large number of OP's and carbamate insecticides are suitable for this purpose. The use of pyrethroids should be avoided in airport insect control, as they are the principal agents used in aircraft disinsection. Space sprays can be employed within buildings under certain circumstances but not when people are present.

In an area where malaria transmission is high the application of indoor residual insecticides to passenger terminal buildings or offices may be considered desirable. Among the insecticides found suitable for this purpose are several OP's and carbamates. Selection of a given compound will depend on the insecticide susceptibility status of the local vectors.

There is a vast literature on insecticide usage for the control of vectors which should be consulted in the selection of a pesticide for any geographical area. Selection of a pesticide, (or for that matter, an environmental technique) for the control of a given vector species, must take into account the bionomics of the target species, the insecticide susceptibility of the target insect, the ecological circumstances in the area in which the pesticide is to be applied, its mammalian toxicity and the local availability for the compound or formulation. A selection of appropriate agents is available.

8.3   CURRENTLY USED PREPARATIONS

(a)   <u>Aerosols</u>

1.   Preparations currently used in aircraft disinsection are based on two currently WHO-recommended active ingredients, namely d-phenothrin and permethrin (cis/trans ratio 25/75) and also natural pyrethrins. The sole use of WHO-recommended active ingredients should be stressed. Other active ingredients considered appropriate should be submitted for evaluation. The difference between d-phenothrin and permethrin is principally one of residual effect. Permethrin is a residual pyrethroid and d-phenothrin a non-residual pyrethroid. Both are considered effective although emerging resistance to this group of insecticides is of concern.

2.   Preparations used currently are based on the propellants Freon 11 and 12 (remaining stock held by airlines), Freon 22 and CO_2. None of these propellants are now considered appropriate. The alternative HFC134a and HFC227ea require testing for efficacy, storage stability, compatibility and effects on the fabric of the aircraft.

3.   Solvents currently used are small amounts (0.067 per cent) of petroleum distillates as recommended by WHO, as well as water as the carrier. Appropriate solvents if required to be used with the new suitable propellants should be tested and submitted for WHO evaluation.

4.   Companies formulating aerosols for aircraft disinsection are many. Although the situations vary, encouragement is given to appropriately register suitable products.

(b)   <u>Residual sprays</u>

Residual sprays currently used are based on permethrin (cis/trans ratio 25/75) as an emulsifiable concentrate. Encouragement is made to use low odour formulations and for the development of new formulations suitable for this type of disinsection. As for aerosols, encouragement is given to those products with appropriate registration.

Aerosols - Products containing the active ingredients:
    2% d-phenothrin
or   2% permethrin (cis/trans ratio 25/75)
or   2% d-phenothrin + 2% permethrin

Residual sprays - emulsifiable concentrates containing the ingredients:
    permethrin (cis/trans 25/75) in varying concentrations.

9.   TOXICOLOGY AND SAFETY ASPECTS

9.1   PYRETHRINS AND PYRETHROIDS

The properties and suitability of pyrethrins and pyrethroids for aircraft disinsection has been considered by the WHO Expert Committee on Vector Biology and Control (WHO, 1991b; WHO, 1985a; WHO, 1973). Comprehensive international evaluations of several pyrethroids have been undertaken by the International Programme on Chemical Safety (WHO, 1989b; WHO, 1989c; WHO, 1989d; WHO, 1990a; WHO, 1990b; WHO, 1990c; WHO, 1990d; WHO, 1990e; WHO, 1990f;

WHO, 1992b). The International Agency for Research on Cancer has concluded that deltamethrin, fenvalerate and permethrin are not classifiable as to their carcinogenicity to humans (IARC, 1991). An extensive review on the toxicological properties of pyrethroids has been published (Aldridge, 1990).

Piperonyl butoxide is commonly used as a synergist with certain pyrethroids. Its toxicology was evaluated by the FAO/WHO Joint Meeting on Pesticide Residues in 1992 (WHO, 1993b).

The potential routes of exposure to aerosols and vapours used for disinsection are: inhalation, ingestion of aerosol deposited in nasopharynx and dermal (via direct skin contact with spray or via spray residues on cabin furniture). The low vapour pressure of pyrethroids likely to be used in aircraft disinsection has not sufficient volatility to make true vapour exposure even a potential hazard (Ray, 1992). Since propellants are highly volatile, pyrethroid absorption would be entirely by inhalation. Oral absorption would be expected to predominate for all aerosols other than those with sub-micron particles.

The pyrethroids show very little absorption potential by the dermal route, but some can produce local effects on skin after heavy exposure. However, under the conditions in aircraft, absorption is most unlikely to be of significant levels unless there was gross mis-use of sprays and copious wetting of skin.

Aerosol sprays produce particles of up to 40 μm: these larger particles fall under the influence of gravity, reducing the inhalation burden with time (Pauluhn et al., 1988). The settling velocity is very dependent on particle diameter, for a spray 3 m above the ground in still air 50% had settled within 3.5 minutes at 30 μm mass median aerodynamic diameter but this took 12 minutes at 15 μm (Pauluhn et al., 1988). In aircraft an aerosol's concentration is further reduced by the ventilation system.

Toxicity:

Since the pyrethroids are rapidly destroyed by metabolism, toxicity is closely related to rate of absorption.

The nature of the toxic effects of both the natural pyrethrins and synthetic pyrethroids are very similar, the only essential difference being the presence of plant flavonoid and protein impurities in crude pyrethrin extracts which have given rise to cutaneous or respiratory allergic reactions extensively reported from 1921 onwards (Ray, 1991). Modern pyrethrin preparations should no longer contain these impurities (Maciver, 1992). The purified active ingredients of both pyrethrin and pyrethroid sprays have not proved positive in patch tests and are not considered allergenic. The only insecticides currently recommended for aircraft disinsection are the pyrethroids resmethrin, bioresmethrin, d-phenothrin and permethrin (cis/trans ratio 25/75). Other permethrin formulations containing a different isomeric ratio of permethrin isomers should be evaluated for aircraft disinsection.

Pyrethroid toxicity generally takes two forms, systemic and dermal. Systemic poisoning is characterized by an acute excitatory action upon the central nervous system, with either tremor, hyperexcitability, chorea or seizures, depending on agent and dose. Recovery from systemic poisoning is generally within hours. No lasting effects are seen in man or animals (Ray, 1991; WHO, 1991b), after either single or repeated doses with a variety of pyrethroids. However, a single experiment in neonatal mice showed that persisting behavioural and neurochemical changes were produced by bioallethrin and deltamethrin (Eriksson & Fredriksson, 1991). The relevance of this finding is not known.

Where seen, direct dermal toxicity (as distinct from systemic intoxication by dermal absorption) is characterized by paraesthesia - a spontaneous tingling sensation of the skin without interference with normal sensation. This effect is not accompanied by inflammation or hyperaemia, develops locally within 0.5-5 hours of dermal exposure, and persists for up to 0.5 - 3 days depending on dose level. It is most readily produced where the skin is thinnest, around the mouth, and probably results from a direct pharmacological effect of the pyrethroid on nerve endings within the skin. The average threshold dose for producing paraesthesia is about 0.2 mg/cm^2 skin in man (Ray, 1991). This exposure level would not be reached by disinsection procedures. During a scabies control programme, a permethrin 5% cream was applied to about one thousand subjects, no paraesthesia was reported (Yonkosky et al., 1990). A retrospective study on the use of a 1% permethrin cream for pedunculitis confirmed the safety profile of permethrin in conditions of general use, as seen in clinical trials (Andrews et al., 1992).

The information available concerning the adverse pulmonary effects of exposure to an insecticide aerosol is very limited. In a study on seven patients with asthma and a history of chest tightness on exposure to domestic insecticide aerosols, respiratory symptoms and lung function were assessed before, regularly for three hours, and at 24 hours after controlled exposure to an aerosol mixture of synergized pyrethrins and tetramethrin (Newton & Breslin, 1983). All patients described chest tightness after exposure but only one demonstrated a fall in FEV_1, a measure of pulmonary function, higher than 20%. Two subjects showed small changes in maximum mid-expiratory flow rate. Assuming good air mixing, air concentrations would have ranged from 1.1 - 6.8 mg spray/l, corresponding to 0.003-0.02 mg/l pyrethrins plus 0.001 - 0.006 mg/l tetramethrin. No subject reported a late asthmatic response and no significant change in the degree of airway responsiveness to inhaled histamine was found at 24 hours after exposure.

A small number of clinical conditions allegedly associated with pyrethroid or pyrethrin exposure have been reported (Wax & Hoffman, 1994; Paton & Walker, 1988; Zellers et al., 1990; Pall et al., 1987).

Limited information on in flight emergencies suggests that medical problems are infrequent (for instance the medical kit available on this procedure of a major airline was used once every 150,000 passengers) (Cottrell et al., 1989; Cummins and Schubach 1989). Absolute pulmonary contra-indications for air travel on commercial flights are pneumothorax and pneumomediastinum (Gong 1989, 1991).

Given the understanding of the mode of action of pyrethroids and low exposure from aircraft disinsection it is unlikely that this procedure will precipitate or influence any pre-existing disease of passengers and crew.

Although there are no reports of adverse human responses to aircraft disinsection identifiable in the literature, the Consultation was informed of anecdotal reports of pulmonary symptoms following aerosol spraying on aircraft. Although details were not available, the following considerations may place these concerns arising from these anecdotes into perspective.

Asthma is a chronic inflammatory disease of the airways characterized by recurrent episodes of respiratory symptoms (cough and/or dyspnea and/or wheezing) usually associated with airway obstruction. Atopy and allergic sensitization are the major risk factors for asthma. Once sensitized, an asthmatic patient may develop asthma attacks not only when exposed to the specific sensitizing agent but also when exposed to "nonspecific" stimuli, e.g. exercise, cold air, smoke. While sensitizing agent (inducers) may cause

immediate as well as prolonged attacks of asthma, which are associated with a further exacerbation of airway inflammation, non specific stimuli (inciters) cause immediate transient asthma attacks, not associated with airway inflammation.

The information regarding the relationship between aerosolized insecticide and particularly pyrethroids and asthma is very limited. From what information is available it can be concluded that aerosolized insecticides may trigger "non specific" bronchoconstriction and respiratory symptoms in asthmatics. By contrast, there is no evidence that aerosolized insecticides may cause asthma by sensitizing a normal subject. Thus there is no evidence that they can induce prolonged asthma exacerbations.

Other potential risk factors of asthma attacks during a flight, e.g. smoke, food, beverages should also be considered (Sheffer, 1995).

Although not of toxicological concern the Consultation also recognized that some individuals may be concerned by publicity regarding multiple chemical sensitivity (MCS). Characteristics of MCS are non-specific symptoms (e.g. headache, dizziness, fatigue, irritability, loss of memory or concentration) in relation to exposure to a variety of chemicals at extremely low levels (e.g. formaldehyde vapour from new carpets, solvents found in perfumes, glues, photocopy machines, dry-cleaned clothes). No laboratory abnormalities were ever found. Since the nature of these subjective complaints is not understood and agent and dose-dependency have not been demonstrated, it would be difficult to forecast whether chemicals used in aircraft disinsection are going to be added to the increasingly long list of chemicals responsible for this bizarre complaint.

9.2 PROPELLANTS

There are several groups of propellants currently in use.

Fully halogenated chlorofluorocarbons (CFC) are non-flammable propellants, generally of very low toxicity, but ever less frequently used because of their ozone-depleting potential. Partially halogenated chlorofluorocarbons (HCFC) are currently in use as non-flammable blends substituting for CFCs. They have similar characteristics to the CFCs, but a generally lower ozone-depleting potential. However, due to their still remaining influence on stratospheric ozone, they are currently accepted only as transitional propellants.

Hydrocarbons (HC), most frequently a blend of propane, iso-butane and *n*-butane, are commonly used propellants. Their main disadvantage is high flammability. Dimethyl ether (DME) is a high-boiling propellant used in some countries. It is, however, highly flammable and corrosive.

The main advantage of compressed gaseous propellants, such as nitrogen, carbon dioxide or air, is non-flammability and no ozone depleting potential. However, they do not dissolve pesticides, thus additional solvent(s) would be needed if used for aircraft disinsection.

In current WHO recommendations for both the standard reference aerosol and the alternative aerosol formulations, dichlorodifluoromethane (CFC 12) and trichlorofluoromethane (CFC 11) were recommended as propellants. In view of the phasing out of the production and use of these compounds, as stipulated by the Vienna Convention (1984), the Montreal Protocol 1987, the Helsinki Declaration (1989), and the London and Copenhagen (1992) amendments (1990), this part of the WHO Recommendation must be altered. The development of acceptable substitutes for CFC 11 and CFC 12 has become a matter of priority.

Three IPCS Environmental Health Criteria Documents (EHCs) have been published to date concerning chlorofluorocarbons or their possible substitutes (WHO, 1990g, WHO, 1991a; WHO, 1992a), for details see Annex 6.

1.   Fully halogenated chlorofluorocarbons CFC 11, CFC 12, CFC 113, CFC 114 and CFC 115 were evaluated in EHC 113, 1990. All the CFCs included in the Montreal Protocol were evaluated. All of them are to be phased out mainly due to their high ozone-depleting potential and long atmospheric residence times.

2.   Partially halogenated chlorofluorocarbons HCFC 21 and HCFC 22 were evaluated in EHC 126, 1991. The ozone-depleting potentials of both HCFCs are considerably lower than those of fully halogenated chlorofluorocarbons.

3.   Partially halogenated chlorofluorocarbons HCFC 141b, HCFC 142b, HCFC 132b, HCFC 133a, HCFC 123 and HCFC 124 were evaluated in EHC 139, 1992. The ozone-depleting potentials of all these compounds are considerably lower than those of fully halogenated chlorofluorocarbons.

In principle, partially halogenated chlorofluorocarbons (HCFCs), having considerably lower ozone-depleting potentials, shorter atmospheric residence times and lower global warming potentials than those of fully halogenated chlorofluorocarbons, could be considered (Valic & Beritic-Stahuljak, 1993). However, some countries are already taking steps not to accept the HCFCs as substitutes because they still have some ozone-depleting potential, which although lower than that of CFCs, may bring about considerable depletion of stratospheric ozone if they were to be used in large amounts as CFC substitutes. The parties to the Montreal Protocol and the European Union have decided to phase out the HCFCs by the year 2030 and 2015 respectively, for any use. The European Union prohibited the use of HCFCs in aerosols from 1 January 1996.

Substitutes for fully halogenated chlorofluorocarbons are the hydrofluorocarbons (HFCs) that contain no chlorine, and consequently have no ozone-depleting potential. Six such compounds have been recently evaluated: HFC 125 (ECETOC/PAFT, 1994; Du Pont, 1995a), HFC 134a (Trochimowicz, 1994; ECETOC/PAFT, 1995a), HFC 32 (Standing et al., 1995; ECETOC/PAFT, 1995b), HFC 143a (Worksafe Australia, 1994a; Brock et al., 1995), HFC 227ea (Worksafe Australia, 1994b) and HFC 152a (Lee, 1990; DuPont, 1995b).

HFC 32, HFC 143a and HFC 152a are flammable. The summary evaluations of the non-flammable HFCs are presented in Annex 6. However, these summaries are based on data bases provided by interested companies or national authorities. They have not been internationally evaluated by the International Programme on Chemical Safety.

In conclusion, there appear to be several possible substitutes for CFC 11 and CFC 12 currently used in aircraft disinsection. The hydrofluorocarbons, containing no chlorine and consequently having no ozone-depleting potential, are the primary choice. Of the six hydrofluorocarbons mentioned above, three (HFC 125, HFC 134a and HFC 227 ea) are non-flammable. HFC 125 has not yet been toxicologically evaluated. Both the HFC 134a and HFC 227ea, and particularly the latter, are likely to be suitable for aircraft disinsection on ecological and toxicological grounds. However, their toxicity has not yet been internationally evaluated; IPCS evaluations are planned for 1996/1997. In addition, their solvent properties for the pesticides to be used in aircraft disinsection, as well as their corrosion potential for aircraft components must also be assessed.

9.3   SOLVENTS

Solvents may be added to aircraft disinsection formulations to enhance the solubility of active ingredients or to modify the vapour pressure.

Any solvent used must meet the criteria of sufficient solvency at all temperatures that come into consideration, non-flammability, no adverse effect on aircraft structures, as well as those of acceptable effects on humans. Of all solvents which could be considered, water is the best solvent from the toxicological viewpoint. Each solvent proposed should be evaluated on a case by case basis as part of the evaluation of each newly proposed formulation.

10.   CONCLUSIONS AND RECOMMENDATIONS

Insects affecting humans, animals and plants directly or as vectors of diseases are transported internationally by aircraft. Cases of malaria, for instance, have been detected around airports apparently due to importation of infective *Anopheles* mosquitos. Transport by air of insects is well documented but the relative importance of aircraft for the transport of insects as compared with other means such as ships, trains, road vehicles and containers is unknown. Nevertheless, it is reasonable to envisage that risks of other diseases to humans, animals and plants might derive from aircraft transportation. Therefore it is concluded that aircraft disinsection, when needed, would continue to prevent spread of insects and if performed appropriately it would not present a risk to human health and to the environment. Relevant Articles of the International Health Regulations (IHR) were reviewed and the existing provisions were considered adequate if adhered to. Therefore it is recommended that:

1.   The existing WHO recommendations for aircraft disinsection published in 1985 and subsequent addenda should be revised and republished.

2.   It may be desirable to reconsider the wording of the International Health Regulations in light of the methods of disinsecting aircraft which are now recommended.

3.   Surveillance for vectors and vector-borne diseases in and around international airports, and other ports of entry should be improved. The extent and severity of these problems should be monitored and the results published. Vector control should also be improved in and around airports.

4.   Active surveillance, monitoring and evaluation for the presence of insect vectors on aircraft should also be improved and the results published.

5.   Surveillance information should guide Member States in considering the implementation of disinsection of aircraft with a view to limiting it to aircraft arriving from areas they consider to pose a threat to public health, agriculture or the environment.

6.   WHO should encourage Member States to designate and support the national focal point responsible for implementation of the International Health Regulations and should also support the development of national and regional strategies for aircraft disinsection.

7.   Training workshops for control of vectors and pests for port health officers and their staff should be organized with the support of the World Health Organization.

8.   Guidelines on methods for disinsection of aircraft should be updated and published.

9.   Acknowledging that some Member States are also concerned about aircraft transportation of insect vectors of animal diseases and plant pests that are not covered by the IHR, but may be under the import requirements of the Member States, aircraft disinsection procedures can also be effective against some of these pests of animals and plants. Therefore Member States may employ aircraft disinsection to control these insects threatening human, animal and plant health.

10.   In order to assure the continuing efficacy of the treatment, the insecticide classes used for airport vector control should be different from those used for aircraft disinsection.

11. The following three methods have been found effective and are to be preferred. They are not listed in order of preference:

(a) Blocks away

The existing recommendations have inadequate reference to treatment of overhead and sidewall lockers. Interior surfaces of overhead and sidewall lockers should be treated along with toilets and flight deck before passengers board. Cargo holds should be disinsected in conjunction with the cabin.

(b) Top-of-descent

(c) Residual

12. Although not regarded as a preferred method, the on-arrival method may be retained as an acceptable back-up method if an aircraft, coming from areas of threat, has not been adequately disinsected by any of the preferred methods.

13. Financial considerations should not preclude any of the preferred methods of aircraft disinsection.

14. Further trials of a new pre-embarkation method of disinsection, recently developed in Australia and New Zealand, should be conducted in other geographic areas.

15. Periodic evaluation of efficacy of disinsection treatments should be carried out and adequate records kept and published.

16. Continuing development and testing by industry and WHO of alternative insecticides and formulations for aircraft disinsection are needed because of emerging pyrethroid resistance among important vector species.

17. Any insecticide, propellant synergist or solvent proposed for aircraft disinsection should be evaluated for the risk to human health and the environment by the International Programme on Chemical Safety. Individual formulations and dispensing equipment should be evaluated for safety and efficacy on a case-by-case basis.

18. The use of fully halogenated chlorofluorocarbon propellants CFC11 (trichlorofluoromethane) and CFC12 (dichlorodifluoromethane), included in the previous WHO Recommendations for aircraft disinsection must be discontinued as a consequence of the Montreal Protocol. Partially halogenated chlorofluorocarbons (HCFCs), having a lower ozone-depleting potential than the CFCs, could be considered as interim substitutes but the parties to the Montreal Protocol and the European Union have decided to phase them out. Alternative propellants are hydrofluorocarbons (HFCs), which do not contain chlorine. The International Programme on Chemical Safety should evaluate their toxicology and environmental aspects.

19. Any solvent system used in aircraft disinsection formulation should meet established criteria for non-flammability, lack of adverse effect on aircraft materials as well as be of low toxicity. Residual disinsection enables the use of water as a carrier.

20.   Although some individuals may experience transient discomfort following aircraft disinsection by aerosol application, there is no objection to any of the recommended methods of aircraft disinsection from a toxicological perspective.

21.   Persons who are responsible for or who practice aircraft disinsection should receive appropriate education and training in correct application techniques for the safety and comfort of passengers and aircrew. Appropriate information should be provided to aircrew and passengers on the reasons for and safety of properly performed aircraft disinsection.

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AGENDA

Monday, 6 November 1995

1.   Opening of meeting (Dr W. Kreisel, EXD)
2.   Nomination of officers and designation of working groups
3.   Adoption of agenda
4.   Review of the present situation concerning potential spread of vector-borne human and plant diseases
    4.1 Human diseases
        4.1.1 Malaria (Dr P. Carnevale, WHO/TDT)
        4.1.2 Dengue and arboviruses (Dr A.B. Knudsen, WHO/FIL)
        4.1.3 Specific problems in the regions
            4.1.3.1 African Region (Dr Ravonjanahary, WHO/AFRO)
            4.1.3.2 American Region (Dr C. Moore, CDC, USA)
            4.1.3.3 Eastern-Mediterranean Region (Dr H. Rathor, WHO/EMRO)
    Discussion of Item 4.1
    4.2 Plant diseases and plant quarantine
        4.2.1 FAO views (Dr N. Van der Graaff, FAO)
        4.2.2 Plant health and aircraft disinsection (Mr J. Bongiovanni, WHO Adviser, New Zealand)

    Discussion of item 4.2
    4.3 Current practice
        4.3.1 Review of WHO recommendations (Dr G. Quélennec, WHO Adviser, France)
        4.3.2 Review of current practice (Mr M. Kelly, IATA)
    Discussion of item 4.3

Tuesday, 7 November 1995

5.   Airports and surroundings
    5.1 Sanitation of airports and surroundings by means of pesticides and by environmental management (Dr N. Gratz, WHO Adviser, Switzerland)
    5.2 Criteria for inclusion/exclusion of airports regarding pest control
        (Dr B. Gushulak, WHO Adviser, Canada)
    Discussion of item 5

6.   Aircraft disinsection
    6.1 Space spraying (Dr P. Guillet, WHO Adviser, France)
    6.2 Residual spraying (Mr D. Aylife, WHO Adviser, Australia)
    6.3 Other methods (Dr L. Manga, WHO Adviser, Cameroun)
    Discussion of items 6.1 - 6.3
    6.4 Biological efficacy of currently used preparations (Ms F. Lebtahi, WHO/SCH)
    6.5 Review of preparations currently available (Mr D. Cary, GIFAP)
    6.6 Review of methods currently used by air companies (Dr C. Curdt-Christiansen, ICAO)
    Discussion of items 6.4 - 6.6

7.   Review of toxicological properties of chemicals intended for use in aircraft disinsection
        7.1 Toxicology of insecticides and repellents (Dr D. Ray, WHO Adviser, UK)
        7.2 Toxicology of propellants (Professor F. Valic, WHO Adviser, Croatia)
        7.3 Toxicology of solvents (Dr A. Black, WHO Adviser, Australia)
        Discussion of item 7

Wednesday, 8 November 1995

8.   Evaluation of the potential risk of disinsection for human health

        8.1 Possible specific health risks (Professor M. Lotti, WHO Adviser, Italy)
        8.2 Risk following single exposure (Dr A. Black, WHO Adviser, Australia)
        Discussion of item 8

9.   Administrative and financial aspects
        9.1 Bases for drafting recommendations for users (Dr J.C. Alary, WHO/HST/ESS)
        9.2 Needs and requirements of national authorities and international organizations for specific
              legislation (Dr M. McMunn, ICAO, Canada)
        9.3 Quality control of disinsection (Dr G. White, WHO Adviser, UK)
        9.4 Costing of disinsection (Dr G. White, WHO Adviser, UK)
        Discussion of item 9

        Separate meetings of working groups

Thursday, 9 November 1995

Discussion on the elements of the report (plenary session)

Drafting report (separate meetings of working groups)

Friday, 10 November 1995

Discussion on conclusions and recommendations (plenary session).

Continuation of discussion on conclusions and recommendations (plenary session).

Adoption of the report and closure of the meeting.

ANNEX 2

LIST OF PARTICIPANTS

Temporary Advisers:

Mr D. Ayliffe, Manager, Border Programs, Quarantine Operations Branch, AQIS - Australian Quarantine and Inspection Service, Dept. of Primary Industries and Energy, Canberra, Australia

Dr A.L. Black, Medical Services Adviser (Toxicology), Dept. of Human Services and Health, Canberra, Australia (Rapporteur)

Mr J.J. Bongiovanni, National Advisor (Border Inspection), Ministry of Agriculture New Zealand MAF Regulatory Authority, Wellington, New Zealand

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Mr R.H. Kleinpaste, Titirangi, Auckland 7, New Zealand

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Dr L. Manga, Malariology Department, OCEAC, Yaoundé, Cameroon

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Dr G. Quélennec, St Julien en Genevois, France

Dr D. Ray, Medical Research Council, Toxicology Unit, University of Leicester, Leicester, United Kingdom

Professor F. Valic, Andrija Stampar School of Public Health, Zagreb University, 10000 Zagreb, Croatia

Dr G.B. White, Royal Society of Tropical Medicine and Hygiene, London, United Kingdom

Representatives of United Nations agencies:

FAO:

Dr E. Feliu, Food and Agriculture Organization of the United Nations, Rome, Italy

Dr N. Van der Graaff, Chief, Plant Protection Service, Food and Agriculture Organization of the United Nations, Rome, Italy

ICAO:

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ILO:

Dr N. Wafta, Senior Officer on Chemicals and the Environment, Head, Occupational Hygiene Section, International Labour Office, 1211 Geneva 27, Switzerland

Representatives of international and national organizations:

BGVV:

Dr K. Schäffer, Schädlingsbekämpfungsmittel, Bundesinstitut für Gesundheitlichen
  Verbraucherschutz und Veterinärmedizin, 14195 Berlin, Germany

CAA:

Dr K. Edgington, Chief Medical Officer, Civil Aviation Authority, Safety Regulation Group, Gatwick Airport South, West Sussex, United Kingdom

CDC:

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GIFAP:

Mr D. Cary, Sumitomo Chemical (UK) Plc, London, United Kingdom

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Secretariat

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Dr M.K. Behbehani, Director, Division of Control of Tropical Diseases, World Health Organization, Geneva, Switzerland

Dr P. Carnevale, Division of Control of Tropical Diseases, World Health Organization, Geneva, Switzerland

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Dr W. Kreisel, Executive Director, World Health Organization, Geneva, Switzerland

Dr M. Mercier, Director, International Programme on Chemical Safety, World Health Organization, Geneva, Switzerland

Mrs F. Mourain-Schut, Office of the Legal Counsel, World Health Organization, Geneva, Switzerland

Dr R. Pleština (Technical Secretary), Programme for the Promotion of Chemical Safety, World Health Organization, Geneva, Switzerland

Dr C. Ravaonjanahary, Disease Prevention and Control, World Health Organization, Regional Office for Africa, Brazzaville, Congo

Dr H.R. Rathor, CSV, World Health Organization, Regional Office for the Eastern Mediterranean, Alexandria, Egypt

Mr T.S.R. Topping, Office of the Legal Counsel, World Health Organization, Geneva, Switzerland

Mrs A. Massy (Administrative Secretary), Programme for the Promotion of Chemical Safety, World Health Organization, Geneva, Switzerland

RESIDUAL DISINSECTION PROCEDURE

1. Residual disinsection of aircraft cabin and hold areas, including flight decks, toilet and locker areas etc., may be approved subject to arrangements to ensure correct procedures are in place. These arrangements are to include the provision to the appropriate authority of an up-to-date listing of treated aircraft, with dates of treatment, to facilitate quarantine clearance on arrival. Aircraft so treated must be issued with a Certificate of Residual Disinsection.

2. Formulation - The formulation used for residual spraying is a 2% emulsion of permethrin prepared on the basis of he following formulae:-

    -   2 parts of 40% emulsifiable concentrate in 38 parts distilled water

    or

    -   2 parts of 20% emulsifiable concentrate in 18 parts distilled water.

3. Quantities - The following approximate quantity will be needed to treat interior surfaces of both cabin and cargo compartments:

    B747   25 litres
    B767   11 litres
    DC10 16 litres
    B737   7 litres

4. Means of application - Suggested means of application is by compressed air spray guns or pressure retaining garden sprayers. Aerosols can be used to spray electrically sensitive areas.

5. Application rates - The required dosage rate is 0.2 g of permethrin per square metre. To achieve this the 2% emulsion needs to be sprayed at a rate of 10 ml per square metre. If the spray equipment is adjusted to deliver 10 ml per second the correct deposit will be achieved if spraying i carried out so as to cover one square metre every second. The aim is to achieve an even pattern of close droplets on all surfaces, not necessarily to achieve total cover, and certainly not to produce run-off.

6. Frequency of treatment - Treatment must be at intervals not greater than two months. If treatment is unable to be scheduled to meet the certification requirements, or if the level of cleaning has removed the residual insecticide film to a greater extent than can be replaced prior to overseas operations, the Certificate of Residual Disinsection will be deemed invalid. Should any failure of treatment be detected while the aircraft is overseas, the appropriate authority for whom the treatment is carried out is to be advised within 24 hours.

Passenger compartments

7. Interior surfaces - prepare the aircraft by opening, clearing and cleaning all lockers, cupboards, storage units etc. and drawing all curtains and window blinds. Remove carpet covers if present. Spray all surfaces including ceilings, walls, lockers, curtains, toilets, galleys and wall areas behind

curtains. Spray both sides of doors and locker lids. At the need of the operation respray the carpets.

(NOTES: Do not remove permanently stored items such as loud hailers, first aid kits, oxygen bottles, fire extinguishers. AVOID SPRAYING WINDOWS, INSTRUMENT PANELS, OVERHEAD CONTROL PANELS OR CIRCUIT BREAKER PANELS. REMOVABLE GALLEY COMPONENTS, SUCH AS FOOD TROLLEYS, WILL NOT REQUIRE TREATMENT.)

8.   After spraying is completed, air conditioning packs should be run for at least one hour to clear the air of the volatile components of the spray. Mirrors and some other surfaces may need to be cleaned of spray deposit. On other surfaces, the treatment should be repeated so as to replenish the insecticide film whenever it is wiped off.

9.   Areas receiving substantial cleaning will require supplementary "touch up" spraying (i.e. areas where cleaning is considered to have removed insecticide film). However, interior cleaning and soiled item replacement of a relatively minor nature at stations other than the treatment station are considered negligible in the overall context of the programme, and will not require retreatment.

Cargo compartments

10.   Spray compartemnt walls, ceilings and floors. Pay particular attention to sidewall and floor cavities.

Operator safety

11.   During the spraying operation it is advisable to wear overalls and either a dustmask or a canister-type respirator.

Certification and oversight

12.   The treatment must be carried out or arranged by the aircraft operator or his agent in accordance with the provisions of a Residual Disinsection Arrangement entered into by the aircraft operator with the appropriate authority. The system must be described in a manual and include an appropriate regime for testing the efficacy of the treatment. (Appropriate authorities may retain the right to test for efficacy the right to monitor for efficacy.)

13.   All treated aircraft are to carry certification attesting to treatment for examination on request by quarantine staff.

<div align="right">**ANNEX 4**</div>

PREFLIGHT CABIN SPRAYING COMBINED WITH
TOP-OF-DESCENT SPRAYING*

PREFLIGHT SPRAYING

1. A preflight spray must be applied to the flight deck, all toilet areas (including upper deck where applicable), lockers and crew rest areas before crew and passengers board, except where approval has been granted for the residual treatment of these areas.

2. Preflight spraying is to be carried out at the last port before departure for (NAME OF COUNTRY REQUIRING DISINSECTION).

3. The aerosol to be used is 2% permethrin, with an approved propellant and solvent recommended for use by WHO. Cans should have a discharge rate of 1 gram per second and mass medium droplet diameter of 8 micrometers with droplet diameters in the range of 3 to 10 micrometers. The recommended can size is 100 grams, and the aerosol formulation must be clearly shown on the label.

    The propellant must be registered with the appropriate Authority for use as a propellant in the disinsection of aircraft cabins.

    All spray cans must conform to the appropriate standard.

4. Overhead and side wall lockers are to be open during treatment.

5. Spraying, equating to a rate of 35 g of formulation per 100 m^3 (10 g per 1000 ft^3) is to be carried out as follows:-

    -**B747** - Two personnel, each using 2 x 100 g cans of the formulation, starting at the rear of the aircraft and moving forward at a slow walking pace of not more than one step or one row per second, the spray being directed into the open lockers.

    .. The upper surfaces of each toilet interior should be sprayed for three seconds.

    .. Each coat locker should be sprayed for three seconds.

    (NB a total of 4 x 100 g cans will be required to treat these areas.)

    .. A fifth 100 g can should be used to complete spraying of the lockers on the upper deck and for treatment of crew quarters (5 seconds), flight deck (5 seconds) and upper deck toilets.

    -**747SP** - Only one can to be used by each of the two personnel walking slowly from the rear of the cabin. Toilets and coat lockers are to be sprayed as with other 747 aircraft.

    (NB A total of 2 x 100 g cans should be fully used for this procedure.)

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* Preflight cabin spraying could also be combined with "blocks away" treatment.

-**747 COMBI** - Only one can to be used by each of the two personnel walking extra slowly from the rear of the cabin. Toilets and coat lockers are to be sprayed as with other 747 aircraft.

(NB A total of 2 x 100 g cans should be fully used for this procedure.)

-**B767/DC10** - Only one can to be used by each of the two personnel walking at a slow pace of not more than one step or one row per second.

(NB A total of 2 x 100 g cans should be fully used for this procedure.)

..   A third 100 g can should be used for spraying the toilets (3 seconds), the flight deck (3 seconds) and for treatment of crew quarters (5 seconds). As this can will not be fully utilized, a smaller can may be substituted.

6.   All cans used for cabin prespraying (along with cans used for the top-of-descent cabin spraying operation and cans used for hold spraying) must be kept for inspection by the relevant Authority. The normal practice is for the empty cans to be delivered to the quarantine office as soon as possible after the aircrafts arrival, but in any case before it departs to it's next port.

7.   Approval has been given in some cases (eg Australia) to a number of airlines to residually treat lockers, flight deck, toilets, etc. in lieu of the preflight spraying requirements detailed above. Treatment must be carried out in accordance with an agreed protocol reflecting the WHO recommendations on disinsection of aircraft. Formulations used for this purpose shall be as specified for full residual treatment of aircraft. Application rates must be sufficient to achieve an even pattern of close droplets on all surfaces, not necessarily to achieve total cover, and certainly not to produce run-off.

(NOTE: These procedures are not to be confused with the alternative full residual treatment procedures for aircraft cabins.)

8.   In the event that itinerant flights arrive without the prespray having been undertaken, the following procedures must be observed:-

-   If the cabin area has been sprayed at top of descent, no further spraying will be necessary.

-   If the cabin area has not been sprayed, the on-arrival spray of the cabin must be extended to include toilets, flight deck and the overhead lockers when cleared of passengers' goods.

TOP OF DESCENT SPRAYING

1.   Cabin disinsection shall be carried out at top of descent after an appropriate announcement is made over the public address system. Such an announcement should be along the following lines:

"Ladies and Gentlemen, to conform with (*agriculture/health*) requirements, the cabin will now be sprayed. This procedure, recommended for this purpose by the World Health Organization, is necessary to avoid the introduction of harmful insects into (*country name*). Please remain seated and keep the aisles clear while the aircraft is being sprayed. Thank you."

2.   The insecticide formulation must be 2% d-phenothrin containing a propellant approved for use in aircraft. Cans and nozzles must be designed and manufactured to deliver an even distribution of spray at an emission rate of one gram per second and a mass medium droplet diameter of 8 micrometers, with droplet diameters in the range of 3 to 10 micrometers. The aerosol formulation is to be clearly shown on the label.

The propellant must be registered with the appropriate authority for use as a propellant in the disinsection of aircraft cabins.

All spray cans must conform to the appropriate standards.

3.   The following procedures must be followed

- **B747**

The spraying is to be applied as near as possible to the ceiling by two member s of the cabin crew, one walking along each aisle holding 2 x 100 g cans at a slow walking pace of not more than one step or one row per second starting at the rear of the aircraft. The upper deck can be disinsected by one of the two crew-members with the remaining crew member completing disinsection of the main cabin at the front of the aircraft.

A total of 4 x 100 g cans should be fully used for the above procedure.

-**747 SP** - Only one can to be used by each of two personnel walking slowly from the rear of the cabin. (NB. A total of 2 x 100 g cans should be fully used for this procedure.)

-**747 COMBI** - Only one can to be used by each of two personnel walking slowly from the rear of the aircraft.

(NB. A total of 2 x 100 g cans should be fully used for this procedure.)

-**B767/DC10** - Only one can to be used by each of the two cabin crew walking at a slow pace of not more than one step or one row per second starting at the rear of the aircraft.

(NB. A total of 2 x 100 g cans should be fully used for this procedure.)

4.   Empty or partly used cans must be kept for inspection and removal by an officer of the appropriate authority boarding the aircraft at the first port of entry into a country when there quarantine formalities will be undertaken.

5. Itinerant flights - spraying of cabins shall be carried out at a rate of 10 g per 1000 ft^3(28m^3).

6. Spray amounts - The volumetric capacity of aircraft may vary because of different configurations. The following table accordingly lists estimates of spray and spraying times per B747. They are based on a standard spray rate of 1 g per second and on the basis of a required coverage of 35 g of the formulation per 100 m^3 (10 g per 1000 ft^3) in aircraft cabins.

Area	Amount of spray (g)	Spraying time (sec)
Main cabin	340	340
Upper cabin	15	15
Extended upper deck	25	25
Lower galley (where applicable)	40	40
Flight deck	10	10

7. Due to the large number of varying types of aircraft, local arrangements based on the prescribed volumes should be made. Generally speaking, if the procedures have been carried out in accordance with these instructions, i.e., one step or one row per second, the correct amount of spray should have been applied irrespective of the size of the aircraft.

8. Some very small aircraft such as executive jets and smaller regular airline and aircraft such as B737, DC9, Fokker F27 and F28 will require a discretionary judgement but obviously relatively small amounts of spray only will be necessary.

**PRE-EMBARKATION DISINSECTION: EFFICACY TRIALS ON A NEW AIRCRAFT
DISINSECTION TECHNIQUE***

Aircraft disinsection has, over the past decades, been shown to be a useful weapon in the fight against the spread of invertebrate vectors of serious human diseases. It also significantly lowers the chances of quarantine pests becoming established in new countries.

The disinsection techniques currently in use around the world involve spraying: "On arrival", at "Blocks Away", or "Top-of-Descent", and the "residual" disinsection technique.

In "Top-of-Descent" and "On-Arrival" techniques, aircraft cabins are treated with aerosol formulations, containing 2% d-phenothrin as the active ingredient. These treatments take place while passengers are on board.

Residual disinsection involves the treatment of interior aircraft surfaces and holds with a water-based solution containing 2% permethrin. Treatment is carried out on the ground when no passengers are present, and it can be easily incorporated into the routine maintenance of the aircraft. It therefore comes as no surprise that the residual disinsection technique tends to be preferred by airlines which frequently fly sectors to countries which require disinsection.

The Quarantine Authorities of Australia and New Zealand decided to initiate research into alternative ways of aerosol disinsection - a technique by which aircraft are disinsected in the *absence* of passengers. This technique was tentatively labelled "pre-embarkation disinsection", and this paper reports on the efficacy trials carried out.

The rationale of the pre-embarkation disinsection technique is to treat the plane after all catering is finished, just before passengers board, and within an hour from departure or closure to the main entrance door. The active ingredients in the aerosol cans are 2% d-phenothrin and 2% permethrin, with non-CFC propellants.

The spray is carried out as a normal "on-arrival" treatment, aiming to disperse 10 grams of the product per 1000 ft^3 (28 m^3). The toilets, cupboards, flight-deck, and crew rest areas are to be sprayed as well.

The d-phenothrin component of the spray will kill soft-bodied insects that may be present inside the cabin at the time of disinsection. With air conditioning packs off, the 10 grams d-phenothrin per 1000 ft^3 (28m^3) has a proven efficacy.

The permethrin component released will give a light and patchy coating of insecticide residue designed to knock down and kill any vectors that may enter the cabin in the time span between disinsection and departure. Moreover, the permethrin residues will continue being lethal to stow-away insects during the flight.

Advantages of pre-embarkation disinsection are:

! It does not inconvenience passengers or cause aircraft delays.

! It is easy to carry out by crew or airline staff, an does not require complicated training.

! It is a simple, inexpensive method, which can be easily audited by Authorities.

! It uses relatively safe insecticides, recommended by WHO for use in aircraft.

METHODS AND MATERIALS

With all trials described in this paper, 10 control houseflies were kept in a clean cage for the duration of each trial.

Pilot trials

Two pilot trials were carried out in June 1995: one inside a small, 381 ft^3 (10.8 m^3) test room, the other in a 1795 ft^3 (50 m^3) room (Trials 1 and 2).

Both rooms were "disinsected" with 10 grams of pre-embarkation formula (2% d-phenothrin and 2% permethrin) per 1000 ft^3 (28 m^3). In the first trial 4 grams, in the second trial 18 grams of product was released. The rooms were left to "air" for one hour, after which live house flies (*Musca domestica*) of a non-resistant laboratory strain, were released.

Thirty-eight flies were used for the first trial, 97 flies were exposed in the second trial. The flies were left in the disinsected room for 25 minutes, after which they were collected, counted, removed from the room and put into clean containers and assessed on their health status at certain intervals until 24 hours had lapsed.

Static trials inside operational aircraft

Three separate trials with live house flies (*Musca domestica*) were carried out inside operational Boeing 737-200 and 737-400 aircraft at the airports of Auckland and Sydney in August and September 1995 respectively. All trials were conducted in the same manner, although disinsection rates were different:

Trial A - 31 August 1995. Auckland Airport

A whole 737 cabin (Air New Zealand ZK-NAD) was sprayed with two aerosol cans containing the pre-embarkation mixture described above.

A total of 47.4 grams of product was used, which is very close to the required amount for a 737-200 cabin (48 grams). The air conditioning packs and re-circulation fans were off during and after the spray. The cans used delivered 1.4 grams per second (recommended nozzle discharge rate is 1.0 grams per second).

To monitor the distribution and efficacy of the pre-embarkation disinsection spray, a total of 42 caged adult house flies (*Musca domestica*) in 4 "netted" or "open" cages, were exposed to the treatment at the time; the cages were put on the carpet under window seats in the cabin. (Trial A$_1$). The health status of the flies in the cages was monitored from time to time until 24 hours after disinsection.

After the insecticide fog had settled, clean, untreated curtain nets were hung up in the cabin to separate off a 5 meter long stretch of aircraft test-cabin which would be able to hold live flies. One hour after the disinsection 447 live house flies were released into this curtained-off section of the cabin and observed for signs of insecticide poisoning. Two hours after the disinsection. (one hour after release of the test flies) the flies were recovered from their disinsected environment, counted, and put into clean containers. They were monitored for their health status for 24-48 hours.

Trial B: 31 August 1995. Sydney Airport

A 737-400 (Qantas VH-TJG) aircraft was partly disinsected: an 8 meter section of the cabin was sprayed with 35 grams of pre-embarkation formulation, utilizing cans which delivered with a nozzle discharge rate of 1.7 grams per second. During and after the treatment, the recirculation fans were operating, while the air conditioning packs were turned off. After an hour 347 live flies were released and exposed to the centre 4 meters of the treated cabin section. The same procedures were followed as in Trial A.

Trial C: 21 September 1995. Sydney Airport

Boeing 737-400 (Qantas VH-TAW) partly disinsected (the same way as in Trial B) to approximately 83% of the recommended WHO dose (16.7 grams of spray; nozzle discharge rate 1.7 grams per second). Air conditioning packs were off and the re-circulation fans were left on during the trial.

A total of 31 adult flies were exposed to the actual spray (Trial C_1): 2 cages under the middle seats (n = 13), 1 cage on middle arm rest (n = 9), and 1 cage on top of locker (n = 9). After an hour 180 live flies were released into the centre of the treated cabin area, and the same procedures were followed as in Trials A and B.

Health status of test flies

The health status of the test flies used in all trials, was determined as follows:

H   Healthy; no discernable deterioration of health.

S   Sick; mobile, but walking or flying erratically; dragging their legs.

KD   Knocked down; no more sustained walking or flying. Often buzzing on their backs, or lying still; but move when prodded.

D   Dead. No more movement observed; not even after prodding.

In all trials control flies were kept in clean cages of the duration of the trials; these flies were also assessed on their health status.

RESULTS

Table 1 presents the results of the two pilot trials

Table 1: Results of test flies released in test rooms

Amount spray released	Trial 1 10 g/1000 ft^3 (28 m^3) 38 hours			Trial 2 10 g/1000 ft^3 (28 m^3) 97 hours		
15 minutes	2S	36KD		-		
20 minutes		38KD		1S	96KD	
30 minutes		38 KD			97KD	
1 hour		38 KD			97KD	
3 hours		35 KD	3D		78 KD	19D
6 hours		35 KD	3D	-		
24 hours	1S	27KD	10D		52KD	45D
% KD or D		97.4%			100%	
CONTROLS		10 H			10 H	

The results of the Static Trials in Boeing 737-200 aircraft are presented in Table 2.

Table 2: Results of test flies released in cabin

Amount Spray Released	Trial A 10 g/1000 ft^3 (28 m^3) 447 hours				Trial B 17.5 g/1000 ft^3 (28 m^3) 347 hours				Trial C 8.3 g/1000 ft^3 (28 m^3) 180 hours			
30 minutes	. 45H				. 97H				-			
1 hour	2H	6S	361 KD			18S	282KD	38D	42S	98 KD	14D	
3 hours	2H	1S	366 KD		-				-			
9 hours		-			2S		166KD		8S	67 KD		81D
12 hours	5S		364KD				112KD		52KD		104D	
24 hours	3H	3S	175KD	188D			338D		6KD		150D	
% KD or D			98.4%				100%				100%	
48 hours	4H		34KD	331D			338D				156D	
% retrieval			82.5%				97.4%				83.3%	
CONTROL 24 hours	10 H				10 H				7H	3D		

The fate of the caged flies exposed to the pre-embarkation spray in Static Trials A and C is presented in Table 3.

Table 3: Results of caged flies exposed to spray

Amount Spray Exposed	Trial A$_1$ 10 g/1000 ft^3 (28 m^3) 42H			Trial C$_1$ 8.3 g/1000 ft^3 (28 m^3) 31H		
30 minutes	1S	41KD		11H	20S	
1 hour	42KD			9S	22KD	
12 hours	42KD			11S	4KD	16D
24 hours	1S	39KD	2D	8S	4KD	19D
% KD or D		97.6%			74.2%	
CONTROL 24 hours	10H			7H	3D	

OBSERVATIONS AND DISCUSSION

When examining the rationale of the pre-embarkation disinsection technique, the first hypothesis - that 10 grams of the spray per 1000 ft^3 (28 m^3) of cabin space will kill soft-bodied invertebrates - seems to be more or less a repeat of the tried and true WHO recommendation[1]. Yet with a mixture of active ingredients, a cocktail of two known pyrethroid disinsectants, this needed to be proven for aircraft cabin areas.

Table 3 clearly shows that, even in the absence of air movement as a result of air conditioning or re-circulation fans being switched off, the recommended dosage of spray reaches the furthest spaces under seats, and that it knocks down the test flies (Trial A$_1$). The trial with only 83% of the WHO recommended amount of spray an the re-circulation fans on (Trial C$_1$), showed some survival patterns and only 74.2% knock down or kill.

The second hypothesis - that the small and scattered amounts of residual permethrin will knock down and kill the free-flying test flies in the cabin - was always a difficult one to test. The results of the two pilot trials (Trials No. 1 and No. 2) indicate that in a straight-walled test room most flies will at some stage come in contact with some permethrin residues, and find themselves mortally affected by this material.

In aircraft cabins, with many surfaces and spaces where the permethrin may not necessarily settle during pre-embarkation disinsection, flies could conceivably hide and perhaps survive. It became apparent that some of the test flies showed a preference to settle on the untreated curtain material, used to separate the cabin section test area from the rest of the interior of the aircraft. Despite some attempts to "shoo" them away from the netting in the first half hour of exposure time, a number used this safe curtain to avoid contact with the pesticide (1.6% Healthy or "Sick" flies; Trial A).

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[1] Anon. 1985. Recommendations on the Disinsection of Aircraft, based on the seventh, eleventh, and twentieth reports of the WHO Expert Committee on Insecticides, and the ninth Report of the WHO Expert Committee on Vector Biology and Control. Weekly Epidemiological Record 60(7): 45-47.

The three Static Trials were all different in the amount of spray used per 1000 ft^3 (28 m^3), yet they showed remarkable similarities in efficacy. After one hour of exposure to the residues, most flies were knocked down (97.8% in Trial A, 94.7% in Trial B, and 71.8% in Trial C). The 24 Hour KD and mortality figures also showed a promising percentage of test flies having been knocked down and rendered immobile: 98.4%, 100% and 100% respectively. When these flies were re-examined 48 hours after exposure began, the mortality figures increased encouragingly, giving the indication that the health status was on a downward trend, and that the flies showed no signs of recovery in their clean containers.

In a pre-embarkation disinsection situation the flies are not removed from the carpet or wherever they may have fallen after knock down; on the carpet they may either be trampled to death by passengers, or receive a lethal dose of permethrin residue. Therefore the mortality figures of these trials are likely to be lower than they would be in a true disinsection situation.

Another point to consider is that house flies are significantly hardier than mosquitos - the prime target for disinsection. They are also less susceptible to d-phenothrin and permethrin insecticides when using non-resistant strains of test insects. (R. Kleinpaste, unpublished reports 1988).

Pre-embarkation disinsection aims at killing the insects present in an aircraft at the time of spraying, and killing any insect that may enter the cabin between treatment and departure. The Static Trials A,B, and C saw hundreds of "blundering" insects released into the cabin, and the results showed that even when the disinsection is carried out at only 83% of the required spray deposit (Trial C), most insects are knocked down.

The retrieval percentages of the test flies were relatively high in the three Static Trials (82.5%, 97.4%, and 83.3%). In an aircraft environment, with seats, seat-pockets, window ledges, dark-coloured carpets, and numerous nooks and crannies, it is nearly impossible to retrieve all the released test insects. Where the "missing" flies disappeared to is always a mystery; in all trials, however, intensive searches within and outside the curtained test areas failed to find or flush out any live or flying insects, leaving us in the firm belief that the missing flies were not alive, healthy or flying after the exposure.

CONCLUSIONS AND RECOMMENDATIONS

The trials carried out so far on the new concept of pre-embarkation disinsection of aircraft, show that this technique knocks down and kills soft-bodied insects. When this form of disinsection is carried out correctly and when the cabin receives the correct amount of spray (10 g/1000 ft^3 or 28 m^3), it not only targets those insects that are present in the cabin at the time, but also guards against flies and mosquitos that may enter the cabin between the treatment and departure.

In view of the current growing opposition to the practice of aircraft disinsection in the presence of passengers, it seems logical that pre-embarkation disinsection be considered as an alternative method of aircraft disinsection. It is important, however, that live trials are carried out on international flights to confirm the results of these static trials, before pre-embarkation disinsection is routinely practised.

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SUMMARIES OF EVALUATIONS OF POTENTIAL CFC SUBSTITUTES

Note: Calculated exposure levels of each of propellants in aircraft would always be less than 100 ppm in usual practice.

1,1,1,2,2-pentafluoroethane (HFC 125): HFC 125 is a non-flammable gas under development as a CFC alternative, mainly as a component for low temperature refrigerant blends and as a total flooding fire extinguishing agent. It is commercially available. The atmospheric lifetime is 40.7 years, GWP is 0.84, and ODP is zero. The acute inhalation toxicity is very low. The 4-hour LC_{50} in the rat is greater than 3 928,000 mg/m^3 (800,000 ppm). The only clinical signs were ataxia, decrease of locomotor activity and dyspnea. Cardiac sensitization in dogs was induced at exposures to 491,000 mg/m^3 (100,000 ppm) followed by an intravenous epinephrine challenge. The NOEL for cardiac sensitization was 386 250 mg/m^3 (75,000 ppm). Inhalation exposure up to 245,000 mg/m^3 (50,000 ppm) 5-days a week, for 4-13 weeks, did not induce any toxic effect in rats. No evidence of embryotoxicity or teratogenicity was observed at exposure levels up to 245,000 mg/m^3 (50,000 ppm) in either the rat or the rabbit. HFC 125 was not mutagenic either *in vitro* or *in vivo* studies using bacteria, mammalian cell lines or the mouse micronucleus assay. An occupational exposure limit (8-hours TWA) of 4910 mg/m^3 (1000 ppm) is recommended by the producers.

1,1,1,2-tetrafluoroethane (HFC 134a): HFC 134a is a non-flammable gas being developed as a substitute for CFCs and HCFCs. Its main current applications are in refrigeration and air conditioning, but other applications are under development: as a blowing agent for polyurethane foams and as a propellant in metered dose inhalers. The production capacity of existing and announced plants is 175 kt/yr, and the future world-wide demand has been estimated around 150 kt/yr in 1995 and 300 kt/yr in 2020. It has GWP 0.3,its atmospheric lifetime 14 years, and its ODP is zero. HFC 134a has an extremely low acute toxicity. Concentrations over 2 000,975 mg/m^3 (700,000 ppm) in inhaled air are required to produce lethal effects. Acute intoxication is characterized by central nervous effects at high inhaled levels. It causes slight irritation in contact with cutaneous or ocular mucosal membranes; it is not a skin sensitizer. It can induce cardiac sensitization in dogs at 340,000 mg/m^3 (80,000 ppm) and above after an exogenous epinephrine challenge. The NOEL for cardiac sensitization was 170,000 mg/m^3 (40,000 ppm). HFC 134a showed no adverse effects on fertility in a limited study in mice. It was not teratogenic in rats or rabbits at 212,000 mg/m^3 (50,000 ppm). Only delayed foetal ossification in the rat was observed at this concentration. It was not genotoxic either *in vitro* or *in vivo* in a large variety of studies. No toxicologically significant effect was observed in rats exposed between 2 and 52 weeks to inhalation exposure levels up to 212,500 mg/m^3 (50,000 ppm). No tumorigenic effects were observed in a limited study in rats with daily oral administration of 300 mg/kg body weight in corn oil over a period of one year, and observed for 16-months post-treatment. In a 2-year inhalation study with exposures up to 212,500 mg/m^3 (50,000 ppm) for 6 hours/day, there were no neoplastic or other adverse toxic effects in female rats. In male rats, a slight increase in the incidence of testicular Leydig cell hyperplasia and rat-specific benign Leydig cell adenomas was observed. In carcinogenicity studies in mice with daily exposures of 1 hour to 10,625, 63,750 and 106,250 mg/m^3 (2500, 15,000 and 25,000 ppm) no tumours were induced. Under similar test conditions HFC 134a was devoid of carcinogenic potential in rats at exposures to 10,625, 42,500 and 212,500 mg/m^3 (2500, 10,000 and 50,000 ppm). An occupational exposure limit (8-hour TWA) of 4250 mg/m^3 (1000 ppm) is recommended by AIHA.

HFC 134a has also been evaluated by the International Pharmaceutical Consortium for Toxicity Testing (IPACT I). This evaluation was not made available.

1,1,1,2,3,3,3-heptafluoropropane (HFC 227ea): Evaluations were available from Worksafe Australia for this propellant for use as a fire extinguishing agent and from Hoechst AG, Frankfurt, Germany. HCFC 227ea is a non-flammable colourless gas with boiling point of -16.4 EC and a vapour pressure of 3.9 bar (20 EC) which is similar to the vapour pressure of CFC 11/CFC 12/CFC 114 mixtures. This hydrofluorocarbon is compatible with all metals and metal alloys (except those with more than 2% magnesium), thermoplastics like polytetrafluoroethene, polyacetal and polyamide, and elastomers like butyl rubber, acrylonitrile butadiene rubber, chloropentene rubber and natural rubber. Its atmospheric lifetime is approximately 42 years, its GWP is 0.6, and its ODP is zero. It has an extremely low acute inhalation toxicity. The 4-hour LC_{50} in rats was > 5 481,440 mg/m^3 (788,696 ppm). It is not an irritat to mucosal membranes. Cardiac sensitization in response to an epinephrine challenge was elicited in dogs only at inhaled concentrations above 625 500 mg/m^3 (90,000 ppm). Hoechst AG conducted a 28-day toxicity study in rats at p73 concentrations of 20,850, 86,875 and 347,500 mg/m^3 (3000, 12,500, and 50,000 ppm). The NOEL was > 347,500 mg/m^3 (50,000 ppm). Genotoxicity studies with *S. typhimurium* and *E. coli*, with and without metabolic activation, did not show point mutations even at a maximum concentration of 2 085,000 mg/m^3 (300,000 ppm).

In addition, comprehensive toxicological data has been generated in programme sponsored by IPACT II in order to obtain international approval of HCFC 227ea for the use in metered dose inhalers (MDI). The studies comprised acute, subchronic and chronic studies in rodents and dogs, carcinogenicity studies in rats and mice, reproductive toxicity studies in rodents and rabbits. A battery of additional studies for possible genotoxic effects was performed. Although the reports of the IPACT II sponsored studies have not been made available, in September 1995 the European Committee for Proprietary Medicinal Products considered that HCFC 227ea is suitable for pharmaceutical MDIs.

Ecological characteristics of some CFCs, HCFCs and HFCs

Compound	Ozone depleting potential	Global warming potential	Atmospheric residence time (years)
CFC 11	1.0	1.0	60
CFC 12	0.9-1.0	2.0008-3.4	120
CFC 113	0.8-0.9	1.3-1.4	90
CFC 114	0.6-0.8	3.7-4.1	100
CFC 115	0.4-0.5	7.4-7.6	400
HCFC 22	0.04-0.05	0.32-0.37	15.3
HCFC 21	0.01-0.02	< HCFC 22	2
HCFC 141b	0.07-0.14	0.12	10.8
HCFC 142b	0.05-0.08	0.34-0.39	19.1
HCFC 132b	0.025	-	4.2
HCFC 133a	-	-	4.8
HCFC 123	0.01-0.03	0.02	1.6
HCFC 124	0.01-0.03	0.09-0.10	6.9
HFC 32	0	0.13	6
HFC 125	0	0.84	40.7
HFC 134a	0	0.25	14.0
HFC 143	0	0.72-0.76	> 40
HFC 152a	0	0.03	1.5
HFC 227ea	0	0.06	42

*relative to reference value CFC 11 = 1.0

CFC 11: trichlorofluromethane, CFC 12: dichlorodifluoromethane, CFC 113: 1,1,2-trichloro-1,2,2-trifluoroethane, CFC 114: 1,2-dichloro-1,1,2,2-tetrafluoroethane, CFC 115: 1-chloro-1,1,2,2,2-pentaflouroethane.

HCFC 21: dichlorofluoromethane, HCFC 22: chlorodifluoromethane.

HCFC 141b: 1,1-dichloro-1-flouroethane, HCFC 142b: 1-chloro-1,1-difluoroethane, HCFC 132b: 1,2-dichloro-1,1-difluoroethane, HCFC 133a: 1-chloro-2,2,2-trifluoroethane, HCFC 123: 1,1-dichloro-2,2,2-trifluoroethane, HCFC 124: 1-chloro-1,2,2,2-tetrafluoroethane.

HFC 125: 1,1,1,2,2-pentafluoroethane, HFC 134a: 1,1,1,2-tetrafluoroethane, HFC 32: difluoromethane, HFC 143a: 1,1,1-trifluoroethane, HFC 152a: 1,1-difluoroethane, HFC 227ea: 1,1,1,2,3,3,3-heptafluoropropane.

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