Austin Journal of Infectious Diseases

Open Access

Austin Publishing Group

Special Issue Article on "Malaria"-A Fighting Moving Target

Impact of Integrated Vector Control Strategy on Malaria Incidence and Disability Adjusted Life Years (Daly) at Bharat Heavy Electricals Limited, Hardwar, India-Results of 25 Years Study

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Received: August 13, 2014; **Accepted:** October 10, 2014; **Published:** October 13, 2014

Abstract

A project on Integrated Vector Control strategy on malaria was launched at Bharat Heavy Electricals Limited, Hardwar, Uttarakhand, India in 1986. Major components of intervention strategy were source reduction, improving drainage, application of Expanded Polysterene Beads (EPS), biological control, use of larvivorous fishes *Poecilia reticulata* and *Gambusia affinis*, bacterial larvicides Bactoculicide (*Bacillus thuringiensis israelensis* and Spherix (*B. sphaericus*), limited use of fogging with malathion for the control of *Culex* mosquitoes, health education and community participation, prompt case detection, proper treatment and follow up of all malaria positive cases. Impact of Integrated Vector Control strategy on malaria incidence with time and estimation of diseases burden in term of Disability Adjusted Life Years (DALY) are presented in this paper.

Implementation of Integrated Vector Control strategy on malaria incidence, at BHEL, Hardwar drastically reduced malaria cases from 2733 in 1986 to 593 in 1987 and constantly decreased up to 1994 with total cases of 96 which implied that there is no indigenous transmission in BHEL area. A slight increase of malaria cases was recorded from 1995 to 1997 with the total cases of 245, 286 and 238 respectively and then decreased constantly till 2011with an overall reduction above 95%. Highest DALY lost was estimated for the age category ≥ 14 in 1986, which showed a sharp decline over the years. However a general decline in DALY was observed in all age groups.

Integrated Vector Control strategy on malaria incidence in industries complex at BHEL Hardwar with limited use of insecticide is highly effective, sustainable in long run, economical and resulted drastic reduction in DALY besides major reduction in malaria cases.

Keywords: Integrated Vector Control strategy on malaria; Disability adjusted life year (DALY); Malaria incidence

Introduction

The control of vector-borne diseases represents one of the greatest global public health challenges of the 21st century. Malaria and other vector-borne diseases contribute substantially to the global burden of diseases and disproportionately affect poor and under-served populations living in tropical and sub-tropical regions [1]. Today, three billion people- almost half of the world populations are at risk of malaria infection in 109 malarious countries and territories with approximately 250 million cases and one million deaths annually. In the absence of effective control, these diseases have a major impact on public health and socio-economic development [2,3]. Integrated vector control is increasingly being recommended as an option for sustainable malaria control [4].

During pre DDT era, environmental and engineering technologies were used to control vector of malaria. In the early 20th century larviciding and environmental management were the only tools available to contain malaria. The historical literature and more recent reviews of this approach show that anti-larval mosquito control measures were powerful tools against malaria [5,6]. Larval Source Management (LSM) provides the dual benefits of not only reducing numbers of house-entering mosquitoes, but, importantly, also those that bite outdoors. Large-scale LSM was a highly effective method of malaria control in the first half of the twentieth century, but was largely disbanded in favour of Insecticide Residual Spray (IRS) with DDT. Historically, antimalarial programmes in the US, Europe, the Middle East and some other previously endemic locations had largely succeeded in eliminating malaria even before the use of chemical pesticides. In 1950 and 1960s, the Global Eradication Campaign, superheated by the WHO, integrated the use of the insecticide DDT, into its control programme. The strategy depended on chloroquine for treatment and prevention and DDT for vector control, whereas environmental management activities almost disappeared. Initially, the campaign was very successful but the programme could not be sustained. The cost was high, many communities objected to repeat spraying of their houses, and resistance emerged to chloroquine

Citation: Dua VK, Srivastava A, Pandey AC and Gupta NC. Impact of Integrated Vector Control Strategy on Malaria Incidence and Disability Adjusted Life Years (Daly) at Bharat Heavy Electricals Limited, Hardwar, India-Results of 25 Years Study. Austin J Infect Dis. 2014;1(2): 7.

among malaria parasites and to DDT among *Anopheles* mosquitoes. Global eradication was abandoned in 1972. Since then, the burden of malaria has increased substantially in many parts of the world and its eradication remains elusive [2,7].

The main tools and strategies currently employed to control malaria are medicines for its prevention and treatment, and chemicals to control the mosquito vectors. Chemical strategies are focused on insecticides treated nets and indoor residual spraying. However, both medical and chemical approaches are posing problems to human health and environment. Pesticides constitute an important element in the current global strategy for the control of major vector-borne diseases such as malaria. Many of these have become ineffective through development of resistance by mosquito vectors to chemicals and by parasites to pharmaceuticals.

Today, many programmes have reduced the use of pesticides for disease vector control. Several countries have eliminated the use of DDT and in pilot projects; environmental management strategies and biological control are being applied for malaria vector control.

An alternative for reducing the incidence of malaria lies in the development of Integrated Vector Management (IVM) which is systematically based on social and ecological approaches. These operations are designed with the objectives of effectively reducing adult vector populations and pathogen transmission with methods which are ecologically, environmentally, socially, economically and politically acceptable [8].

India is one of the major industrial forces in the world. Most of these industrial complexes are located in areas with a moderate to high risk of malaria. The approach to control malaria adapted in industrial areas is mainly by chemical larvicides, adulticides and chemotherapy [9,10].

The available methods of malaria control which include chemotherapy (antiparasite), insecticides spraying and fogging operations were not producing desired levels of transmission reduction threatening equitable socio-economic development of the area. To contain the disease severity, there was imperative need for alternatives intervention which are operationally feasible, cost effective, community based and sustainable. A study on integrated vector control strategy on malaria was launched in Bharat Heavy Electrical Limited, Hardwar, India in 1986. The aim of the present study was to control malaria by using integrated vector control methods with limited use of insecticide. Impact of integrated vector control strategy on malaria with time and estimation of disease burden in terms of disability adjusted life years (DALY) are presented in this paper. The study was aim to control malaria in cost effective manner, sustainable in long run, free from environmental contamination and provide the opportunity for community participation.

Methods

Study area

A project on integrated vector control strategy on malaria was launched at Bharat Heavy Electricals Limited, Hardwar, Uttarakhand in 1986, It is spread over an area of 25 km^2 and is situated south-west of Hardwar between $78^0$9' and $78^0$22'E and $29^0$57' and 30^0 18'N. The terrain is composed of foothills of Shivalik range. The average rainfall is 1200 mm per annum (average of 11years), and minimum and maximum temperatures are 2.5-22.7^{0}C (average 11.4^{0}C) and 24.4-42.0^{0}C (average 35.2^{0}C) respectively with relative humidity 40-90% (average 58%). The area is conducive for mosquito proliferation and longevity. Mosquito fauna of the area is rich and breeding habitats are numerous and diverse [11]. The total population of the area is approximately 70,000.

The campus has innumerable breeding sites, both natural and man made resulting in active malaria transmission and high mosquito nuisance. These include large number of discarded tins, tyres, pots, dissert coolers burrow pits, ditches, low lying areas, community water supply taps in low lying areas of the unauthorized colonies without disposal of waste water, open and blocked drains, over head tanks, seasonal river and stream. The industrial area was highly malarious. *Anopheles culicifacies* is the primary vector in the area [11,12].

Intervention strategy

Integrated vector control strategy on malaria was started during 1986. The strategy was aimed to utilize the existing infrastructure of BHEL industry by involving the civil maintenance, water supply and sewage, medical and publicity departments as well as volunteer and other government organizations and the local community in vector control programme [13].

Major components of invention strategy were i).Source reduction ii). Improving drainage iii). Application of expanded polysterene beads (EPS) [14] and iv). Biological control, use of Larvivorous fishes *Poecilia reticulata* and *Gambusia affinis* [15] v). Bacterial larvicides Bactoculicide (*Bacillus thuringiensis israelensis* and Spherix (*B. sphaericus*) [16]. vi). Limited use of Fogging with malathion for the control of *Culex* mosquitoes, vi). Health education and community partipation [13]. vii). Involvement of Medical department for Prompt case detection, proper treatment and follow up of all malaria positive cases [12].

Parasitological survey

Weekly active surveillance of malaria cases was carried in BHEL, Hardwar by project staff to detect all fever cases through house to house visit. Passive surveillance of malaria at BHEL Hospital was maintained by the BHEL hospital staff. Thin and thick blood smears were prepared. All blood slides were brought to the malaria clinic, and stained with JSB-1 and JSB-11 (Jaswant Singh and Bhattacharjee stain). Blood slides collection and examination was made by the same team uniform over all the years. The blood slides were examined at malaria clinic on the same day with the project staff. All the blood slides examined and found positive for malaria cases were recorded. Radical treatment was provided to all malaria cases within 24 hours by the project staff. Surveillance in the control area was not possible due to practical limitations.

Entomological survey

Indoor resting adult mosquito densities were monitored by searches with flashlight and aspirator in experimental and control area at fortnightly interval. Man hour density of mosquito was recorded. Weekly peridomestic and intradomestic larval surveys were conducted and positive larval habitats were subjected to intervention measures in the experimental area [12].

Estimation of diseases burden

The Disability-Adjusted Life Year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. DALYs for a disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences, numerically it is calculated as [17,18].

DALY = YLL + YLD

Since there was no death due to malaria, the factor YLL is not taken into consideration. YLD is calculated as follows:

Life time lost due to morbidity: According to the Population Reference Bureau's 2000 World Data Sheets, life expectancy at birth for Indians was between 60 and 61 years. Only 4% of our population is over the age of 65. Malaria data was available in four age groups namely 0 – <4, 5 – 8, 9 – 14 >14, age at onset of disease in each group was taken as the average age of each group i.e. 2.5, 7, 12 and 37 average expected life was taken as 60 years. Duration of morbidity in two types of infections namely, *P. vivax* and *P. falciparum* is taken as 7 and 9 days respectively,, however since the data of two type of infection was not available separately, duration of illness was taken as average of two i.e.8 days [12].

Disability weights : A group of independent experts established weights for two disability classes associated with *P. vivax* and *P. falciparum* infection as 0.70 and 0.75 respectively falling within (0,1). For the reason given above average weight was 0.725 [12].

Age-weights: These are used to indicate relative importance of healthy life at different ages. The age weights used in the World Bank report rise from birth until age 25 and decline slowly thereafter. The formula to calculate age weights is defined as follows [12].

Age weighting function = $C \times e^{-\beta x}$ …(2)

Where C - Constant (= 0.16243), ß - Constant (= 0.04), x - Age and e - Constant (= 2.71).

Age discounting function: It indicates the value of health gains today compared to the value attached to health gains in the future, also discounted if they are spread over more than one year to determine cost-effectiveness. The discount rate used in the DALY formula is 3 percent. The formula to discount for time preferences [12].

Discounting function = $e^{-r(x-a)}$ …(3)

Where r - Discount rate (= 0.03), x - Age, e - Constant (= 2.71), a - disease onset year.

Sum across individuals: It is generally added linearly but to give priority to fewer people suffering for long intervals over more people suffering for shorter intervals is weighed non-linearly. In the present study individuals are added linearly.

Results and Discussion

Malaria cases during study period i.e. from 1983 - 2011 are given in Table 1. Data revealed that the implementation of Integrated Vector Control strategy on malaria, at BHEL, Hardwar drastically reduced malaria cases from 2733 in 1986 to 593 in 1987 and constantly decreased up to 1994 with total cases of 96. Moreover, *P.falciparum* also declined from 207 in 1986 to 9 in 1994 which implied that there is no indigenous transmission in BHEL area. A slight increase of malaria cases was recorded from 1995 to 1997 with the total cases of 245, 286 and 238 respectively and then decreased constantly till 2011with an overall reduction above 95%. Follow up of malaria cases revealed that more than 30% cases were either imported from other part of the Country or from nearby areas where no interventions work by the project staff was carried out [12]. It is to point out that *P.vivax* cases were followed for relapsed rate and 10. 2% cases were relapsed in spite of 5 day radical treatment with primaquine each time as per National Drug policy [19,20].

Table 1: Malaria incidence at BHEL Hardwar.

YEAR	BSE*	Positive cases	*P.vivax*	*P.falciparum*	SPR*
1983	11620	1129	959	170	9.7
1984	15785	1623	1368	225	10.3
1985	20593	3049	2620	429	14.8
1986	17655	2733	2526	207	15.5
1987	14767	593	569	24	4.0
1988	13669	433	379	54	3.2
1989	8516	425	414	11	5.0
1990	8757	482	469	13	5.5
1991	7153	347	336	11	4.8
1992	5430	105	102	3	1.9
1993	3341	91	84	7	2.7
1994	3404	96	87	9	2.8
1995	2573	245	233	12	9.5
1996	5796	286	268	18	4.9
1997	4963	238	233	5	4.8
1998	4186	70	67	3	1.7
1999	3545	88	78	10	2.5
2000	2538	42	36	6	1.6
2001	1457	8	8	0	0.5
2002	1244	7	6	1	0.6
2003	1515	11	8	3	0.7
2004	890	22	17	5	2.5
2005	1170	42	42	0	3.6
2006	1013	24	22	2	2.3
2007	724	21	19	2	2.9
2008	960	31	28	3	3.2
2009	959	47	40	7	4.9
2010	1423	49	41	8	3.4
2011	1411	69	68	1	4.9

Abbreviation: *SPR: Slide Positive Rate; BSE: Blood Slide Examined

Age wise distribution of malaria cases is given Table 2. Data revealed that year wise malaria cases in the different age group were recorded 180(2.7%), 243 (3.7%), 725 (11.0%) and 5457(82.6%) were recorded in the age group 0-4, 5-8, 9-14 and >14 years respectively out of a 6605 cases. There was a reduction of number of cases in all age group in 1987 as compared to 1986.

Table 2: Year-wise Malaria cases in different age-groups in BHEL Hardwar.

Year	No. malaria cases (Age wise)				Total malaria cases
	0-4 years	5-8 years	9-14 years	>14 years	
1986	82(3.0)*	75(2.7)*	302(11.1)*	2274(83.2)*	2733
1987	21(3.5)	19(3.2)	79(13.3)	474(80.0)	593
1988	6(1.4)	15(3.5)	49(11.3)	363(83.8)	433
1989	12(2.8)	21(4.9)	48(11.3)	344(81.0)	425
1990	15(3.1)	19(3.9)	53(11.0)	395(82.0)	482
1991	7(2.0)	23(6.6)	53(15.3)	264(76.1)	347
1992	1(0.9)	9(8.6)	7(6.7)	88(83.8)	105
1993	3(3.3)	3(3.3)	10(11.0)	75(82.4)	91
1994	4(4.2)	5(5.2)	8(8.3)	79(82.3)	96
1995	4(1.6)	10(4.1)	29(11.8)	202(82.5)	245
1996	10(3.5)	8(2.8)	32(11.2)	236(82.5)	286
1997	6(2.5)	8(3.4)	16(6.7)	208(87.4)	238
1998	4(5.7)	2(2.9)	4(5.7)	60(85.7)	70
1999		8(9.1)	6(6.8)	74(84.1)	88
2000		1(2.4)	1(2.4)	40(95.2)	42
2001		-	-	8(100)	8
2002		-	-	7(100)	7
2003	-	-	1(9.1)	10(90.9)	11
2004	-	1(4.5)	1(4.5)	20(90.9)	22
2005	-	2(4.8)	4(9.5)	36(85.7)	42
2006	-	-	1(4.2)	23(95.8)	24
2007	-	1(4.8)	1(4.8)	19(90.4)	21
2008	-	4(12.9)	5(16.1)	22(71.0)	31
2009	1(2.1)	4(8.5)	6(12.8)	36(76.6)	47
2010	1(2.0)	2(4.1)	5(10.2)	41(83.7)	49
2011	3(4.3)	3(4.3)	4(5.8)	59(85.5)	69
Total	**180(2.7)**	**243(3.7)**	**725(11.0)**	**5457(82.6)**	**6605**

*Figure in parenthesis indicates percent Malaria cases.

Attempts were made to correlate the number of malaria cases in different age group recorded at BHEL Hardwar with year wise estimated Disability Adjusted life Year (DALY) and results are given in Table 3. Highest DALY lost was estimated for the age category ≥ 14 in 1987, which showed a sharp decline over the years and more than 99% reduction in DALY was observed in 2007. However a general decline in DALY was observed in all age groups.

Year wise DALY difference in different group is given in table 3. It was observed that total DALY difference in age group 0-4, 5-8, 9-14 and ≥ 14 was 307.34, 416.89, 2080.57 and 15164.47 respectively during the year 2008.

Year wise reverted DALY in different age-groups in BHEL Hardwar is given in Table 4. It is observed that DALY has totally reverted in the age group 0-4 after 1998. In 2007, in the age groups 5-8,9-14 and ≥ 14 it reduced from 422.5, 2080.6 and 15171.1 to 5.63, 6.89 and 126.76 respectively. Thus DALY reverted in age groups 0-4, 5-8, 9-14 and ≥ 14 were 307, 422, 2081 and 15171respectively.Year wise percent reverted DALY in different age-groups is compiled in Table 4. The reverted DALY from 1986 to 2008 in percentage in different age groups were 100, 98.7, 99.7 and 99.1 percent namely, 0-4 (307.34 to 0.0 i.e. 100%) , 5-8 (422.52 to 5.63 i.e 98.7%) , 9-14 (2080 – 6.89 i.e. 99.7) and ≥ 14 (15171 – 126.76 i.e. 99.1%) . Total DALY estimated for the year 1986 was 19,968 which gradually reduced to 153 in 2007.

In industrial complex of BHEL, Hardwar, malaria cases were very high before the implementation of integrated vector control strategy on malaria in the year 1986. Routine methods of vector control using insecticides were not successful. However, after the integrated disease vector control measures, number of malaria cases drastically reduced from 2733 in 1986 to 593 in 1987 (79.7%) and the downward trends continued except in the years 1995 to 1997.

Keiser et al [21] have reported the reduction of burden of malaria in different eco-epidemiological settings with environmental management in Africa. Malaria control programmes that emphasize environmental management are highly effective in reducing morbidity and mortality. In India Sharma et al [22] reported over

Table 3: Year-wise estimated DALY in different age-groups in BHEL Hardwar.

Year	0-4 years	DALY	5-8 years	DALY	9-14 years	DALY	>14 years	DALY
1986	82		75		302		2274	
1987	21	228.63	19	315.48	79	1536.31	474	12008.82
1988	6	284.85	15	338.02	49	1742.99	363	12749.37
1989	12	262.37	21	304.21	48	1749.88	344	12876.12
1990	15	251.12	19	315.48	53	1715.44	395	12535.87
1991	7	281.11	23	292.95	53	1715.44	264	13409.85
1992	1	303.59	9	371.82	7	2032.34	88	14584.05
1993	3	296.10	3	405.62	10	2011.68	75	14670.78
1994	4	292.35	5	394.35	8	2025.45	79	14644.09
1995	4	292.35	10	366.18	29	1880.78	202	13823.49
1996	10	269.86	8	377.45	32	1860.11	236	13596.65
1997	6	284.85	8	377.45	16	1970.34	208	13783.46
1998	4	292.35	2	411.25	4	2053.01	60	14770.85
1999	0	307.34	8	377.45	6	2039.23	74	14677.45
2000	0	307.34	1	416.89	1	2073.68	40	14904.28
2001	0	307.34	0	422.52	0	2080.57	8	15117.77
2002	0	307.34	0	422.52	0	2080.57	7	15124.44
2003	0	307.34	0	422.52	1	2073.68	10	15104.43
2004	0	307.34	1	416.89	1	2073.68	20	15037.71
2005	0	307.34	2	411.25	4	2053.01	36	14930.97
2006	0	307.34	0	422.52	1	2073.68	23	15017.70
2007	0	307.34	1	416.89	1	2073.68	19	15044.38
2008	0	307.34	4	416.89	5	2080.57	22	15164.47

Table 4: Year-wise reverted DALY in different age-groups in BHEL Hardwar.

Year	DALY (0-4)	DALY (5-8)	DALY (9-14)	DALY (>14)	DALY (Total)
1986	307.34	422.52	2080.57	15171.14	19968.57
1987	78.71	107.04	544.25	3162.32	4332.73
1988	22.49	84.50	337.58	2421.78	3163.70
1989	44.98	118.31	330.69	2295.02	3105.25
1990	56.22	107.04	365.13	2635.27	3521.72
1991	26.24	129.57	365.13	1761.29	2535.34
1992	3.75	50.70	48.23	587.10	767.18
1993	11.24	16.90	68.89	500.37	664.89
1994	14.99	28.17	55.11	527.05	701.42
1995	14.99	56.34	199.79	1347.66	1790.08
1996	37.48	45.07	220.46	1574.49	2089.65
1997	22.49	45.07	110.23	1387.69	1738.94
1998	14.99	11.27	27.56	400.29	511.45
1999	0.00	45.07	41.34	493.70	642.97
2000	0.00	5.63	6.89	266.86	306.87
2001	0.00	0.00	0.00	53.37	58.45
2002	0.00	0.00	0.00	46.70	51.15
2003	0.00	0.00	6.89	66.72	80.37
2004	0.00	5.63	6.89	133.43	160.74
2005	0.00	11.27	27.56	240.18	306.87
2006	0.00	0.00	6.89	153.45	175.36
2007	0.00	5.63	6.89	126.76	153.44

95% reduction in malaria incidence over a four year period for continuous water source reduction activities and biological control. Dua et al 1997 [12] have reported the reduction of vector density of Anopheles culicifacies, was recorded in experimental area than control and difference was statistically significant.

Our study clearly shows that there was a sharp decline in the number of cases during 1986-1987 as a result of implementation of the integrated vector control strategy. Since then the downward trend has been observed (Table 1). Table 2 shows age wise malaria cases, it is observed that highest cases are found in > 14 age group, same trend is being seen in DALY loss (Table 3).

Implementation of Integrated vector control strategy in BHEL, Hardwar was most successful. Implementation of intervention strategy was visible in the elimination and reduction of major breeding sites of mosquitoes in the industrial area and detection and prompt radical treatment of malaria parasites resulted in reduction of malaria transmission.

Since the high *Culex* mosquito density in BHEL Hardwar was recorded during the month of April- May every year due to its profuse breeding in open drains, sewage, manholes and abundant tanks, It was decided to use fogging with Malathion for the control of *Culex* mosquito which effectively reduced mosquito nuisance [13]. It is to point out that application of larvivorous fish Poecillia *reticulata* was unsuccessful in polluted water in open drains to control *Culex* larva [23]. A nine years study (1987-1995) on bio-environmental control of malaria at BHEL, Dua et al 1997 [12] have reported that malaria control through bio-environmental strategy in industrial complex is sustainable in long run and economical. Patnayak et al [10] have recommended that selective application should be guiding force in the development of rational vector control of strategy which includes use of engineering methods, biological control, legislative measures and minimum use of insecticides.

A bio-environmental control of malaria was demonstrated for successful malaria control in a few major industries viz. BHEL, Hardwar [12], IDPL Rishikesh [24], IOC Mathura (Unpublished work) and NTPC Shakti nagar [25] in India. The strategy utilized the existing infrastructure of the industries by involving the civil maintenance, water supply and sewage, medical, publicity department as well as local government organization and community in vector control programme [13].

Conclusion

The present study clearly showed that malaria control through and integrated approach is practical, sustainable in the long term and economical. Implementation of intervention strategy and detection and prompt radical treatment of malaria parasites resulted in reduction of malaria transmission. Drastic reduction in DALY was observed besides major reduction in malaria cases. As most of the industries have very good infrastructures, there is need to mobilize different department's particularly civil maintenance and health department to initiate vector control measures.

Acknowledgement

The authors are thankful to staff of Integrated Disease Vector Control Project on Malaria at BHEL Hardwar Field Unit for field work. Financial support under Integrated Disease Vector control project is sincerely acknowledged. Editorial assistance by Dr. M. Ramar is sincerely acknowledge.

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Austin J Infect Dis - Volume 1 Issue 2 - 2014
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Citation: Dua VK, Srivastava A, Pandey AC and Gupta NC. Impact of Integrated Vector Control Strategy on Malaria Incidence and Disability Adjusted Life Years (Daly) at Bharat Heavy Electricals Limited, Hardwar, India-Results of 25 Years Study. Austin J Infect Dis. 2014;1(2): 7.