



# Human exposures to by-products from animals suspected to have died of anthrax in Bangladesh: An exploratory study

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## Abstract

Anthrax is a zoonotic disease caused by the bacterium *Bacillus anthracis* that is considered endemic in Bangladesh, where cases among animals and people have been reported almost annually since 2009. Contaminated by-products from animals are suspected to play a role in transmission to people, but minimal information is known on the supply chain of these potentially contaminated products. Between April 2013 and May 2016, we conducted a qualitative study in 17 villages located in five districts in Bangladesh, which had experienced suspected anthrax outbreaks. The study explored how by-products from suspected animal cases were collected, discarded, processed, distributed and used by people. We conducted open-ended interviews, group discussions and unstructured observations of people's exposure to animal by-products. The practice of slaughtering acutely ill domestic ruminants before they died was common. Respondents reported that moribund animals were typically butchered, and the waste products were discarded in nearby rivers, ditches, bamboo bushes, or on privately owned land. Regardless of health status before death, very few carcasses were buried, and none were incinerated or burned. The hides were reportedly used to make wallets, belts, shoes, balls and clothing. Discarded bones were often ground into granular and powder forms to produce bone meal and fertilizer. Therefore, given anthrax is endemic in the study region, livestock with acute onset of fatal disease or found dead with no known cause of death may be an anthrax case and subsequently pose a health risk to those involved in the collection and processing of the carcass, as well as the end-user of these products. Improved bio-security practices and safe carcass disposal measures could reduce the risk of human exposure, but resource and other constraints make implementation a challenge. Therefore, targeting at-risk animal populations for vaccination may be the most effective strategy to reduce anthrax outbreaks, protect the supply chain and reduce the risk of exposure to *B. anthracis*.

## KEYWORDS

anthrax, Bangladesh, by-products, qualitative, supply chain, zoonotic disease

## 1 | INTRODUCTION

Anthrax is an acute zoonotic disease caused by a Gram-positive spore-forming bacterium, *Bacillus anthracis*. Anthrax is endemic in many countries around the world, including Bangladesh. The spore form of *B. anthracis* is highly resistant to environmental stress, disinfectants, and in specific environmental conditions, can remain viable for several decades in soil or contaminated animal by-products (Dragon & Rennie, 1995; Pyper & Willoughby, 1964). Domestic ruminants such as cattle, sheep and goats can contract anthrax when they are exposed to *B. anthracis* spores through grazing in contaminated pastures, consumption of fodder grown in contaminated soil, or ingestion of feedstuff made from a contaminated bone meal or meat (Blood et al., 1979; Davies & Harvey, 1972; Mongoh et al., 2008; Saile & Koehler, 2006). A recent study conducted in Bangladesh by Rume et al. (2020) found statistically significant associations with anthrax outbreaks among cattle to a number of activities, including slaughtering a sick animal on the same area in the recent past, history of heavy rains 2 weeks before outbreak onset, and disposing of carcasses suspected of dying of anthrax in adjacent water bodies (Rume et al., 2020). Human anthrax cases occur through exposure to infected animals, consumption of infected meat, or contact with animal by-products such as hides, bones or hair contaminated with *B. anthracis* spores (Pyper & Willoughby, 1964). Most commonly, humans develop cutaneous anthrax after contact with contaminated carcasses, meat, hides or other animal by-products, and less commonly develop gastrointestinal anthrax from consumption of contaminated meat (World Health Organization, Food, and Agriculture Organization of the United Nations, & World Organisation for Animal Health, 2008). Rarely humans may develop inhalation anthrax through exposure to aerosolized spores during the processing of hides, bones, hair or wool (Bell, 1980).

In Bangladesh, anthrax is endemic among domestic ruminants, and cases have been reported since 1986 (Samad & Hoque, 1986). Due to social, economic and cultural factors, slaughtering acutely sick animals are common (Chakraborty et al., 2012; Islam et al., 2013). Moreover, the practice of removing hides from dead animals and discarding the remaining carcass without burying or burning has been reported in prior studies (Chakraborty et al., 2012; Islam et al., 2013), despite global recommendations of anthrax control and prevention (World Health Organization et al., 2008). The unsafe handling and disposal of carcasses suspected of anthrax infection can further contaminate the environment and the by-product supply chain (World Health Organization et al., 2008).

From 2009 to 2017, approximately 57 suspected outbreaks of anthrax in humans were identified by the Institute of Epidemiology Disease Control and Research (IEDCR), Government of Bangladesh, and the International Centre for Diarrheal Diseases Research, Bangladesh (icddr,b) (Institute of Epidemiology Disease Control & Research, 2018). Limited epidemiological studies have been conducted to understand the proximate individual-level risk factors

for anthrax infections among people in these areas (Chakraborty et al., 2012; Islam et al., 2018). Even fewer studies have examined the economic, social and cultural factors, including market behaviours, and the risk posed by the use of animal by-products possibly contaminated with *B. anthracis* (Biswas et al., 2012; Chakraborty et al., 2010; Islam et al., 2013). This study focused on anthrax endemic areas and aimed to explore how by-products from domestic ruminants that were slaughtered and/or died were collected, discarded, processed, distributed and in general used in Bangladesh.

## 2 | METHODOLOGY

Between April 2013 and May 2016, this study was conducted during 19 investigations of suspected anthrax outbreaks, affecting 17 individual villages in five districts in Bangladesh: Rajshahi, Meherpur, Kushtia, Sirajgonj and Tangail (Figure 1). Laboratory confirmation of animal outbreaks was not possible during the study period due to the limited availability of confirmatory laboratory diagnostics in Bangladesh and restrictions of exporting animal specimens to other laboratories for testing. Prior studies in the region found minimum to no differences in the behaviours of persons handling or processing carcasses or by-products, regardless of the cause of death; therefore, we assumed that the behaviours investigated in this study would also be the same regardless of the cause of death (Chakraborty et al., 2010; Islam et al., 2013; Rume et al., 2020).

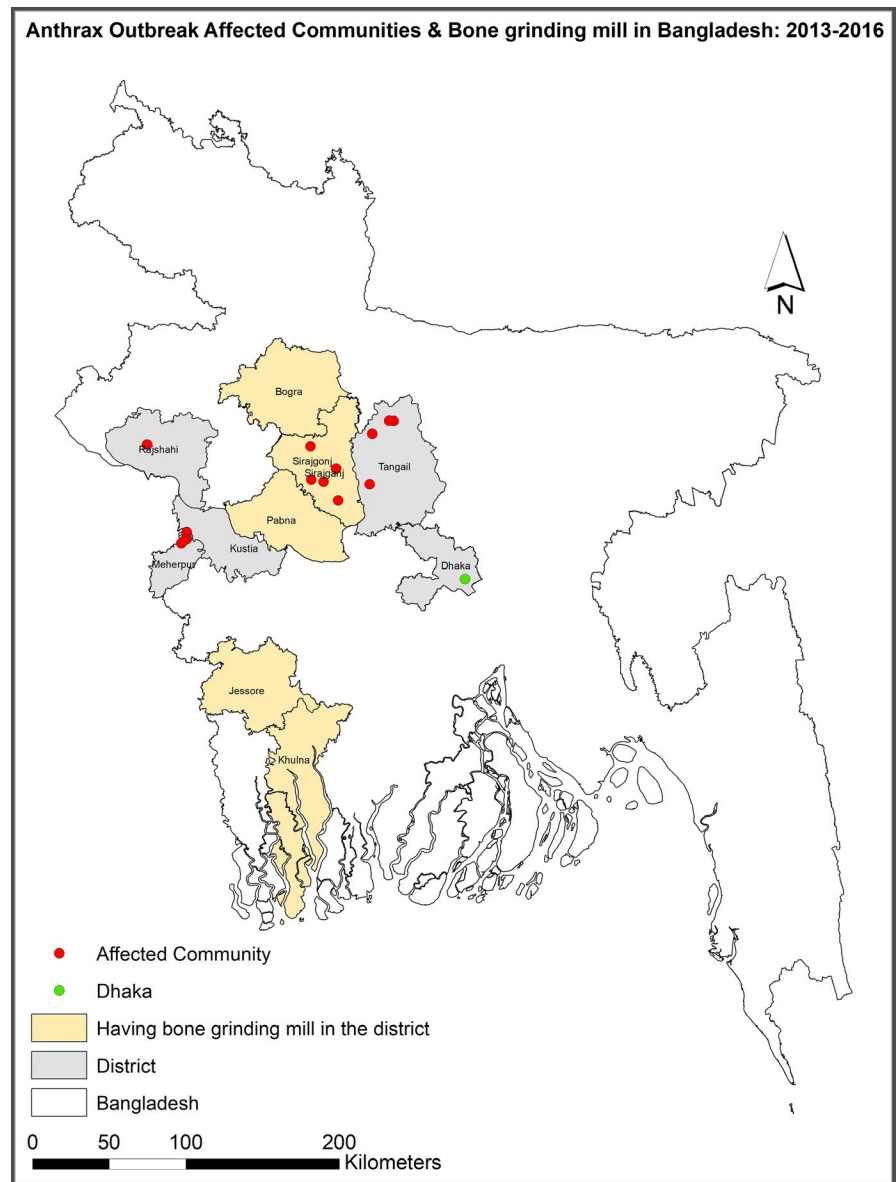
### 2.1 | Study design, study population and data collection

We conducted a qualitative study in villages with a history of suspected human or animal anthrax outbreaks, as reported to IEDCR. Suspected anthrax outbreaks were defined as reports of cutaneous lesions, consistent with anthrax infection, among people who had contact with a dead or acutely sick ruminant within 30 days prior to lesion onset (Chakraborty et al., 2012).

The field team, consisting of three sociologists and one anthropologist, visited villages with suspected anthrax outbreaks to conduct interviews with village residents who had participated in the slaughtering of potentially affected animals, and people who owned sick or dead animals. The team also interviewed skimmers (locally known as *muchi*), bone collectors (people who collected animal bones and horns) and local bone traders (people who buy bones at the village level and then sell them at the district level) in the affected village. The team interviewed one bone grinding mill owner and its workers, wholesale hide traders and market workers at the district level.

We used open-ended interviews, group discussions and unstructured observations as data collection tools. Through 86 open-ended interviews, 15 group discussions and 30 hr of unstructured

**FIGURE 1** Anthrax outbreak affected communities and bone grinding mills in Bangladesh-2013-2016



observation, the team explored the practices of slaughtering sick animals and the process of using or discarding by-products and waste from animals slaughtered or experiencing sudden death. We also explored the social, cultural and traditional supply chain and use of animal by-products in the community through these interviews and group discussions.

## 2.2 | Study definitions

### 2.2.1 | Supply chain

Supply chain was defined as the entire process from collection of raw materials to distribution of the animal by-products and, more specifically, includes gathering, transporting, storing and transforming raw materials, as well as distribution to or procurement by end-users (Vamsi, 2019).

### 2.2.2 | By-product

Adopted from the United States Department of Agriculture, items including edible (including different kinds of meat) and inedible offal, hides, blood, fats, hair, horns, teeth, bone and feet were categorized as by-products (Marti et al., 2011).

## 2.3 | Data analysis

All the data were collected in the local language, Bengali, and then translated into English. The team took detailed field notes during the interviews, group discussions and observations. Interviews and group discussions were also audio-recorded and then transcribed and translated by the field team. Two members of the field team reviewed all interviews, group discussions, and field notes and developed a code list. The code list was based on the initial research

By-products	Price (BDT)	Price (USD)
Cattle hides (each)	1,200–2,000	15–25
Goat or sheep hides (each)	60–150	0.8–1.8
Bones and horns (buying price per kg)	7	0.08
Bones and horns (selling price per kg)	9	0.11
Ground bones and horns (per metric ton)	11,000	135

**TABLE 1** Animal by-products and its local price in the anthrax outbreak affected areas, Bangladesh

questions and objectives, theoretical concepts, and emergent themes (Braun & Clarke, 2006). Team members shared the code list with the lead author for discussion and consensus. The data were then organized according to the codes and categorized under themes. Within the themes, we compared and contrasted data from different data collection tools to verify the results.

### 3 | RESULTS

#### 3.1 | Slaughtering sick animals, selling and consuming the meat

People within these communities reportedly slaughtered sick animals, which was further verified through field team observation. There were 50 suspect anthrax cases slaughtered in the study sites during our investigation, of which 32 were cattle and 18 were goats. Meat collected from these animals included, but not limited to, the intestines and stomach and edible bones, which were cut into small pieces for cooking. The animal's owner regularly reported retaining some of the meat for themselves and sold or gave the remaining meat to neighbours or residents of neighbouring villages. Some farmers reported cleaning the intestines and stomach contents in open water sources, such as ponds or rivers, or water collected in ditches before butchering.

#### 3.2 | Discarding the carcass and slaughtering waste

The respondents reported discarding waste products from the slaughtered animals in nearby ditches, bamboo bushes, or in privately owned agricultural fields. These waste products were reported to include, but are not limited to, meat, blood, bones, hooves, horns, teeth, skin, fat, bladder, stomach contents and eyes. Farmers and community residents reported observing scavengers such as crows, dogs, foxes and cats feeding on discarded carcass waste and moving pieces of the carcasses to other locations. Specifically, dogs were often seen carrying the carcass waste to other locations, both in and around household premises.

When ruminants died before they could be slaughtered, the carcasses were often skinned, but reportedly not butchered. These skinned carcasses were then discarded either in a nearby river, ditch or agricultural field. Very few carcasses were buried. Smaller

species, such as goats, were an exception since they were easy to move and were sometimes buried in shallow pits on privately owned land. However, much like the discarded waste from slaughtered animals, foxes and dogs reportedly often dug up these carcasses and scattered pieces or remains the carcass across larger areas. None of the ruminants that had died were burned or incinerated.

#### 3.3 | Collection, processing and supply chain of animal by-products

In general, animal by-products were collected and processed in similar ways in all villages, sub-districts and districts included in this study. Community residents reported that *muchis* would often collect or buy hides from the discarded carcasses from farmers in order to sell in the local market. We observed that cattle hides were sold for Tk. 1200–2000 (US\$ 15–25), whereas goat or sheep hides were sold for Tk. 60–150 (US\$ 0.8–1.8) to local hide traders.

Local hide traders reported washing the hides in water, removing the flesh, ear, hair and fat from the hides, and discarding this waste in agricultural fields, on riverbanks, or other water bodies. After processing, they reportedly spread salt on the hides' flesh side, stacked them, and stored them in their homes or a warehouse for hours to days, until the hides were sold. The local hide traders often hired a rickshaw or a tri-cycle van or used their own bicycle to transport the processed hides to a wholesale market.

While conducting observations at a hide wholesale market in Tangail, most people carried the hides on their heads or bare shoulders during loading and unloading from vehicles. Most workers did not wear a shirt, and none of them were observed wearing gloves, masks or face coverings while working in the wholesale markets. The hides were stored flat in multiple stacks at the wholesale market.

Community respondents reported that bone collectors often visited outbreak affected villages and collected discarded bones, horns and hooves from the site of the carcass free of cost. The bone collectors did not process the bones before selling to local bone traders. At the time of the observations, the local bone traders bought the bones and horns for TK 7 (USD 0.08) per kilogram from bone collectors (Table 1). The local bone traders kept the purchased bones in their residence, agricultural fields or warehouses before selling to wholesale traders. One local trader from Meherpur stated that he stored bones and horns in a large hole beside his house for 3 months before selling them. A few local bone traders stated that they often

spread sand, lime (calcium carbonate) and/or kerosene on the decaying bones to prevent odours. Only one respondent mentioned using bleach, not for disinfection, but to prevent the bones' decaying odour. A local bone trader from Tangail stated that the bone business was his primary source of income, and he described the processing in this way,

I keep the collected bones in a sack and put them in water for 2–3 days so that the fat and tissue wash away. Then I dry them under the sun beside my house and spread bleach to avoid the bad smell from the decaying bones.

Local bone traders sold these bones to wholesale bone traders at a price of TK 9 (USD 0.11) per kilogram without any processing (Table 1). The wholesale bone traders then supply bones and horns to various bone grinding mills located in the districts of Sirajgonj, Bogura, Pabna, Jessore and Khulna (Figure 1). The bone grinding mills also purchased bones from other sources, including directly from bone collectors, butchers and local bone traders.

One bone grinding mill owner stated that the mill grinds an average of 25 tons of bone per month. The mills' workers dried and separated the bones, horns and hooves before grinding and then sifted and filtered the bones to separate the granular pieces from the powder. The work was conducted in a room with bamboo walls and a tin roof that lacked natural ventilation. While conducting this work, employees did not use any masks, gloves, aprons or facial protection. Ground bone materials of different sizes are then packed separately and sold to different industries. One local mill owner stated that he sold an average of 5 metric tons of ground bones and horns per month to other bone industries. One metric ton of ground bones and horns was reported to sell at a price of TK. 11,000 (USD 135).

### 3.4 | Different uses of animal by-products

We did not find any variation in the general use of by-products collected from animals with suspected anthrax across the different study districts. The local hide traders from all five study districts sold the hides in a reportedly one of the largest wholesale hide market, located in Natore District in the northern part of Bangladesh. The field team identified 288 individual hide traders who worked for 70 hide warehouses in this specific market. In addition to the Natore wholesale market, the hide traders from Tangail also sold hides in a weekly market, a large wholesale and retail hide market in this district. The hide traders and tannery owners from Dhaka reportedly purchased hides from wholesalers across Bangladesh.

We identified a wide range of consumer goods produced from animal by-products. The wholesale hide traders stated that Dhaka's leather industries used the processed hides to make wallets, belts, shoes, gloves, soccer balls, leather clothing and sandals. The upper layers of hides were used for making special paper, and the ears of cattle were used to make glue. Moreover, different types of shaving

and shoe brushes were made from the hair of cattle tails. Several respondents informed us that community members often used small pieces of hide in traditional medicine, such as the homeopathic treatment of asthma. One respondent recounted that a resident suffering from asthma reported recovering after he kept a piece of hide from a male goat in his room. Community members also reported that traditional healers often recommend children wear a necklace with a piece of dry hide attached to protect them from evil spirits.

Bones from domestic ruminants were used to produce a wide variety of goods. Bone mill owners informed us that animal horns were used for making handles for knives and briefcases, combs, buttons, and X-ray film. Community members also mentioned using the jawbone (mandible) for a scarecrow in agricultural fields. Bone traders stated that ground bone materials were used to make fertilizers, prepare poultry feed, fish meal, melamine and plastic products. One wholesale trader mentioned that a pharmaceutical company in Bangladesh purchased ground bones to make capsule covers. One bone grinding mill owner stated that odour from decaying bones was believed to cure cardiac problems and many community residents came to their mill to smell the odour. However, he did not sell the ground bones for this purpose. The ground bone materials were sold to different feed industries and fertilizer companies throughout Bangladesh.

## 4 | DISCUSSION

By-products that are sourced from animals that become suddenly ill or die are sold through an extensive supply chain spanning a large geographical area within Bangladesh. Because anthrax is endemic in Bangladesh, these animal by-products are at risk of being contaminated with *B. anthracis* spores or other zoonotic pathogens and, therefore, may pose a health risk to humans and animals in Bangladesh if contaminated products are further distributed (Biswas et al., 2012; Chakraborty et al., 2012; Fasanella et al., 2013). Moreover, the by-products from suspected anthrax animals may further contaminate products from healthy animals if processed together at bone mills or tanneries. Improperly discarding of carcasses and butcher waste may pose a significant threat to further environmental contamination with *B. anthracis*, leading to additional animal and human cases of anthrax.

The observed practice of discarding animal carcasses or by-product waste in rivers or agriculture field was inconsistent with current recommendations for anthrax control and prevention, which include incineration or complete burning of carcasses to ash, or deep burial of carcasses associated confirmed or suspect anthrax infections (World Health Organization et al., 2008). A prior study from the same outbreak areas in Bangladesh reported that monsoon floods and limited workforce were barriers to moving large carcasses and digging burial pits to properly discard of carcasses per the WHO guidelines (Islam et al., 2013). Additionally, due to a lack of incineration facilities, and the labour and fuel required for burning, this recommendation was also not practiced among low-income areas in

rural Bangladesh (Islam et al., 2013). Moreover, the WHO, FAO and the OIE recommend that after incinerating the carcass or burying it at least six feet below the ground, the soil associated with the carcass and other waste materials that are likely to harbour *B. anthracis* spores should be disinfected with hypochlorite solutions, bleach or formalin (World Health Organization et al., 2008). Historically, lime (calcium carbonate) had been applied in effort to kill *B. anthracis* spores, but studies have shown the use of lime in these situations may increase the viability of spores in the environment and they may instead facilitate the preservation of the spores in contaminated environments (Himsworth, 2008; Himsworth & Argue, 2008). Therefore, the Canadian Food Inspection Agency forbade the use of lime for *B. anthracis* disinfection (Himsworth, 2008; Himsworth & Argue, 2008)). In our study, it was reported that some individuals used lime to reduce the odour from the decaying carcasses and bones, which may facilitate the long-term survival of the spores on the bones and in the environment.

The supply chain of animal by-products identified in our study included local, regional and national destinations. It may pose a risk for the spread of *B. anthracis* spores. Bone meal and fertilizer originating from anthrax infected animals may lead to anthrax's emergence in new geographical areas in Bangladesh. Contaminated bone meal may have contributed to the geographical expansion of anthrax in Bangladesh (Ahmed et al., 2010; Chakraborty et al., 2012; Islam et al., 2013).

Occupational exposures associated with the processing of hides and hairs have historically been linked with increased risk of anthrax in humans. A previous study looking at anthrax outbreaks between May and September 2013 showed hides and skins from outbreak areas were supplied to 60 tanneries in Dhaka that employed approximately 70,000 tannery workers (Hossain et al., 2013). Additionally, a different study found that nineteen anthrax cases were reported among 624 tannery workers in Dhaka, following exposures to contaminated hides (Ahmed et al., 2010). These studies show that tannery workers were at risk of occupational exposures to *B. anthracis* when they handled hides originating from anthrax outbreak areas, including potentially hides originating in our study sites. Furthermore, people involved in processing contaminated bones to make gelatine for use in medical capsules and X-ray films might also be at risk of exposure to *B. anthracis* spores. Given the risk of occupational exposure, it is critical to protect the animal by-product supply chain from raw materials potentially contaminated with anthrax spores.

This study has several limitations. First, we restricted the study to areas with historically reported outbreaks reported through IEDCR's passive surveillance system. There may have been unidentified human and animal outbreaks in other areas of the country that may be associated with different behaviours and practices associated with handling animal carcasses and by-products. However, given the highly consistent practices we observed across the five districts included in this study, it is likely that the practices around animal by-product processing would be similar in other areas of Bangladesh (Biswas et al., 2012; Chakraborty et al., 2010; Islam et al., 2013; Rume et al., 2020). Second, this study did not investigate animal by-products' industrial processing that may inactivate the

pathogen and any potential links to the international market chain. Additional qualitative and environmental studies are recommended to study these important steps in the by-product chain.

Although current slaughter and carcass handling practices in these communities pose a risk for further anthrax transmission, live-stock owners are driven by a desire to recuperate financial losses associated with the animal's death. Therefore, recommendations to use costly and challenging carcass disposal methods are unlikely to be successful. In anthrax endemic areas, the WHO, FAO and OIE recommend the use of proper personal protective equipment and treating hides and skins at tanneries by putting them into 10% formalin for 10 hr before dehairing of the hides at the industry level (World Health Organization et al., 2008). Additionally, it is recommended to sterilize bones, hoof and horn using chemical disinfectants before grinding for bone meal, fertilizers or other uses (World Health Organization et al., 2008). However, implementing these recommendations in Bangladesh may require technical and financial support from the government or non-government organizations. Instead, animal vaccination programs likely represent the most effective method to reduce the risk of anthrax among people and animals (Islam et al., 2013). In Bangladesh, animal anthrax vaccine is available, produced locally, and is sold at a reduced price of TK. 50 (approximately \$0.60 US) for a vial of 100 doses (Islam et al., 2013). In addition to reducing the direct and indirect (by-product processing) human risks, animal vaccination would also reduce anthrax deaths in domestic ruminants and, hence, provide a financial incentive for annual vaccination. Finally, future studies that explore by-product processing practices and testing of by-products at different points in the supply chain should be conducted to understand whether there is actually contamination of the supply chain and the extent of the contamination which would guide mitigation measures.

The areas identified as anthrax endemic were detected through passive surveillance, meaning that the community had to report signs or symptoms of anthrax in humans or animals, or seek care from a government healthcare facility. We recommend establishing active surveillance that would target occupational groups at risk of exposure to *B. anthracis* spores in Bangladesh. Moreover, people who work closely with potentially contaminated by-products should be educated on appropriate prevention measures and symptoms of different forms of anthrax and how and where to seek treatment if symptoms occur.

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co-authors reviewed the manuscript and have given their approval for submission. There is no conflict of interest among the authors.

## ETHICAL APPROVAL

All participants provided informed consent for interviews and observations. In the first few outbreaks, informed consent and the investigation were done with the support of the Government of Bangladesh, as part of the emergency outbreak response. Later, we sought informed written consent following the IRB review and approval of the anthrax outbreak investigation protocol # PR-14072 by icddr,b. The icddr,b IRB has two separate committees: Research Review Committee (RRC) and Ethical Review Committee (ERC). The icddr,b's RRC reviewed the research integrity to ensure the scientific rigour and the validity of the study methods. The ERC reviewed from the perspective of human subject's research in Bangladesh. United States Centers for Disease Control and Prevention (CDC) relied on icddr,b's IRB review and provided assistance and guidance with the technical aspects of this study.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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