*Research Paper*

**An integrated approach to developing an anthrax-free model area in Bangladesh**

Md. Shahjahan Ali Sarker1, Md. Ahosanul Haque Shahid1, Md. Muket Mahmud1, Ajran Kabir1, Md. Bahanur Rahman 1, Md. Asaduzzaman Sarker 2, Ratna Parvin3, K. H. M. Nazmul Hussain Nazir 1,\*

1. Department of Microbiology and Hygiene, Faculty of Veterinary Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
2. Department of Agriculture Extension, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
3. Department of Animal Nutrition, Faculty of Veterinary, Animal and Biomedical Sciences, Sylhet Agricultural University, Sylhet, Bangladesh.

**\*** Correspondence: [nazir@bau.edu.bd](mailto:nazir@bau.edu.bd) (K.H.M.N.H.N.)

**ABSTRACT**

An integrated approach was sought to establish an anthrax-free model, where there will be no anthrax in an anthrax-prone area of Bangladesh. The integrated approach included regular vaccination, increased public awareness, rapid confirmation, and prompt disposal, setting up an effective surveillance system, developing an emergency prevention system, enforcing regulations, and enhancing veterinary services' collaboration. Before the research work, a study area reported anthrax in cattle or humans almost every one or two years. The location remains Jamtoil village in Kamarkhanda Upazila of Sirajganj district located between 24°18' and 24°27' north latitudes and amidst 89°35' and 89°42' east longitudes. Numerous interventions that included both social and laboratory work were implemented from 2017 to 2020. After rigorously implementing the study works, it showed that most community members (97.5%) were aware of the nature, occurrence, public health importance, and management of the disease. The risky habits and attitudes of the farmers toward the slaughtering of sick cattle reduced significantly (<85%). Vaccination coverage expanded from 40 to 85%, and the percentage of farmers who can presumptively diagnose anthrax by its notable clinical findings has increased from 30% to 85%. A PCR-based confirmation protocol was applied. Soil samples were collected to examine the pathogenic spores of *Bacillus anthracis*, and researchers developed a map so that the farmers in the area would be more cautious about grazing their cattle. A steering committee was formed with the administration, law enforcement agency, local government, livestock, health department, and political elites. This committee periodically reviewed the progress of research work. At the beginning of the investigation, the score was 18, but after implementing research interventions, it increased to 100 out of 120. The locals set up a slaughterhouse in that region, and people slaughtered their animals after examining their animals by qualified veterinarians. As a result of all these works, the model area has been free of anthrax infection for four years. The research finding concluded that the integrated approach is an efficient, effective, and suitable method to establish an anthrax-free model area where there will be no anthrax outbreak.

**Keywords:** Anthrax, model, integrated approach, interventions, livestock.

1. **INTRODUCTION**

Anthrax is an infectious disease caused by the spore-forming bacterium *Bacillus anthracis*,having zoonotic importance.It is an OIE-listed disease and must be reported to the OIE as indicated in its Terrestrial Animal Health Code (OIE, 2012). Carlson et al. (2019) mentioned that globally an estimated 20,000 to 100,000 cases occur annually, as an estimated 1.8 billion people live within anthrax-suitable areas, the vast majority of whom live in rural areas in Africa, Europe, and Asia. Anthrax is more common in developing countries and countries that do not have veterinary public health programs that routinely vaccinate animals against anthrax. Before developing the vaccine in the 1930s, anthrax was regarded as a disease of major health or economic importance. It was the foremost cause of uncontrolled mortality in cattle, sheep, goats, horses, and pigs worldwide (WHO, 2008). The disease is still enzootic worldwide, and *B. anthracis* has always been high on the list of potential agents concerning biological warfare and bioterrorism (Spencer, 2003; Thavaselvam and Vijayaraghavan, 2010). Several countries in temperate or cool parts of the globe, for example, Scandinavian countries in the northern hemisphere and New Zealand in the southern hemisphere, have harbored anthrax in the past through importation of contaminated animal materials, have now become free of the disease through appropriate import controls. Other countries are striving to do the same, and several smaller countries have succeeded, such as Belize, Cuba, Cyprus, Czech Republic, Iceland, Ireland, Jamaica, Malta, and Taiwan. Malaysia has also succeeded in becoming anthrax-free (Rahim, 1997). Many European countries, North America and Australia, controlled the anthrax disease. The disease is absent or only sporadic in those countries (Inglesby et al., 2002, Wiesen and Littell, 2002, Mongoh et al., 2008). In Africa, Zambia was identified as a model country for the anthrax control program (WHO, 2006). Regular vaccination increased public awareness, and proper quarantine was considered a major strategy to control anthrax worldwide (Odontsetseg et al., 2007; Simbotwe et al., 2019).

Anthrax is common among domestic ruminants (Rume, 2018). Samad and Hoque (1980) reported the first anthrax case in 1980. Mustafa (1984) first isolated *B. anthracis* from an elephant. Although anthrax has been reported in Bangladesh since 1980, the outbreak was severe from 2008 to 2010, affecting 58 districts out of 64. Still, outbreaks have been reported almost every year in some districts. After that, anthrax outbreaks have persistently been recorded every year in animals and humans from different country areas. Institute of Epidemiology, Disease Control and Research (IEDCR), Bangladesh, reported a total 1802 of the human case of anthrax from 2010 to 2019. However, the actual incidence of anthrax in livestock in Bangladesh is unknown, most owing to under-reporting and reluctance to report by the Department of Livestock Services (DLS). Only after the human outbreak of anthrax and tremendous interest of the media made the situation of reporting anthrax. From 2010 to 2012, 5937 animal anthrax were reported, mostly in rural areas in Bangladesh (Mondal and Yamage, 2014). Due to repeated outbreaks causing the deaths of hundreds to thousands of animals negatively impacts overall livelihoods and can also restrict international markets. The outbreak of anthrax has a direct and indirect effect on the country's national economy and negatively impacts overall livelihoods. Livestock is an integral component of the agricultural economy of Bangladesh, performing a central role in the livelihoods of poor people. Financial loss due to anthrax disease is not fully calculated. In 2010, from August to October, the Government of Bangladesh declared a red alert for three months. A Germany-based dairy research center named International Farm Comparison Network (IFCN) calculated the loss and reported beef prices decreased by 126%, 17% foreign exchange slipped, and tannery industries fell sharply. And their estimated loss was USD 85 million (Rume, 2018).

Based on the previous reports, it was concluded that lack of efficacy of human anthrax treatment, inadequate vaccination program, improper washing of grass before feeding, lack of awareness of anthrax and transmission, the slaughter of moribund cattle, selling meat from cattle that died of unknown causes to the community were associated with the repeated outbreak of anthrax in Bangladesh (Samad, 2011; Siddiqui et al., 2012; Chakraborty et al.,2012; Islam et al.,2013; Fasanella et al., 2013; Ahsan et al., 2013; Hassan et al., 2015). Every year, sporadic outbreaks of animal anthrax occur in some Bangladesh districts, followed by human anthrax.

Most studies have identified the gap of repeated anthrax outbreaks but have no studies on filling the gap. Through successful research and national planning, we can also control this disease in Bangladesh. The present study developed an anthrax-free model area by implementing integrated approaches.

1. **MATERIALS AND METHODS**

The methodology of the research work was based on the combination of social and microbiological outcomes at the community and laboratory levels. These included Area Selection, implementation of an Integrated Approach, Monitoring, and Evaluation Process. The various methodologies were figured out using data from past research findings and following international guidelines and were led by an advisory committee consisting of a special technical team. Although the research work was predetermined at distinct stages, it was flexible and open to maximum output.

**2.1 Study area**

Jamtoil village of Kamarkhanda Upazila is one of the dense cattle populated villages, located between 24°34' and 24°36' north latitudes and in between 89°64' and 89°68' east longitudes (Figure 1). The diameter of that area is 4.68 sq. kilometers. Repeated anthrax outbreaks in 2010, 2011, 2012, 2014, and 2016 were seen in this village, and it was reported in a different local and national newspapers.

**2.2 Situation assessment**

A situation assessment was done by using the process of transect walk, key informant interviews, surveys, and focus group discussions in the model area before starting the integrated approaches. The objective of this situation assessment was to know the overall situation like socio-economic condition, anthrax related knowledge, skill and practice, existing husbandry practice, carcass disposal method, vaccination rate, disease management, existing law regarding livestock, slaughter policy, the role of law enforcing agencies to prevent the slaughter of a sick animal, market inspection, etc., in that particular area. It gave us a guideline for our overall work, and helped us to prioritize our activities plan. On the other hand, those values served as baseline values that enabled us to monitor and evaluate our works' overall progress.

**2.3 Integrated approaches model**

We had seven approaches (Figure 2) which we called integrated approaches. First Vaccination, Second Community Awareness, Third Confirm diagnosis and prompt disposal facilities, Forth Surveillance, Fifth Emergency prevention system, Sixth Implementation of existing law regarding animal slaughter, and finally, strong collaboration between Animal and Human health departments.

**2.3.1 Approach-1: Cattle Vaccination**

All cattle over six months were covered under a mass vaccination program through a door-to-door visit. Cows more than six months pregnant were not vaccinated. In addition, twice a year, free deworming of cattle were provided to all the animals in the model area. After each vaccination campaign, a livestock census was performed.

**2.3.2 Approach-2: Community Awareness**

Bangladesh Agricultural University and Livestock department jointly developed vaccination card, disease information card, Billboard, Leaflet, script for proclamation, the module for training, session guide for yard meeting, resourced based area mapping. Build a network with different stakeholders to reach the critical message in the community. A customized information card of anthrax disease was used for the awareness program. Regular announcing, leaflet, poster and brochure of illness distributions, pictorial billboard setup, newspaper reports, and key message broadcast using local cable channels were applied as a standard method to raise awareness about anthrax disease. Primary and High school training programs, sensitization workshops, meat market inspections, butcher's training, farmer's training were added to improve knowledge, skill, and practice levels. Speaking out by law enforcement agencies, Imam (religious leader), politically influenced persons strengthened the disease

**2.3.3 Approach-3: Confirm diagnosis and Prompt disposal facilities**

Kit based DNA extraction protocol and a real-time PCR based qualitative detection method were used. Using TaqMan real‐time PCR, specific primers and probes were used to identify pathogenic *B. anthracis* strains from S*ap* gene on S-layer locus, *Pag* gene, and *Cap* gene on two plasmids pXO1, and pXO2.

**2.3.4 Approach-4: Surveillance**

Both active and passive surveillance was done. Regular commutation with the officer of Upazila Livestock and Health Departments, Paravet/ community vaccinators, meat sellers, community volunteers, village chowkidars, ward members, regular and need-based field visits as a part of active Surveillance and Secondary data collection from Upazila livestock department and Upazila Health complex patient register book was our part of passive surveillance. If any sudden death or suspected case find, it is informed to the research unit immediately by community providers like a para vet, meat seller, volunteer through mobile phone communication; after that research unit has taken necessary measures like sample collection, and contact with DLS, Upazila administration, etc (Figure 3).

**2.3.5 Approach-5: Emergency Prevention system**

Anthrax is a notifiable disease that means that if the disease occurs in an area, the authorities will inform the government. For Bangladesh, anthrax is a B-class disease according to the Animal disease act 2008. The research team made appropriate preparations to promptly ensure the detection work, such as collection and transportation of samples, preparation of used equipment, proper equipment for detecting the disease in the laboratory, and adequate storage for reagents. A deep burial method was recommended to dispose of Anthrax Carcasses and Contaminated Materials. Evaluate each animal before disposal and ensure that all body openings are plugged with an absorbent material (e.g., non-perforated paper towel, cloths, etc.) before a carcass is moved. 10% formalin was recommended for disinfection of the contaminated area.

**2.3.6 Approach-6: Implementation of existing law regarding animal slaughter**

The following legislation governed the livestock sub-sector in Bangladesh: Animal welfare act, 2019; Bangladesh Zoo Act, 2009 (Draft); Animals Slaughter and Meat Control Act, 2011; Fish Feed and Animal Feed Act, 2010; National Livestock extension policy, 2012 (http://www.dls.gov.bd/livestockdevpolicy.php). These existing laws and regulations were informed and implemented through mass community awareness and enforcement by public administration and law enforcement agencies.

**2.3.7 Approach-7: Strong Collaboration between human and animal health department**

The introduction of 'One Health' takes a holistic approach to addressing human, animal, and ecosystem health to mitigate and counter anthrax disease. The process calls for strong multi-sectoral and multidisciplinary collaboration, which moves beyond the strengthening of veterinary-public health systems to more clearly encompass disease control.

**2.4 Indicator for the presence of anthrax and targets set up**

Identification and reporting are more sensitive for human cases than for animal causes. Therefore, human case reports were our indicator for the presence of anthrax disease in our Model area. Some targets were identified to evaluate the progress of the research work, such as bringing at least 80% of the cattle population (more than R0 value) under the vaccination coverage, raising awareness of 90% of the people, positively changing the knowledge, skills, and attitudes of at least 75% of the farmers, collecting samples within 12 hours. The report was submitted within 24 hours, 100% of the dead animals were burial of in a scientific way, 100% of the health examination certificate was confirmed before slaughter.

**2.5 Monitoring and Evaluation Committee**

A monitoring and evaluation committee was formed locally, which evaluated the progress of research outcomes every six months. This committee was formed on the advice of renowned experts from the Department of Microbiology and Hygiene and the Department of Agricultural Extension, Bangladesh Agricultural University. The committee details are given in Table 1. The research team provided the committee with the logistical support that needed to meet regularly and checked the progress of each intervention that was fixed in the model area every six months. The indicator scores were determined considering the overall improvement of the works.

**2.6 Score of interventions for evaluating overall progressive (Monitoring tools):**

Since it was a combination of social and lab work, social work is not straightforward. We set up some monitoring tools that regularly helped evaluate the research progress. Some of the monitoring tools used to monitor the progress of anthrax research in the area were based on data from the situation assessment of the site and following international guidelines. Each instrument was again given a score based on its significance (Figure 4). Initially, the research tools and how long their scores would be evaluated and when they would be evaluated were also determined early in the research work. A score was given based on the discussion and consensus of all of them based on whether each indicator exists in the area or not, if it existed, whether it is very efficient, not efficient, less efficient, or not at all. This assessment was done regularly by the local committee—that committee chaired by Upazila Livestock Officer.

**Major activities are done during the study period**

During the study, several activities were carried out, which were covered under a single approach and covered multiple methods. Some of these were done once and some more than once. To be easily understood, lists of the works done during the study period are presented in Table 2.

**Data management and statistical analysis**

Data were summarized in Microsoft Excel 7 (Microsoft Corporation, Redmond, WA, USA) spreadsheet and statistically analyzed using Epi-Info 3.5.3 (CDC, Atlanta, USA). Descriptive analysis was performed, and results were expressed in frequencies and proportions. Categorical response variables like ELISA value, FGD findings, etc., were presented as proportions and their associations determined by chi-square tests. One-way analysis of variance (ANOVA) was used to compare baseline and evaluation survey data.

1. **RESULTS**

**3.1 Major finding after situation assessment of the model area**

Main sources of income Agriculture 47.06%, non-agricultural labourer 4%, industry 1.14%, commerce 16.57%, transport and communication 3.87%, service 8.70%, construction 0.87%, religious service 0.27%, rent and remittance 0.26% and others 17.26%. About 90% of the people in this model area are involved in cattle rearing. The landowner's ownership of agricultural land is 57.74%, landless is 42.26%, agricultural landowner: urban 39.18%, and rural is 59.17%. Hat and Bazar are 2, most noted are Jamtoil Bazar and Kamarkhanda Hat. Average literacy 42.59%; male 47.42%, female 37.49%. All valuable information found after situation assessments are shown in Table 3.

**3.2 Integrated approaches for anthrax free model area development**

**3.2.1 Approach-1: Vaccination**

Cattle vaccination coverage expanded from 40 to 85% through individual home delivery services and arranged anthrax vaccination campaigns every 6 months.

**3.2.2 Approach-2: Community Awareness**

Awareness of anthrax in the model area was raised within a short period during the study period. For that, an Integrated Extension Model was designed and implemented. It showed that the majority of community members (97.5%) were made aware of the nature, occurrence, public health importance, and management of the disease. Their dangerous habits and attitudes toward the slaughtering sick animals were reduced (<30%). The percentage of farmers who can diagnose anthrax has increased from 30% to 40%.

**3.2.3 Approach-3: Rapid confirmation and prompt disposal facilities**

A total of eight suspected tissue samples (ear clipping) of sudden death animals were collected from the model area for rapid confirmation during the study period but were not found positive cases by this period. For the validity of our testing procedure, one positive sample was collected from Central Disease Investigation Laboratory (CDIL), Dhaka. On the other hand, 50 soil samples were collected from the model area, and 7 samples were found positive for the presence of viable anthrax spores.

**3.2.4 approach- 4: Effective surveillance system**

The surveillance system that was introduced in the Model Area was highly efficient. In this system, area staff such as para vets, community vaccinators, meat sellers, community volunteers, village chowkidars, and ward members act as a primary informers for the research unit. In case of any untoward animal death or anthrax symptoms in the area, this primary informant would immediately inform the research unit via mobile phone. The research team immediately inspected the ground and told the concerned authorities. The concerned authorities would then be informed at each stage of sample collection and sample identification. Primary informers were given regular motivation and some roaming expenses for this work. In addition, regular visits to the register of patients, especially regular contact with the Upazila Health Complex and the Upazila Livestock Office, were part of our indirect surveillance activities. Eight suspected samples of sudden death animals were collected within the noticeably shortest period (< 12 hours) during the three years and sent to the laboratory for rapid confirmation for these active and passive surveillance network systems.

**3.2.5 approach- 5: Emergency Prevention system**

An alternate emergency backup, including trained staff, disposal team, community volunteers, disinfectant materials, and the required vaccine, was prepared for our model area. The District Livestock Department and Upazila Administration were informed and regularly updated at every step, from collecting samples to disposal. The eight sudden animal death samples were collected during the study. Although they were tested negative for anthrax in the laboratory, each animal was adequately disposed of using the recommended standard carcass disposal method. These works have been done to improve the capacity build-up of the people in the model area. People of the Upazila Livestock Office and local administration were also involved in the procedure.

**3.2.6 Approach-6: Implementation of existing law regarding animal slaughter**

Existing laws on animal slaughter were regularly circulated through leaflet distribution. 450 leaflets were distributed, and nine mobile courts were executed in the model area. It helped the community members be aware of existing laws and regulations about the slaughtering of animals. The mobile court allowed the community member to obey the law. Awareness and knowledge about animal slaughter also increased among the area's people due to these leaflets and regular mobile court operations. Which was observed in the finding of survey works. At the baseline, where only 2% of the population knew about existing laws, the rate increased to 65% during the evaluation period.

**3.2.7 Approach-7: Strengthen the collaboration**

Six advocacy and sensitization workshops with local administrations were done in the model area, where all Upazila administrations and departments were attended as per our plan. In these workshops, the objective and progress of the activity were demonstrated, and members gave recommendations, and suggestions and evaluated the role and responsibilities of different stakeholders. They also assist in monitoring, and some of them, directly and indirectly, help in awareness-raising programs. As a result of working together involving different departments, each department helped them as much as they could. For example, the Upazila Education Officer, whose primary job is to improve the quality of education in the Upazila educational institutions, but through our sensitization workshops, he also motivated and worked on disseminating anthrax related information himself and instructing his subordinate teachers so that the teachers too could make their students aware of anthrax. On the other hand, the law enforcement department kept safe food under their watch on a priority basis. That's why they regularly sent their patrol team to the market and worked to force everyone not to slaughter any sick animal.

**3.3 Periodical evaluation of overall progress in the model area**

The research program was started based on the information obtained from the Situation Assessment (baseline data) in the Model Area. All the activities were designed and implemented for the scale-up in every approach during the period. An optimum score of each monitoring tool was determined periodically. The steering committee regularly carried out these works, and they were completely independent of the evaluation process without bias. They did not discriminate against anyone but worked with a solid conviction to prevent anthrax in their area. The total score of each indicator and the obtained periodical score of the study area are shown in Table 4.

**3.4 Cumulative Index score**

The cumulative index score showed that the overall progress of the project is based on different indicators. After a consultation with the steering committee of anthrax control and their recommended score, it was seen that, in the beginning, the cumulative score was only 18. After implementing all activities, it was increased to 100, shown in Figure 5. Ultimately with the cooperation of all, the key components that were developed in the model area were:

* Establish an effective surveillance system in the public health and the veterinary sectors.
* Rapid confirmation and prompt disposal of dead animals, bedding, and contaminated materials, and control of scavengers.
* Regular vaccination of susceptible livestock animals in areas by using quality-assured vaccines.
* Increased public awareness and observation of general hygiene principles, including the use of personal protective measures by people who may have contact with diseased or dead animals.
* Enforcement of regulations of anthrax control.
* Developed an emergency prevention system.
* Strengthen the collaboration of veterinary services within the area to control anthrax in both animals and humans.

**3.5 Outcomes**

After successfully implementing all the activities of an integrated approach, we can see that there was no animal and human anthrax case during this period. The historical event of the anthrax case in the model area is shown in Figure 6.

**4 DISCUSSION**

Anthrax is supposed to be one of the most potent biological weapon agents because its spores are highly resistant to natural conditions and can survive for several decades in the environment. It is a public health concern in many countries where agriculture is the primary source of income. It was also described as "an economic disaster" (Turner, 1980). However, many countries like Canada, the United States, Austria, the Czech Republic, Denmark, Finland, Luxembourg, Malta, Colombia, and the Guianas, Malaysia, Taiwan, and Sweden have been able to control the disease. In this case, they followed different methods. Sweden and, probably, Austria, the Czech Republic, Denmark, Finland, and Luxembourg have eliminated Anthrax (Schmid and Kaufmann, 2002). In African countries like Zambia, Ghana, Georgia, South Africa, Zimbabwe, previously known as Rhodesia, mostly centered on anthrax surveillance and reporting systems, diagnosis, vaccine production, and immunization, disinfection, and decontamination, carcass disposal, treatment of human cases, health systems, as well as intersectoral cooperation between public health services, veterinary services, and other services such as wildlife conservation (WHO, 1994; Balogh et al.,1994; Siamudaala et al., 2006; Karacalik et al., 2006). It was considered their national control program and successfully handled anthrax epidemic situations in Africa. Department of Natural Resources and Environment, Victoria, Australia, applied for a control program in response to an outbreak of anthrax in cattle affecting some 83 farms during the first half of 1997 was subsequently established as an Australian standard and serves well as a global model for anthrax control (Turner et al., 1999; Durrheim et al., 2009). Vaccination and movement restrictions have been the key methods used to control anthrax in pasture‐based livestock systems in Australia (Turner et al., 1999). It is now very infrequent to rare in Canada, the United States, and many countries in Europe. An increasing list of countries like Cyprus, New Zealand, Belize, the Caribbean except for Haiti (and thus possibly the Dominican Republic), Malaysia, Taiwan, Sweden, Eire, and I am tempted to add Austria, the Czech Republic, Denmark, Finland, Luxembourg, Malta, Colombia, and the Guianas can truly claim freedom from Anthrax (Hugh-Jones, 1999). Analyzing the initiatives of different countries and their results in anthrax control shows that since their methods were effective, it is natural that our integrated approaches and various components should be highly effective in controlling anthrax in any region. Although some countries have some differences in their control strategy. For example, many developed countries like Canada, the USA have a depopulation program aimed at preventing the spread of Anthrax (Dragon and Elkin, 2001; Levings, 2012). But the socio-economic condition of a developing country like Bangladesh does not support it. In Bhutan, to stop the spread of anthrax, animal and public health authorities initiated various prevention and control measures: a campaign to create awareness among villagers and students; ring vaccination of cattle against anthrax; treatment of sick animals with antimicrobial drugs; disposal of carcasses in deep burial pits; recall, collection, and disposal into burial pits of all potentially infected meat and hides from cattle that died of suspected or confirmed anthrax, and monitoring and treatment of persons in whom cutaneous anthrax developed. These control measures have proved effective (Thapa, 2014). In Nepal, several strategies like vaccination, awareness, and capacity build-up were applied along with improvement in animal slaughtering and meat inspection in rural and urban areas, which helped for anthrax prevention (Joshi et al.,2003). In India, it emphasizes step-up inter-sectoral coordination, collaboration, and sensitization among departments (especially health, veterinary, forestry, education, nutrition, and tribal welfare) to reduce the prevalence and control the outbreaks of anthrax. Still, they recommended raising community literacy, particularly on safe carcass disposal, changing behavior on dead-livestock consumption, and compliance with livestock vaccinations (Sahoo et al.,2020). In the model area, anthrax almost every year- 2010, 2011, 2012, 2014, and 2016, but no anthrax was observed in the last three years due to the application of our approach. Similar approaches applied to our model proved successful in most countries like Zambia, Ghana, Georgia, South Africa, Zimbabwe, and Zambia became a model country for anthrax control (WHO, 2008). On comparing their results, our results were very similar. In North America, one interesting finding was seen. While the disease occurs sporadically in western Canada, they were not maintaining vaccination and had a simple surveillance program. Anthrax was seen again in Ontario after an apparent absence of some decades (Hugh-Jones, 1999).

The components of the Integrated Approach that were used to create the anthrax model area were highly rational and recommended by various recognized organizations like the World Health Organization (WHO), World Organization for Animal Health (OIE), Food and Agriculture Organization of the United Nations (FAO). Many African countries like Zambia, Tanzania, Kenya, and South Africa primarily focused on emergency and compulsory vaccination, proper carcass disposal, public education campaigns by community health and veterinary staff, and quarantine of an affected area (Balogh, 1994). Education is an essential part of the control program for anthrax, as an infectious disease. This has to be pitched at diverse levels within different societies and social groups. However, an excellent model was established in Zambia with material prepared to help villagers recognize the nature of anthrax, the reasons for the need to control it, and the methods to do so (Dietvorst, 1996). The widespread use of a live spore vaccine in South Africa has reduced the incidence of anthrax in cattle in this area by more than 99% (Ahmed et al., 2010). Human Anthrax has been virtually eliminated in many developed countries because of effective control measures, including mass animal vaccination, governmental law and veterinary supervision of animal slaughter, and quality control of animal products (Turnbull et al., 1999). A multi-sectoral team from animal and public health offices in Bhutan visited the outbreak area to investigate and establish a control program in Bhutan. To halt the spread of the disease, the team recommended a campaign to encourage awareness among villagers and students. Ring vaccination of cattle against anthrax; treatment of sick animals with antimicrobial drugs; disposal of carcasses in deep burial pits; recall, collection, and dumping into burial pits of all potentially infected meat and hides from cattle that died of suspected or confirmed anthrax; and monitoring and treatment of people in whom cutaneous anthrax developed (Thapa et al., 2014). Chen et al. (2016) mentioned a comprehensive and in-depth retrospective epidemiological study on the spatiotemporal dynamics and risk factors of anthrax is needed to control anthrax. He prepared a map for the demonstrated distribution of anthrax. Patil (2010) highlighted the proper legislation for meat handling, behavioral change communication, and effective immunization of animals to control anthrax disease in India. In Bangladesh, researchers like Ahmed et al. (2010); Roy et al. (2013); Islam et al. (2013); Hasan et al. (2015); Ahsan et al. (2015) recommended a formulation of comprehensive preparedness and response guidelines (strategies), including the activities relating to surveillance, communication, vaccination, outbreak investigation and to be approved by the government and implemented in the risky high districts towards minimizing animal anthrax at source are demanded.

Progressive control pathway (PCP) is a staged approach increasingly used for the reduction, elimination, and eradication of a range of human and animal diseases, including foot-and-mouth disease (FMD), *Peste des Petits ruminants* (PPR), brucellosis, and rabies (Sumption et al., 2012; OIE, 2012; FAO, 2015). Within the PCP acronym, the word 'control' can encompass the full range of strategies against diseases and reducing the disease burden to elimination and eradication. Although our research work is not eradicated, we think this work is the first step in eradicating the disease. Our approaches to controlling anthrax were implemented step by step without managing them all simultaneously. We called the continuation of this work the Progressive Control Pathway. Some work was dependent on one another. For example, if people in the area have no idea about anthrax, they will not refrain from buying the meat of infected animals. On the other hand, cattle owners will not vaccinate cows if they do not know the dangers and consequences of anthrax. Again, if the people are not aware of the overall situation, they will not want to abide by the existing laws regarding animal slaughter. Considering all these factors, we sorted out our research work. On the other hand, since awareness and vaccination rates were meager, these issues were given the highest priority. Such pathways are used in disease prevention and eradication works. The progressive control pathway is also recognized as an effective and more sustainable method applied in many countries (Diall et al., 2017).

Since the research work was time-based, the results of three years were seen. If the work could have been done for a longer time and the effects could have been observed for more time, it would have been more confident to say how practical our integrated approach is.

1. **CONCLUSIONS**

In Bangladesh, climate, soil properties, rainfall pattern, temperature, animal population, husbandry pattern, management practice, feeding, and disease management is the potential threat for anthrax disease. Besides, the economic status of farmers, their knowledge level, the capacity of anthrax control measures, the awareness level of meat sellers and consumers, animal slaughter practice, inadequate vaccination coverage, limited application of existing laws, all these things have created a re-attack of the disease in the future. Any time there may be an epidemic, and there is an urgent need for Bangladesh to make a concerted effort to avoid such a situation arising. Based on the research finding, it can be concluded that the integrated approach is an efficient, effective, and suitable method to set up an anthrax-free model in the area where there will be. And this model may extend to the other parts of Bangladesh and in similar geographic regions like India, Nepal, and other South Asian countries where anthrax is still a problem in both animals and humans.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**ETHICAL STATEMENT**

The authors confirm that the ethical policies of the journal, as noted on the journal’s author guidelines page, have been adhered to, and the appropriate ethical review committee approval has been received. An approval was taken from the Animal Welfare and Experimentation Ethics Committee (AWEEC) of Bangladesh Agricultural University, Mymensingh-2002, Bangladesh [No AWEEC/BAU/2018(21)].

**DATA AVAILABILITY STATEMENT**

The data that support the findings of this study are available from the corresponding author upon reasonable request

**ORCIDs**

Md. Shahjahan Ali Sarker (ORCID: 0000-0001-7480-3576)

Md. Ahosanul Haque Shahid (RCID: 0000-0002-0281-4644)

Md. Muket Mahmud

Ajran Kabir

Md. Bahanur Rahman

Md. Asaduzzaman Sarker

Ratna Parvin

K. H. M. Nazmul Hussain Nazir (ORCID: 0000-0002-3893-754X)

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Table 1. Structure of Monitoring and Evaluation Committee

|  |  |  |
| --- | --- | --- |
| Sl no. | Monitoring & Evaluation Committee | Responsibility |
| 1 | Upazila Livestock Officer | Chairperson |
| 2 | Representative of Upazila Parishad | Member |
| 3 | Representative of Bangladesh Police | Member |
| 4 | Chairman of Union Parishad | Member |
| 5 | Ward Member of Union Parishad | Member |
| 6 | Head teacher of Primary school | Member |
| 7 | Imam of Mosque | Member |
| 8 | Representative of Meat seller | Member |
| 9 | Representative of Hat committee | Member |
| 10 | Representative of Cattle farmers | Member |

Table 2. List of activities done during the study period (July 2017 to December 2020)

|  |  |  |
| --- | --- | --- |
| Sl no. | Name of activities | Number of Achievement |
| 1 | Livestock census | 6 (after each vaccination program) |
| 2 | Situation assessment and project end survey for assessment of knowledge, attitude, and practice regarding anthrax and common husbandry practice of livestock. | 2 |
| 3 | Anthrax vaccination program | 6 (every 6 months interval) |
| 4 | Serum collection for Vaccine efficacy test | At least 25 cows in every 3 months interval |
| 5 | Suspected tissue sample collection, processing, and PCR based laboratory diagnosis | 09 |
| 6 | Soil sample collection, processing, and PCR based laboratory diagnosis | 50 |
| 7 | Vaccination record card distribution | All farmers having cattle |
| 8 | Secondary data collection from Upazila livestock department and Upazila Health complex | 03 times |
| 9 | Sensitization workshop with Upazila administration | 01 |
| 10 | Farmer’s awareness training | 03 |
| 11 | Student’s awareness training | 09 |
| 12 | Workshop with Meat sellers | 01 |
| 13 | Local elite's awareness training | 02 |
| 14 | Advisory committee formation with Upazila administration, law enforcing agencies, livestock department and health department | 01 |
| 15 | Pictorial Billboard set up | 4 |
| 16 | Anthrax information placard distribution | 60 |
| 17 | Anthrax related poster and leaflet distribution | 800 pcs |
| 18 | Publicity of existing law on animal slaughtering and other needful information on anthrax disease control through miking | 3 |
| 19 | Scientific field visit with the research team | 02 |
| 20 | Attend an Upazila coordination meeting and raise an issue on a slaughterhouse setup. | 03 |
| 21 | Seminar participation & presentation National (Ministry of Science and Technology)-1 and international (Tamil Nadu Veterinary and Animal Sciences University)-1 | 02 |
| 22 | Progress poster presentation (Annual Workshop on BAU research progress 2018–2019) | 01 |

Table 3. Anthropological and epidemiological findings of model area

|  |  |
| --- | --- |
| Geological information | Jamtoil is one of the dense cattle populated villages, located in between 24°34' and 24°36' north latitudes and in between 89°64' and 89°68' east longitudes. The total area 4.68 sq. kilometers |
| Household information | 1189 Households |
| Occupation | Main occupation was Agriculture 47.06%, non-agricultural labourer 4%, industry 1.14%, commerce 16.57%, transport and communication 3.87%, service 8.70%, construction 0.87%, religious service 0.27%, rent and remittance 0.26% and others 17.26%. |
| Soil topography information | Land type: Medium low land  Soil type: Sandy, loamy, and clay type soil  Moisture content: 17.04± 2.45  Ca (PPM): 782.60±45.90  Organic carbon (%): 0.82±0.12  Total N (%):0.05  P (PPM): 12.7  K (PPM):0.32 |
| Water lodging and Flood information | Floods occur almost every year, and most of the area's roaming land is submerged at a significant time of year. |
| Information about cattle population | About 90 percent of the people are involved in cattle rearing. In addition, there are many families involved in the cattle trade who regularly bought cows from different parts of the country and kept them at home for a few days, and then sold them at various markets. Among the farmers, small and marginal farms (1-5 cows) were 50%. Medium farms (8-10 cows) were 20%, large farms (10 upstairs) were 10%, and the remaining 20% of cows belonged to the traders. For this reason, it was difficult to calculate the number of cattle accurately, but during the census, it was found that.  There were 2753 cattle. Among them, 334 were calves, 782 were pregnant cows, bulls were 1202, and the rest were milch and dry cows. |
| Information about farmhouse | Usually, farmers (more than 60%) used to keep cattle in a semi-intensive system. Some farmers (less than 20%) maintained their cattle day and night in sheds, especially bulls. They would take out the cattle just for bathing, and the rest of the time, they would be tied up in a sleeping place. Most of the farmers (more than 75%) tied their cattle in the yard during the day and in the surrounding pastures and kept them in the barn at night. The cowsheds were semi-paved, with most bricks on the floor attached to their bedrooms. |
| Information on Livestock husbandry | Traditionally, this area was inhabited by cattle. For a long time, the people of this area were involved in cattle rearing. People used to cultivate improved varieties of fodder such as Napier, maize, and jumbo. Those who had cultivable land used to cultivate their land. Those who did not have their cultivable land cultivated these fodders on the side of the road and on the slope of the railway line. The sale of grass was a regular business here. The farmer would come in the morning to sell milk, and when he left, he would buy fodder and granular food for the cows. Some low-income farmers and their families regularly mown grass from the aisles and fallow lands to feed their cattle. The average farmer gave 5 to 10 kg of concentrate feed to a cow. |
| Market and meat sales information | There was a Hat in the area, which was open two days a week, and a bazaar. The bazaar was the largest marketplace in the Upazila, which was open from morning till noon every day. Cows were regularly slaughtered in these Hat and Bazar, and about 20 butchers were regularly involved in selling meat. |
| Information about animal slaughterhouses | There was no specific place in the area for slaughtering cows, and the meat was slaughtered for sale next to the filthy piles of rubbish next to the hats and markets. Besides, animals were slaughtered in the house's yard in various social ceremonies. |
| Information on animal import and export from outsides | Cows were imported from the country's northern districts almost every day in the area. The cows were located in the village and were gradually sold to traders in the surrounding hats and other districts. In this case, the area was used as a hub for importing and exporting cattle. |
| Animal burial information | The people of the area do not follow any rules regarding the burial of dead animals. Usually, where there were facilities such as bushes on the side of the house, pasture, submerged land, or the road or rail line along, the dead animals were thrown. The butcher would take the skins of these dead animals, and the dead animals would be exposed to foxes, dogs, and wild birds. Some conscious farmers buried the dead animal, but their number was minimal (less than 10%). |
| Knowledge of the people of the area about anthrax | Although there was repeated anthrax in this area, a baseline survey reported that the anthrax knowledge in the community was found to be very low; 87% of the people did not have the proper understanding about anthrax. |
| People's perceptions about veterinary service | The people of the area were reluctant to involve the livestock department in the treatment of cattle, and they were usually more receptive to rural para vet doctors. In cases where the treatment of para vets was not practical, he only contacted the livestock department. He also provided necessary advice on veterinary medicine shops and treatment in the area. If the treatment of animals were not effective, people would sell the animals to the butchers at low prices. In case of sudden death, the owners of the animals were usually afraid of harassment, and the Animal Resources Office did not even inform their neighbors. |
| Public perceptions about the livestock department | The idea of ​​the people's livestock department was that there were usually prominent doctors sitting there, they were all skilled, but they wanted a lot more money when they went home. Many said they gave very little time. |
| Public opinion about anthrax vaccination | Due to repeated anthrax outbreaks, a sporadic anthrax vaccination program was implemented by the Livestock Department and the Upazila Administration. Although their coverage was less than 40% the people of the area believed that if the vaccine were used in all animals, it would be possible to prevent anthrax. |
| Animal vaccination rate | Less than 40% of the cattle population was conducted once a year. |
| Sick Animal Information Informing the Livestock Department | In the case of long-term illness, if the para vet were not treated effectively, only then would the livestock department be informed or the doctors there be contacted. Information was usually withheld in sudden or accidental animal death. Many times sick animals were slaughtered and sold in the meat market. The situation assessment also revealed that people in the area buy meat at a relatively low price by slaughtering sick animals in the area. |
| Public perceptions about government vaccine and vaccination program | Although people were satisfied with their medical care, many had mixed reactions to vaccine preservation and delivery methods. Many of them felt that the livestock department needed to improve further the technique of preserving and providing vaccines. In some cases, their criticize the quality of the vaccine. |
| Public perceptions of animal slaughter law | The general public did not know any law related to animal slaughter in Bangladesh, not even the butchers involved in animal slaughter. |
| Administration's approach to preventing anthrax | There were no reportable initiatives of the local administration regarding anthrax prevention. |
| Status of all departments against anthrax prevention | Had no coordination between the livestock and health department. Everyone worked from their respective positions |
| Civic awareness | There was not enough information to prevent this disease even among the conscious citizens. Some of them knew or got information from different media, but their number was deficient. |
| Knowledge of butchers, animal traders on anthrax disease | Meat sellers and animal traders had no clear idea about anthrax. They only knew that the disease was transmitted to humans from an unhealthy animal, but 95% of people had no idea why, by which germ, how the germ invaded the animal, what the symptoms were, and how it came to humans. In addition to the dormancy of the disease, what to do to prevent the disease or to prevent people from becoming infected, or what to do and what to do if the disease occurs they were very unclear. |
| Anthrax history | There were reports of repeated anthrax in the Jamtoil village; according to the print media and IEDCR, Bangladesh it was in 2010, 2011, 2014, and 2016. Both human and animal cases were reported here. |
| Major challenges | Low Awareness level (only 13% of people were known about the anthrax disease)  Had no scientific disposal method of carcass.  Poor vaccination rate (less than 40%)  Had no slaughterhouse for animals.  Only very few people know that a certificate was needed before slaughter the animal (less than 5%)  People were not aware of existing laws regarding animal slaughter (98%)  No collaboration with different departments to prevent anthrax especially Health and Livestock department  No steering committee for market monitoring |
| Strengths | Upazila Livestock Department, Kamarkhand, Sirajganj, and Upazila administration were very sincere in preventing anthrax. They showed great sincerity when the research team visited the area. And promised to co-operate in all of our research work.  Besides, the elected political personalities of the area, especially the Union Parishad Chairman, Upazila Chairman, were very sincere; they also assured us of cooperation in all our work. |

Table 4. Indicators and their obtained score over time

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indicator | Total score | Score obtained by the committee | | | | | | |
| Baseline | After 6 months | After 12 months | After 18 months | After 24 months | After 30 months | After 36 months |
| Community awareness | 20 | 3 | 6 | 9 | 12 | 15 | 18 | 20 |
| Farmer's KAP on Livestock management | 20 | 1 | 3 | 5 | 7 | 11 | 13 | 15 |
| Mass animal vaccination | 35 | 12 | 24 | 25 | 26 | 27 | 28 | 30 |
| Active and passive surveillance | 10 | 0 | 2 | 5 | 7 | 10 | 10 | 10 |
| Preparation for Emergency response | 5 | 1 | 2 | 3 | 4 | 5 | 5 | 5 |
| Disposal of carcass | 15 | 1 | 1 | 1 | 6 | 6 | 8 | 10 |
| Certification of slaughtering animal | 15 | 0 | 0 | 0 | 5 | 8 | 10 | 10 |

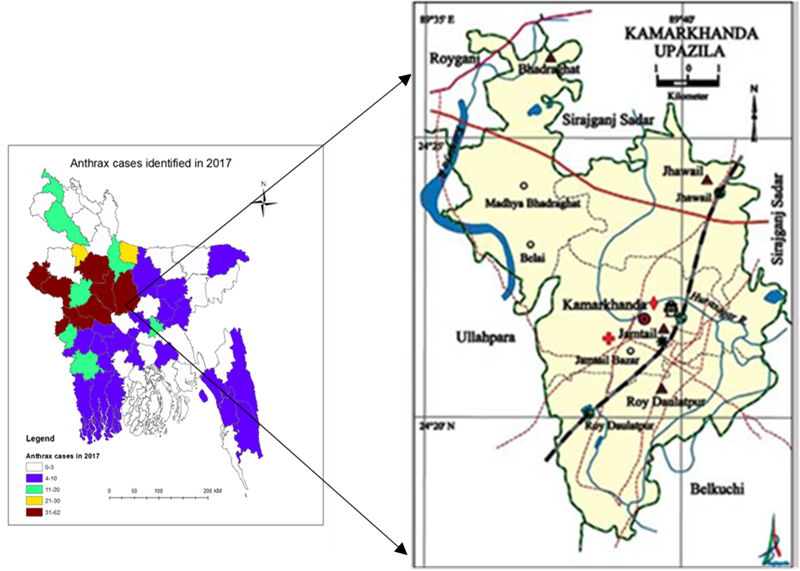
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Figure 1. Map of Bangladesh and location of our model area

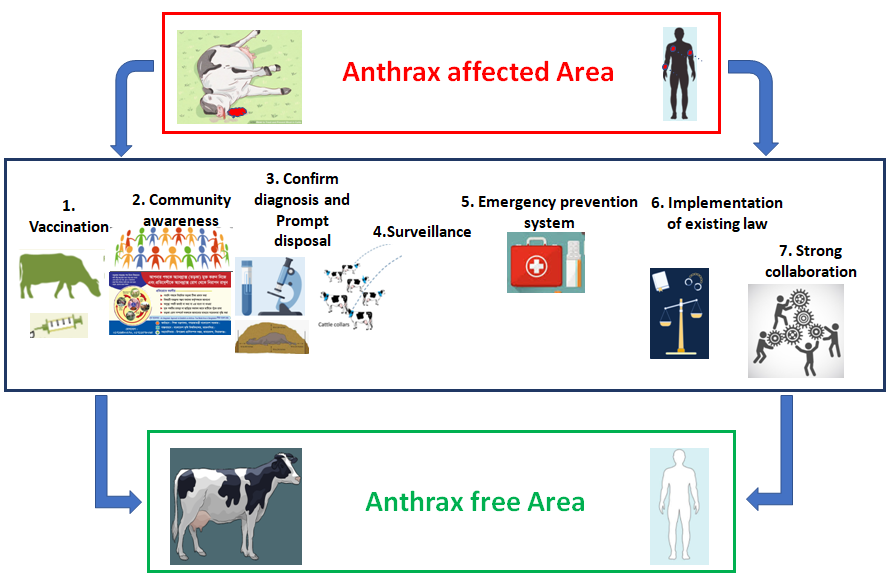


Figure 2. Integrated approaches for anthrax free model area development.

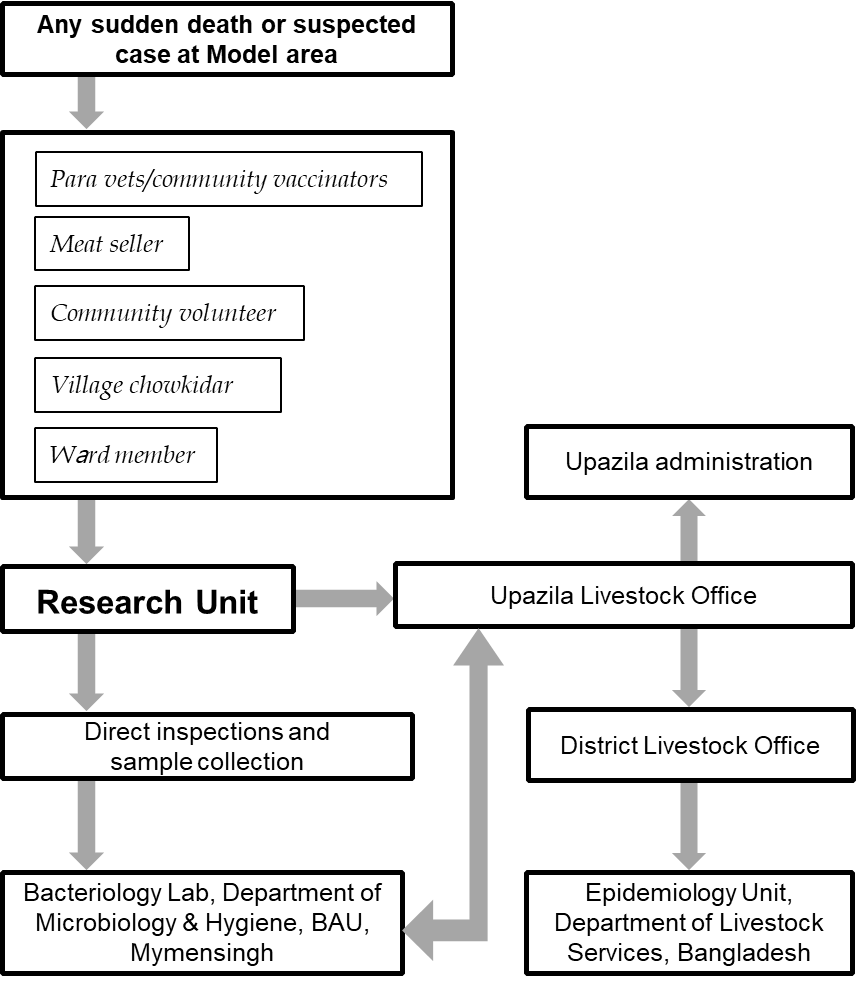
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Figure 3. Active surveillance network in the model area.

Figure 4. Score of interventions for calculating overall progressive.

Figure 5. Cumulative index score of model area.

No anthrax

Figure 6. Anthrax outbreaks in model area from 2010 to 2020.