Modelling the Expected Short-Term Distribution of Incidence of HIV Infections by Exposure Group

Manual

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Acknowledgements

The spreadsheet was developed by Geoff Garnett and Peter White (Imperial College) in collaboration with Neff Walker and Peter Ghys (UNAIDS), John Stover (TFGI), Tim Brown (East West Centre) & Elizabeth Pisanie (FHI) in 2002, Bangkok; and revised by Peter White and Eleanor Gouws in 2005.

The model is based on formulae of Weinstein et al and employed in the model Avert.

AIM

The aim of the spreadsheet is to calculate the expected number of new infections over the coming year on the basis of a description of the current distribution of infections and patterns of risk within the population. The model serves firstly to explore the user's knowledge of the influences on the pattern of infection in the population of interest, and secondly to identify exposure / risk groups where estimates of new infections can be expected to help plan interventions.

Methods

The spreadsheet uses

(i) the current prevalence of HIV infection,

(ii) numbers of individuals with particular exposures, and

(iii) the rates of these exposures to calculate the expected incidence of HIV infection over the coming year.

The user of the spreadsheet has to supply biological and behavioural surveillance data to inform the values in the cells for the spreadsheet. Some of these may be reasonably well estimated, whereas others may be poorly specified. Estimates of transmission probability per contact are derived from published literature, but can also be specified by the user.

The population can be divided into groups with particular risks of acquiring HIV (see below). By estimating the size of these risk groups and their exposure to HIV infection (i.e. the extent of behaviours which allow for the transmission of HIV and the prevalence of HIV infection in their contacts) we can identify where most new HIV infections will occur, which in turn will help to sensibly focus interventions.

Note of caution

The model uses crude groupings of the population according to their main exposure to HIV infection. The results are only as good as the data entered to estimate the size of the group, the current distribution of HIV and other sexually transmitted infections, and the risk behaviours of those within these groups. Even with reliable estimates the model does not take account of the distribution of behaviours within the risk groups, the patterns of mixing by demographic, social, geographic and economic variables and the influence of specific sexually transmitted diseases. It can therefore not be used to generate accurate predictions without a full description of these many complexities. Nonetheless, it does allow the user to identify where most of the new HIV infections

will be found and the relative orders of magnitude of the incident infections possible within risk groups. Further, it allows programmes to see the type of data required, even for crude predictions. The coverage and focus of the interventions can also be explored and the benefits of both increased coverage and efficacy can be illustrated.

Instructions

Data required:

The model categorizes the population into groups according to their main source of exposure to HIV. Children are not included in this spreadsheet. The risk groups are defined as:

Row 9	Injecting drug users (IDU)
Row 10	The sex partners of IDU
Row 11	Sex workers
Row 12	Clients of sex workers
Row 13	The other (non-commercial) sex partners of clients of sex workers
Row 14	Men who have sex with men (MSM)
Row 15	Female sex partners of those MSM who also have sex with women
Row 16	Those who have 'casual' heterosexual sex (e.g., those who have more than one partner or who have premarital sex)
Row 17	The regular sex partners of those who have casual heterosexual sex
Row 18	Adults with low-risk behaviour (including those of former high-risk behaviour)
Row 19	Adults who are at no risk of HIV (those that do not inject drugs and are not involved in any sexual activity)
Row 20	Adults who receive medical injections (assumed to include the total population)
Row 21	Adults who receive a blood transfusion

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Country:	Example ctry					Blue cells: Input necessary					Transmission per act					
2	Adult (15-49) population size:	20,000,000					Peach cells: Input optional					Male -> female		0.0020			
3	Adult (15-49) HIV prevalence (%	6.7					Orange cells: Output					Female -> male		0.0020			
4												% men circumcised		0.0%			
5												STD cofactor		3			
6		Use either method 1 or 2 to determine number with risk behaviour for each group (column F).															
7		Method 1: Percent of population with risk behaviour (%)		Method 2: Population with risk behaviour									probability per risky exposure act				
8	Adult Risk Behaviour	Male	Female	Male	Female	Total number with risk behaviour	Prevalence of HIV (%)	Number HIV+	Prevalence of STI (%)	Number of partners per year	Number of acts of exposure per partner per year	Percentage of acts protected (%)	with STI	No STI	Incidence	% of incidence	Incidence per 100,000
9	Injecting Drug Use (IDU)	0.30%				30,000	20.0%	6,000	3.5%	5	50	50%	NA	0.01	4,879	2.42	16,263
10	Partners IDU		0.15%			15,000	12.0%	1,800	NA	1	70	7%	0.006	0.002	341	0.17	2,275
11	Sex workers		0.65%			65,000	40.0%	26,000	65.0%	163	4	65%	0.006	0.002	1,850	0.92	2,846
12	Clients	2.90%				290,000	8.1%	23,490	15.0%	16	9	65%	0.006	0.002	23,857	11.82	8,227
13	Partners of Clients		1.45%			145,000	9.0%	13,050	NA	1	70	7%	0.006	0.002	1,630	0.81	1,124
14	MSM	1.00%				100,000	20.0%	20,000	15.0%	3	10	35%	0.030	0.010	3,800	1.88	3,800
15	Female partners of MSM		0.50%			50,000	15.0%	7,500	NA	1	50	7%	0.006	0.002	953	0.47	1,907
16	Casual heterosexual sex	26.89%	12.41%			3,929,820	13.1%	513,971	7.0%	2	35	35%	0.006	0.002	44,719	22.16	1,138
17	Partners CHS	9.93%	21.51%			3,143,856	6.5%	205,588	NA	1	70	7%	0.006	0.002	52,390	25.96	1,666
18	Low-risk heterosexual sex	36.73%	37.53%			7,426,324	7.5%	556,974	3.5%	1	70	7%	0.006	0.002	66,596	33.00	897
19	No risk	22.25%	25.80%			4,805,000	0.0%	-	0.0%	0	0				0	0.00	0
20	Medical injections					20,000,000	6.7%		NA	2.2	1	80%	NA	0.001	557	0.28	3
21	Blood transfusions	0.50%	0.50%			100,000	6.7%		NA	1	1	96%	NA	0.9	244	0.12	244
22	TOTAL ADULT POPULATION	100%	100%			20,000,000	6.87%	1,374,374					Total incidence		201,817		1,009
23										Total incidence in partners of high-risk individuals					55,315	27.408	1,649
24																	
25	NB The prevalence of STD in the group with the risk behaviour is used for STD prevalence of the spillover group																

Figure 1. Spreadsheet for estimating incidence of HIV infection by 'risk' group.

For each risk group a number of variables are required (columns B to N), as shown in *Figure 1*.

User-specified inputs are required for the cells with a blue background and are optional in the cells that are colored light orange. The cells with a dark orange background are program outputs and the contents of these cells should not be changed. The steps to follow are explained below.

1. **Specify the size of the risk groups (cells B9 to C21 or D9 to E21)**

   - Either the percentage of males and females with a certain risk behaviour (cells B9 to C21) or the absolute numbers of males and females with a certain risk behaviour (cells D9 to E21) need to be filled in. This information will be used to calculate the total number of adults with a certain risk behaviour, given in cells F9 to F21.
   - The 'risk groups' are defined according to the main source of exposure to HIV. For medical injections, it is assumed that the entire population is "exposed".
   - If a risk group does not apply to your population then set its size to zero.
   - Note that the sum of all adults across risk groups (cell F22) should be equal to the total adult population in the country (specified in cell B2).
   - Potential data sources for obtaining the number or percentage of people with

certain risk behaviours are summarized in table 1.

2. **Specify the current estimated HIV prevalence in the various risk groups (cells G9 to G21)**

   - If a risk group does not apply to your population then set its HIV prevalence to zero.
   - Check that the total population HIV prevalence (cell G22) is similar to the national adult prevalence specified in cell B3 – if not then you should adjust the HIV prevalence in one or more of your risk groups. (The adult prevalence in G22 is the weighted average of the prevalences across the risk groups).
   - The number of HIV infections is calculated from the prevalences and are given in cells H9 to H22. This information can be used to cross-check the prevalence data against other or known data sources.

3. **Specify the prevalence of sexually-transmitted infections (STI) in the various risk groups (cells I9 to I19)**

   - Risk groups that do not require this information are partners of IDU, partners of sex-work clients, female partners of MSM, regular partners of those who have casual heterosexual sex partners, those who receive medical injections, and those who receive blood transfusions.

4. **Specify the average number of partners per year (cells J9to J21)**

   - For most risk groups, with the exception of IDU, medical injections and blood transfusions, this is the average number of sexual partners per year.
   - For injecting drug users, this is the average number of needle-sharing partners per year.
   - For medical injections and blood transfusions, this is the number of injections or transfusions received in the year of study: each one is counted as a 'partner'.

5. **Specify the average number of acts of potential HIV risk exposure per partner per year (cells K9 to K21)**

   - For most risk groups, with the exception of IDU, medical injections and blood transfusions, the mode of HIV transmission is sexual, and the number of acts of exposure per partner per year is the average number of sex acts with each partner per year.
   - For the IDU risk group, it is the average number of acts of needle sharing with each injecting partner per year.

- For medical injections and blood transfusions, the number of acts of exposure per 'partner' is fixed at one, because each blood transfusion or injection is regarded as having a new 'partner'.

6. Specify the average percentage of acts of exposure that is protected (cells L9 to L21)

- For most risk groups, with the exception of IDU, medical injections and blood transfusions, the mode of HIV transmission is sexual, and the percentage of acts that are protected equals the percentage of sex acts in which condoms are used correctly. Remember that this percentage is the average over all partnerships.
- For the IDU risk group, it is the average percentage of injection events that involve safe needle use. Again, remember that this percentage represents the average over all partnerships.
- For the medical injections risk group, the percentage of acts of exposure that are 'protected' equals the proportion of injections that involve safe needle use.
- For the blood transfusions risk group, it is the percentage of units of blood that are screened effectively: this is the percentage of units that are tested, multiplied by the % sensitivity of the test used (i.e. the proportion of HIV+ blood units that are detected as being HIV+ and hence not used).

7. Optional: Specify the transmission probability per risky exposure act (cells M9 to M21 & N9 to N21)

Default transmission probabilities, based on an extensive literature review, are provided and it is recommended that these are used. However, the probability estimates can be changed if country specific data are available.

In this spreadsheet, the transmission probability for each risk group represents the *average* infectivity of HIV+ partners to whom they are exposed. For example, the transmission probability for IDU represents HIV infectivity of sharing needles with other IDU, whilst the transmission probability for sexual partners of IDU represents HIV infectivity of sexual contact.

HIV+ individuals who are also infected with a sexually-transmitted infection (STI) are more likely to transmit HIV during sexual contact than HIV+ individuals who do not have an STI. This is why there are two transmission probabilities for each risk group (except for the IDU, blood transfusions and

medical injections risk groups, because for those groups HIV transmission is not sexual). Cells M10 to M18 contain the transmission probabilities for sexual transmission of HIV from HIV+ individuals who also have an STI, and cells N10 to N18 contain the transmission probabilities for sexual transmission of HIV from HIV+ individuals who do not have an STI. Cell N9 contains the transmission probability for HIV transmission among injecting drug users; cell N20 contains the transmission probability for unsafe medical injections; and cell N21 contains the transmission probability for blood transfusions (which is very high).

Optional: Male circumcision

In countries where the level of male circumcision is expected to affect HIV prevalence, specifically in countries with generalized epidemics, the transmission probabilities can be adjusted according to the level of circumcision and the expected reduction in transmission of HIV. The percentage of men that are estimated to be circumcised can be entered into cell N4. If country specific transmission probabilities are known, i.e. transmission per act among heterosexual couples, this can be entered in cell N2, otherwise the default value can be assumed. Assuming that male circumcision reduces transmission of HIV by 60%[1,2,3], the female to male transmission will be adjusted according to the male circumcision rate, and transmission probabilities in cells M9 to N18 will be automatically adjusted. Until further data become available, it is assumed that male circumcision does not impact male to female transmission.

8. Examine the resulting incidence pattern (red cells O9 to Q23 and charts)

- The resulting pattern of incidence by risk behaviour is shown in columns O to Q and in the charts. The incidence, defined as the cumulative number of cases of HIV infection over one year in each 'risk group', is shown in cells O9 to O21, along with the total incidence in O22 and the total incidence among 'partners' (i.e. partners of IDU + partners of sex-work clients + female partners of MSM + regular partners of those who have casual heterosexual sex) in cell O23.
- Cells P9 to P21 and P23 show the percentage of the total incidence that occurs in each risk group. The contents of cells P9 to P21 are shown

[1] Auvert B et al. Randomized, Controlled Intervention Trial of Male Circumcision for Reduction of HIV Infection Risk: The ANRS 1265 Trial. PLoS Medicine 2005; 2(11): e298.

[2] Gray R et al. Male circumcision for HIV prevention in men in Rakai, Uganda : A randomised trail. Lancet 2007; 369: 657-666

[3] Bailey R et al. Male circumcision for HIV prevention in young men in Kisumu, Kenya: a randomised controlled trial Lancet 2007; 369:643-656.

graphically in the charts (*Figure 2*).

- Finally, cells Q9 to Q21 show the incidence in each risk group per 100,000 population in that risk group.

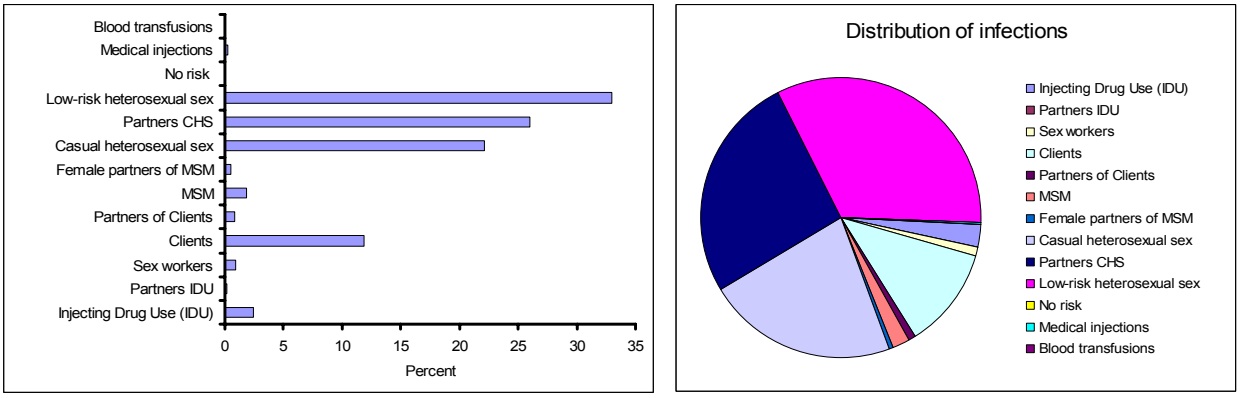

Figure 2. Percentage of total incidence by risk group

Summary of data required

A summary of the data required for each risk groups, and potential sources of data, is provided in *Table 1*.

Table 1: Data required and possible sources of information

Data required for each risk groups	**Potential sources of data**
Number (or percentage) of individuals in risk group	Surveillance (HIV, STI, Behavioural), Population based surveys (e.g., DHS), other published reports/papers. In countries with DHS reports, data can be found in the chapter on "*HIV/AIDS-related Knowledge, attitudes and behaviour*" Medical Injections : See Hutin et al.[1] Blood transfusions: See Rapiti et al.[2] tables (*Appendix 2*)
HIV prevalence in risk group	HIV surveillance, Population based surveys, UNAIDS/WHO Epi Fact sheets. In countries with DHS reports, data can be found in the chapter on "HIV Prevalence and associated factors"
Prevalence of STI	Surveillance (Behavioural and biomedical) and special studies. In countries with DHS reports, data on self-reporting of STIs can be found in the chapter on "HIV/AIDS-related Knowledge, attitudes and behaviour"
Average number of partners per year	Behavioural surveillance, population based surveys, published papers/reports In countries with DHS reports, data can be found in the chapter on "*HIV/AIDS-related Knowledge, attitudes and behaviour*" Blood transfusions and Medical injections: Number received should be reported (usually 1 per year)
Number of acts per partner per year	Behavioural surveillance, population based surveys, published papers/reports. In countries with DHS reports, data can be found in the chapter on "*HIV/AIDS-related Knowledge, attitudes and behaviour*" Blood transfusions and Medical injections: Fixed at 1
Percentage of potential exposure acts protected	Behavioural surveillance, population based surveys, published papers/reports Medical Injections : See Hutin et al.[1] Blood transfusions: See Rapiti et al.[2] tables (*Appendix 2*)
Transmission probability per act of exposure with and without STIs	Recommended to use default values that are derived from published literature

[1] Hutin YJF, Hauri AM, Armstrong GL. Use of injections in healthcare settings worldwide, 2000: literature review and regional estimates. BMJ 2003; 327: 1075 (Review)

[2] Rapiti E, Hutin Y, Dhingra N. The global burden of HBV, HCV and HIV infections attributable to unsafe blood transfusions. Unpublished report

Box 1. **Definitions**

1 **Size of risk behaviour groups**: The number of people who engage in the risk behaviour and for whom this is their main source of HIV infection risk. People can only be 'counted' in one risk group, even though they may have several different means of exposure (except in the medical injections and blood transfusions groups, which are counted independently).

2 **HIV prevalence by risk group**: the percentage of people in the particular risk group who are infected with HIV.

3 **STI prevalence by risk group**: the percentage of people in the particular risk group who have a sexually transmitted infection.

4 **Number of partners per year**: the number of different partners per year. Note that for blood transfusions, each donor counts as a 'partner' and for medical injections, each unsafe use of a needle counts as having a 'partner'.

5 **Number of acts of exposure per partner per year**: the number of contacts per partner per year. For blood transfusions and unsafe medical injections there is one 'act' per 'partnership'.

6 **Percentage of acts protected**: The fraction of acts that are protected by condom use / safe needle use / screening of blood used for transfusions.

Appendix 1

Model assumptions:

If we assume that the risk of infection in a susceptible individual is a simple binomial function of their number of partners and number of sex acts with each partner we can derive a risk per susceptible which depends upon the current prevalence of infection within their contacts. We can further take account of the different transmission probabilities when another STI is or is not present. If we multiply this by the number of susceptibles at risk in the population we get an expected incidence for the coming year using the following equation:

$$I = S\left[1 - \left\{p\left(B(1-\beta'(1-\upsilon))^a + (1-B)(1-\beta)^{a(1-\upsilon)}\right) + (1-p)\right\}^n\right]$$

where I is the incidence of HIV in the target population, which depends upon the number susceptible, S, and the HIV prevalence in the partner population, p. The variable B is prevalence of STIs in the target or partner population, whichever is higher, β' and β represent the probability of transmission of HIV during a single contact in the presence or absence of an STI (in the case of transmission by needle-sharing $\beta' = \beta$), υ is the proportion of acts currently protected by effective condom use or the use of sterile needles, a is the number of contacts per partner and n is the number of partners (*Figure 1*).

Appendix 2

Table 2. **Blood transfusions per person and per year and data sources used, by region, 2000**

(Source: Rapiti E, Hutin Y, Dhingra N. The global burden of HBV, HCV and HIV infections attributable to unsafe blood transfusions. Unpublished report)

	AFR D	**AFR E**	**AMR A**	**AMR B**	**AMR D**	**EMR B**	**EMR D**	**EUR A**	**EUR B**	**EUR C**	**SEAR B**	**SEAR D**	**WPR A**	**WPR B**
Proportion of screening HBV	76.9%	70.0%	100%	91.3%	61.2%	100%	94.0%	100%	97.3%	100%	100%	78.0%	100%	94.0%
Worse-case scenario	50%	50%	100%	50%	50%	50%	50%	100%	80%	80%	50%	50%	100%	50%
Published studies	-	-	100%	93.9% (84-100)	78.1% (60-95.5)	-	95%	100%	-	-	-	-	100%	-
Proportion of screening HCV	11.8%	32%	100%	77.9%	46.6%	90%	29%	100%	89.2%	100%	45%	34%	100%	48%
Worse-case scenario	11.8%	32%	100%	50%	46.6%	50%	29%	100%	80%	80%	45%	34%	100%	48%
Published studies	-	-	100%	66.7% (14.8-100)	43.6% (37.2-53)	-	17%	100%	-	-	-	25%	100%	-
Proportion of screening HIV	92.8%	96%	100%	92%	67%	100%	97%	100%	97.8%	100%	100%	74%	100%	94%
Worse-case scenario	50%	50%	100%	50%	50%	50%	50%	100%	80%*	80%	50%	50%	100%	50%
Published studies	-	82.5% (72-93)	100%	95.9% (85-100)	81.8% (60-100)	-	52%	100%	-	-	-	-	100%	-

Table 3. **Estimates of the proportion of blood donations screened for HBV, HCV and HIV according to (a) the Global Database on Blood Safety and (b) the "worse-case scenario", (c) published studies review by region, 2000**

(Source, Rapiti E, Hutin Y, Dhingra N. The global burden of HBV, HCV and HIV infections attributable to unsafe blood transfusions. Unpublished report)

	AFR D	**AFR E**	**AMR A**	**AMR B**	**AMR D**	**EMR B**	**EMR D**	**EUR A**	**EUR B**	**EUR C**	**SEAR B**	**SEAR D**	**WPR A**	**WPR B**
Number of blood transfusions per 1000 persons and per year	4	5	43	11	7	18	4	57	11	20	5	4	36	15
Countries for which age-specified estimates of transfusion frequency were used	Came-roon	Cote d'Ivoire Congo Kenya Mozambique Tanzania Zambia	USA	NA	NA	NA	NA	France	NA	NA	NA	India	NA	NA
Use of other regions' age-specific estimates											SEAR D		AMR A	SEAR D

Regions for which the burden of infections has been estimated

REGION	COUNTRIES
AFR D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo
AFR E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
AMR A	Canada, Cuba, United States of America
AMR B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
AMR D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
EMR B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EMR D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
EUR A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom
EUR B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
EUR C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SEAR B	Indonesia, Sri Lanka, Thailand
SEAR D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal
WPR A	Australia, Brunei Darussalam, Japan, New Zealand, Singapore
WPR B	Cambodia, China, Cook Islands, Fiji, Kribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam