REPORT OF AN INTERNATIONAL CONSULTATION

METHODOLOGY FOR RISK MAPPING OF THE INTERNATIONAL SPREAD OF VECTOR-BORNE DISEASES VIA AIR TRAVEL

GENEVA, SWITZERLAND
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Welcome and introduction

The meeting was opened by Dr Jaouad Mahjour, Director of the WHO Department of Country Health Emergency Preparedness & IHR (CPI), who welcomed the participants, noting the importance of the meeting in the context of globalization and climate change, which favour the spread of infectious diseases, often to areas where they were not found before. Vector-borne diseases – such as malaria, dengue, chikungunya, Zika and yellow fever – are reported in over 100 countries, and up to 60% of the world’s population is at risk of infection. At the same time, international traffic via air travel has increased hugely, with more than 4 billion people travelling by aircraft in 2017. The number of cases of vector-borne diseases has increased in endemic regions and imported and locally-acquired infections have also appeared in regions where these pathogens had not previously been found. Participants were thanked for their readiness to assistWHO in its attempts to counter this global threat.

Objectives

The agenda of the meeting was introduced by Dr Carmen Dolea, Team Leader IHR Committees Travel and Trade in WHO/CPI. The meeting was organized in the context of the requirements of the International Health Regulations (2005) for WHO to “publish, on a regular basis, a list of areas where disinsection or other vector control measures are recommended for conveyances arriving from these areas.” (Annex 5). The aim of the 2-day consultation was to arrive at a methodology to map the risk of international spread of vector-borne diseases via air travel, not only during outbreaks but also routinely. The methodology will allow WHO to identify areas and airports with a risk of international spread of vector-borne diseases and will help inform policy decisions to implement effective vector control measures to prevent the spread of vectors via aircraft, including aircraft disinsection, as appropriate.

Although WHO provides guidance on methods and products for disinsection of aircraft,¹ there is currently no standardized decision-making process to decide if, when and how disinsection of an aircraft should be carried out. Consequently, the challenge is to document a list of areas for the implementation of effective vector control measures. In 2016, during the public health emergency of international concern represented by the Zika virus and associated neurological complications, a WHO ad-hoc advisory group on aircraft disinsection recommended that the Organization should make a global map available, classifying areas on the basis of the presence of mosquito vector species and pathogens, and should use risk modelling to map mosquito vector presence.²

A copy of the agenda of the consultation on the methodology for risk mapping of the international spread of vector-borne diseases via air travel is attached to this report as Annex 1.

Participants then introduced themselves around the table. The list of participants is attached as Annex 2. Professor Patricia Schlagenhauf (WHO Collaborating Centre for Travellers’ Health, Zürich) chaired the meeting.

Consultation on disinsection methods and procedures

A consultation on methods and operating procedures for aircraft disinsection was held on 3–4 July 2018, prior to the consultation on the methodology for risk mapping. That consultation recommended use of the pre-embarkation method of disinsection in preference to others and recommended studies on disinsection and vector control in and around airports. It also recommended the testing of new chemical products, which are urgently needed. It was reported that efforts are being made to lower the permethrin levels in the insecticide used in aircraft to match the limits imposed by the European Union (EU). The consultation on disinsection also urged further research, especially on new products and alternative non-chemical methods for disinsection.

Needs and challenges related to prevention of importation of vectors/pathogens and disinsection of aircraft

Input from WHO regional offices

The Chair, Prof. Patricia Schlagenhauf, of the WHO Collaborating Centre for Travellers’ Health at the University of Zurich, Switzerland, introduced the session by stressing the need to seek a roadmap for going ahead with mapping in an evidence-based way. Representatives of WHO regional offices offered their comments.

African Region

Dr Emanuel Musa Onuche introduced the situation for the Africa Region, which experiences regular outbreaks of a number of deadly vector-borne diseases such as Rift Valley fever, chikungunya, Crimean-Congo haemorrhagic fever, Zika virus, West Nile virus, malaria, dengue and yellow fever. The region has held training-of-trainers sessions in Ghana on public health management in air transport with participants from 16 countries. Induction training has taken place on management of public health events in air transport and the reinforcement of the IHR requirements at points of entry with participants from 40 countries during a meeting of the Collaborative Arrangement for the Prevention and Management of Public Health Events in Civil Aviation (CAPSCA) in Zambia. In addition, training took place in Ghana on management of public health events in air transport, including aircraft and airport inspection and sanitation. Aircraft disinsection is a concern since many African airlines are private or being privatized, and the extent and effectiveness of government supervision is unclear.

Americas Region

Dr Roberta Andraghetti introduced the situation of the Americas Region. Vector-borne diseases circulating in the Americas include dengue, Zika, chikungunya, malaria, Chagas disease, leishmaniasis, yellow fever, onchocerciasis, plague and lymphatic filariasis. Brazil is endemic for a large number of these diseases. However, the view of the Pan American Health Organization (PAHO) is that the spread of disease by air travel is due to infected persons and not due to mosquitoes. Because of this view, PAHO considers that disinsection of aircraft in the Americas remains a non-issue so there is no need to develop guidance on it. Currently PAHO, like WHO, uses maps of diseases, not maps of vectors. Member States in the Americas are asking WHO for the list of countries where aircraft vector control measures are needed; this list was mandated by the IHR but has not yet been produced, due to conflicting views among Member States on the evidence of effectiveness of aircraft disinsection in preventing the spread of vectors and vector-borne diseases. It was noted that vector control at airports is often carried out by contractors, since in many cases
airports and everything within the perimeter are private businesses. However, national authorities are responsible for implementing the IHR, and also ultimately responsible for the outcome of the vector control activities, even if these are conducted by private entities.

Eastern Mediterranean

Mr Martin Walker introduced the experiences in the EMR region, where the main mosquito-borne diseases are malaria, dengue, chikungunya, lymphatic filariasis, yellow fever and Crimean-Congo haemorrhagic fever, while further diseases spread by other vectors include schistosomiasis (freshwater snails), leishmaniasis (sandflies) and onchocerciasis (blackflies). Vector control is currently targeting the mosquito vectors transmitting malaria, dengue and chikungunya and the sandfly vectors transmitting leishmaniasis. Controls for schistosomiasis (and their snail vectors) also take place within the region.

However joint evaluations in 14 (of 23) Eastern Mediterranean countries in 2016–2017 showed that nine countries had no regular vector surveillance at points of entry. The humanitarian situation and complex emergencies in some countries in the region exposes vulnerable and migrating populations to infectious bites leading to outbreaks, and the need for additional resources to implement effective vector control is urgent.

European Region

Dr Jetri Regmi introduced the situation in the WHO European Region. A 2017 assessment of IHR core capacities showed that work on points of entry must be strengthened. This is essential because Europe has some of the busiest airports in the world. The main challenges for the spread of vector-borne diseases by air travel are found in the countries closest to the Mediterranean, where the main risk factors are the presence of Aedes vector, climatic stability, connections via shipping and aircraft, population density and urbanization. The capacity of countries to contain transmission is variable. The regional office supports countries in building capacity for vector surveillance and control around points of entry.

Western Pacific Region

A set of PowerPoint slides describing the situation in the Western Pacific Region was made available to participants. Aedes aegypti and Anopheles are widespread in the region and vector-borne diseases found commonly in the region include dengue, Japanese encephalitis, malaria and chikungunya. Diseases such as yellow fever and Rift Valley fever have been imported into the region and various pathogen strains are known to have been exported. For instance, 11 cases of yellow fever were imported into China from Angola in 2016, and – as of September 2016 – Zika virus had been imported into seven Western Pacific countries. Not all health measures taken by countries conform to WHO’s recommendations. The region has some of the world’s least developed economies as well as the most rapidly developing countries, and there is frequent air travel, but some populations are immunologically naïve and there is no routine vaccination against yellow fever in some areas. In addition to ongoing support to countries to strengthen their IHR core capacities, a regional meeting on points of entry was held in China.

Aviation legislation and a decision tool for disinsection

Dr Joanna Jordaan of the International Civil Aviation Organization (ICAO) presented the responsibilities of this UN organization for public health. ICAO issues standards (considered necessary, and to which Member States will conform) and recommended practices (which are considered desirable, and to which Member States will endeavour to conform). ICAO initially
developed and continues to amend disinsection standards and recommended practices in accordance with WHO recommendations and guidelines. These are contained in Annex 9 (Facilitation) to the Convention of International Civil Aviation. One of the standards of ICAO states that Contracting States should limit any routine requirement for aircraft disinsection while passengers and crew are on board the aircraft.

ICAO was instructed by its 39th Assembly in 2016 to engage with WHO to develop performance-based criteria for non-chemical and chemical disinsection, to provide Member States with guidance on the components of a scientifically-based risk assessment model for use in determining whether aircraft require disinsection, and to share information on vector control and disinsection measures at international airports. ICAO has developed a vector control register of airports which shows a very mixed picture, with many airports having no vector control. In addition, ICAO has developed a weighted decision-making tool to assist states to assess the residual risk of transmission of vectors via air travel, taking into account the following factors: the prevailing risk at an airport, the elements for risk modification that have been implemented, the acceptability of the risk to the state, and the potential need for implementing additional measures at both the departure and arrival airports. One of the main objectives of the decision-making tool is to promote dialogue between states in the prevention of vector-borne diseases. Participants were shown the questions used in the tool.

ICAO has applied a step-based multi-layer approach to the decision-making tool (including vector maps) which now has five categories: region indicators related to vector presence and regional flight volume, vector surveillance indicators at the departure airport, technical indicators at the departure airport (e.g. type of flight operations, methods and areas of disinsection); technical indicators at the arrival airport and technical conveyance indicators. However, it is often difficult to find out information since airports are run by different groups in different places – some airports are run by the local municipality, some by the national authorities, some by private companies and some by airlines. The decision-making tool not only helps countries to assess and mitigate risk at their own airports, but also helps them to assess the risk en route and at arrival airports. Should a state be concerned about the level of risk at a specific airport, the state can enter into a dialogue with the relevant state to discuss the implementation of additional measures to mitigate the risk of transmission of vectors; either at the departure airport, transit airport, on the conveyance or at the arrival airport.

ICAO can also analyse air traffic in terms of number of flights departing from specific airports and the destination airports of these flights. Historical data provide more detail on the flight routes and specific airlines using these routes. In addition, ICAO monitors NOTAMS (Notices to Airmen – issued by national governments) and if there is any concern relating to an outbreak of disease, ICAO notifies the Airport Council International, WHO, IATA and other relevant bodies and aviation stakeholders.

The ICAO decision-making tool was welcomed, especially as it enabled arrival airports to understand the state of vector control at airports from which aircraft had departed. It was noted that the recent concern about disinsection arose during the Zika outbreak when Italy began to require that all aircraft arriving in Italy from other countries with local Zika virus transmission or where the Aedes aegypti vector is present should have been disinfected.

**Stakeholders’ needs and operational challenges**

Dr. Walter Gaber introduced the perspectives of Airports Council International (ACI), which is an association established in 1991 as the global trade representative of the world’s airports. ACI
represents airports’ interests with governments and international organizations and develops standards, policies and recommended practices for airports. ACI also provides information and training to raise standards around the world. While many airports are owned by states or provinces, most are owned privately. However, disinsection is the legal responsibility of the local public health authorities. Participants were shown elements of airport vector control. A challenge was noted in the fact that, if there is a health event at an airport, both the Ministry of Health and the Ministry of Transport become involved although these two bodies do not traditionally collaborate. ACI was reported to be working on aviation disinsection guidelines with a number of partners and these guidelines will be shared with WHO when published.

Participants were informed that all disinsection materials need to be compatible with aircraft materials, which differ between types of aircraft. If a person is identified as having an infectious disease aboard an aircraft, the captain is responsible for calling ahead to warn the authorities at the arrival airport. It is important to inform the media when there is a problem (as in the case of the Zika outbreak) and it is essential to issue new information each day (even though sometimes it may be similar to that of the day before).

Close links to the airline are essential if disinsection is to be carried out effectively. Airline staff must understand the importance of the procedure and must receive training in order to carry it out safely and effectively.

Models for risk mapping of importation of pathogens/vectors

Existing models for risk mapping of the importation of vectors and pathogens

Dr Oliver Brady of the London School of Hygiene and Tropical Medicine, United Kingdom, presented various models for risk mapping of vector or disease importation. There are different ways to map infectious diseases — most commonly by occurrence or by prevalence. It was stated that prevalence mapping is in many ways the most accurate way to map diseases since the data are usually based on research-based activities, but this cannot really be applied to diseases that are not systematically sampled, including many emerging infectious diseases that are at high risk of spread by air transport. Occurrence data tend to come from outbreak reports, news reports or peer-reviewed literature without clear information on catchment population and usually indicate either that X cases of a disease have been reported in A location or that a particular vector has been found in B location. However, it is also important that there are reliable data not just on the presence of a disease but also on its absence, as an indicator of effective vector surveillance. This especially applies where vector mapping is concerned.

Species distribution modelling (SDM) aims to build a model that can predict where a species occurs. In the case of such modelling for mosquitoes, important variables may include temperature, altitude and rainfall of the area. Models can estimate not only where the species is at present but also areas to which it could potentially spread — because of accessibility and the suitability of the habitat. The output of such a map is the probability of occurrence.

There are places where, on the basis of vector and habitat data, a disease may be predicted but has not been reported (e.g. Mexico and the southern USA). In this situation, the reason for this could be that 1) cases occur but are unreported, 2) the model does not capture a key determinant of risk, 3)
the introduction of the vector or pathogen has not yet occurred or 4) no infected viraemic person is present to have the disease transmitted/spread by the present vector.

Maps of vectors can be combined with data on human movement – i.e. movement of pathogens in infected humans to areas without the disease but with the vectors, and movement of vectors to areas without vectors but with suitable habitats. Such maps generate predictions such as an estimated number of persons travelling from areas with disease to areas that could have outbreaks. Other considerations include seasonality of travel and vector populations, vector behaviours and habitats, full itineraries (i.e. with multiple connections, especially for diseases in remote areas), trends in travel volumes, epidemiological changes, and movement of passengers after they leave the airport.

**Modelling the risk of importation and onward transmission of mosquito-borne diseases**

Dr Shengjie Lai, of the University of Southampton, United Kingdom, presented on models for risk of importation of mosquito-borne diseases. Data on importation risk show the number of travellers in terms of traffic volume at exit and entry points, the number of imported infections reported in surveillance, and the networks between communities of origin and destination. A traveller infected in a source location and arriving at a destination can be considered part of a process that is dependent on the force of infection, the time and duration of stay and the probability of further travel.

There are various ways to estimate the number of infected travellers – using the importation index of travel volume multiplied by incidence rate in mechanistic, probabilistic or statistical regression models. Probabilistic models can be used, for instance, to quantify changing seasonal importation risks. Moreover, the risk of onward transmission after arriving at the destination airport can also be calculated by using ecological suitability estimates. Other possible ways of assessing onward transmission potential is the probabilistic branching model by considering the risk of an infected traveller arriving, the risk of a mosquito acquiring the infection, and the risk of the mosquito infecting someone else in destination.

Participants were shown how the rise in introduction of dengue from South-East Asia into China correlates with the increase in travel of persons from South-East Asia. The importation risk per year in Chinese provinces and the risk of onward transmission, which is more likely in May to October, increased from 8 cities in 2005 to 35 cities in 2015. Most of the Chinese at-risk cities are in the south of China. However, it is difficult to define accurately the final destinations of infected travellers when they leave the destination airport.

In their discussion on existing models for risk mapping, participants noted that:

- It is theoretically possible in mapping to use one disease as a proxy for another, though this would require very good data on vectors.
- The validity of decision-making on the basis of mapping models may not be definite, but the maps bring an extra perspective to the basic data, although maps of likely future movement reflect much more uncertainty.
- The United States Centers for Disease Control and Prevention (CDC) does not consider that disinsection is an effective way to prevent the spread of vector-borne diseases because evidence shows that infected travelers are the primary cause of spread. In addition, the evidence of its effectiveness in preventing the international spread of disease is insufficient. CDC recognizes the need for disinsection in certain situations and understands why Australia
and New Zealand would do it, but overall CDC does not feel the effectiveness of disinsection has been proven.

- The lack of data shows the need for modelling, noting that the models are also limited by lack of data.
- Disinsection is one way to prevent the import of vectors. Under the IHR, countries can use either disinsection or other effective control measures.
- Mapping of precisely where diseases are and where the vectors are found are both important means of guiding future activities to prevent the spread of pathogens, whether disinsection or another method is used.
- A systematic review of the literature on disinsection and the international transport of vectors is an outcome goal of the meeting.

**Identifying targeted diseases and vectors for risk mapping**

**The spread of vector-borne diseases by air travel**

Dr Kamran Khan of the University of Toronto, Canada, presented a model to predict the spread of vector-borne diseases via air travel. Vector-borne diseases have been shown to spread rapidly from their origins to distant locations. A study on “Anticipating the international spread of Zika” showed the spread of the Zika virus from areas of vector presence to areas of vector absence but with suitable environmental conditions in a surprisingly short time frame. One third of the world’s 300 highest-volume airports are within 10 km of occurrences of *Aedes albopictus* mosquitoes, while there has been a 72% increase in air travel over the past decade.

A study focused on pairs of airports suitable for presence of *Aedes albopictus* of which one had the mosquito within 50 km and the other did not. When the search for such pairs was limited to international flights and local conditions suitable to *A. albopictus*, and pairs of which both airports already had the vector were excluded, it showed 3800 such airport pairs. The study thus showed global suitability for the establishment of disease in a new area.

It was noted that the modelling took place in a situation where disinsection is occurring, which could influence judgement. There seem to be few cases of evidence of transmission by vectors, which might indicate that disinsection is effective or that mosquitoes are unlikely to be transported by air, or that human travellers are also unlikely to spread disease. It was felt that capturing mosquitoes on aircraft would be likely to produce a low yield, and that surveillance and control at airports would be more effective.

**Distribution and susceptibility of vectors**

Dr Jan Semenza of the European Centre for Diseases prevention and Control (ECDC) presented a European study to predict the occurrence of emerging infectious diseases. The drivers of emerging infectious diseases in Europe can be grouped into three main categories, namely globalization and environmental change, social and demographic change (including social inequality and lifestyle), and effectiveness (or not) of public health systems (including animal health and food and water quality). Travel and tourism, migration and global trade fall into the first group. A study by the European ECDC, published in 2016, showed that the top five drivers of infectious disease threat events are travel and tourism, food and water quality, natural environment, global trade, and climate.
Some 600 million people fly into Europe’s airports every year from dengue-endemic areas. Further research shows that the highest risk period is in August, September and October, and that 50% of passengers from areas where dengue is prevalent travel through two Italian airports. Similar statistics exist for the risk of transmission of Zika virus. ECDC is able to identify the times of the year when the risk is much higher than at other times. When notifying the Italian cities of the high threat in late summer, ECDC advised them to institute sentinel surveillance for the vectors. The chikungunya outbreak in Italy in 2007 is evidence of the importation of the virus and the interaction between viraemic travellers and competent vectors.

At the same time, the *Aedes albopictus* is currently widespread in countries bordering on the Mediterranean and the mosquito vector is spreading — simply because it is possible to spread (typically along waterways and road networks moving northwards to the interior of the continent). Conversely, however, as the vector takes hold further north it is now likely to decline in some Mediterranean regions as a result of long summer droughts.

There was discussion on the difficulty of tracing outbreaks to mosquitoes as opposed to viraemic persons. *Aedes albopictus* is sturdy and can survive cold conditions (it has been found in Chicago), but whether enough mosquitoes can survive to cause an epidemic is questionable. It was noted that the study had focused on airline travel but had not included data on cargo aircraft or shipping.

**Information available and gaps to be filled to assess the spread of vector-borne diseases**

Participants discussed the key criteria for risk mapping — such as the diseases to be targeted, the vectors and vulnerable areas. The initial proposal was to start with areas with a high volume of disease, next to consider airports in such areas, then to look at the places where air travel from these areas may terminate, and finally to consider steps to be taken there (if the disease is not already established in those destinations).

Maps of diseases and disease spread exist, as do some maps of vectors, but it was clear that there was no one source through which the various maps can be found. Various groups have made maps for different regions but it would be important to draw those together, fill up the maps for some parts of the world, and to understand the level of uncertainty of current maps. One criterion for vector mapping would be a certain level of travel from the infected area. Number of flights is a useful criterion if the risk is based on vector importation, while the number of passengers is more useful if the risk is based on viraemic travellers. It was recommended that the next effort should be the continental maps and in-country maps considering the risk to the neighbouring countries and to the areas within the countries because of the importation of infective vectors.

It was agreed to limit the scope of the models to two mosquito genera — *Aedes* (albopictus and aegypti) and *Anopheles* — and five diseases (chikungunya, dengue, Zika, yellow fever and malaria). Maps for *Aedes* species could be assembled based on the current work of the research groups present at the meeting.

Participants further noted the following:

- In 2017 the World Health Assembly adopted the global vector control response which is now part of WHO’s Global Programme of Work, thus giving an impetus to the outcomes of the consultation.
• Any map created by WHO has to be open-source so that it can be made widely available. A number of maps developed by university researchers are open-source, but huge datasets are held by ministries of health and disease programmes and are not generally made available to wider audiences. A WHO map would have disclaimers and would state what the sources are.

• WHO regions have been collecting data on vector control in their areas, so there may well be sufficient data available to start the mapping. The more confident one is with the data, the more likely it is that one will be able to move to another level of risk assessment.

• It was recommended to start with one map and then add layers with further elements. For instance, if the focus is vectors, the data should follow where the aircraft go. Alternatively, if one is interested in viraemic persons one must find data on passengers. ICAO said it has a lot of data on passengers, which can be tapped as resource.

• A layered map would be helpful not only for maps on air travel but also for the development of maps for other points of entry such as ports and border crossings.

• In discussing how to classify vulnerable areas, it was felt that vulnerability is defined by the characteristics of the vector and the susceptibility of the environment.

• The earlier consultation on operating procedures for disinsection had stressed the need to look more closely at non-chemical means of disinsection. Participants in that consultation had stressed the urgent need for increased surveillance (and if countries do surveillance they should report data). The risk mapping consultation could therefore consider calling on those doing vector surveillance to share their data.

• Disinsection of some kind is still required by many countries. Following a recent dengue outbreak in Madeira, Portugal, 19 European countries had cases of dengue infection as a result and many stressed the need for effective disinsection of aircraft for potential vector invasion, as well as other means of ground transportation such as lorries, passenger buses and trains.

• The issue of vulnerability may need to be addressed from the perspective of both the departure airport and the arrival one. Small island states are vulnerable locations, as are places with poor surveillance and a lack of diagnostic capacity.

• Malaria discussions distinguish vulnerability (how likely it is that someone will be exposed) and receptivity (how likely it is that the vector will be successful). Seasonality is also an aspect of vulnerability, though this could vary by area.

• The maps should be based on those areas of the world from which special measures are required because of the risk of exportation of vector-borne diseases.

Sources of information on vector-borne diseases

Dr Raman Velayudhan, Coordinator, Vector and Ecology Management, Department of Control of Neglected Tropical Diseases, presented on sources of information for vector-borne diseases. Almost all WHO data are from ministries of health. The Organization does not generally use subnational data unless special permission is requested and granted. Participants were shown a list of a variety of vectors, the diseases they spread, and the estimated annual number of cases and deaths. Vector-borne diseases cause some 750,000 deaths every year, half of them from malaria. In that regard, data are available on the use of bednets and on resistance to insecticide.

For dengue and chikungunya, data are available from PAHO and the WHO regional offices for Europe, South-East Asia and Western Pacific. Data sources are also developing in Africa. European Union data show increases in travel-related dengue cases each year, while in Switzerland dengue cases have gone up from 50 per year to 200 over the past 2 years. Countries worldwide are now
affected by Zika virus. WHO Internet links were provided for data on malaria, dengue, chikungunya, yellow fever, Zika virus, leishmaniasis, lymphatic filariasis, Chagas disease and human African trypanosomiasis.

Government data are approved by ministries of health and should therefore be used for any mapping that will be an open source. Data that are approved by ministries of health for publication will form one layer of the Aedes map that is to be prepared. Some countries report suspected cases and, in any case, a large proportion of cases with arboviruses are asymptomatic, so there are clear caveats that must accompany the use of these data. For vector-borne diseases, a steep increase in vector activity can be observed (where there is surveillance) three weeks before an outbreak. Consequently, airport surveillance is essential in reducing disease spread via air travel. WHO has 20 years of dengue data from 115 countries, while the WHO collaborating centre at the Institut de recherche pour le développement (IRD) in Montpelier, France, has data on resistance and leads a network of institutions that report infectious disease data.

Surveillance networks for vector-borne diseases

Oliver Brady

Dr Oliver Brady presented on additional data sources for vector-borne diseases. These include the Global Biodiversity Information Facility (www.gbif.org) and national and regional surveillance groups. Human disease data are also available at Healthmap (www.healthmap.org), ProMED-mail and country surveillance activities. Additionally, there is the scientific literature and a number of georeferencing surveys on dengue, chikungunya, Zika, yellow fever, Crimean-Congo haemorrhagic fever, as well as Culex, Anopheles and other disease vectors. It should also be possible to obtain data on airline itineraries, shipping and human movement models (using mobile telephones to track people’s movements) since all three should be considered together. Some countries will have data on imported cases of diseases.

There are networks of travel clinics that accumulate data – such as at Geosentinel which is organized by the International Society of Travel Medicine and which collates clinician-verified data on infections and traveler itineraries. Malaria elimination programmes should have full data on all malaria cases, so travel history, with contacts and places, can be reconstructed.

There is, however, a data gap with regard to which vectors and pathogens, are spreading. Past or current data exist, but one also needs to consider those vectors and species that have the potential to spread – for instance through their adaptation to urban environments or their resistance to insecticide. Such data need to be considered along with identification of currently-unaffected environments that have, or could have, a suitable environment for spread.

Ideally data are required on human behaviour at the travel destination and the home environment to which travellers return (e.g. distance from airport, home environment, treatment-seeking behaviour). Mapping of vectors would also need to take account of whether vector control is done and, if so, what it consists of. Finally, any new disease maps would need to be validated.

Participants further noted:

- The use of telephone data to track people’s movements was questioned from the perspective of privacy – and laws that aim to protect privacy. Additionally, although the telephone connection is lost when someone travels by air, it reconnects at the destination;

however, it is difficult to identify a particular telephone among vast number of sources. Different telephone service providers have their own data, and roaming may also complicate identification.

- Data on the arrival of vectors may exist in some places at points of entry, but these are most likely at ports rather than airports. It was reported that there are some data from the ports of Felixstowe (United Kingdom) and Hamburg (Germany) but there seems to be some lack of consistency. The port of Hamburg imports a lot of flowers, and mosquitoes – not *Aedes* or *Anopheles* spp – have been found among them on occasion.

- There was a reminder that an airport should not necessarily be classed as safe just because it is in an area with no vectors. Mexico City airport, for instance, is free of mosquito vectors, but it is very likely that many passengers leaving from there will have started their journey in parts of the country where vectors are common. Taking this into account adds another element of complexity to any mapping project.

- It was reported that a lot of the data that are being collected in Africa are not being collated or shared. For instance, the vertical programmes on infectious diseases are very strong and they each collect data, yet much of these data are not being shared with other programmes.

### Trends in global traveller numbers

Dr David Powell of the International Air Transport Association (IATA) presented on global trends in travel. While the ICAO is the regulatory authority that provides air travel standards which virtually all countries sign up to, the IATA is a commercial association, representing the airlines (280 airlines in 120 nations). In 2017, 4.1 billion passengers flew on 41.8 million flights and 53 billion tonnes of cargo were transported by air. In 1978, it was calculated that the frequency of air travel was equivalent to every person on the globe flying once every 7 years; in 2017 that frequency was once every 2 years. Most travel starts in one place and ends eventually in the same place.

The demand for air travel is forecast to double over the next two decades due to the increase in the middle classes of current middle-income economies in the south and east. Interestingly, the new growth in air travel matches closely the spread of Zika virus. The 20-year growth outlook shows that in 2037 half of all global travel will be in Asia Pacific.

### Planning for future collaboration and a possible research agenda

The choice between protective efforts at destinations or preventive efforts at points of departure: plenary discussion

Annex 5 of the IHR requires WHO to produce a list of affected areas where there are disease vectors, and the consultation should help this to be achieved. However, despite this focus, it is important to note concerns about the bigger issue. There has also been a call from airports for more collaboration of airlines in ensuring that travellers have valid yellow fever certificates when leaving affected areas.

Anita Plenge-Bonig and Walter Gaber agreed to see if it would be possible for them to collaborate on possible collection of mosquitoes on flights from affected areas of mosquito-borne diseases in order to obtain some evidence on the number of vectors travelling. Participants supported the idea of establishing just what the burden of mosquito risk is via aircraft.

There was general support for focusing on vector control at points of departure, and also for testing for the presence of mosquitoes on passenger airbridges between the airport building and the aircraft. The persons leading the test would consider whether to broaden it to include also flights
and areas around airports. It was proposed to install some mosquito traps on aircraft and at points of entry and to identify places where compliance with the IHR is suboptimal.

There was a call for a third-party assessment of airports to establish whether or not additional measures are required for aircraft departing from that area. The meeting was reminded that the IHR require vector control at “designated airports”; however, there are many cases where a country’s traditional main airport has vector control but another airport in the same country with international flights is not “designated” and therefore does not see the need to do vector control.

It was pointed out that many airports already do insect control in and around their buildings so as to discourage birds in the airport area as these can damage engines. If they are already taking measures to remove grasshoppers and all kinds of insects from the airport, the removal of disease vectors should be combined with these efforts.

While different airports may have a variety of different owners, the IHR makes clear that the responsibility for vector control and disease prevention lies with the States Parties to the regulations. Governments also certify airports.

In order to compile the list demanded by the IHR, it is necessary to identify airports from which disinsection is required. To do that, further information is needed. Airports need to be identified and the ones in areas of risk must be defined. Then the presence of vectors must be established, as well as the extent of current vector control measures. This would mean there must be a clear definition of what vector control measures should be in place. It was stressed that there are airports in the southern USA in areas where the vectors are present, and yet these airports do not create travel risks because of extensive control measures. These airports could provide an indication of what measures should be in place in order to prevent the transport of known vectors.

The Chair asked that a subgroup for *Aedes* mapping be formed to identify gaps in the currently available information. This led to a request for long-term sampling of the vector population in a given area to find out the impact of seasonality. Intervention data – what is being done where – would also be helpful.

**IHR requirements for vector control measures at airports**

Mr David Bennitz, Technical Officer, Transport, Tourism and Mass Gathering, in the Department of Country Health Emergency Preparedness and IHR, presented on the vector control measures at the airport. The IHR require all countries to implement vector surveillance and control at points of entry, as per articles of annexes 3, 4, 5 and 9. The steps recommended were explained – such as recognizing the threat, instituting vector surveillance and evidence-based vector control, surveillance of conveyances and cargo, and emergency measures when needed. WHO’s Lyon office has produced guidance that is available in five languages. This provides an explanation on how vector surveillance and control at points of entry can function effectively. The handbook addresses issues such as the vulnerability of a point of entry, making a risk assessment, setting up a plan for surveillance, and the emergency plan in case of an outbreak.

Mosquitoes can be controlled through 1) environmental management actions such as source reduction, habitat modification and habitat manipulation, and 2) mechanical actions such as screening doors and windows and drilling holes in old tyres (such as those often used as fenders on

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cargo ships) to discourage mosquito breeding. Then there are 3) biological control methods that include introducing larvivorous fish into water sources and using biolarvicides, and 4) chemical control using antilarval spraying for larvae, indoor residual spraying for adults, insecticide-treated bednets and repellents.

Participants were shown the Internet website of PAGnet (the Ports, Airports and Ground Crossings Network), which has a variety of documents and guidelines on vector surveillance and control at points of entry in multiple languages. It was noted that Western Australia has a mobile application for mosquito trap inspectors to upload data, including information on identification of mosquitoes and other data.

In a brief discussion on which airports to exclude from disinsection, it was suggested that these should be: 1) airports in countries that have reported reaching core capacity, 2) airports in regions with no evidence of mosquito vectors, and 3) airports in regions where vectors are never likely to occur (e.g. because of cold temperatures year-round). However, these are the criteria for exclusion from disinsection only and they do not exclude an airport from taking other necessary sanitary measures.

Conclusion and next steps

Summary

Dr Carmen Dolea summarized the deliberations and proposed the next steps. Participants were reminded of the IHR’s legal mandate to WHO to “publish a list of areas where disinsection or other vector control measures are recommended for conveyances arriving from these areas”. Both airport departures and conveyances are the responsibility of national or regional public health authorities. It was clarified that the meeting was not recommending only disinsection, but that the IHR require WHO to produce a list of areas from which “disinsection or other vector control measures” need to be applied to conveyances departing from these areas.

Evidence shows that the international spread of vector-borne diseases via air travel occurs mostly via viraemic/parasitaemic travellers and far less via infected vectors. For ship or land travel, other vectors are involved and the international spread appears to be more frequent via infected vectors than via infected travellers, although this aspect was not within the scope of this meeting.

The decision of States Parties and airlines operators to apply vector control measures to conveyances is informed by the risk of international spread of vectors from the departing areas. The decision of States Parties to require the application of vector control measures (including disinsection) to arriving conveyances is informed by the risk of establishment of exotic vectors in a susceptible environment.

Factors that influence the risk of international spread of vector-borne diseases, and associated sources of information, include: seasonal distribution of mosquito vectors (Global maps of *Aedes aegypti* and *albopictus* developed by Kramer et al. to be used, and *Anopheles* maps from the Malaria Atlas Project); prevalence / occurrence of vector-borne diseases (maps and/or models of occurrence of VBDs: maps of dengue, chikungunya, Zika, yellow fever, and malaria, developed by WHO, and various models developed by research groups); local capacity for vector control5 (ICAO Airport vector control registry, although still in prototype, Points of Entry capacity scores from IHR

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5 To take into account the situation of airports with good vector control but located in countries endemic for vector-borne diseases
core capacities assessments); **volume of air travel** (data on seats/travellers from ICAO and IATA); and **aircraft routes** (ICAO, IATA). The map showing the global spread of *Aedes aegypti* and *Aedes albopictus*, developed by Moritz Kramer et al, will be the starting point for the proposed *Aedes* vector map. This could be combined with other data in order to arrive at a list of areas with risk of international spread of vector species, which is the IHR requirement for WHO. Further mapping of disease risk could inform the implementation of broader measures to reduce the risk of vector-borne disease spread in addition to the vectors themselves.

As a means of obtaining information about airports and vectors, ICAO’s decision-making tool should be considered. In response to a question as to whether there is an ethical element in the decision-making tool, it was pointed out that this is included in terms of occupational health and safety of airline and airport staff. The decision-making tool will come into play once the relevant areas are identified.

**Next steps**

WHO will produce a position paper on the application of Annex 5 requirements, which will be informed by the report of this consultation. Also, WHO will produce a position paper on aircraft disinsection, informed by systematic reviews on effectiveness of disinsection in reducing the international spread of vector-borne diseases (which Patricia Schlagenhauf and the WHO collaborating centre in Zurich are currently working on) and recent research from Michael Johansson and colleagues), as well as narrative reviews of compliance issues (Andrea Grout). A mapping team formed of Oliver Brady, Moritz Kramer and Shengjie Lai, with input from Kamran Khan and Michael Johansson, will work towards the development of a vector map for *Aedes albopictus* and *Aedes aegypti*, as well as for Anopheles species. Anita Plenge-Bonig and Walter Gaber will be looking into a project to gather data on the numbers and types of mosquitoes on airbridges and in aircraft. Andrea Grout’s literature review on disinsection will be also considered.

WHO’s list of areas (not airports) for the application of vector control measures to conveyances will be informed by the planned maps, as well as by the airport vector control registry and the volume of travel. The European decision-making tool was said to be based on the ICAO tool, though questions still need to be answered regarding the deadline and who is going to be involved. WHO’s position paper on aircraft disinsection will be informed by a systematic review on effectiveness of disinsection in reducing the international spread of vector-borne diseases.

A reminder of the need for yellow fever certification could be a part of the online ticket purchasing system. Yellow fever regulations state that travellers are required to have a valid certificate of yellow fever vaccination when returning from an endemic area. The importance of compliance was insisted on.

In closing the meeting, Dr Mahjour thanked all participants for their important contributions and for reaching consensus on a range of issues. WHO needs the assistance and advice of experts to achieve its work, and the input of the health and travel experts was of particular value in relation to ongoing work with to ensure implementation of the IHR.

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Appendix 1. Agenda

WHO International Consultation
Methodology for risk mapping of the international spread of vector-borne disease (VBD) via air travel

World Health Organization, Geneva, Switzerland, Room M105 - 5-6 July 2018

Chair: Prof. Dr. Patricia Schlaginhauf, PhD

Day 1: Thursday 5th July - Review challenges & risk mapping methods

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>09h00-09h45</td>
<td><strong>Welcome and introduction</strong>, Director CPI, J. Mahjour</td>
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<td>Introductory remarks and meeting orientation</td>
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<td>Introduction of participants, Declaration of Interests</td>
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<td>Team Lead, IHR Committees, Travel and Trade - C. Dolea</td>
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<td>Status for implementation of recommendations to WHO Secretariat from last meeting</td>
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<td>Feedback from the meeting on methods and operating procedures for aircraft disinsection</td>
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<td>Objectives and expected outputs for this consultation</td>
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<td>09h45-11h00</td>
<td><strong>Session 1: Needs &amp; challenges related to importation of vectors/pathogens and disinsection of aircraft</strong></td>
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<td>Regional perspectives.</td>
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<td>Presentation on decision tool for disinsection and on the legal framework to enforce disinsection (J. Jordan, ICAO).</td>
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<td>Presentation of stakeholders needs and operational challenges for disinsection as well as vector control activities at airports (W. Gaber, ACI).</td>
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<td></td>
<td><strong>Plenary discussion</strong> – Identify challenges and effective public health measures to prevent spread of VBDs via air travel including vector control measures at airports and on board of conveyances. Agree on objective of the risk mapping tool.</td>
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<tr>
<td>11h00-11h15</td>
<td><strong>Coffee break</strong></td>
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<tr>
<td>11h15-12h30</td>
<td><strong>Session 2: Models for risk mapping importation of pathogens/vectors</strong></td>
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<td>Presentation on existing models for risk mapping importation of vectors and pathogens (O. Brady)</td>
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<td>Modelling importation risk and onward transmission risk of mosquito borne diseases (S. Lai)</td>
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<td><strong>Plenary discussion</strong> – Determine key factors and challenges to assess the risk of VBDs spread via air travel and onward transmission.</td>
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<tr>
<td>12h30-14h00</td>
<td><strong>Lunch</strong></td>
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<td>Time</td>
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<tr>
<td>14h00-15h30</td>
<td><strong>Session 3: Identify a list of targeted diseases and vectors for risk mapping</strong></td>
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<td>• Presentation on spread of VBDs via air travel, (K. Khan)</td>
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<td>• Presentation on vectors distribution and susceptibility (J. Semenza)</td>
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<td><strong>Plenary discussion</strong> – Determine key criteria for risk mapping such as targeted diseases, vectors and vulnerable areas.</td>
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<tr>
<td>15h30-15h45</td>
<td><strong>Coffee break</strong></td>
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<tr>
<td>15h45-17h30</td>
<td><strong>Session 1, 2 and 3: Plenary discussion continued. Summary of day 1 discussion.</strong></td>
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**Day 2: Friday 6th July – Data required & collaboration to develop a risk mapping tool**

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<tr>
<th>Time</th>
<th>Session/Activity</th>
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<tbody>
<tr>
<td>09h00-10h30</td>
<td><strong>Session 4: Data required: information available and gaps to assess spread of VBDs via air travel</strong></td>
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<tr>
<td></td>
<td>• Presentation on source of information available for vector-borne diseases at WHO (R. Velayudhan).</td>
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<td>• Presentation on other surveillance networks for vector-borne diseases and vectors (O. Brady).</td>
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<td>• Presentation on trends global travellers numbers and int. airport (D. Powel, IATA).</td>
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<td><strong>Plenary discussion</strong> – identify available information and gaps, issue recommendations on future collaboration and research.</td>
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<tr>
<td>10h30 -11h00</td>
<td><strong>Coffee break</strong></td>
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<tr>
<td>11h00-12h30</td>
<td><strong>Session 5: Planning for future collaboration and possible research agenda</strong></td>
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<td><strong>Plenary discussion</strong> – identify future collaboration to compile and analyse key data for risk mapping of VBDs spread and evaluate resources needed to maintain this process.</td>
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<tr>
<td>12h30-14h00</td>
<td><strong>Lunch</strong></td>
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<tr>
<td>14h00-15h30</td>
<td><strong>Session 6: IHR requirements for vector control measures at airport</strong></td>
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<td>• Presentation on WHO activities for Points of entry, vector control in airports (D. Bennitz).</td>
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<td><strong>Plenary discussion</strong> – Identify key challenges and issue recommendations for vector control measures as requested by the IHR for airports (Annex 1) and conveyances (Annex 5). Review possible criteria and processes to exclude airports from disinsection.</td>
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<tr>
<td>15h30-15h45</td>
<td><strong>Coffee break</strong></td>
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<tr>
<td>15h45-17h30</td>
<td><strong>Session 7: Wrap up and next steps, C. Dolea</strong></td>
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<td></td>
<td>Closing points, Director CPI, Dr J. Mahjour</td>
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Appendix 1. List of Participants

**WHO International Consultation**

**Methodology for risk mapping of the international spread of vector-borne disease (VBD) via air travel**

**World Health Organization, Geneva, Switzerland, Room M105 - 5-6 July 2018**

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AFRO - Dr Emanuel Musa Onuche, Risk Analysis Advisor, AF/RGO/WHE/CPI
AMRO - Dr Roberta Andraghetti, Advisor, International Health Regulations (IHR),
EMRO - Martin Walker, Consultant
EURO - Dr Jetri Regmi, Technical Officer (Preparedness), EU/RGO/WHE/CPI

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Ms Veronica Riemer, Technical Officer HQ/WHE/CPI/IHR
Mr David Bennitz, Technical officer, HQ/WHE/CPI/PCB
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Dr Annelies Wilder-Smith, Consultant, HQ/FWC/IVB/IVR