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Strategies for Combating and Eradicating Important Infectious Diseases of Animals with Particular Reference to India: Present and Future Perspectives

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ABSTRACT

Since, last several years, efforts are going on to eradicate or eliminate a number of infectious diseases of animals, with mixed success. Basically for eradicating, eliminating or controlling any infectious disease isolation and quarantine of sick animals as well as animals suspected for disease; strengthening disease monitoring and surveillance, effective vaccines and vaccination strategies along with other control measures including of treatment are of utmost importance. Most importantly a significant knowledge is required for countering infectious diseases and assessing the criteria for selection of disease to be eradicated next. The role of environmental factors in the process of disease dynamics need to be understood which further plays a contributory role in the process of combating and elimination of diseases. Despite continuous efforts against animal diseases like Rinderpest, Contagious bovine pleuropneumonia (CBPP) and Foot-and-mouth disease, Rinderpest (cattle plague) is the only one that is successfully eradicated till date in India. However, control programmes on CBPP also brought a significant reduction in the incidence of the disease but eradication status is yet to be declared. While the other disease control programmes viz., Foot-and-Mouth Disease Control Programme (FMDCP), National Control Programme on Brucellosis (NCPB), National Control Programme of Peste des Petits Ruminants (NCPPPR) and Avian Influenza: Preparedness, Control and Containment could not achieve the desired success. Nowadays, with the achievement of the global eradication status on rinderpest there is again a renewed interest in disease eradication and control of infectious diseases of animals and alleviating their public health concerns. The focus is also being given in the 12th five year plan of the country on monitoring and control of certain animal diseases of economic importance. In view of above facts, this is right time to discuss the strategies for combating and eradicating important infectious diseases of animals with particular reference to India, achievements of global rinderpest eradication programme and reasons thereof and possibly apply lessons while planning for the future activities. This article describes various prevention and control strategies for controlling the infectious diseases of animals that have been or should be targeted for eradication or elimination, direct and indirect benefits from control programmes, issues and opportunities for the future.

Key words: Infectious diseases, eradication, elimination, FMD, PPR, rinderpest, brucellosis, BHV-1, diagnosis, vaccination, prevention, control, treatment, zoonosis, one health

INTRODUCTION

A number of infectious diseases have been targeted during the past 60 years either for controlling and subsequently eradication or elimination with mixed results. This has led to renewed interest in eradication of disease. In view of the developments in the field of disease eradication it is now appropriate time to revisit the concept of eradication of diseases along with their elimination; to analyse the achievements as well as failures of eradication programmes in the past and reasons thereof; along with possible application of these lessons while planning for the activities in future (Narain, 2011). The reduction in prevalence and incidences of animal diseases will help in increase in livestock production which is very crucial for achieving the goal of food safety in 2050 (Mahima *et al*., 2012a). After declaration of the world free from rinderpest, the first animal disease and second to smallpox; diseases successfully eradicated from this planet; on June, 28, 2011 by the Food and Agriculture Organization (FAO) of the United Nations, renewed interest and fascination for eradication animal disease. This ultimate achievement in animal health was due to firm commitment, international collaboration and the efforts of dedicated and committed animal health professionals across the globe with the efforts that were started in 1761 with the foundation of the world's first veterinary school in Lyon, France and the World Organization on Animal Health (OIE) in 1924. FAO information indicates rinderpest epizootics were also associated with the fall of the Roman Empire, the conquest of Christian Europe by Charlemagne, the French Revolution, the impoverishment of Russia and extensive famines in Africa (Cleaveland *et al*., 2001).

In India also there are several diseases which are severely affecting economy and social system of rural India viz., Foot and Mouth disease (FMD), Haemorrhagic Septicaemia (HS), Brucellosis, Infectious Bovine Rhinotracheitis (IBR), Japanese Encephalitis (JE), Mycoplasma infections etc (Kumar *et al*., 2009, 2011; Verma *et al*., 2012a, 2014a; Singh *et al*., 2013a; Chakraborty *et al*., 2014). Therefore, the focus is being given in the National livestock policy on monitoring and control of these infectious animal diseases viz., FMD, PPR, brucellosis, swine fever etc (NLP, 2013). Most of the times, complete eradication of disease is not economically possible, therefore, in such cases attempts can be made to mitigate the disease or its infections effect on economics. Control of diseases and subsequently eradication requires isolation and quarantine of sick animals as well as animals suspected for disease; strengthening disease monitoring and surveillance, vaccines and vaccination strategies along with other control measures (Thrusfield, 2007). However, a healthy debate is going on among the scientists, researchers and animal health professionals about the large investment of resources on single disease while there are many other important health issues to combat and particularly when the financial resources are restricted (Morens *et al*., 2004; CDC, 2009).

In view of above facts, this is right time to discuss the strategies for combating and eradicating important infectious diseases of animals with particular reference to India, achievements of global rinderpest eradication programme and reasons thereof and possibly apply lessons while planning for the future activities. This article describes various control strategies for controlling the livestock infectious diseases that have been or should be targeted for eradication or elimination, direct and indirect benefits from control programmes and issues and opportunities for the future.

ERADICATION AND ELIMINATION

A general definition of Eradication is the reduction of an infectious disease's prevalence in the worldwide host population to zero (Dowdle, 1998), thereby creating an environment where intervention measures are no longer needed (Dowdle, 1998; WHO, 1998; Thrusfield, 2007). Most of the time, it is confused with elimination i.e., either reduction in prevalence of infectious disease to zero or negligible amount in a regional or global population but infectious agent may be allowed to persist in the environment thus intervention measures are still required (Thrusfield, 2007). It can be also defined as a reduction of incidence of disease below the level achieved by control or reduction of prevalence to such a low level that it is no longer considered a health problem, based on an arbitrary criteria or definition. Due to these confusions in the definitions of these terms, efforts are going on to clear these ambiguities (Dowdle and Hopkins, 1998; Enserink, 2010). A significant knowledge is required for assessing the criteria for selection of disease to be eradicated next. Eradication of a disease helps in reducing the direct or indirect economic losses either due to decrease in production or mortality. It also benefits in the free trade of livestock and their products across the regional boundaries. However, the success of eradication depends on the epidemiology of disease, along with social and political factors. In India, during past several years, a number of animal diseases such as Rinderpest (RP), contagious bovine pleuropneumonia (CBPP), Foot-and-Mouth Disease (FMD) have been targeted for eradication or control. Although, the progress of eradication programmes over the years is rather mixed. Till now, Rinderpest is the only one successfully eradicated disease (Sinha, 1998; Roeder *et al*., 2013). The campaigns on CBPP brought about a dramatic reduction in the incidence and the country is free from CBPP from October, 2003. The dossier for seeking the freedom from this infection has also been submitted to Office International des Epizooties (OIE) (DADH, 2013). However, the physical surveillance is going on to detect any re-occurrence of Rinderpest and Contagious Bovine Pleuro-Pneumonia (CBPP) for maintain the freedom of country from these diseases (DADH, 2013).

The term end game is used for referring to the final stages of an elimination or eradication programme at the time of circulation of the disease but at levels much less than the normal. Guidance is provided by several international organizations like WHO and OIE along with Food and Agricultural Organization (FAO) for target-specific elimination of any disease. Such operational definitions are helpful distinctly for specific pathogens. But for multiple pathogen perspective more conceptually the term 'end game' is applied which is particularly used to a stage in the elimination programme when the goal seems in sight and the target of operation becomes time bound (Klepac *et al*., 2013).

Eradication process: This involves the establishment of a management team followed by the conduct of the eradication programme and established plan (Yekutiel, 1980). Three main activities are included in the programme:

- **Surveillance:** To fully investigate the distribution of the disease
- **Containment:** To prevent the spread of the disease
- **Treatment/control:** To eradicate the etiological agent when it is found

However, an eradication programme should include certain steps to make it a success story as:

- **Administration:** It requires the a team for maintaining the routine administrative process for the permission of programmed activities to be readily conducted more efficiently involving the human resources, materials and financial ones
- **Legislation and compensation:** Control and eradication programmes are more effective when supported by formation of suitable regulations, upgradation of existing regulations along with development of legislative framework, suitable compensation and sometimes accompanied by penalties when legislation is contravened. These measures will permit easy interpretation and comprehensive application
- **Training programmes:** These are required to achieve the training necessary for their assigned duties of personnel of organizations that participate in the programme and also to create awareness in them against the target disease
- **Public education:** The target of this is to improve the community's knowledge of the disease in order to increase the amount of reporting and also to inform the community of the Program's activities and objectives in order to achieve its cooperation. For example slaughter of animals for controlling of diseases may be an important issue in certain regions and communities due to social and religious attitudes. Public education plays a crucial role in influencing these attitudes
- **Research and epidemiological surveillance:** If a control and eradication programme is to be initiated at national or international level, there is requirement of adequate surveillance (Thrusfield, 2007). This can be supported by existing data-gathering procedures or development of some alternative new systems for collection of data. To know the evolution in space and time of factors influencing the presentation of disease and to evaluate the risk of introduction and dissemination of the etiological agent
- **Laboratory diagnosis:** A disease can be controlled or eradicated successfully if it can be recognized (Thrusfield, 2007). It is essential for quick and confirmed diagnosis of infectious diseases
- **Control strategies:** These are the measures which are adopted for controlling the disease, whenever, it is detected and to take the necessary steps to stop its transmission and further spread (House *et al*., 2000) according to the strategy defined for its epidemiological zones as
  - **Control zone:** In the control zone the disease is endemic, not permitting the suspension of vaccination for the disease. Actions are oriented to reducing the sources of infection via., strict control of outbreaks to levels compatible with eradication
  - **Eradication zone:** This zone is one which has ceased to have outbreaks, permitting measures to accelerate the disease's eradication, such as suspending vaccination according to OIE norms. When an outbreak should occur a team of specialists will destroy infected and possibly exposed swine, in addition to adopting among others the following measures
  - **Free zone:** The OIE International Animal Health Code defines a free country as one that has had no disease for a minimum period of time. For countries which destroy all animals in outbreaks and vaccinate in the area, however, this period is reduced and for countries which destroy the animals in outbreaks without vaccinating

- **Ecological consequences:** Sometimes it is possible that control and eradication of infectious disease particularly involving biological vector or intermediate host may disturb the ecosystem or ecological balance (Yekutiel, 1980). There may be chances that the space free by one infectious agent may be occupied by another more pathogenic infectious agent. Therefore, these factors are also important in relation to animal disease control

- **Biostatistics and analysis:** Ultimately these are necessary to establish and maintenance of an information system which will permit continuing knowledge of the evolutions of the disease and development of the Program regarding its activities and progress in accomplishing it goals and objectives

Factors associated to animal disease eradication: The lessons that can be learnt from the global rinderpest eradication programme are the need to understand epidemiology of the disease, transmission of etiological agent, effective diagnostic tool, treatment and preventive measures, insight of social, cultural and political factors and finally the availability of clear and sound strategy before targeting the disease (Henderson, 1987; Aylward *et al*., 2000; Sharma, 1980).

According to Dr. Cowen, associate professor of epidemiology and public health, North Carolina State University, "eradication required tremendous efforts involving testing and clinical monitoring and the participation of local residents to prove that the disease no longer existed". Eradication of RP was particularly difficult in politically unstable countries such as Somalia and Sri Lanka. While he noted that polio could be the next target for eradication, he declined to speculate on what animal disease could be the next target.

The eradication of rinderpest was possible due to the single serotype genetically stable morbillivirus, availability of good diagnostic tools and effective vaccine.

The future issues in eradications are some degree of confusion in definitions of eradication and elimination, agreement in strategies of eradication like, understanding of natural history of disease, planning and clear goals and coordination in efforts. The disease to be targeted for eradication or control programme should be selected on epidemiology, the natural history of disease, susceptible hosts and reservoir of pathogen, availability of tool in the form of an effective vaccine or treatment could be available or vector control, if any. Moreover, along with these there is a need for continuously and systematically improving the tools and the techniques to deliver them, political willpower, finance strength, cost benefit analysis and other social feasibilities.

In order to establish eradication surveillance is a huge challenge. Either for surveillance or for prophylaxis political as well as military events do not make access possible in certain parts of the world. There may be shift in the geographical areas wherein infectious diseases are likely to endure or recur. There is compounding of these problems when it comes to mounting other efforts for eradicating infectious diseases. There is lack of surveillance capacities in many nations for knowing about the recurrence of disease in wild-type form or if it is present in populations of animals with a chance of spreading back to human beings. In certain nations (like Indonesia) informations are with held on the infectious disease incidence as a bargaining chip to help securing the requisite resources for combating outbreaks of infectious diseases that are pandemic in nature (Dowdle and Hopkins, 1998; Caplan, 2009).

THREE ESSENTIAL KEY ELEMENTS SUPPORTING ERADICATION/ELIMINATION OF INFECTIOUS DISEASES

Rapid and confirmatory diagnosis, enhanced monitoring/surveillance and networking of diseases: Especially in developing countries like India the livestock productivity is decreased to a greater extent due to animal diseases. The correct assessment of livestock health in country is of utmost important in formulating the disease eradication or control programmes (Lefevre *et al.*, 1993). Adequate capability and capacity of diagnostic facility is prime requirement. The test for diagnosis should be accurate and ensure the true positive detection of the diseases. The diagnostic laboratories should have quality control coordinated by reference laboratory. There are two general types of tests for specific diagnosis viz., tests demonstrating the presence of agents of infection or major antigens that are expressed by the agent or the agents' nucleic acid and tests demonstrating the presence of antibodies against the agent of infection. In the process of development of animal disease diagnostics a major thrust has been towards the methods that are rapid and have the provision for a definitive answer in less than 24 h period. In order to achieve rapidity of this kind the methods must fulfil the prerequisites of speed and simplicity; sensitivity as well as specificity; reproducibility and low cost. The prerequisites of sensitivity as well as specificity can be fulfilled by certain conventional immunoassays like indirect immunoperoxidase test (to detect antigens of duck swollen head haemorrhagic disease virus) or dot immunoperoxidase test (to detect Blue tongue virus). Such assays also include improved version of ELISA for typing as well as differentiation of strain of FMD virus as well as fluorescent polarization assay in diagnosing brucellosis in bovines. The pen-side diagnostics in addition like immunochromatographic method on the basis of the principle of lateral flow for diagnosing rabies or the reverse transcriptase loop mediated isothermal amplification (RT-LAMP) to detect 5' Non-Translated Region (NTR) gene of the classical swine fever virus aids to rapid diagnosis. The classical Polymerase Chain Reaction (PCR) based diagnosis has been exploited widely for detecting the nucleic acids in clinical specimen for diagnosis based on laboratory methods. Various versions of PCR like nested-PCR (for sequencing the whole genome of pesti virus); Real-Time PCR (RT-PCR) for differentiating morbilli virus for analysis of insertion sequence of *Mycobacterium paratuberculosis*) as well as multiplex PCR (in order to differentiate the cluster of various viruses that cause disease in swine) have helped in improving the skills of diagnosticians in veterinary medicine from time to time. Advances in the field of molecular biology have provided new diagnostic tools that are powerful. Refined techniques of diagnostics along with nano-based diagnostics are receiving greater attention increasingly due to development in the field of agricultural biotechnology. Uses of deoxyribonucleotide (DNA) biotechnology like diagnosis based on microarray may significantly contribute in improving the animal disease control programme thereby stimulating both production of food and trade of livestock. Identification of microbes has also become easier due to development of 16 SrRNA gene sequencing along with the advent of sequencing technologies of new generation like massive parallel signature sequencing; pyrosequencing or Solexa (Jain, 2003; Krah and Jungblut, 2004; Schmitt and Henderson, 2005; Verma *et al.*, 2010a, b; Deb and Chakraborty, 2012; Dhama *et al.*, 2012a). Another important factor in this is effective monitoring and surveillance system which provide the roadmap on the priorities of the disease interventions. For this, active surveillance is required along with detailed investigation of outbreaks and quick reaction of this situation (Thrusfield, 2007). The important constituents of effective surveillance system are disease reporting, epidemiological and laboratory investigation, data and sample collection, analysis and communication, information management and then rapid action.

Effective vaccines and vaccination strategies: Possible way to control most of the animal diseases including zoonosis is vaccination which play essential role in the control of many diseases. A vaccination strategy alone is not useful unless it is the part of disease control strategy along with other control measures. Use of vaccination along with other control measures will help in eliminating the epidemics of animal diseases. If vaccination is applied then, the factors like role of vaccination, its type, quality, delivery and availability should also be considered. Different types of vaccines are available with all their advantages and disadvantages. Vaccines should always be obtained from reliable manufacturers having international quality control standards. Vaccine should protect the animals along with reducing the transmission of infectious agents. Ideally the herd immunity is obtained after 70-80% of vaccination coverage but some disease like Foot-and-mouth disease requires higher than this. Extemporaneous manufacture of autogenous vaccines has been done by using infectious agents that are isolated from a specific holding for using in the same holding. On a small scale such kind of products serves a useful purpose but it is quite evident that they will not be able to replace the requirement of safe as well as effective vaccines available commercially in the event of emergency of a disease (Videnova and Mackay, 2012). Molecular development recently has led to development of recombinant and subunit; DNA as well as non-pathogenic virus-vectored vaccines including the approaches for reverse vaccinology that uses expression library. This helps in achieving the most cost-effective methods to produce antigens which are free from the exogenous materials as associated with the vaccines that are used conventionally (Dhama *et al.*, 2008a; Weiner, 2008). In dairy enterprise many such cost-effective vaccines are available nowadays (Deb *et al.*, 2013a). The procedures for delivery systems that include: nanoparticle and liposome; viral vector as well as vaccination that are cell based need to be explored and their application is required for achieving effective as well as protective response of the immune system (Emerich and Thanos, 2003; Suri *et al.*, 2007). There are several pathogens causing infectious diseases that gain entry through the mucosal sites thereby establishing infection initially in such sites. Lower costs as well as better accessibility; medical waste-free delivery as well as immunization in mass at a higher capacity are provided by mucosal vaccines (Dhama *et al.*, 2013a). Against pathogenic entities such types of vaccination provides protective immunity both locally as well as systemically. Administration of majority of vaccines (licensed) are done parenterally for which efforts are required more for designing and developing mucosal vaccines that are effective as well as potent (Pavot *et al.*, 2012; Wani *et al.*, 2013; Dhama *et al.*, 2013a). More flexibility is moreover required to regulate governing registration as well as marketing of vaccines for livestock as well as wildlife in such a way that these vaccines can meet the requirements in the field of epidemiology. In case of emergency of an animal disease it is of vital importance to have access to information on availability of vaccines. In order to address a variety of needs in animal health authorisation of various products have been done in the member states of the European Union and for a range of stakeholders informations regarding such products have been made available (Videnova and Mackay, 2012).

Appropriate prevention, control and treatment measures: Animal disease prevention and control requires insights into occurrence of disease. There is thus need for a system for the monitoring as well as surveillance of occurrence of disease. At herd level in health control systems for recording disease can be based on observational results such as at slaughter recording of lesions or data of production such as gain in weight; rate of pregnancy as well as farrowing. Such kind of data even though they are of non-aetiological type) are valuable tools as a basis for evaluating further possible involvement of infectious diseases that are specific in nature. The basic concept of hygiene can be defined as measures taken for preventing sources of pathogens building up and methods that are applied for prevention of exposure to possible target animals. Prevention of exposure to manure should be the primary focus in animal production. A basic measure to limit the exposure of pathogens excreted to neighbouring animals in a herd is isolating the sick animals. Large amount of infectious doses are excreted by sick animals. For instance calves infected with *Salmonella* Dublin excrete up to 100 (Lethal dose 25) infectious doses per gram of faeces. Isolation of such kind of animals may well be the threshold preventing an isolated outbreak of salmonellosis in one or a few animals that ends up in an enzootic spread of infection within a herd. It is also recommended not to transport or introduce animals that are sick because transport itself is known to be a factor triggering the exacerbation of a subclinical infection to fulminant status along with associated pathogen excretion. A simple recommendation is therefore isolating new animals for a specific incubation period before their introduction into a herd thereby allowing clinical observation and when required testing for infections specifically. Along with this undertaking specific biosecurity measures is also mandatory. Importation of live breeding animals has also led to improvement of genetic status of a herd traditionally. Cooperation at the international level has led to decrease in the risk of introducing epizootic diseases but for endemic diseases this is not the case. This risk is however considerably decreased when live animal importation is replaced by semen as well as embryos (Holmgren and Lundheim, 1994; Isacson *et al*., 1997; Doherr and Audige, 2001; Stark *et al*., 2006).

Between batches of farm animals the all-in, all-out system of production also helps in cleaning as well as disinfection which is a step further for minimising the pathogen spread from older animals (growing) to newer as well as younger ones. At present in beef as well as swine herd this strategy is generally a routine standard. There may be break down of status of health due to empirical violation of such procedures (Berndtson, 1996; Wierup and Wegener, 2006).

In wild life the control of diseases involves challenges substantially in comparison to their control in animals that are domesticated. Fruitful efforts have been made whenever possible for protecting health of human against wild life zoonoses like rabies or for preventing diseases in the wild life from being transmitted to animals kept for production of food (For instance: Classical swine fever and *Brucella suis*). Another aim is protecting wild life from certain diseases that are destructive in nature (for instance bovine tuberculosis threatening the existence of certain species of wild animals in animal parks as well as zoos). Control of badger population is especially important to prevent the spread of bovine tuberculosis whereas domestic swine population can be protected by controlling the population of wild boar (Michel *et al*., 2003; EFSA, 2009).

The availability of antibiotics that are effective in nature has revolutionized animal health care and has been found to be responsible to enable countless advancements in medical care. Some of the most widely used drugs worldwide are antimicrobial agents but their injudicious uses have led to development of resistant infectious agents. For prescribing antimicrobial therapy therefore it is necessary to diagnose the infection accurately along with the process of understanding the distinguishing features between empiric as well as definitive therapy. Along with this identification of the opportunities for switching to narrow-spectrum as well as cost effective oral agents for the shortest necessary duration; understanding characteristics of drugs that are peculiar to antimicrobial agents (like the pharmacodynamics profile) help in their judicious uses (Spellberg *et al*., 2008; Leekha *et al*., 2011). Over a century antibodies have been used in the prevention as well as treatment of infectious diseases like rabies and varicella as well as tetanus and vaccinia. Antibiotics have largely replaced them for the treatment of bacterial infections but they (antibodies) have remained a critical component for treating tetanus and botulism. The process of developing and using monoclonal antibodies in addition may help in defining further protective humoral responses and can lead to new approaches for preventing as well as treating infectious diseases (Keller and Stiehm, 2000).

Other important factors are traceability, regional integration, social participation, training and capacity building and research programmes in support of disease control programmes are very important. An efficient traceability system will help in finding the affected animals easily and quickly. A regional and inter-sectorial agreement in countries and veterinary organizations should be formed for proper coordination. Awareness campaign, sufficient communication and involvement of stakeholders are very crucial and it should be on-going process. Some areas in control strategies need certain research so a proper communication with research organization should be established. Development of infrastructure along with trained personnel helps in effective controlling of infectious diseases, so involvement of trained and veterinary para-professionals can be a useful tool to increase the veterinary presence in the field. Apart from this some countries have followed the indemnity eradication programme for controlling the diseases that have public sector problems. In this government agencies purchase the diseased or infected animals from the farmers or breeders so that these animals cannot become the part of food chain or breeding (Kuchler and Hamm, 2000).

Success story of rinderpest (RP) eradication programme: Rinderpest (commonly known as cattle plague) was a viral disease of cattle, buffalo, sheep, goats and wild animals such as antelope, giraffe, kudu and wart hogs and characterized by fever, erosive lesions in the mouth, discharge from the eyes and nose, profuse diarrhoea, dehydration, protein loss and immunosuppression resulting from lymphocyte depletion (Roeder *et al*., 2013). It could kill entire naive cattle and buffalo herds, but susceptibility varied among species.

Although, the process of eradication of the disease was a development activity rather than research in the scientific field in the field of development of vaccine as well as epidemiology its success owed much to various seminal research efforts. It has also shown what the process of scientific decision making as well as management can accomplish with resources that are limited (Mariner *et al*., 2012). The story of rinderpest eradication began in 1714 when Giovanni Lancisi developed disease control measures in response to rinderpest outbreaks. Subsequently in 1744 animals were vaccinated against rinderpest in England and the Netherlands. The severity of RP outbreaks lead to the establishment of first world veterinary schools in Lyon, France (1761), Egypt (1827). In India first Asian civilian veterinary school was founded in 1872 following the outbreak. Later on in 1924, World Organization on animal Health (OIE) and in 1945, FAO were established. In 1956, for field use live virus rinderpest vaccine was developed by Walter Plowright (1969) is remembered for pandemic in Afghanistan which in 1971 reached to various countries like Bahrain, Iran, Jordan, Lebanon, Syria, Turkey and Yemen. In 1980s rinderpest outbreak killed millions of animals in Africa, southern Asia and the Middle East.

Due to heavy losses and availability of suitable vaccine FAO initiated the process of worldwide eradication of rinderpest and the Global Rinderpest Eradication Programme (GREP) was launched in 1994. GREP focused its activities in developing an understanding of the epidemiology of the virus, appropriate disease surveillance techniques, provision of support to national laboratory services in support of serological surveillance activities, assistance to national veterinary services in organising intensive and sustained surveillance programmes, assistance to national veterinary services in conforming to relevant OIE (World Organisation for Animal Health, Paris) guidelines for declarations of freedom from disease and infection, articulating an effective strategy for prevention or response to the reintroduction of rinderpest virus, developing effective national/regional emergency plans including a pre-rehearsed action programme in case of an outbreak, promoting the use of high quality vaccines and coordination of focussed vaccination campaigns. Seven years after the world-wide campaign was launched, the last case was reported in 2001 in buffalos of Kenya. In 2006 the last known use of vaccine was reported. The World Organisation for Animal Health (OIE) proclaimed May 25, 2011 that all 198 countries and territories with rinderpest-susceptible animals were free of the disease and at press time, on June 28, 2011 the Food and Agriculture Organization of the United Nations announced world free from rinderpest (Roeder *et al*., 2013).

FAO and GREP have relied on partnerships with the OIE as well as regional organizations that include the African Union and South Asian Association for Regional Cooperation along with numerous donor agencies. The donor agencies include the European Union and the United States Agency for International Development; United Kingdom Department for International Development (DFID) etc. For rapid control of rinderpest in several situations funding of the Technical Cooperation Programme project of FAO have been used. This has also helps in undertaking activities for promoting strengthening of laboratory diagnostics along with planning of emergency preparedness and surveillance; capacity building. This rapid response capability is possessed by few donors and it is an FAO function which has been appreciated highly by recipient countries. The GREP secretariat in addition has contributed in addition to the standard-setting activities of the OIE that include drafting as well as revising the OIE pathway. In developing surveillance strategies along with other guidelines for confirming eradication it also has played a crucial role (www.fao.org/ag/grep/html).

Ultimately centuries of advances in veterinary science and technology has culminated in the year 2011 with the declaration of rinderpest eradication globally by the FAO and World Health Organization (WHO). This success has become possible especially due to the development of innovative strategies for the last mile for overcoming diagnostic as well as surveillance challenges during the last decade (Roeder *et al*., 2013).

The eradication of rinderpest is a remarkable achievement for veterinary science, every veterinarian everywhere and it shows the evidence of national commitments to public good as well as progress of the veterinary profession, both in developed as well as developing countries that are still developing in their veterinary infrastructures. This successful mission for eradication was only possible by collaboration and teamwork of animal health professionals from multiple countries under the leadership of FAO.

Existing challenges for eradication: The increased knowledge of geographical distribution of disease and presence of suitable infrastructure in India motivated us to raise the question whether there are any other infections or diseases that could be considered for elimination. This can be answered as Foot-and-mouth disease (Biswal *et al*., 2012; Verma *et al*., 2012b), peste des petites ruminants (Singh *et al*., 2009), Brucellosis (Renukaradhya *et al*., 2002) and Bovine Herpes Virus-1 (Mars *et al*., 2001; Singh *et al*., 2013a; Verma *et al*., 2012c). These are having candidature for effective control programme and further stage of eradication.

Foot-and-mouth disease: Foot-and-Mouth Disease (FMD) is an acute highly contagious disease of cloven hoofed animals and causes high morbidity (upto 100%) and mortality particularly in young animals (50%) (Verma, 2008; Verma *et al*., 2008a, 2012b; Naranjo and Cosivi, 2013). The disease is caused by seven serotypes (O, A, C, Asia-1, SAT-1, 2 and 3) of *Apthovirus* of Picornaviridae family and characterized by pyrexia, salivation, vesicles on mouth, gums, tongue and feet. In India, FMD remains endemic and was first officially documented in 1864 during extensive outbreaks in many parts of the country (Government of India, 1868). The disease is endemic in India with only four prevalent serotype (O, A, C and Asia-1) and causes direct and direct losses (Verma *et al.*, 2008a, 2010a, 2012b). The disease is the most important constraint on international trade in animals and animal products. As per the report of an English daily "The Financial express" newsdaily April 24, 2008, India annually suffers a staggering revenue loss of about Rs 20,000 crores due to FMD that affects the bovine population (Venkataramanan *et al.*, 2006; Verma *et al.*, 2012b). About 80% of total direct loss due to FMD is by reduction in milk production (Mathew and Menon, 2008). Various diagnostic tests viz., sandwich ELISA (Bhattacharya *et al.*, 1996; Singh *et al.*, 2007b, 2012), liquid phase blocking ELISA (Hamblin *et al.*, 1986; Singh *et al.*, 2007a, 2008; Verma *et al.*, 2009), Reverse Transcription Polymerase chain Reaction (RT-PCR) (Reid *et al.*, 2001; Mohapatra *et al.*, 2007; Verma, 2008; Raies-ul-Islam *et al.*, 2009; Verma *et al.*, 2010c, 2012b), Non Structural Protein-ELISA (Verma *et al.*, 2010a, b, c, 2012b) are available for the diagnosis of the disease with good sensitivity and specificity along with cell culture based live attenuated vaccine. In 1929, Indian Council of Agricultural Research (ICAR) had started research on FMD. In 1968, epidemiological studies on FMD in India were initiated by ICAR as "All India Co-ordinated Research Project (AICRP) for virus typing" with a central laboratory at Mukteshwar, Nainital, Uttarakhand and 3 regional centres. Later on, the project was expanded in 1971 to "AICRP for Epidemiological studies on FMD" with addition of 4 more regional centres. Currently the project directorate has 8 regional centres and 15 network units covering the length and breadth of the country (Biswal *et al.*, 2012). In 1982, National Dairy Development Board (NDDB) of India initiated a Pilot project for the FMD control in the Nilgris district of Tamil Nadu with financial and technical assistance from the Overseas Development Administration of the UK. All cattle, buffaloes, sheep and goats were vaccinated at six-monthly intervals. In 1984, the programme was extended to 23 districts later on 29 districts of the southern peninsula covering Tamil Nadu, Kerala and Karnataka in a phased manner to. However, as project region was extended further north it encountered serious problems related to difficulties in controlling animal movement e.g., the transhumance of small ruminants and a critical short-fall in the availability of vaccine. The knowledge generated in epidemiology, diagnosis and surveillance of the disease in India has been instrumental in formulation of FMD control programme through regular biannually vaccination with the objective to create disease free zones (Biswal *et al.*, 2012). Baby Hamster Kidney (BHK) suspension culture technique is used by all the manufacturers for manufacturing the tissue culture vaccine which is oil adjuvated and aluminium hydroxide precipitated; along with binaryethyleneimine (BEI) inactivated. Harmization of the strains for production of vaccines in India has been harmonized by the Project Directorate on FMD (PDFMD), Indian Council of Agricultural Research (ICAR), Government of India. For marketing of vaccines in a proper way validation of inactivation kinetics must be undertaken by manufacturers of vaccines for introduction of new batches of BEI. Along with this the vaccine potency must be increased to 6 PD_{50} along with which post-marketing surveillance must be made mandatory (Remond *et al.*, 2002; Aarthi *et al.*, 2004).

FMD control programme: Both globally as well as in India economic consequence is the primary driver to control FMD. Notification to the authority on priority basis along with sero-monitoring and sero-surveillance of non-vaccinated and vaccinated animals; animal movement restriction (both inter-state as well as transboundary) are the major measures that are needed to be undertaken (Grubman and Buxt, 2004; Verma *et al.*, 2008a; Nishiura and Omori, 2010; Longjam *et al.*, 2011). In 2004, Government of India launched Foot and Mouth Disease Control Programme (FMD-CP) in 54 specified districts of the country in the first phase with 100% central funding as cost of vaccine, cold chain maintenance and logistic support to undertake vaccination with the objectives like prevention of economic losses due to FMD and development of herd immunity in cloven-footed animals (Singh *et al.*, 2008; Verma *et al.*, 2009, 2012a). Due to impact of regular vaccination and building up of herd immunity only a few sporadic cases of FMD could be recorded in the states like Punjab and Haryana. With the success of the FMDCP in 54 districts, additional 167 districts (means another 80-90 million cattle and buffalo) have been included under the programme in 2010-11 bringing total districts under FMD-CP to 221 covering states of Southern peninsula (Kerala, Tamilnadu, Puducherry, Karnataka and Andhra Pradesh), Maharashtra, Goa, Daman and Diu, Gujarat, Punjab, Haryana, Delhi, Dadra and Nagar Haveli andaman and Nicobar Islands, Lakshadweep and 16 districts in Uttar Pradesh. Recently, a proposal was put forward to establish of a National FMD Commission for the coordination of activities related with FMD control programme. In 2011-12, about 115.9 million animals have been vaccinated against FMD (DADH, 2013). Due to limited resources, the use of vaccines based on epidemiological data for controlling FMD in India has several challenges that have to overcome and become the matter of discussion.

Recent molecular diagnostic tools, effective disease surveillance/monitoring systems are required to be applied widely for detecting FMD virus and its disease outbreaks in animals so as to follow appropriate prevention and control measures timely (Clavijo *et al.*, 2004; Longjam *et al.*, 2011; Mohapatra *et al.*, 2011; Deb and Chakraborty, 2012; Deb *et al.*, 2012a, 2013b; Verma *et al.*, 2012b; Madi *et al.*, 2012; Teifke *et al.*, 2012; Madhanmohan *et al.*, 2012; Xu *et al.*, 2013; Chakraborty *et al.*, 2014). Apart from strengthening diagnostics and use of available vaccines, potential of novel advances in vaccines and vaccination strategies, immunomodulatory and alternative/emerging therapeutic modalities also need to be explored, supported with proper prevention and control measures for curbing disease outbreaks and incidences of FMD (Bae *et al.*, 2009; Parida, 2009; Gakuya *et al.*, 2011; Rodriguez and Gay, 2011; Deb *et al.*, 2012a; Dar *et al.*, 2012; Kim *et al.*, 2012; Li *et al.*, 2012; Subramanian *et al.*, 2012; Pattnaik *et al.*, 2012; Uddowla *et al.*, 2012; Ayelet *et al.*, 2013; Ding *et al.*, 2013; Zheng *et al.*, 2013; Chakraborty *et al.*, 2014).

Peste des petits ruminants (PPR): Peste des Petits Ruminats (PPR) is an acute highly contagious disease disease of sheep and goats present worldwide and causes high morbidity and mortality that may reach upto 100 and 90%, respectively (Kumar *et al.*, 2006, 2013a; Munir *et al.*, 2013). The disease is caused by morvilivirus of family paramyxoviridae (Van Regenmortel *et al.*, 2000; Munir *et al.*, 2013) and characterized by pyrexia, occulo-nasal discharge, necrotising and erosive stomatitis, pneumonia and enteritis (Singh *et al.*, 2009). Since, the first report of PPR from Arasur, Tamil Nadu (Shaila *et al.*, 1989), the disease is endemic with 33% sero-prevalence in India (Pal *et al.*, 2007; Balamurugan *et al.*, 2012; Kumar *et al.*, 2013a) and neighbouring countries viz., Bangladesh, Nepal and Pakistan (Sinha, 1998). The disease causes direct and direct losses. In an estimate, the disease alone accounts for direct economic losses of 3.6 million USD, if overall mortality rate is considered as 5% (Venkataramanan *et al.*, 2005) but this figure may reach upto 13 million USD at mortality rate of 17 and 29% for sheep and goats, respectively. A battery of diagnostic tests viz., sandwich ELISA, competitive ELISA, Reverse Transcription Polymerase chain

Reaction (RT-PCR), RT-PCR ELISA are available for the diagnosis of the disease with good sensitivity and specificity along with three effective cell culture based live attenuated vaccine (one from African isolate and two from Indian isolates) (Singh *et al.*, 2009). This disease is also having some specific features like rinderpest such as rapid spread in susceptible population, maintenance of virus in host, seasonal occurrence etc. (Anderson, 1995; Lancelot *et al.*, 2002; Abubakar *et al.*, 2009). To decrease the incidence of PPR, better knowledge of sheep and goat population dynamics, herd management and restriction of animal movement, co-ordination of farmers, veterinary professionals and animal health workers are utmost important and play a crucial role. In India, PPR Control Programme was started in 2010 with 100% central assistance in vaccination of susceptible animals (sheep and goat) and three subsequent generations. In the first phase, states viz., Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Goa and Union Teriitories like Lakshadweep, Daman and Diu, Dadra and Nagar Haveli Andaman and Nicobar Islands and Puducherry were covered. This control programme will remain continue in the next phase.

Bovine herpes virus (BoHV)-1 infection: Infectious Bovine Rhinotrachitis (IBR) is highly contagious disease of animals caused by Bovine herpesvirus-1 (BoHV-1), a member of the genus Varicellovirus, family Herpesviridae, subfamily Alphaherpesvirinae and lead to different clinical syndrome such as Infectious Bovine Rhinotracheitis (IBR), Infectious Pustular Vulvovaginitis (IPV), infectious pustular balanoposthitis (IBP), abortion, conjunctivitis, encephalitis (Lata *et al.*, 2009; Nandi *et al.*, 2009; Jacevicius *et al.*, 2010; Raaperi *et al.*, 2012) and generalized symptoms in young calves (Raizman *et al.*, 2011). The disease affects primarily respiratory and genital tract. The disease was first time reported in India from Uttar Pradesh and then spread in different states of the country (Mehrotra *et al.*, 1976; Renukaradhya *et al.*, 1996; Rajkhowa *et al.*, 2004; Nandi *et al.*, 2011). In India, the seroprevalence of IBR in animals is within the range 14.75-68.90% (Singh and Sinha, 2006; Ganguly *et al.*, 2008; Lata *et al.*, 2008; Nandi *et al.*, 2011; Verma *et al.*, 2014a). The effective conrol measures for this important disease are screening, surveillance and monitoring along with vaccination (Raizman *et al.*, 2011). Farm management that includes hygienic measures, schedules of vaccination along with removal of animals that are infected forms the basis of prevention and control of BoHV-1 infection. For cattle that are newly introduced quarantine for 4 weeks period is imposed ideally provided the animals are not from certified farms that are BoHV-1 free. Inclusion of only those cattle that are BoHV-1 seronegative is taken into account then. Mating the animals naturally must be avoided and use of semen from solely BoHV-1 negative bulls must be given priority. Both attenuated as well as inactivated vaccines against BoHV-1 are available currently. Such vaccines have undergone multiple passages in cell culture. Certain strains of vaccine virus have a phenotype that is sensitive to temperature without replicating at temperatures of 39°C or higher. Administration of attenuated vaccines is done either intranasally or intramuscularly. High levels of inactivated viruses are contained in inactivated vaccines. Portions of the glycoproteins of the virus supplemented with an adjuvant have been used for stimulating immune response adequately. Inactivated vaccines against BoHV-1 must be used either intramuscularly or subcutaneously. In several countries vaccines that can differentiate between infected and vaccinated animals are used widely. Such vaccines are either attenuated or inactivated marker vaccines which are based on deletion mutants (gE deleted) or are based on a virion sub unit like glycoprotein D. In countries or regions wherein animals infected with field virus are more infected and vaccinated animals can be distinguished by the use of such marker vaccines in association with companion diagnostic tests. This also forms the basis of eradication programme of BoHV-1. The prevalence of infected animals can be reduced by the use of intensive vaccination programme. The ultimate goal of the vaccination programme however should be protecting the animals from the outcome of infection clinically along with aiding in control as well as eradication programme (Perrin *et al*., 1993; Suresh *et al*., 1999; Mars *et al*., 2001).

Brucellosis: Brucellosis is highly contagious disease of cattle, buffalo, sheep, goats, pig, dogs and human (Kumar *et al*., 2009; Neha *et al*., 2013). *B. abortus* biotype-1 in cattle and buffaloes and *B. melitensis* biotype-1 in sheep, goats and man are the predominant infective biotypes (Chand *et al*., 2012). The disease is characterised by abortion, retained placenta, orchitis, epididymitis and, rarely, arthritis, with excretion of the organisms in uterine discharges and in milk (OIE, 2008). Since, the first report of brucellosis in 1942 from India, the disease is endemic now. The long-term serological studies showed that 5% of cattle and 3% of buffaloes are infected with this disease (Renukaradhya *et al*., 2002). The disease causes significant economic losses to dairy industry. Various diagnostic tests viz., Rose Bengal plate Test (RBT) (Alton *et al*., 1988), ELISA (Chand *et al*., 2005) are available for the diagnosis of the disease with good sensitivity and specificity along with various vaccines. The selection of strategy for brucellosis control in animals could vary from nation to nation and even ecologically distinct areas within the nation, depending on the prevailing epidemiological and socioeconomic factors. For eradication of the disease, test and slaughter policy is feasible when incidence of the disease is very low (WHO, 1986) and adequate financial support is available. In the developing countries like India, where the disease is endemic and widespread, control by immunization of animals is strongly recommended as the preliminary step for the final elimination of infectious agent. In a closed population such as on a farm, where re-entry of infection can be prevented, diagnostic facility is available and vaccination of clean animals is coupled with removal of reactors, the success of controlling brucellosis and achieving rapid elimination of the infectious agent from the area/flock is very high (Alton, 1987). Therefore, the basic problems of ban on cow slaughter, distress sale of animals following positive serological diagnosis, availability of indigenous serum and milk based diagnostic test and calf-hood vaccine arises the need to start the National Control Programme on Brucellosis (NCPB). By reduction in abortion, new calves will be added that will lead to increased milk production. The cost of one dose of *Brucella abortus* strain-19 is Rs. 20 calf^{-1} that will give a long lasting immunity. Therefore, in 2010 almost 100% assistance is given to states and union territories for the vaccination against *Brucella* in endemic areas.

There are two vaccines available against *B. abortus* viz., Strain 19 and RB-51 that can be used for controlling the disease wherein there is endemicity or can be used as a part of programme to eradicate the disease. In order to minimize the production of antibodies that are persistent in nature interfering with serological tests often vaccination is done in calves routinely. RB51 has replaced Strain 19 by and large in the United States and is less likely to induce antibodies that are persistent in nature and for humans is considered as safer. Vaccination however should be avoided in cattle that are pregnant as both the vaccines are live in nature (Manthur and Amarnath, 2008; Deb *et al*., 2012b). For brucellosis control strategies are based on vaccination of susceptible population and test and slaughter/separation, other complementary tools like animal identification and registration system, certification of holding's health status, control of livestock movements and gatherings in livestock trade fairs, market and establishment shows, compensation to farmers for obligatory slaughter of animals should also be considered (Crespo Leon *et al*., 2012).

Other important diseases including zoonosis needing attention and implementation of effective countering strategies: Other important infectious diseases of animals that need proper attention include diarrhoea (associated with rotavirus, coronavirus, parvovirus, *Escherichia coli* (Malik *et al*., 2013a; Kumar *et al*., 2013b, 2014), Haemorrhagic Septicaemia (HS), black quarter, anthrax, *Campylobacter* infections (Kumar *et al*., 2012a, b, 2013a), tuberculosis, paratuberculosis (Singh *et al*., 2013b, 2014a), mastitis (Deb *et al*., 2013a), mycoplasma infections, protozoan diseases and others (Kumar *et al*., 2011, 2012b; Singh *et al*., 2014b). Economically important poultry diseases viz., avian influenza, infectious bursal disease, Newcaste disease, Marek's disease, infectious bronchitis, chicken infectious anaemia, hydropericardium syndrome, salmonellosis (fowl typhoid, pullorum disease), colibacillosis, fowl cholera, chlamydiosis and others also require proper prevention and control measures as well as implementation of eradication approaches for alleviating economic losses to poultry producers (Leslie, 2000; Saif *et al*., 2003; Kataria *et al*., 2005, 2013; Dhama *et al*., 2009, 2013b, c, d; Bhatt *et al*., 2011; Singh *et al*., 2012; Sumi *et al*., 2012; Barathidasan *et al*., 2013). Along with these infectious diseases of livestock and poultry, special care need to be emphasized for diseases/pathogens having high zoonotic impacts and pandemic threats like rabies, plague, anthrax, brucellosis, salmonellosis, leptospirosis, listeriosis, tuberculosis, glanders, West Nile virus, avian flu (bird flu), swine flu and others which are posing lurking dangers to the animal health and production as well as life of humans (Bengis *et al*., 2004; Zinsstag *et al*., 2007; Verma *et al*., 2007, 2008b; Kumar *et al*., 2009; Pawaiya *et al*., 2009; Dhama *et al*., 2005, 2008b, 2011, 2012b, 2013d, e; Osburn *et al*., 2009; Cascio *et al*., 2011; Grunkemeyer, 2011; Verma *et al*., 2014b, c). Nowadays, viral encephalitis, dengue, chikungunya, Crimean Congo hemorrhagic fever are also emerging in our country (Dhama *et al*., 2013e, f, g; Goswami *et al*., 2014). Wild animals and migratory/wild birds, important reservoirs of various disease causative pathogens, also play crucial roles in transmission of various infectious pathogens/diseases like avian/bird flu, Hendra and Nipah viruses, West Nile virus, rabies, viral encephalitis, brucellosis, leptospirosis, psittacosis, plague, tuberculosis and others which pose threat to animal and poultry production as well as human health (Daszak *et al*., 2000; Bengis *et al*., 2004; Dhama *et al*., 2005, 2008b, 2013d, e; Zinsstag *et al*., 2007; Ahmed *et al*., 2012; Sakoda *et al*., 2012). In this context, prevention and control of wild life diseases, vector-borne infectious diseases, emerging/re-emerging pathogens and checking their transmission and spread to animals and humans is also of paramount importance (Taylor *et al*., 2001; Daszak *et al*., 2000, 2004; Bengis *et al*., 2004; King, 2004; Chakraborty, 2012; Dhama *et al*., 2013e, f). Recent episodes of various infectious diseases like Severe Acute Respiratory Syndrome (SARS), bird flu (H5N1), swine flu (H1N1) necessitates corrective global health measures and effective planning, preparedness and immediate responses for countering these highly devastating diseases (Slingenbergh *et al*., 2004; Amonsin *et al*., 2008; Pawaiya *et al*., 2009; Ali *et al*., 2012; Dhama *et al*., 2005, 2012b, 2013d, f).

KEY FACTORS, ADVANCES AND SALIENT POINTS TO COUNTER INFECTIOUS DISEASES

Multidisciplinary approaches and coordinated/collaborative activities at International and national as well as local levels are warranted for tackling and eradication of infectious diseases of animals. This would help in alleviating economical losses being suffered due to huge burden of infectious diseases by the livestock and poultry producers/industry and lessen the burden of zoonotic pathogens. In this regard, the importance of One Health, One World, One Medicine

Concept need to be kept in mind and necessary steps and strategies must be implemented to achieve the novel goal of eradicating and eliminating important animal and human pathogens, or lessening their disease burdens, outbreaks, epidemics, incidences and socio-economical impacts (Osburn *et al.*, 2009; Dhama *et al.*, 2013f). For this purpose, few of the burning global issues need proper attention and due care viz., emerging global warming and climate changes, population explosion, liberalization and globalization, international trade and travel/tourism, modernization and industrialization, changes in ecosystem and biodiversity, increasing emergence and re-emergence of infectious and zoonotic diseases with their global spread and pandemic threats, food safety matters, lack of effective treatment modalities for viral diseases, challenges of emerging antimicrobial resistance (drug resistance), complexity of human-animal relationships, changes in life style and food habbits, increase in consumption of animal proteins, intensified animal production systems and immune pressures (WHO, 2006; Jones *et al.*, 2008; Wittemyer *et al.*, 2008; Bloom, 2011; Dhama *et al.*, 2013f, g; Tiwari *et al.*, 2013). These variables and changes have given rise to increased exposure of animals and humans to newer and emerging/re-emerging pathogens, maintaining and developing diseases, along with their increased zoonotic impacts which need appropriate veterinary and medical attention (Morse, 1995; Taylor *et al.*, 2001; Slingenbergh *et al.*, 2004; Patz *et al.*, 2005; Rogers and Randolph, 2006; Kahn *et al.*, 2007; Nolen and Kahler, 2007; Wolfe *et al.*, 2007; Myers and Patz, 2009; Osburn *et al.*, 2009; Pawaiya *et al.*, 2009; Ahmed *et al.*, 2012; Dhama *et al.*, 2012b, 2013d, e, f; Mahima *et al.*, 2012a). Also, emergence of pathogens with antimicrobial drug resistance is nowadays a problem of much concern, like for Mycobacterium, Campylobacters, *Salmonella*, *Escherichia coli*, *Staphylococcus aureus* infections and others (Cosivi *et al.*, 1998; Gupta, 2001; Hamburg and Lederberg, 2003; Kumar *et al.*, 2012a; Tiwari *et al.*, 2011, 2013). Trends and advances in diagnostics tools/techniques of molecular biology, biotechnology and nanotechnology along with effective disease surveillance, strengthening of networking programmes and early warning systems must be exploited to their full potentials for rapid, confirmatory and timely detection of economically important infectious pathogens of animals (Black *et al.*, 2002; Kataria *et al.*, 2005; Balamurugan *et al.*, 2010; Schmitt and Henderson, 2005; Belak, 2007; Bollo, 2007; Ratcliff *et al.*, 2007; Siddiqui, 2010; Bergquist, 2011; Taddele *et al.*, 2011; Deb and Chakraborty, 2012; Dhama *et al.*, 2010, 2012a, 2013f, h, 2014; Deb *et al.*, 2013b). Regional and local disease surveillance, monitoring and networking systems need to be supported with highly sensitive and specific diagnostics including of conventional, serological and molecular tools and field level/pen-side diagnostic tests to detect pathogens in a rapid way and at the earliest so that effective and time diseases prevention and control strategies can be implemented timely. There is utmost need of implementing a judicious and regular vaccination programmes against various infectious diseases with wider applicability and positive impacts. Recent advances and developments in vaccines, immunomodulation and treatment regimens need to be explored with their fully potentials along with formulating and implementing effective prevention and control strategies for countering infectious diseases of animals, thus lessening their economical impacts and public health concerns (Meeusen *et al.*, 2007; Dhama *et al.*, 2008a, 2013a, i, j, k; Mahima *et al.*, 2012b; Tiwari *et al.*, 2011, 2012, 2014a, b, c, d; Amarpal *et al.*, 2013; Bhatt *et al.*, 2013; Malik *et al.*, 2013b; Rahal *et al.*, 2014; Saritha *et al.*, 2014; Singh *et al.*, 2014b, c). Innovations for safer and effective new generation vaccines and advanced vaccine delivery systems are the need of the hour. Good management practices, strict biosecurity measures including of good hygiene and sanitation practices, isolation and quarantine, curbing the disease on the spot/at local level and checking its spread, appropriate trade restrictions and other preventive and control measures require special attention and effective implementation. Strengthening of research and development activities and following a holistic approach would help alleviating economic losses being caused by various infectious diseases of animals and altogether safeguard health of animals and humans and boost animal production and economy of the country in the right directions.

CONCLUSION AND FUTURE PERSPECTIVES

Significant animal health issues and other direct and indirect benefits compel us for eradication of animal diseases. Eradication of some diseases like smallpox in human and rinderpest in animals has already occurred but not easy for many other diseases like FMD, PPR etc. The existing physical infrastructures created during rinderpest eradication programme would help to mount the other disease control programme. Today the dynamicity of pathogens in terms of antigenic and genetic diversity and the movement of animals are putting the challenges to control. However, by the firm commitment, will and dedication of animal health professional the goal can be achieved. Most importantly, veterinarians, animal health researchers and other para-veterinary staff will have to take a leadership role in making suitable control strategies for combating and eradicating important infectious diseases of animals, thereby increasing the livestock production and alleviating poverty in the country initially and continents of Asia thereafter. So, a careful analysis like knowledge of epidemiology, quick and effective diagnostic techniques, quantity and quality of vaccines and support of the public and regulatory backing is needed before going for these control strategies. The brucellosis, due to its economic importance, ban on slaughtering and availability of effective diagnostic tools not only for diagnosis but also for differentiation of vaccinated and infected animals along with good protective vaccine, appears the disease to be targeted. *Bovine herpes virus* control through improved farm management and use in large scale of advanced vaccine (marker vaccines) are quiet challenging and should also be kept under prime focus of a veterinarian. Efforts must be taken in order to control the diseases of wild life at the same time as well. Training and curricula must be developed by veterinary institutions for allowing veterinarians to engage effectively in missions that are envisaged by the Office International des Epizooties (OIE) for the purpose of participating in animal welfare programmes globally. In summary, in the 21st century the development in the field of scientific medical practices has led to a much greater understanding of disease epidemiology and will further help in eradication of several economically important diseases of livestock and wild life in near future as well.

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