



Ranking of zoonotic diseases using composite index method: An illustration in Indian context

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ABSTRACT

This study illustrates the method of ranking the most important zoonotic diseases in India based on composite index method. Every reported zoonotic disease in India was ascertained a composite index, based on 7 indices or factors as follows: Incidence and prevalence of the disease in human and in animal populations, severity of the adverse health effects in humans, trends and distribution of the zoonotic disease in human and in animal populations, the economic loss in production and the negative impact on trade and industry. Based on these composite indices, the most important zoonotic diseases in India were identified and ranked accordingly. The 8 most important identified zoonoses ranked in the order of descending impact are: rabies, highly pathogenic avian influenza, anthrax, brucellosis, leptospirosis, bovine tuberculosis, Japanese encephalitis and porcine cysticercosis. Ranking based on the composite index method is highly useful in identifying the impacts of zoonotic diseases in diverse contexts. This will improve the decision making among planners at national and international levels, for better utilization and prioritization of available resources for the control and eradication of these diseases.

Key words: Composite index, Impact, India, Ranking, Zoonoses

Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals and man (Beran 1994, Hubalek 2003). These diseases create very serious public health concern throughout the world (Lipton *et al.* 2008). Approximately, 61% of the emerging infectious diseases are caused by zoonotic pathogens and create significant burden on global economics and public health (Jones *et al.* 2008). Zoonotic diseases pose a genuine threat to health and survival of people, livestock and companion animals. This is enhanced by the constant and inevitable interaction that occurs between humans and animals (Anonymous 2005).

The livestock segment in India contributed, over 3.64% to the total gross domestic product (GDP) during the year 2010–11 (Anonymous 2012). About 74% of the Indian population lives in villages and its 70% depends on agriculture and live in close contact with domestic and wild animals (Anonymous 2006). This close proximity, along with unhygienic living conditions and poverty, provides a very conducive environment for the spread of zoonotic diseases (Mantur *et al.* 2008).

The main factors for perpetuation of zoonoses in India are: (a) the close association between human and animal

population, (b) consumption of unpasteurized milk and dairy products, (c) large number of stray dogs, (d) illegal slaughtering and inappropriate waste disposal, (e) illegal trade of animals and animal products (Sherikhar *et al.* 2005). Transboundary human migration and travel also contribute to the emergence and spread of zoonotic diseases in India (Mavroidi 2008).

Zoonotic diseases hamper efficient production in food-animals and generate obstacles for trade of animals and animal products, both at a national and international level and have significant negative impact on public health and very deleterious effect on trade and industry, leading to severe socio-economic consequences (Anonymous 2008, Bhasin 2009, Jones *et al.* 2008, Sherikhar and Waskar 2005). There is a cluster of neglected zoonotic diseases that exists in developing countries which affects the poor and the marginalized population, and plays a key role in perpetuating poverty. Overall, most of these diseases neither attract appropriate amounts of health resources nor adequate measures of control due to their unknown status and impact (Anonymous 2005).

The two major factors that contribute to failure to control of zoonotic diseases are: the lack of quantitative data on its true impact, and the cost effectiveness of the programmes designed to control them (Coleman *et al.* 2004, Singh *et al.* 2008). These deficiencies impair the setting up of priorities for the control of these diseases by decision makers at the local, national and international level (Anonymous 2005,

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Mathers *et al.* 2007). The objective of this study was to identify and rank the most important zoonotic diseases in India using a Composite Index (CI) method. This method of scoring was based on the trends and distribution of each disease and their adverse effects on human health, economy, trade and industry.

MATERIALS AND METHODS

The data available from the online resources of World Health Organization (WHO), World Animal Health Organization (OIE), United Nations Commodity Trade Statistics Database and other related resources were primarily used for collecting the basic information for this study.

The data on diseases of animals in India from 2005 to 2011 were collected from online resources of WHO and OIE. These details were weighed against the reports of zoonoses in humans during the same period. Using this information, a primary list of 22 zoonotic diseases prevalent in the country were identified : Japanese encephalitis, leptospirosis, rabies, anthrax, bovine tuberculosis, porcine cysticercosis, leishmaniosis, listeriosis, toxoplasmosis, salmonellosis, tularaemia, highly pathogenic avian influenza, glanders, Rift Valley fever, echinococcosis, trichinellosis, screw worm disease, Venezuelan equine encephalitis, avian chlamydiosis, swine erysipelas, bovine cysticercosis, and brucellosis. These diseases were then ranked considering 7 factors, using composite indices which were relevant and accountable for their impact.

The scoring for each disease was done, considering 7 factors, pertinent in Indian context. The following 7 factors or the impact these cause were considered and a score or index was ascertained to each: Incidence and prevalence in humans, incidence and prevalence in animal population, morbidity and mortality in humans, morbidity and mortality in animals, adverse health effects in humans, economic impacts, and the effects on trade and industry.

Each factor was considered for every disease and a score was assigned based on the impact. The degrees of impact were considered and a score in the range of 1 to 5 was assigned to each of the 7 factors. All the individual indices for a particular disease were added up finally, to obtain a final score or composite index (CI) and the zoonotic diseases were ranked based on the CI. The maximum possible score for each disease was 35, considering all 7 factors. However, for the ease of illustration, a cut-off mark of 14 was considered to include all the imperative diseases and hence, zoonotic diseases with a CI of 14 and above were only considered for short listing.

The scoring for each entity was done, considering a variety of factors that are prevalent in the country. A few of the factors that were considered for assigning a score to a particular factor, are mentioned below for illustrative purpose:

Incidence and prevalence in human population: The reported outbreaks from 1996 to 2011 (15 year prevalence rate) were considered to estimate numbers of cases in

humans for calculating the degree of impact of incidence or prevalence. A score of 1 to 5, was assigned as per the absolute number of reported cases per 100,000 head of population in humans as ≤ 10 ; $> 10 \leq 100$; $> 100 \leq 2000$; $< 2000 \leq 20000$; and > 20000 , respectively. In addition, a qualitative assessment based on the case fatality and underreporting were considered for assessment, depending on the context.

Incidence and prevalence in animal population: As above, indexing was done considering these factors in animal population.

Morbidity and mortality in humans: The morbidity and the case mortality rate for each disease in humans were scored. The risk factors, conditions perpetuating the disease in the Indian subcontinent, control measures in place, surveillance and underreporting were also accounted for when scoring. A score of 1 to 5, was assigned as per the reported mortality and the morbidity in humans as ≥ 10 ; $> 10 \geq 100$; $> 100 \geq 200$; $> 200 \geq 1000$; and > 1000 , per 100,000 head of population in humans, respectively.

Morbidity and mortality in animals: As above, indexing was done considering the same factors in animal population.

Adverse health effects in humans: The adverse health effect of a particular disease was calculated based on disability adjusted life years (DALY), health implications and consequences, the outcome of the disease and its effects on other diseases and health conditions. The social attributes of the diseases were evaluated along with the socio-economic adversities (Coleman 2002). Considering all these factors, the adverse effects were assessed qualitatively as – ‘null effect’, ‘very low’, ‘low’, ‘high’ and ‘very high’ and a score of 1 to 5 were assigned, respectively.

Economic impacts: The economic outcomes were quantified based on the impact on animal productivity, reduction in product quality, waste of input for animal production and the depressing animal welfare effects. Likewise, cost of treatment in humans and animals, lost of work days, costs of disease prevention and control in animal as well as human population were also assessed (Anonymous 2004, Coleman 2002). In addition to these factors, the depressing values of output to GDP due to each disease were considered to assign an index of 1 to 5 (Table 1) depending on the economic impact.

Effects on trade and industry: The impact of trade restrictions due to a particular zoonotic pathogen on animal industry, environment, tourism and rural livelihood were determined. The United Nations Commodity Trade

Table 1. Scoring pattern of economic impacts of a particular disease

Score	Total loss assessed in US\$
1	≤ 1 million
2	> 1 million but ≤ 2 million
3	> 2 million but ≤ 3 million
4	> 3 million but ≤ 4 million
5	> 4 million

Table 2. Scoring pattern of effects on trade and industry of a particular disease

Score	Total loss assessed in US\$
1	≤ 2 billion
2	> 2 billion but ≤ 4 billion
3	> 4 billion but ≤ 6 billion
4	> 6 billion but ≤ 8 billion
5	> 8 billion

Statistics Database (COMTRADE) was also compared to account for the effects. Along with this, the direct economic losses to the industry were also assessed for measuring the effects of particular zoonoses on trade and industry. A score of 1 to 5 was ascertained as in Table 2, based on this estimation from available data.

RESULTS AND DISCUSSION

Zoonotic diseases (22) that were relevant in Indian context were identified based on available data. These were ranked based on the CI and the 8 most important zoonotic diseases were selected for illustrating the scoring method (Table 3). They were ranked according to their importance and are in the order: rabies, HPAI, anthrax, brucellosis, leptospirosis, bovine tuberculosis, Japanese encephalitis and porcine cysticercosis. The method of composite index adopted for this study, was very flexible and appropriate for taking decisions on national level policy making issues (Anonymous 2007, Anonymous 2002).

This ranking based on CI helps in identifying the diseases of utmost importance. The individual index for each aspect of the disease helps in identifying the most important impact factor for a particular disease. This helps in prioritizing policies for reducing the specific impact of the disease to lessen the burden on population. In addition, the composite index as well as individual index for a particular aspect of the disease can be evaluated from time to time, to ascertain the efficacy of the disease control programmes.

The 8 most important zoonotic diseases identified are discussed below, with the disease status, causative agent or agents, host population, risk factors, and other relevant information, which were considered for ranking.

Rabies: Rabies is one of the earliest recognized, deadliest and the most important zoonotic disease in India (Anonymous 2008, Traub *et al.* 2005). The causative agent is rabies virus under genus lyssavirus of the family rhabdoviridae (Beran 1994). Rabies is primarily a disease of terrestrial and air-borne mammals and dogs are the main reservoir in India (Anonymous 2008). Humans contract this fatal encephalitis by bites, licks or scratches from rabid animals (Sudharshan *et al.* 2007).

Approximately, 25 million dogs are present in India, with an approximate dog to human ratio of 1:36. Every year, around 15 million people are bitten, mainly by dogs. It is estimated that the annual human death toll due to rabies is 25,000–30,000. Since 1985 stray dogs are estimated to be responsible for 95% of human deaths due to rabies (Anonymous 2008, Sudharshan *et al.* 2007). Several studies revealed that 96% of at-the-risk population in Asian countries including India, belongs to the lower socioeconomic category (Dodet *et al.* 2008).

An estimated US \$25 million is expended on post bite treatment annually and 38 million person days are lost every year due to animal bites in India (Anonymous 2008, Goswami *et al.* 2005). The severity of the impact of this disease makes it, the one of prime importance.

Highly pathogenic avian influenza: The highly pathogenic avian influenza (HPAI) is a major zoonotic in poultry and continues to spread and pose a major challenge to animal and human health (Peiris *et al.* 2007). This disease, directly or indirectly impacts both economic and social well being in developing countries, taking a huge toll on the poultry industry and has become a serious menace in recent years (Adhikari *et al.* 2009).

HPAI is caused by the highly pathogenic strain H5N1, which is a subtype of the *Influenza A virus* of the family *Orthomyxoviridae* (Adhikari *et al.* 2009). The main source of human infection is live poultry markets, where affected chickens, ducks, geese, and other poultry species are sold (Peiris *et al.* 2007). Direct handling of infected birds, slaughter and preparation of sick poultry for food, consumption of uncooked poultry products and close contact with live birds are the major risk factors for transmission of the disease. Even though, HPAI is primarily

Table 3. Ranking the most important zoonotic diseases in india based on composite index

Disease	Scores/indices based on the impact caused by the disease							Total (CI)
	Incidence/prevalence in animals	Incidence/prevalence in humans	Adverse health effects in humans	Mortality and morbidity in humans	Mortality and morbidity in animals	Economic effects	Effects on trade and industry	
Rabies	5	4	5	4	4	5	2	29
HPAI	3	2	3	4	4	5	5	26
Anthrax	3	2	4	3	4	4	5	25
Brucellosis	4	3	4	2	3	4	5	25
Leptospirosis	4	3	4	3	4	3	2	23
Bovine tuberculosis	3	2	2	3	3	4	3	20
Japanese encephalitis	2	3	4	4	1	2	2	18
Porcine cysticercosis	1	2	4	2	1	2	2	14

an infection of avian species, the infection had extended its host range to several mammalian species (Smallman-Raynor *et al.* 2008).

Approximately, 128,044 birds died of the disease and 5,693,262 birds were destroyed in India up to 2008 (OIE 2012). The public health risk was significant enough with potential for huge loss of life and adverse socioeconomic consequences (Chakraborti 2009). Influenza caused by this agent has a case fatality rate of 54% in humans (Lahariya *et al.* 2006). The economic impact due to loss from trade and travel has had a severe effect in developing countries (Lahariya *et al.* 2006, Moore *et al.* 2006). The economic loss to the Indian poultry industry which employs around 3 million farmers, is enormous. The Asian Development Bank predicted a total loss of 1.8–5.8 percentage points of GDP due to avian influenza in the country (Lahariya *et al.* 2006).

Anthrax: Anthrax is an endemic disease of tropical and subtropical areas of India. The causative organism is a Gram positive, spore-forming bacteria, *Bacillus anthracis*. Among herbivores, cattle, sheep, goats, bison, deer, etc. are more susceptible to the disease, whereas, pigs and carnivores are less susceptible (Beran 1994). Humans get infected by direct contact with infected animals, by occupational exposure, through ingestion of meat from infected animals or by contact with contaminated soils. The incidence of the disease is not known accurately due to under-reporting and to the fact that only a fraction of the cases receive medical attention (Thappa *et al.* 2002). There are reports of 411 outbreaks in India between 2005 and 2008 with 2,722 cases and 2,176 deaths in the livestock population (OIE 2012). The cutaneous form of anthrax accounts for 95% of the infection (Thappa *et al.* 2001).

Brucellosis: Brucellosis is a common zoonotic disease in India, which is often neglected (Mantur and Amarnath 2008). *Brucella melitensis* and *Brucella abortus* are the most virulent and common species found in India (Renukaradhya *et al.* 2002). The disease is transmitted to humans by animal contact and through the consumption of milk and meat. Cattle, sheep, goat, pigs, yaks, camels and dogs transmit the disease to humans through different routes (Smith *et al.* 2005).

Increased and unrestricted national and international trading, rapid movement of animals, free grazing, mixing of different animal species and natural mating are the most important contributing factors for the spread and maintenance of brucellosis in animal population (Renukaradhya *et al.* 2002). Bovine brucellosis has increased in recent times and is more of an occupational hazard, and serological evidences suggest a high endemicity of this disease in India (Manish *et al.* 2013).

Proper reporting of the disease will facilitate prioritizing the control measures like vaccination and restricted movement of infected or suspected animals (Smith and Kadri 2005).

Leptospirosis: Due to the epidemic proportions and the increasing incidence of the disease, leptospirosis is recognized as an important emerging public health problem

in India (Sambasiva *et al.* 2003, Vijayachari *et al.* 2008). It is now considered as an endemic disease in India and is a major health problem (Pappas *et al.* 2008). Farming is the main occupation of the general population in India and is the main risk factor for acquiring leptospiral infection (Gangadhar *et al.* 2008).

It is an acute bacterial infection caused by spirochaetes of the genus *Leptospira*. Domestic and wild animals are the maintenance host for *Leptospira*. Direct or indirect contact with infected animal urine is the main vehicle for human infection (Beran 1994, Victoriano *et al.* 2009, Vijayachari *et al.* 2008). Rodents and domestic mammals like cattle, pigs and dogs are the major reservoir hosts in India (Victoriano *et al.* 2009). The disease shows a seroprevalance of up to 55% in the general population during October to November, every year and is more commonly associated with natural disasters with resulting acute epidemics (Victoriano *et al.* 2009). From the 3,526 human cases reported to OIE in the year 2008, 259 cases were fatal and the case fatality rate was 7.34%.

Bovine tuberculosis: Tuberculosis is the most frequently reported opportunistic disease associated with immunosuppressive infections (HIV), in the developing world (Beran 1994, Collins 2006, Cosivi *et al.* 1998). Zoonotic tuberculosis is a major risk in rural areas, where humans and domesticated animals share a common environment (Moda *et al.* 1996, Prasad *et al.* 2005). The incidence and mortality estimates are very high in countries with a similar environment to India (Cosivi *et al.* 1998, Michel *et al.* 2010).

Mycobacterium bovis of the *M. tuberculosis* complex cause tuberculosis mainly in cattle and other animals. Humans get infection primarily from bovine species and from other animals kept for milk and meat production (goats, buffalo and sheep (Moda *et al.* 1996)). Consumption of milk and milk products from infected animals and aerosol transmission are the main route of infection in humans (Grange *et al.* 1994, Prasad *et al.* 2005, Michel *et al.* 2010).

India accounts for nearly 30% of the global burden of human tuberculosis (Chakraborty 2004, Gopi *et al.* 2005). The data on prevalence of human disease due to *M. bovis* infection are limited in developing countries like India. Cosivi *et al.* (1998) estimated the proportion of human cases due to *Mycobacterium bovis* as 3.1%, for all forms of tuberculosis. This is mainly due to the technical field level inabilities in identifying and differentiating the species and also due to the fact that tuberculosis is not a notifiable disease in India (Moda *et al.* 1996, Chakraborty 2004).

Japanese encephalitis: Japanese encephalitis (JE) is the most important epidemic and sporadic encephalitis in the tropical regions of Asia (Beran 1994). It is a major problem of pediatric concern and epidemics are reported from different parts of India (Saxena *et al.* 2008). The estimated global burden was 709,000 DALY lost in 2003 (Arunachalam *et al.* 2008). The annual estimate of JE cases around the globe is 50,000 with 10,000 deaths (Parida *et al.* 2006).

JE is caused by Japanese encephalitis virus belonging to genus *Flavivirus* is a vector-borne viral infection that affects the neurons of the brain and is primarily transmitted to humans and animals by the bite of mosquitoes, commonly *Culex tritaeniorhynchus* (Beran 1994, Erianger *et al.* 2009). Pigs act as primary as well as amplifying host for the virus whereas birds like heron, ducks and chicken act only as primary hosts (Erianger *et al.* 2009).

The disease is common in rural areas of the country with many reports from rice-growing areas. Domestic pig rearing is an important risk factor in the transmission of the disease to humans. The incidence of JE is increasing in India and the case fatality rate of reported cases is high as 10% to 30% (Erianger *et al.* 2009).

Porcine cysticercosis (PC): Neurocysticercosis is the most common parasitic disease of public health concern in the developing world, including India and Latin America (Prasad *et al.* 2002, Prasad *et al.* 2008). It is a chronic disease and the prevalence varies between regions. Risk factors include poverty, consumption of pork, poor pig husbandry practices, lack of basic sanitary facilities and hygiene, and poor educational status. The incidence of PC is considered as a biological marker of socio-economic development (Rajshekhar *et al.* 2003).

Cysticercosis is caused by *Cysticercus cellulosae*, which is the larval stage of tapeworm *Taenia solium* and the only definitive host of this larvae is humans (Radhalkar *et al.* 2000). Taeniosis is seen only in humans and the adult worms reside in the intestinal tract. Cysticercosis occurs in human and pigs, where, the larval stages can be seen in different internal organs. Neurocysticercosis is the condition which develops, when the larvae reach the brain of the intermediate hosts. The infection occurs mainly through the ingestion of eggs in faeces, excreted by the human *T. solium* carrier.

Prevalence of taeniosis ranges from 0.1% to 6% in India and other developing countries (Senanayake *et al.* 1993, Rajshekhar *et al.* 2003). About 26.3% to 53.8% of active epilepsy cases in humans in India are due to neurocysticercosis (Prasad *et al.* 2008). Some studies reveal the prevalence of anti-cysticercus antibodies to be 17.3% among different population groups in certain parts of India (Khurana *et al.* 2006).

Limitations of this study

The major limitations of this study are the lack of exact data for many of the factors considered and the under-reporting of cases in humans and animals. The lack of data was a major hindrance in exact ranking of these zoonotic diseases. The authors do not recommend the use of results from this study for any kind of planning in disease control measures. But, this method of ranking using more real life data will be highly useful for identifying the most important diseases, planning and implementing control strategies and for the time-to-time evaluation of the control and eradication programmes.

The exact burden of zoonoses is difficult to estimate due to under-reporting and misdiagnosis of these diseases.

Insufficient laboratory diagnostic facilities, and lack of awareness of these diseases among public and health professionals, exacerbates the problem. Relatively few data exist to illustrate the socioeconomic impact of neglected zoonotic diseases (Anonymous 2007). The ranking of important zoonotic diseases based on CI will greatly assist decision makers at the national and international level, when prioritizing the allocation of available resources. The ranking and evaluation of the impact and consequences of zoonoses using CI will facilitate making better decisions and preeminent usage of available resources for its control and eradication (Coleman *et al.* 2004). In addition, the CI can be used as a specific tool for evaluating the effectiveness of the eradication and control programmes from, time to time. The advantage of CI over other methods of ranking is that a factor of interest can be added to this composite index and find the overall impact of the diseases. It also helps in using the individual index to determine the impact of a particular factor of interest. CI also facilitates in adding weightage to a particular index. These diverse outputs make the composite index method, a better option for ranking zoonotic diseases.

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REFERENCES

- Adhikari D, Chettri A and Barik S K. 2009. Modelling the ecology and distribution of highly pathogenic avian influenza (H5N1) in the Indian subcontinent. *Current Science* **97**(1): 73–78.
- Anonymous. 2004. *Report of the WHO/FAO/OIE- joint consultation on emerging zoonotic diseases*. pp. 1–65. World Health Organization, Geneva.
- Anonymous. 2005. *The control of neglected zoonotic diseases- A route to poverty alleviation*. pp. 1–55. World Health Organization, Geneva.
- Anonymous. 2006. *Basic Animal Husbandry Statistics - AHS*. pp. 198. Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Government of India, New Delhi.
- Anonymous. 2007. *Regional Meeting on Zoonotic Diseases*. pp. 1–51. World Health Organization, Jakarta.
- Anonymous. 2008. *The economic and social impact of emerging infectious disease: mitigation through detection, research, and response*. pp. 48. Marsh & McLennan Companies, New York.
- Anonymous. 2008. Rabies in India. *Canadian Medical Association Journal* **178**(5): 564–66.
- Anonymous. 2012. *Basic Animal Husbandry Statistics - AHS*. Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Government of India, New Delhi.
- Anonymous. 2002. *Investing in Animal Health Research to Alleviate Poverty*. Perry B D, Randolph T F, McDermott J J, et al. International Livestock Research Institute, Nairobi.
- Arunachalam N, Samuel P P, Paramasivan R, Balasubramanian A and Tyagi B K. 2008. Japanese encephalitis in Gorakhpur Division, Uttar Pradesh. *Indian Journal of Medical Research* **128**:775–77.

- Beran G W. 1994. *Handbook of Zoonoses*. pp. 61–79. (Ed.) Steele J H. CRC Press Inc., Florida
- Beran G W. 1994. *Handbook of Zoonoses*. pp. 582. CRC press Inc., Florida
- Bhasin N R. 2009. President's Desk. *Indian Dairyman* **61**(7).
- Chakraborti C. 2009. Pandemic management and developing world bioethics: bird flu in West Bengal. *Developing World Bioethics* **9**(3):161–66.
- Chakraborty A K. 2004. Epidemiology of tuberculosis : Current status in India. *Indian Journal of Medical Research -A* **120**:248–76.
- Coleman P G. 2002. Zoonotic diseases and their impact on the poor. (Eds) Thorton P K, Kruska R L and Henninger N. *Mapping Poverty and Livestock in the Developing World*. International Livestock Research Institute.
- Coleman P G, Fevre E M and Cleaveland S. 2004. Estimating the public health impact of rabies. *Emerging Infectious Diseases* **10**(1):140–42.
- Collins J D. 2006. Tuberculosis in cattle: Strategic planning for the future. *Veterinary Microbiology* **112**:369–81.
- Cosivi O, Grange J M, Daborn C J, Raviglione M C, Fujikura T, Cousins D, Robinson RA, Huchzermeyer H F A K, Kantor I D and Meslin F X. 1998. Zoonotic tuberculosis due to *Mycobacterium bovis* in developing countries. *Emerging Infectious Diseases* **4**: 59–70.
- Dodet B, Goswami A, Gunasekara A, Guzman Fd, Jamali S, Montalban C, Purba W, Quiamboia B, Salahuddin N, Sampath G, Tang Q, Tantawichien T, Wimalaratne O and Ziauddin A. 2008. Rabies awareness in eight Asian countries. *Vaccine* **26**: 6344–48.
- Erianger TE, Weiss S, Keisser J, Utzinger J and Weidenmayer K. 2009. Past, present, and future of Japanese encephalitis. *Emerging Infectious Diseases* **15**(1):1–7.
- Gangadhar NL, Prabhudas K, Bhushan S, Sulthana M, Barbudde SB, Rehaman H. 2008. *Leptospira* infection in animals and humans: a potential public health risk in India. *Revue Scientifique Et Technique - Office International Des Epizooties* **27**(3):885–92.
- Gopi P G, Subramani R, Santha T, Chandrasekharan V, Kolappan C, Selvakumar N and Narayanan P R. 2005. Estimation of burden of tuberculosis in India for the year 2000. *Indian Journal of Medical Research -A* **122**:243–48.
- Goswami A, Plun-Favreau J, Nicoloyannis N, Sampath G, Siddiqui M N and Zinsou J-A. 2005. The real cost of rabies post-exposure treatments. *Vaccine* **23**:2970–76.
- Grange J M and Yates M D. 1994. Zoonotic aspects of *Mycobacterium bovis* infection. *Veterinary Microbiology* **40**:137–51.
- Hubalek Z. 2003. Emerging human infectious diseases: Anthroponoses, Zoonoses, and Saproponoses. *Emerging Infectious Diseases* **9**(3): 403–04.
- Jones K E, Patel N G, Levy M A, Storeygard A, Balk D, Gittleman J L and Daszak P. 2008. Global trends in emerging infectious diseases. *Nature* **451**:990–94.
- Khurana S, Aggarwal A and Malla N. 2006. Prevalence of anti-cysticercus antibodies in slum, rural and urban populations in and around Union territory, Chandigarh. *Indian Journal of Pathology and Microbiology* **49**(1): 51–53.
- Lahariya C, Sharma A K and Pradhan S K. 2006. Avian flu and possible human pandemic. *Indian Pediatrics* **43**:317–25.
- Lipton B A, Hopkins S G, Koehler J E and DiGiacomo R F. 2008. A survey of veterinarian involvement in zoonotic disease prevention practices. *Journal of the American Veterinary Medical Association* **233**(8):1242–49.
- Manish K, Puran C, Rajesh C and Teena R K S. 2013. Brucellosis: An updated review of the disease. *Indian Journal of Animal Sciences* **83**(1): 3–16.
- Mantur B G and Amarnath S K. 2008. Brucellosis in India - a review. *Journal of Biosciences* **33**(4): 539–47.
- Mathers C D, Ezzati M and Lopez A D. 2007. Measuring the burden of neglected tropical diseases: The global burden of disease framework. *Neglected Tropical Diseases* **1**(2): 1–15.
- Mavroidi N. 2008. Transmission of zoonoses through immigration and tourism. *Veterinaria Italica* **44**(4): 651–56.
- Michel A L, Muller B and Helden P D V. 2010. *Mycobacterium bovis* at the animal - human interface: A problem, or not? *Veterinary Microbiology* **140**(3–4): 371–81.
- Moda G, Daborn C J, Grange J M and Cosivi O. 1996. The zoonotic importance of *Mycobacterium bovis*. *Tubercle and Lung Disease* **77**:103–08.
- Moore T and Morgan N. 2006. Avian Influenza: Trade issues. *CAST Commentary QTA 2*
- OIE. 2012. Detailed country disease incidence.
- Pappas G, Padadimitriou P, Siozopoulou V, Christou L and Akritidis N. 2008. The globalization of leptospirosis: worldwide incidence trends. *International Journal of Infectious Diseases* **12**:351–57.
- Parida M, Dash P K, Tripathi N K, Ambuj, Sannarangaiah S, Saxena P, Agarwal S, Sahni A K, Singh S P, Rathi A K, Bhargava R, Abhyankar A, Verma S K, Rao P V L and Sekhar K. 2006. Japanese Encephalitis outbreak, India, 2005. *Emerging Infectious Diseases* **12**(9): 1427–30.
- Peiris J S M, Jong MD d and Guan Y. 2007. Avian Influenza Virus (H5N1): a threat to human health. *Clinical Microbiology Reviews* **20**(2): 243–67.
- Prasad H K, Singhal A, Mishra A, Shah N P, Katoch V M, Thakral S S, Singh D V, Chumber S, Bal S, Aggarwal S, Padma M V, Kumar S, Singh M K and Acharya S K. 2005. Bovine tuberculosis in India: potential basis for zoonosis. *Tuberculosis* **85**:421–28.
- Prasad K N, Chawla S, Jain D, Pandey C M, Pal L, Pradhan S and Gupta R K. 2002. Human and porcine *Taenia solium* infection in rural north India. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **96**: 515–16.
- Prasad K N, Prasad A, Verma A and Singh A K. 2008. Human cysticercosis and Indian scenario: a review. *Journal of Biosciences* **33**(4): 571–82.
- Radhalkar M D, Shetty D D, Kelkar A B, Kelkar A A, Kinare A S and Ambardekar ST. 2000. The many faces of Cysticercosis. *Clinical Radiology* **55**: 668–74.
- Rajshekhar V, Joshi D D, Doanh NQ, De N V and Xiaonong Z. 2003. *Taenia solium* taeniosis/cysticercosis in Asia: epidemiology, impact and issues. *Acta Tropica* **87**: 53–60.
- Renukaradhya G J, Isloor S and Rajasekhar M. 2002. Epidemiology, zoonotic aspects, vaccination and control/eradication of brucellosis in India. *Veterinary Microbiology* **90**: 183–95.
- Sambasiva R R, Naveen G, Bhalla P and Agarwal S K. 2003. Leptospirosis in India and the Rest of the World. *Brazilian Journal of Infectious Diseases* **7**(3): 178–93.
- Saxena V and Dhole T N. 2008. Preventive strategies for frequent outbreaks of Japanese encephalitis in Northern India. *Journal of Biosciences* **33**(4):505–14.
- Senanayake N and Roman GC. 1993. Epidemiology of epilepsy in developing countries. *Bulletin of the World Health Organization* **71**(2): 247–59.

- Sherikhar A T and Waskar V S. 2005. Emerging zoonoses and social-economic impact in India - a review. *Indian Journal of Animal Sciences* **75**(6):700–05.
- Singh B and Prasad S. 2008. Economic evaluation of important cattle diseases in India. *Indian Veterinary Journal* **85**:1207–10.
- Smallman-Raynor M and Cliff AD. 2008. The geographical spread of Avian Influenza A (H5N1): Panzootic transmission (December 2003–May 2006), pandemic potential, and Implications. *Annals of the Association of American Geographers* **98**(3): 553–82.
- Smith H L and Kadri S M. 2005. Brucellosis in India: a deceptive infectious disease. *Indian Journal of Medical Research -A* **122**(5):375–84.
- Sudharshan M K, Madhusudana S N, Mahendra B J, Rao N S N, Narayana D H A, Rahman S A, Meslin F X, Lobo D, Ravikumar K and Gangaboraiah. 2007. Assessing the burden of human rabies in India: results of a national multi-center epidemiological survey. *International Journal of Infectious Diseases* **11**: 29–35.
- Thappa D M and Karthikeyan K. 2001. Anthrax: an overview within the Indian subcontinent. *International Journal of Dermatology* **2001**(40): 216–22.
- Thappa D M and Karthikeyan K. 2002. Cutaneous anthrax: An Indian perspective. *Indian Journal of Dermatology, Venereology and Leprology* **68**:316–19.
- Traub R J, Robertson ID, Irwin PJ, Mencke N, Thompson RCAA. 2005. Canine gastrointestinal parasitic zoonoses in India. *Trends in Parasitology* **21**(1):43–48.
- Victoriano A F B, Smythe L D, Gloriani-Barzga N, Cavinta L L, Kasai T, Limpakarnjanarat K, Ong B L, Gongal G, Hall J, Coulombe C A, Yanagihara Y, Yoshida S-i and Adler B. 2009. Leptospirosis in the Asia Pacific region. *BMC Infectious Diseases* **9**:147.
- Vijayachari P, Sugunan AP, Shriram AN. 2008. Leptospirosis: an emerging global public health problem. *Journal of Biosciences* **33**(4): 557–69.