

## Global tuberculosis incidence and mortality during 1990–2000

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*Forecasts of tuberculosis morbidity and mortality are presented for the decade 1990–99. An estimated 88 million new cases of tuberculosis, of which 8 million will be attributable to HIV infection, will occur in the world during the decade; 30 million people are predicted to die of tuberculosis in the same period, including 2.9 million attributable to HIV infection.*

*The number of new tuberculosis cases occurring each year is predicted to increase from 7.5 million (143 cases per 100 000) in 1990 to 8.8 million (152 per 100 000) in 1995 and 10.2 million (163 per 100 000) in the year 2000. In 1990, 2.5 million persons were estimated to have died of tuberculosis; at the same level of availability of treatment, it is predicted that 3.0 million tuberculosis deaths will occur in 1995 and 3.5 million in 2000.*

*Demographic factors, such as population growth and changes in the age structure of populations, will account for 79.5% of the predicted increases in new cases. Age-specific incidence rates in sub-Saharan Africa are increasing due to the HIV epidemic and will account for the remaining 20.5% of the forecast increase in new cases. In WHO's South-East Asian Region and in Central and South America the age-specific incidence rates are expected to fall during 1990–2000, but at a slower rate than in previous years because of the expected increase in HIV seroprevalence. In the Western Pacific and Eastern Mediterranean Regions the age-specific incidence rates are expected to fall during 1990–2000 because of the effects of intervention strategies, but the total number of new cases will continue to increase until the end of the decade because of population growth.*

Estimates of tuberculosis incidence in 1990 for the developing countries by Murray (1) were extended by Sudre (2) to include the industrialized countries. Both authors used estimates of the annual risk of infection (ARI) in developing countries<sup>a</sup> to calculate the expected incidence. The present study forecasts the future global and regional burden of tuberculosis morbidity and mortality using tuberculosis notification data (i.e., cases reported to the Ministries of Health) to complement the ARI-based calculations. This dual approach was used to provide a separate set of estimates from those based on ARI data alone.

The impact of demographic factors (such as global population growth and aging of the world's populations) and epidemiological factors (such as adverse effects of the human immunodeficiency virus (HIV) epidemic and the beneficial effects of intervention programmes) is discussed.

### Methods

#### *Tuberculosis incidence*

*In 1990.* WHO routinely collects data on the number of tuberculosis cases in Member States each year.<sup>b</sup> Within each WHO region, except the African region, an overall regional crude incidence rate was calculated by estimating the incidence in the most populated countries. Notification data were considered reliable when provided by programmes with an established

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<sup>a</sup> Cauthen GM, Plo A, ten Dam HG. *Annual risk of tuberculosis infection* (unpublished document WHO/TB/88.154, 1988). This document is available upon request to the Tuberculosis Programme, WHO, Geneva, Switzerland.

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<sup>b</sup> World Health Organization. *Tuberculosis notification update, July 1992* (unpublished document WHO/TUB/92.169, 1992). This document is available upon request to the Tuberculosis Programme, WHO, Geneva, Switzerland.

surveillance system. Reliable notification data were preferentially used for these estimates. For countries with unreliable notification data, the annual risk of infection was used to estimate incidence. Notification data are relatively poor for the African region (sub-Saharan Africa), so a slightly different approach was used; the region was divided into four geographical areas and within each area, a crude incidence rate was estimated, based on the most reliable notification data (e.g., United Republic of Tanzania for East Africa, South Africa for southern Africa, Côte d'Ivoire for West Africa).

This approach differs from previous estimates of the 1990 incidence (1, 2), which were based solely on annual risk-of-infection data<sup>a</sup> and gave equal consideration to data from countries with different population sizes. While notification data are of poor quality for many countries, and any estimates based on such data will risk underestimating the incidence, reliable data are available from other countries, particularly those where good tuberculosis control programmes are established. The estimates presented in this paper must be considered conservative owing to the fact that tuberculosis cases are generally underreported.

**In 1995 and 2000.** In estimating future incidence, allowances were made for demographic factors (changes in the size and age structure of regional populations) and epidemiological factors (changes in underlying incidence rates). To accurately allow for both demographic and epidemiological factors, regional age-specific incidence rates for the years 1995 and 2000 were estimated and then applied to regional age-specific population projections for 1995 and 2000.

This was undertaken in two steps. First, data available at WHO on the age distribution of notified cases in each region during 1990 were applied to the 1990 regional crude incidence rates to derive the 1990 regional age-specific incidence rates. Second, trends in regional notification rates during 1985–90 were applied to the 1990 regional age-specific incidence rates to derive estimates of regional age-specific incidence rates for the years 1995 and 2000. This assumes that future age-specific trends will remain unchanged. These rates were then applied to regional age-specific population projections (3) to calculate the number of incident cases expected in 1995 and 2000. A more detailed description of these methods is reviewed elsewhere.<sup>c</sup>

### **Mortality in 1990, 1995 and 2000**

Published case-fatality rates of 7% for industrialized countries (4) and reported rates of 15% for Eastern Europe were used. These deaths probably resulted from late presentation for treatment and failure to diagnose tuberculosis as the underlying disease. For Central and South America around 20% of tuberculosis cases were assumed to die of the disease. For other regions, case-fatality rates of 35–40% were estimated, based on a case-fatality rate of 15% for cases receiving treatment and 55% for those not treated (1, 5–7). It was further assumed that all cases notified to WHO were treated, that 5% of treated patients are not reported, and that the proportion of cases receiving treatment remains at the 1990 level. In the South-East Asian and Western Pacific regions around half of all cases are estimated to have received treatment in 1990.

### **HIV-attributable tuberculosis**

Current data suggest that between 5% and 10% of persons co-infected with HIV and *Mycobacterium tuberculosis* will develop tuberculosis each year, compared with less than 0.2% of persons infected with *M. tuberculosis* but not HIV (8, 9). From these data, we estimate that around 95% of HIV-infected tuberculosis cases are attributable to HIV infection (i.e., attributable risk = 95%), and the remaining 5% of co-infected cases would have developed tuberculosis regardless of their HIV status. This attributable risk was applied to estimates of HIV seroprevalence among patients with tuberculosis (9) to derive the number of HIV-attributable tuberculosis cases (i.e., population attributable risk) in 1990, 1995 and 2000. The numbers of tuberculosis deaths attributed to HIV infection were estimated by applying the regional case-fatality rates to the estimated number of HIV-attributable cases.

### **Total incidence and mortality during 1990–99**

The total number of new cases and deaths in the 10-year period 1990–99 was calculated using the 1990 estimates for the period 1990–mid-92, the 1995 estimates for mid-1992–mid-97, and the 2000 estimates for the period mid-1997–1999.

## **Results**

### **Tuberculosis incidence**

**In 1990.** It is estimated that there were 7 537 000 incident cases of tuberculosis in 1990 (Table 1). Over 4.9 million cases (65%) occurred in the South-East Asian and Western Pacific regions, including

<sup>c</sup> Dolin PJ, Raviglione MC, Kochi A. *A review of current epidemiological data and estimation of future incidence and mortality from tuberculosis*. This document (WHO/TB/93.173) is available upon request to the Tuberculosis Programme, WHO, Geneva, Switzerland.

Table 1: Estimated tuberculosis (TB) incidence and HIV-attributable tuberculosis cases in 1990, 1995 and 2000, by region

Region	1990			1995			2000		
	Total TB cases	Rate <sup>a</sup>	HIV-attributed TB cases	Total TB cases	Rate <sup>a</sup>	HIV-attributed TB cases	Total TB cases	Rate <sup>a</sup>	HIV-attributed TB cases
South-East Asia	3 106 000	237	66 000	3 499 000	241	251 000	3 952 000	247	571 000
Western Pacific <sup>b</sup>	1 839 000	136	19 000	2 045 000	140	31 000	2 255 000	144	68 000
Africa	992 000	191	194 000	1 467 000	242	380 000	2 079 000	293	604 000
Eastern Mediterranean	641 000	165	9 000	745 000	168	16 000	870 000	168	38 000
Americas <sup>c</sup>	569 000	127	20 000	606 000	123	45 000	645 000	120	97 000
Eastern Europe <sup>d</sup>	194 000	47	1 000	202 000	47	2 000	210 000	48	6 000
Industrialized countries <sup>e</sup>	196 000	23	6 000	204 000	23	13 000	211 000	24	26 000
Total	7 537 000	143	315 000 (4.2%)	8 768 000	152	738 000 (8.4%)	10 222 000	163	1 410 000 (13.8%)
Increase since 1990				16.3%			35.6%		

<sup>a</sup> Crude incidence rate per 100 000 population.

<sup>b</sup> Includes all countries of the Western Pacific Region of WHO, except Japan, Australia and New Zealand.

<sup>c</sup> Includes all countries of the American Region of WHO, except USA and Canada.

<sup>d</sup> Eastern European countries, and independent states of the former USSR.

<sup>e</sup> Western European countries, USA, Canada, Japan, Australia and New Zealand.

2.1 million in India, 1.3 million in China, and 0.4 million in Indonesia. One million cases are estimated to have occurred in Sub-Saharan Africa, 0.2 million cases in Eastern Europe and independent states of the former USSR, and 0.2 million cases in Western Europe and other industrialized countries.

**In 1995 and 2000.** The predicted number of incident cases of tuberculosis in 1995 and 2000 is shown in Table 1. Global incidence is predicted to increase from 7.5 million new cases annually in 1990 to 10.2 million new cases by the year 2000, an increase of 36%. Over 3.9 million new cases annually are expected in South-East Asia, 2.3 million in the Western Pacific, and 2.1 million in sub-Saharan Africa by 2000.

Table 2 shows the age-specific incidence in each region for the years 1990 and 2000; 70% of new cases are aged between 15 and 59 years (when people are economically most productive), 20% at least 60 years, and 10% under 15 years.

In the Western Pacific and Eastern Mediterranean regions, small decreases in age-specific incidence rates are expected. However, the actual number of new cases in each age group is forecast to increase due to population growth. In addition, the crude incidence rates (all ages) for these regions are also forecast to increase, even with decreasing age-specific rates, because of the demographic aging of regional populations.

In sub-Saharan Africa, age-specific rates are expected to increase during the decade. In spite of the effects of some national tuberculosis programmes, the incidence of tuberculosis in sub-Saharan Africa is

rapidly increasing because of the HIV epidemic. The number of new cases per year in sub-Saharan Africa is predicted to double by the year 2000.

For South-East Asia and Central and South America, age-specific and crude incidence rates are expected to fall during 1990–2000. However, the rate of decline is slower than in previous years because of the expected spread of the HIV epidemic. The actual number of new cases will continue to increase because of population growth. For Central and South America, it is estimated that the effects of falling age-specific incidence rates will counter population growth by around the year 2005, at which point the number of new cases in Central and South America should fall.

In Eastern Europe and states of the former USSR, notifications fell during 1985–90. However, it is not clear that this decline in incidence rates can be maintained under current social conditions in these countries. It is predicted that tuberculosis incidence rates in Eastern Europe and states of the former USSR will remain at their 1990 level in the near future. Notification rates for some Western European and other industrialized countries (e.g., Netherlands, Norway and USA) have recently increased after years of decline (4). Rates in other Western European and industrialized countries may also increase in the near future, partly because of increasing migration of people from regions of the world with a higher incidence of tuberculosis, and partly because of the increasing number of persons with dual HIV and *M. tuberculosis* infection. It is estimated that tuberculosis incidence rates in Western Europe and the

Table 2: Estimated total tuberculosis incidence in 1990 and 2000, by region and age group

Region and year	0-14 years		15-34 years		35-59 years		≥60 years		All ages	
	Cases	Rate <sup>a</sup>	Cases	Rate <sup>a</sup>	Cases	Rate <sup>a</sup>	Cases	Rate <sup>a</sup>	Cases	Rate <sup>b</sup>
<i>South-East Asia:</i>										
1990	155 000	31	932 000	207	1 398 000	515	621 000	740	3 106 000	237
2000	175 000	30	1 126 000	206	1 835 000	514	816 000	739	3 952 000	247
<i>Western Pacific (excluding Japan, Australia and New Zealand):</i>										
1990	248 000	70	423 000	80	579 000	166	589 000	487	1 839 000	136
2000	274 000	68	420 000	79	776 000	165	785 000	486	2 255 000	144
<i>Africa:</i>										
1990	99 000	42	447 000	266	347 000	380	99 000	398	992 000	191
2000	447 000	142	857 000	366	606 000	480	169 000	498	2 079 000	293
<i>Eastern Mediterranean:</i>										
1990	64 000	41	224 000	170	257 000	346	96 000	435	641 000	165
2000	67 000	40	294 000	164	372 000	340	137 000	429	870 000	167
<i>Americas:</i>										
1990	57 000	35	199 000	125	228 000	240	85 000	272	569 000	127
2000	36 000	20	206 000	110	295 000	225	108 000	257	645 000	120
<i>Eastern Europe and former USSR:</i>										
1990	19 000	20	58 000	45	68 000	56	49 000	75	194 000	47
2000	19 000	20	55 000	45	81 000	56	55 000	75	210 000	48
<i>Industrialized countries:<sup>c</sup></i>										
1990	20 000	10	59 000	22	68 000	27	49 000	37	196 000	23
2000	19 000	10	55 000	22	82 000	27	55 000	37	211 000	24

<sup>a</sup> Age-specific incidence rate per 100 000 population.

<sup>b</sup> Crude incidence rate per 100 000 population.

<sup>c</sup> Western Europe, USA, Canada, Japan, Australia and New Zealand.

other industrialized countries will either remain at their current levels or increase slightly during the decade. For both Eastern and Western Europe, the number of new cases per year is expected to increase because of population growth.

### **HIV-attributable tuberculosis**

It is estimated that 0.3 million (4%) of the 7.5 million new tuberculosis cases in 1990 were attributable to HIV infection (Table 1). Around 0.2 million of the HIV-attributable cases occurred in sub-Saharan Africa. By the year 2000, 1.4 million (14%) of the 10.2 million new cases occurring each year will be attributable to HIV infection. Around 40% of these HIV attributable cases will occur in sub-Saharan Africa and a further 40% in South-East Asia. A more detailed analysis of the impact of the HIV epidemic on tuberculosis incidence and mortality is presented elsewhere.<sup>d</sup>

### **Impact of demographic factors on incidence**

Table 3 shows the predicted number of additional cases of tuberculosis in 1995 and 2000, compared with the 1990 incidence, due to demographic and epidemiological factors. Over three-quarters of the

predicted increase in incidence will result from demographic factors, such as population growth and changing age structure of populations. Less than 25% of the predicted increase will result from changes in underlying incidence rates. In sub-Saharan Africa, epidemiological factors (rising incidence rates due to HIV epidemic) are stronger than demographic factors. For the South East Asian, Western Pacific and Eastern Mediterranean regions, and Central and South America, the decreases in age-specific rates will yield a reduction in new cases, but this will be outweighed by additional new cases due to population growth.

### **Total incidence during 1990-99**

For the 10-year period 1990-99, it is estimated that 88.2 million people will develop tuberculosis, 8.0 million of which will be attributable to HIV infection. In South-East Asia, 35.1 million new cases of tuberculosis are expected during the decade, including 2.8 million (8%) HIV-attributable cases (Fig. 1). Around 20.5 million new cases are predicted for the Western Pacific region, including 0.4 million (2%) HIV-attributable cases, while 15.0 million cases are expected in sub-Saharan Africa during the decade, including 3.9 million (25%) cases attributable to HIV infection.

<sup>d</sup> See footnote c on p. 214.

**Table 3: Estimated additional cases of tuberculosis in 1995 and 2000, compared with 1990, by region, attributable to changes in demographic factors (population growth and changing age distribution) and epidemiological factors (changing incidence rates)**

Region	1995		2000	
	Demographic	Epidemiologic	Demographic	Epidemiologic
South-East Asia	399 000	-6 000	860 000	-14 000
Western Pacific <sup>a</sup>	218 000	-12 000	442 000	-26 000
Africa	171 000	304 000	378 000	709 000
Eastern Mediterranean	119 000	-15 000	266 000	-37 000
Americas <sup>b</sup>	74 000	-37 000	157 000	-81 000
Eastern Europe <sup>c</sup>	8 000	0	16 000	0
Industrialized countries <sup>d</sup>	8 000	0	15 000	0
All regions	997 000 (81.0%)	234 000 (19.0%)	2 134 000 (79.5%)	551 000 (20.5%)

<sup>a</sup> Excluding Japan, Australia and New Zealand.

<sup>b</sup> Excluding USA and Canada.

<sup>c</sup> Eastern Europe and independent states of former USSR.

<sup>d</sup> Western Europe, USA, Canada, Japan, Australia and New Zealand.

### Mortality from tuberculosis

The estimated number of tuberculosis deaths in 1990, 1995 and 2000 is shown in Table 4. Some 2 530 000 tuberculosis deaths occurred in 1990, including 1.1 million in the South-East Asian region and 0.6 million in the Western Pacific region. Globally, 116 000 tuberculosis deaths (4.6%) were attributable to HIV infection in 1990, most of which occurred in sub-Saharan Africa.

By the year 2000 it is predicted, assuming the proportion of cases receiving treatment remains at the 1990 level, that 3 509 000 tuberculosis deaths will occur annually, 39% more than in 1990. In South-East Asia, 1.4 million deaths annually are anticipated by the year 2000. Globally, 0.5 million tuberculosis deaths per year will be attributable to HIV infection by then. The HIV-related deaths will occur mainly in sub-Saharan Africa and South-East Asia.

**Total deaths during 1990–99.** During the 10-year period 1990–99 it is estimated that 30.0 million people will die of tuberculosis; 2.9 million of these deaths (9.7%) will be attributed to HIV infection (Fig. 2). In South-East Asia, 12.3 million tuberculosis deaths will occur during the decade, including 1.0 million HIV-attributable deaths. Around 6.0 million tuberculosis deaths are expected in sub-Saharan Africa, 1.5 million (25%) of which will be attributed to HIV infection.

### Discussion

Nearly 90 million new tuberculosis cases and 30 million tuberculosis deaths are expected to occur during the present decade at the present level of interven-

tions. For a disease where intervention is known to be cost-effective (10), this is truly staggering.

These estimates are based on notification data and, because of underreporting of tuberculosis cases, must be considered conservative. This is reflected in our estimated 1990 incidence of 7.5 million new cases being slightly lower than previous estimates, which were based on annual risk-of-infection data (2). Similarly, the estimates of tuberculosis mortality should be considered conservative, e.g., the estimated 2.5 million tuberculosis deaths in 1990, compared with previous estimates of 2.9 million deaths (2). While the exact number of new cases and deaths is not known, the current and previous estimates are consistent in suggesting that between 7.5 and 8.0 million new cases and 2.5–3.0 million tuberculosis deaths occurred in 1990.

Current intervention strategies are expected to result in substantial reductions in age-specific incidence rates in the Eastern Mediterranean region and Central and South America, and to a lesser degree in the Western Pacific and South-East Asian regions. However, the total number of new cases in these regions is predicted to increase in the near future because of population growth.

The impact of the HIV epidemic is most evident in sub-Saharan Africa where the number of new cases per year is forecast to double by the end of the decade. In South-East Asia and other regions there has been little impact, to date, of the HIV epidemic on tuberculosis. However, by the year 2000 over 500 000 new cases and 200 000 deaths in South-East Asia will be attributable to HIV infection.

A number of assumptions were made in these analyses. It was estimated that 5% of all treated

Fig. 1. World map showing estimated cumulative tuberculosis cases, 1990–99.

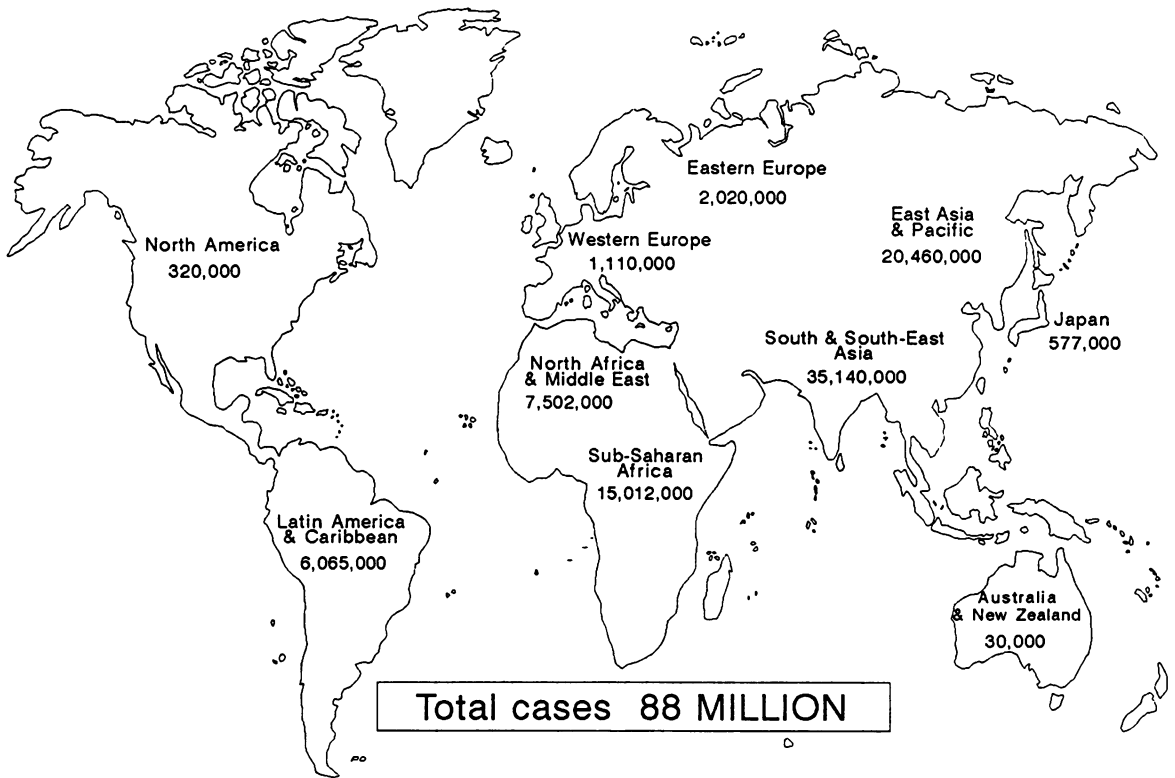


Table 4: Estimated total tuberculosis deaths and HIV-attributable tuberculosis deaths in 1990, 1995 and 2000, by region, assuming that regional treatment coverage rates remain at their 1990 level

Region	Deaths in 1990		Deaths in 1995		Deaths in 2000	
	Total	Attributed to HIV	Total	Attributed to HIV	Total	Attributed to HIV
South-East Asia	1 087 000	23 000	1 225 000	88 000	1 383 000	200 000
Western Pacific <sup>a</sup>	644 000	7 000	716 000	11 000	789 000	24 000
Africa	393 000	77 000	581 000	150 000	823 000	239 000
Eastern Mediterranean	249 000	4 000	290 000	6 000	338 000	15 000
Americas <sup>b</sup>	114 000	4 000	121 000	9 000	129 000	19 000
Eastern Europe <sup>c</sup>	29 000	<200	30 000	<600	32 000	<900
Industrialized countries <sup>d</sup>	14 000	<500	14 000	1 000	15 000	2 000
All regions	2 530 000	116 000 (4.6%)	2 977 000	266 000 (8.9%)	3 509 000	500 000 (14.2%)
Increase since 1990			17.7%		38.7%	

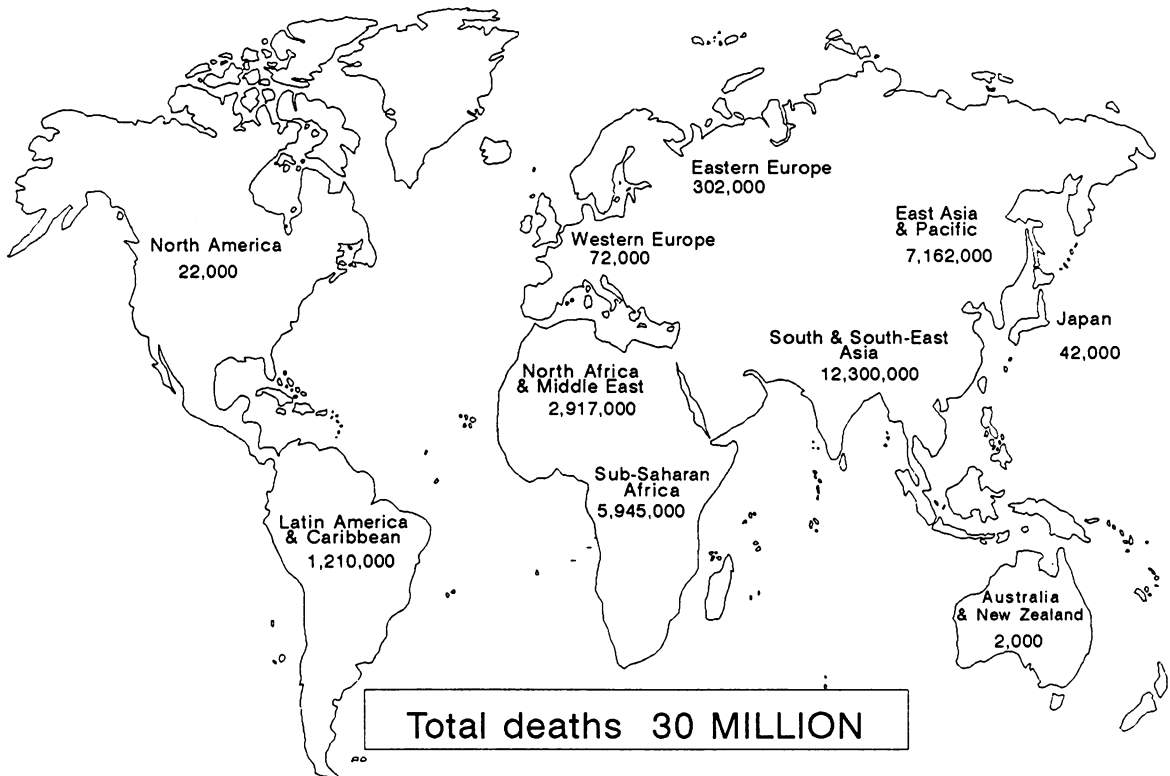
<sup>a</sup> Excluding Japan, Australia and New Zealand.

<sup>b</sup> Excluding USA and Canada.

<sup>c</sup> Eastern Europe and independent states of former USSR.

<sup>d</sup> Western Europe, USA, Canada, Japan, Australia and New Zealand.

Fig. 2. World map showing estimated cumulative tuberculosis deaths, 1990–99.



cases are not reported to WHO and that 100% of reported cases were treated. Limited global data are available on the completeness and quality of notifications. These levels were chosen as conservative estimates of the global situation. Earlier mortality estimates (2) used a case-fatality rate of 50% for HIV-positive tuberculosis cases, whereas the current estimates did not assume that mortality was different between HIV-positive and HIV-negative cases.

Forecasting future incidence and mortality is difficult and can only be based on data available at the time of the modelling. Substantial changes in epidemiological factors, such as greater than expected increases in the seroprevalence of HIV among persons infected with *M. tuberculosis*, would increase the future burden of disease. Conversely, increased availability of treatment would reduce the forecast number of future cases and deaths.

It has been demonstrated that effective application of short-course chemotherapy in well-managed

national tuberculosis programmes produces excellent results, even under the most adverse conditions (11). Short-term chemotherapy of smear-positive tuberculosis cases is one of the most cost-effective health interventions available (10). A higher priority must be given to this disease, both by the countries most severely affected and by donor countries which invest in health care programmes in those countries.

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## Résumé

### Incidence mondiale de la tuberculose et mortalité de 1990 à 2000

Des prévisions de la morbidité et de la mortalité dues à la tuberculose sont présentées pour les années 1990–99. On estime que, pendant cette décennie, 88,2 millions de nouveaux cas de tuberculose seront enregistrés dans le monde, dont 8,0 millions imputables à l'infection à VIH; il est prévu que 30 millions de personnes mourront de la tuberculose pendant la même période, dont 2,9 millions par suite de l'infection à VIH.

On prévoit que le nombre des nouveaux cas de tuberculose se produisant chaque année passera de 7,5 millions (143 cas pour 100 000 personnes) en 1990 à 8,8 millions (152 pour 100 000) en 1995 et 10,2 millions (163 pour 100 000) en 2000. D'après les estimations, 2,5 millions de personnes sont mortes de la tuberculose, en 1990; si les traitements disponibles restent au même niveau, il est prévu que 3,0 millions de décès par tuberculose auront lieu en 1995 et 3,5 millions en 2000.

L'accroissement prévu du nombre de cas nouveaux sera dû pour 77% à des facteurs démographiques, par exemple l'augmentation de la population et l'évolution de la pyramide des âges. Les taux d'incidence spécifiques de l'âge sont en voie d'accroissement en Afrique subsaharienne par suite de l'épidémie d'infection à VIH et ils représenteront les 23% restants en ce qui concerne l'augmentation prévue des cas nouveaux. Dans la Région OMS de l'Asie du Sud-Est, ainsi qu'en Amérique centrale et en Amérique du Sud, on pense que les taux d'incidence spécifiques de l'âge baisseront pendant la période 1990–2000, mais plus lentement que les années précédentes à cause de l'accroissement prévu de la séroprévalence du VIH. Dans les Régions du Pacifique occidental et de la Méditerranée orientale, les taux d'incidence spécifiques de l'âge devraient baisser durant la période 1990–2000 grâce aux stratégies d'intervention, mais le nombre total des

cas nouveaux continuera à augmenter jusqu'à la fin de la décennie à cause de l'expansion démographique.

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