Future AIDS Pandemic and its impact on Adult Mortality in Maharashtra, India.

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Abstract: Simple straight forward models like EPI model to complicated mixing pattern models were evolved by WHO and others to project AIDS cases and to estimate new HIV infections. These models are easy to apply, but they are having their own limitations when applyed for Indian data. In this paper an attempt has been made to understand the adult mortality due to HIV/AIDS indirectly through cause specific death rates There were almost 250,000 number of estimated HIV cases by 1997 in Mumbai, the capital city of Maharashtra. The impact of HIV/AIDS on adult mortality in Mumbai is investigated using census as well as Mumbai muncipal corporation reports from different input parameters and assumptions. A further analysis of cause of deaths among 25-54 year old males and females showed that the excess deaths were largely due to tuberculosis and 'other' causes which are not classified. Overall, tuberculosis-related deaths increased by 70-140 percent in 25-44 year old during the 10 year period. Back-calculation model was applied to project the AIDS cases upto year 2005. The paper discusses on different modelling approaches to understand demographic impact of HIV/AIDS and concludes with policy implications to face the AIDS related excess mortality in future.

key words: AIDS, Projection, Mortality.

1. Background of this study:

After almost a decade long fight against human immunodefiency virus (HIV) in Maharashtra, a state in western part of India, now there needs to study the demographic impact of AIDS and its future implications. By the end of October 1998, there were 3315 AIDS cases reported to the Directorate of health services, government of Maharashtra. Mumbai, the capital of Maharashtra, shares almost 81 per cent of the reported AIDS cases in Maharashtra. Since the first detection of HIV in 1986 in India there was a speculation on the prediction of the spread of this virus. Studies conducted in India in the past ten years indicate heterosexuality is the main mode of transmission of this virus (Salunke, Shaukat, Hira and Jagtap, 1998). Short-term projection models like back-calculation model uses assumed incubation distribution, which is modelled from transfusion associated individuals. Most of the natural history studies are on homosexual and injection drug users. The natural history

cohort formed on heterosexual population in Mumbai[1] can be useful in constructing incubation distribution for heterosexual population, by which one can predict the impact of AIDS for the near future. Natural history of individuals from sero-negative to AIDS can be used to substitute the incubation distribution in back-calculation method to project the AIDS cases (Longini and others, 1989, 1992). EPI model developed by WHO (Chin and Lwanga, 1991) uses gamma incidence curve and progression rates to project the AIDS cases. It also estimates the number of deaths due to AIDS. Discussions were held on the models that study demographic impact of AIDS (United Nations, 1991). Estimates of AIDS related mortality rates from African countries (United Nations, 1994), can be taken as guidelines to study other countries data. Recent study in India indicates AIDS is causing increase in adult mortality in Mumbai, indirectly through tuberculosis (Hira, Srinivasa Rao and Thanekar, 1999) Understanding of the demographic impact of HIV/AIDS is very important in a city like Mumbai, where the population density is high. Impact of this virus on fertility will follow, long term changes in the mortality patterns. In Indian context it needs to generate the data sets for model building and for which attempts are being made. In Maharashtra, as in India, reporting of cause of death as AIDS is not complete. So there needs to develop proper methods for indirect estimation of HIV/AIDS related adult mortality.

In this paper we have projected the AIDS cases up to 2005 using back-calculation and EPI model and also tried to understand the impact of HIV on adult mortality in Mumbai with the available data from Mumbai Municipal Corporation and Directorate of Health Services, Government of Maharashtra. The reason behind using the method of back-calculation is that,

[1] Natural history of HIV asymptomatic individuals, predominantly from heterosexual population is studied at the AIDS Research and Control Centre (ARCON), Sir J. J. Hospital, Mumbai.

it is simple and is not sensitive to the individuals behaviour and mode of transmission of the virus. In sections 2 and 3 the methods of estimating adult mortality and projection of AIDS is explained. In Section 4 estimates of adult mortality and AIDS are given for the past as well as future. Paper concludes with the discussion in section 5.

2. Assessment of adult mortality:

Excess mortality is defined in this as the difference between total reported deaths in Mumbai Municipal corporation during 1987 to 1997 and estimated deaths corresponding to the exponential population growth rate (for age group 15-54) during the same period. Using the exponential population growth between the censuses 1981 and 1991 and adult population during the study period is estimated.

HIV population for males and females were obtained by applying[2] prevalence of HIV among STD clinic attenders as 1 per cent, among CSWs as 2 per cent and among pregnant women as 0.1 per cent for 1987 and those of 1996 are 33 per cent, 72 per cent and 4.2 per cent respectively. These number of HIV infections is also used in EPI model to estimate number of AIDS related deaths.

Population for the Mumbai city is projected for the age groups 15-24, 25-34, 35-44 and 45-54. Estimated deaths for the age group 15-54, in the study period are estimated by using total reported deaths and projected population. Here 1987 is taken as base year for estimating deaths for rest of the years upto 1997. Here say P1 , P2 and D1, D2 are population and number of deaths for years 1987 and 1988, then D2 is estimated arithmatically from other three figures. Here D1 is reported data from Mumbai Municipal

corporation (BMC). In other way by fixing D1, the other death numbers D2, D3, D4.....D10 for the years 1988, 89, 90,.....97 are estimated by taking population growth in this period. The difference between reported and expected deaths are tried to explain by muncipal corporation's public health reports. There were 43 causes of deaths were given in BMC public health reports. Data has been collected for all the causes and from them five major causes of deaths namely 'tuberculosis' (TB), 'Pneumonia', 'Cancer', 'Accidents' and 'others' causes were taken to study the impact of AIDS related adult mortality. AIDS deaths are supposed to come under 'others' in public health reports of Mumbai Municipal Corporation. There is lot of stigma and other reasons are associated for incomplete reporting of AIDS cases and at the same time natural history study (Hira and others, 1999 unpublished manuscript, AIDS research and control centre, Mumbai) also indicates there is a significant correlation of TB and HIV related deaths. As a result, TB deaths are given due attention for understanding HIV related mortality. From the trend of death rate per one lakh population (per 100,000) for each cause of death, excess mortality due to AIDS is assessed.

3. Projection of AIDS cases:

Here the method of back-calculation and EPI model are used. This Back-calculation method is basically developed by Brookmeyer and Gail (Brookmeyer and Gail, 1986, 1988) and has been extensively used by many others. This method gives reliable estimates for the short-term projections. The method is simple, in the sense that it uses assumed incubation distribution and reported AIDS cases to project the future number of AIDS cases. Here in this work, the method followed is same as that used by Kakehashi (Kakehashi, 1996).

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[2] Number STD clinic attenders are 225000, adults 15-59 are 3205618 for males and CSWs as 100,000 , STD clinic attenders are 25000, adults are 2408656 for females)

Let T_I, be the i^{th} calender year,

n_{Ti} {i=1,2,3,....k}, be the number of reported AIDS cases in the year Ti

A(t), the cumulative number of AIDS cases upto time 't'

P_i {i=1,2,3,....k}, the conditional probability, which defines number of HIV individuals who developed AIDS before T_k, but actually developed in the time interval $[T_{i-1}, T_i]$

These above defined quantities are calculated as

$$P_i = \frac{A(T_i) - A(T_{i-1})}{A(T_k)} \quad \ldots\ldots \quad 3.1$$

Here the incidence density function I (s), is assumed as quadratic exponential with

$$I(s) = \exp(as - bs^2) \ldots\ldots\ldots\ldots 3.2$$

The Parameters of this I(s) is calculated by maximising the log-likelihood, $\mathbf{LogL} = \sum_{i=1}^{k} \mathbf{n_{Ti} log P_i}$. Then cumulative number of AIDS cases upto time 't', A(t) is calculated as

$$\mathbf{A(t) = \int_0^t I(s)F(t-s)ds} \ldots\ldots\ldots\ldots \mathbf{3.3}$$

Incubation distribution is assumed to be Weibull with $\mathbf{F(t) = 1 - exp(-\mu t^{\delta})}$, where μ=0.0243 and δ=2.286 (Brookmeyer and Gail, 1988). Projection of AIDS cases using EPI model are explained, elsewhere (chin and Lwanga, 1991). For all the calculations gamma-6 and position 218 are fixed in this model for Indian situation.

4. Results:

There was an increase in mortality rates for the age group (15-54) between 1990 and 1992 and again from 1995 onwards (fig 1). Significant difference between observed and

expected deaths can be seen in table 1. These rates were splitted into four ten-year intervals for both the sexes and plotted (fig 2). Deaths are mainly concentrated above age 35, so the cause specific death rates for five major reasons mentioned in section 2 are studied for three ten year intervals 25-34, 35-44 and 45-54 to explain reasons for increase in mortality.(see table 2). More or less mortality in Mumbai for the age group 25-34 remained constant up to 1989, and then there was rapid increase in mortality up to 1992-93 for TB and 'others' for both the males and females. Again from 1994 onwards there was an increase in TB, 'others' and pneumonia deaths among males and 'others' deaths in females. Cancer deaths were almost remained constant and there was a significant decline in accidental deaths for the 25-34 age group during the study period. Similar trends can be seen for the age group 35-44. The 'other' cause shared high percentage for females in the age group 35-44 and also for both the sexes for 45-54 age group. TB remains major cause of death during the past ten years in all three ten year intervals, except for 45-54 females, where cancer mortality rate dominated TB mortality. Proportion of TB deaths in total deaths are mainly concentrated between 25-44 age group. The change in total number of deaths over the decade is mainly due to TB deaths for males and females between 25 and 44, followed by pneumonia (see table 3). Cancer deaths in females shared major part between 45 and 54. Over all 25 per cent increase in male TB mortality rate after 1994 in this age group, where as other deaths either remained constant or declined.

Application of the back-calculation method explained in section 4 is used to project the AIDS cases in Maharashtra. The results show that there will be 230 thousand (case II, table 5) AIDS cases in Maharashtra by the year 2000. Values of 'a' and 'b' in case II ($a=2.75$ and $b=0.15$) are slightly below than the MLE values, given in case I ($a=3.05$,

b=0.15). The projected values at MLE are giving very high estimates represented in column (1) table 5. Case III values are obtained for a=3.05 and b=0 (i.e for simple exponential). One of the plausible reason for this may be incomplete reporting of the AIDS cases in Maharashtra. Reported number of cases to directorate of Health Services, Government of Maharashtra up to 1996 are given in table 4. Incubation distribution is assumed as Weibull with median time of 4.3 years, $F(t)= 1-\exp(-0.0243t^{2.286})$. The projected values in column (1) & (2) are plotted in the figure 3(a) & 3(b). These values are taken for gamma-6 and position 218 (see for details Chin and Lwanga, 1991)

5. Discussion:

Projection of AIDS cases, by incorporating demographic variables is a up coming topic for Indian scenario. The study attempts to bring the impact of AIDS related mortality in Mumbai city with available data sources. Evidence of excess mortality for the past 4-5 years can be seen in TB deaths. The explanations are more argumentative and the AIDS related mortality shown is indirect. This research is first of its kind in India, which gives some indication of mortality due to HIV. This may lead in future for more statistically designed studies.

Here in this paper AIDS cases are projected, without taking demographic parameters. Projections will vary depending on the assumption of the incidence curve used in the back-calculation method. Assumption of exponential incidence density is better than using logistic or gamma, since the disease is new and WHO also predicted, HIV infections are fastly growing in India. If the spread of this virus stabilised, or shows an indication of attaining stability, it would be more suitable to assume either logistic or gamma. The

controversies related to prediction is well studied (Anderson, 1993). Another plausible source of error in projected values may be because of using directly incubation distribution, F(t), as Weibull with parameters taken directly from a US study. This F(t), is constructed using a transfusion associated AIDS cases and likely, this incubation period is less than that of heterosexual population. The method becomes purely numeric, once the form of F(t) is taken and also this method does not incorporate any biological or epidemiological features of the virus. Incompleteness of the reported cases (see table 3) are causing much difference in the projected values for different input parameters. Actual MLE estimates are obtained at a=3.05, b=0.15, but the projections obtained slightly below than MLE are giving acceptable results in Maharashtra. There need to generate the missing data by some statistical techniques using computer packages.

Mortality estimation done in this work is not informative on exact number of excess deaths due to HIV/AIDS, but it gives the trend in mortality rates due to HIV related causes. The study technique is unique, where there is incomplete reporting of AIDS deaths in a population. There were no reporting of any other disease hitting the Mumbai population for the age group 25-54 and life expectancy is also increasing because of public health measures. In this context increase in TB deaths out of five major causes can be thought of HIV related ones. Especially, between 25 and 44 other causes like cancer, pneumonia did not showed any increase and accidents declined over the period. Incidence TB related deaths among the HIV individuals of Mumbai is high (Srinivasa Rao and Hira, 1998). This indicates among the HIV individuals persons are having faster chance of dying, if they get TB In the absence of major diseases TB deaths mostly may be of HIV.

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Table 1: Observe and expected deaths in Mumbai for the 15-54 age group.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Observed	24123	24824	25516	27837	29239	28241	29250	27421	28782	28172
Expected	24253	24733	25222	25721	26231	26752	27284	27826	28380	28946

Table 2: Adult Mortality rate per 100,000 population in Mumbai city.

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1) TB											
25-34											
Male	79.52	78.29	77.09	96.41	113.14	106.22	99.40	91.24	106.25	116.78	122.26
Female	33.11	32.88	32.51	37.38	42.33	42.25	42.04	37.98	46.25	46.59	37.79
35-44											
Male	135.55	124.94	114.60	150.62	175.71	166.84	158.27	163.99	189.27	198.63	197.71
Female	30.66	37.03	42.96	47.78	53.62	52.76	51.74	54.46	55.00	55.46	56.96
45-54											
Male	53.71	53.80	53.67	62.24	71.09	71.58	71.85	65.47	80.43	81.73	66.87
Female	49.07	51.17	52.83	80.28	74.33	74.65	74.64	77.97	79.30	80.27	77.29
2) Pneumonia											
25-34											
Male	13.89	13.97	14.04	16.40	16.99	16.09	15.20	17.12	17.56	18.51	18.39
Female	12.53	10.53	8.63	8.65	9.48	7.97	6.41	9.63	9.06	9.65	7.48
35-44											
Male	21.95	22.14	22.32	24.91	25.62	23.59	21.63	18.93	24.72	29.02	25.19
Female	15.14	14.28	13.47	12.87	13.49	11.25	9.13	13.34	9.47	12.66	10.15
45-54											
Male	52.21	45.60	39.01	51.90	44.80	42.05	39.19	37.74	41.51	45.14	43.44
Female	29.19	26.04	23.02	24.46	25.25	25.43	25.59	22.09	22.55	22.72	20.95

Continuation of table 1

3) Accidents

25-34											
Male	51.55	49.08	46.68	32.71	19.15	14.70	10.29	8.78	9.44	9.99	6.76
Female	8.84	8.35	7.75	4.99	2.37	1.73	1.12	1.09	1.39	1.66	1.01
35-44											
Male	40.33	42.00	43.45	30.69	18.34	27.27	11.30	6.58	8.51	10.24	8.36
Female	6.45	7.11	7.74	5.01	2.26	2.83	0.96	0.71	1.03	1.35	1.10
45-54											
Male	43.65	43.71	43.55	16.22	13.94	12.52	10.95	4.91	6.67	8.37	6.26
Female	8.77	7.78	6.61	3.45	4.38	3.52	2.69	0.75	1.48	1.82	1.79

4)Cancer

25-34											
Male	4.70	5.02	5.33	8.77	8.26	7.40	6.46	5.74	5.03	5.39	3.94
Female	8.84	6.81	4.88	7.31	7.47	7.50	7.53	7.88	6.50	6.54	4.85
35-44											
Male	16.46	17.31	17.98	22.86	21.35	18.92	16.46	23.16	21.39	15.30	11.11
Female	30.08	32.70	34.95	37.91	38.94	34.57	30.44	31.81	33.06	21.40	21.01
45-54											
Male	59.27	66.20	72.66	75.83	69.30	68.46	67.62	56.61	50.96	45.51	38.26
Female	95.34	87.50	79.99	84.31	91.16	99.27	106.63	90.96	78.03	65.70	58.51

5) Others

25-34											
Male	63.63	64.52	65.37	63.41	77.84	83.76	89.39	71.07	94.69	117.48	122.94
Female	34.95	40.97	46.65	42.98	42.68	32.79	56.99	55.71	58.19	60.50	62.04
35-44											
Male	46.37	50.86	55.00	36.08	50.11	58.97	67.42	68.18	68.99	69.85	74.26
Female	180.08	175.17	170.21	163.09	196.90	208.24	218.51	255.39	265.40	269.13	270.25
45-54											
Male	252.70	245.89	239.24	304.11	308.66	287.90	344.44	349.07	375.65	401.00	384.56
Female	142.86	124.13	105.96	143.87	159.89	167.36	174.08	179.32	180.39	181.04	208.28

Table 3: Change in the major causes of death over the decade.

	TB		Pneumonia		Accidents		Cancer	
	Males	Females	Males	Females	Males	Females	Males	Females
25-34								
1987	22.14	13.41	3.87	5.07	14.35	3.58	1.31	3.58
1988	21.15	13.58	3.77	4.36	13.26	3.43	1.36	2.82
1989	20.33	13.35	3.71	3.54	12.33	3.18	1.41	2
1990	24.63	16.2	4.19	3.75	8.36	2.16	2.24	3.17
1991	27.07	17.01	4.07	3.81	4.58	0.95	1.98	3
1992	23.45	16.29	3.55	3.05	3.24	0.67	1.62	2.9
1993	22.82	16.51	3.49	2.52	2.36	0.44	1.48	2.96
1994	20.44	14.72	3.84	3.73	1.97	0.42	1.29	3.05
1995	24.95	19.31	4.12	3.78	2.21	0.58	1.18	2.71
1996	25.59	19.33	4.05	4	2.19	0.69	1.18	2.71
1997	26.54	16.25	3.99	3.21	1.47	0.43	0.85	2.09
35-44								
1987	22.67	9.02	3.67	4.45	6.75	2.68	2.75	8.85
1988	20.41	11.2	3.62	4.32	6.85	3.01	2.82	9.86
1989	18.43	12.95	3.59	4.06	6.99	3.24	2.89	10.54
1990	23.59	15.28	3.9	4.12	4.8	2.17	3.58	12.13
1991	25.05	16.35	3.65	4.11	2.61	0.94	3.04	11.87
1992	22.46	16.26	3.18	3.47	3.67	1.17	2.54	10.67
1993	23.24	17.25	3.18	3.04	1.66	0.43	2.42	10.15
1994	24.04	18.31	2.77	4.49	0.97	0.31	3.39	10.69
1995	27.22	18.48	3.55	3.18	1.22	0.45	3.08	11.11
1996	27.56	18.81	4.03	4.29	1.42	0.59	2.12	7.26
1997	26.95	19.12	3.43	3.41	1.14	0.47	1.51	7.05
45-54								
1987	19.19	7.32	4.24	4.36	1.63	1.9	4.81	14.23
1988	17.74	7.8	3.71	3.97	1.47	1.71	5.39	13.34
1989	16.62	8.37	3.24	3.65	1.34	1.5	6.04	12.67
1990	19.85	12.19	4.23	3.72	1.41	0.74	6.19	12.81
1991	18.62	11.38	3.35	3.86	1.34	0.94	5.18	13.95
1992	19.53	11.63	3.19	3.96	1.38	0.77	5.19	15.47
1993	21.83	12.37	3.2	4.24	1.51	0.62	5.53	17.67
1994	22.48	13.22	3.21	3.75	1.36	0.18	4.82	15.43
1995	22.47	11.74	3.47	3.34	1.38	0.3	4.26	11.55
1996	21.44	14.25	3.55	4.03	1.32	0.44	3.58	11.66
1997	19.45	12.74	3.45	3.45	1.24	0.4	3.04	9.64

Table 4: Reported number of AIDS cases in Maharashtra

Year	1990	1991	1992	1993	1994	1995	1996
AIDS cases	27	29	43	132	57	919	371

Source: Directorate of Health Services, Govt. of Maharashtra.

Table 5: Projected Values of AIDS in Maharashtra.

Year	Case I a=3.05, b=0.15	Case II a=2.75, b=0.15	Case III a=2.75, b=0
1990	0	0	0
1991	0	0	0
1992	9	5	9
1993	93	43	134
1994	787	283	2111
1995	5159	1461	33039
1996	26556	5979	516820
1997	108660	19719	8.08×10^{6}
1998	358383	53283	1.26×10^{8}
1999	968386	120148	1.97×10^{9}
2000	2.18×10^{6}	230658	3.09×10^{10}
2001	4.19×10^{6}	384930	4.84×10^{11}
2002	6.99×10^{6}	570031	7.57×10^{12}
2003	1.03×10^{7}	763882	1.18×10^{14}
2004	1.38×10^{7}	943295	1.85×10^{15}
2005	1.88×10^{7}	1.09×10^{6}	2.89×10^{16}

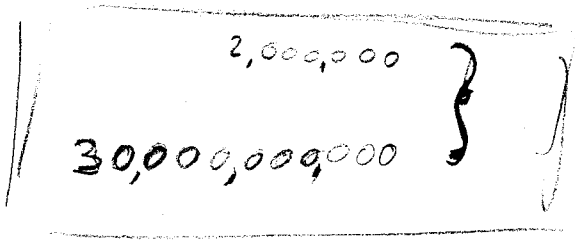


Figure Captions:

Figure 1. Trend of Mortality Rate / 100,000 (15-54)

Here the expected deaths per 100,000 population were plotted against reported deaths per 100,000 by considering population growth.

Figure 2. Adult mortality rate / 100,000 population in Mumbai.

Number of deaths per 100,000 population for the age groups 15-24, 25-34, 35-44 and 45-54 were plotted for male and female separately.

Figure 3. Projected AIDS cases in Maharashtra

AIDS cases estimated by back-calculation method for two different cases were plotted separately.

Case I : Here $a=3.05$ and $b=0.15$ were taken in the incidence density function I(s).

Case II : Here $a=2.75$ and $b=0.15$ were taken in the incidence density function I(s).

Figure 4. Projected HIV, AIDS and Death.

Here projections were done using EPI model

A : New infections were assumed after the reference year.

B : No new infections were assumed after the reference year.

Figure 1: Trend of Mortality Rate / 100000 (15-54 yrs)

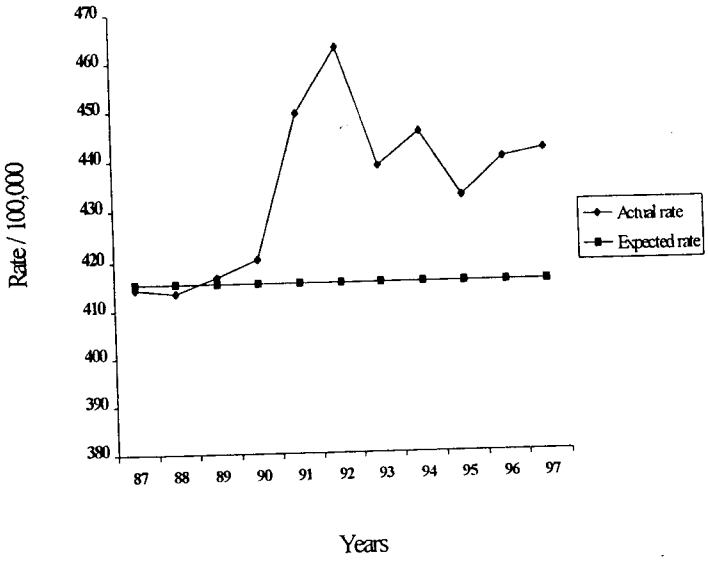


Figure 2: Adult mortality rate/100,000 population in Mumbai

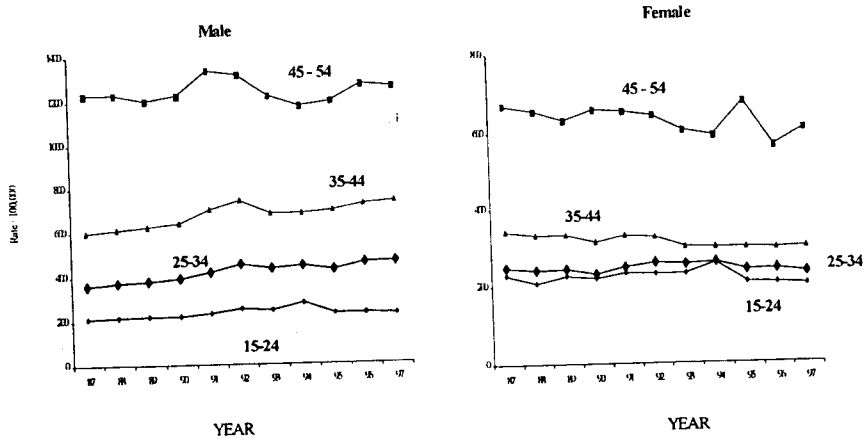


Figure 3. Projection of AIDS cases in Maharashtra.

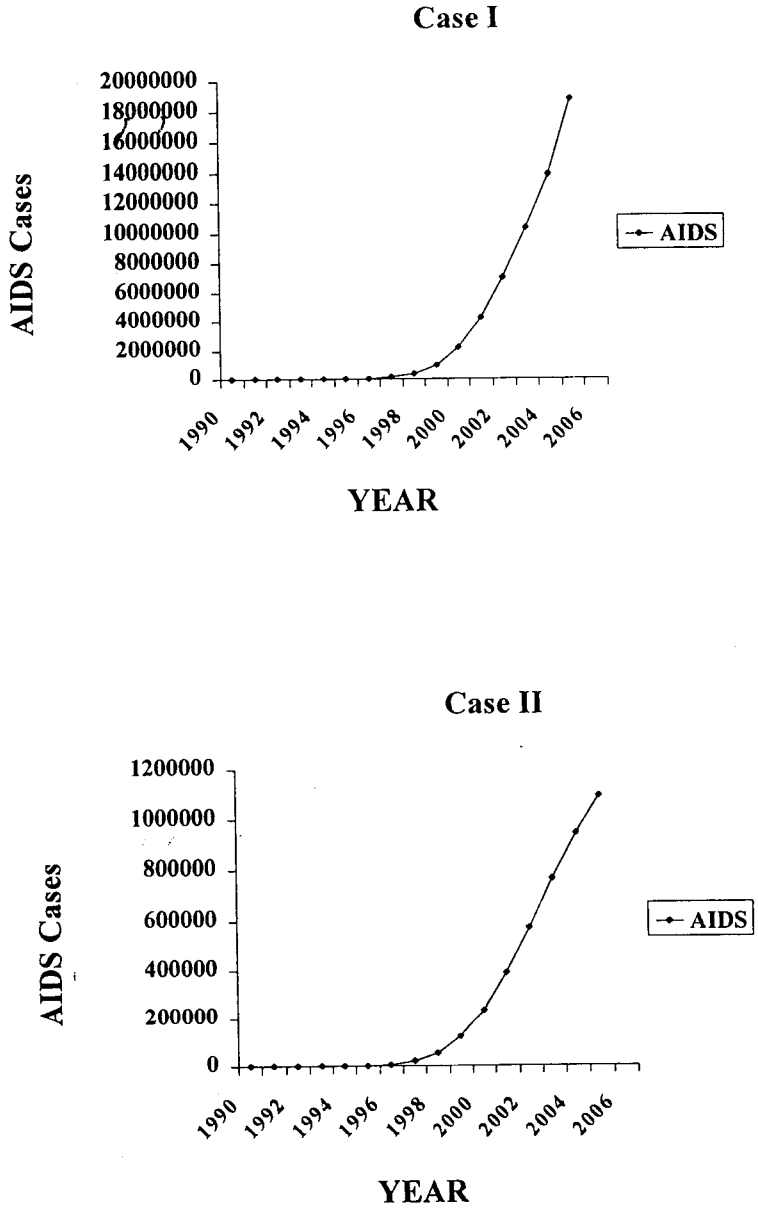
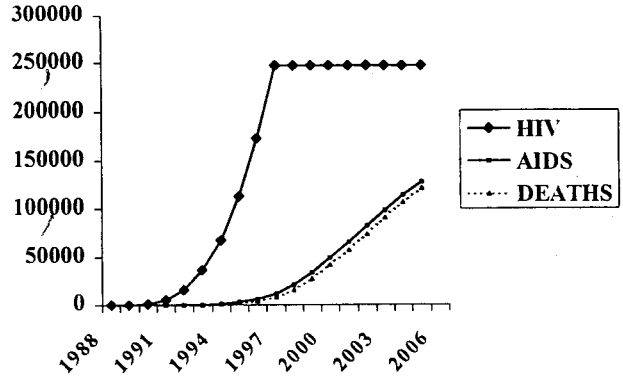


Figure 4. Projected HIV, AIDS and Death

A



B