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Animal Diseases

REVIEW

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Management practices and technologies for efficient biological sample collection from domestic animals with special reference to Indian field conditions

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Abstract

Management strategies and the use of advanced technologies are equally important for determining the sample number and sampling frame for successful field sampling for animal disease prevalence studies. The quality of the biological samples collected in the field has a direct bearing on the integrity of the data generated, prevalence estimates and subsequent policy decisions on disease control. Hence, compromising the quality of biological samples collected in the field could potentially undermine the priority setting principles in disease control strategies. Biological samples collected from domestic animals in the field are precious materials and require meticulous planning for sample collection, sample storage in the field, transportation, and storage in the laboratory. Poorly managed field sampling has a significant detrimental impact on the sample quality and quantity and directly affects the accuracy of disease prevalence data. A bad choice of sampling tools, containers, storage and transport all have a negative impact on the integrity of the sample and consequently have an impact on the outcome. Over the last two years, as part of our one health animal sampling work in India, we have observed challenges and opportunities in the field sampling of animals for disease prevalence studies. This paper aims to provide information on management practices and technologies for efficient biological sample collection from the field and ensure that good quality samples are available for testing.

Keywords One health, Domestic animals, Sample quality, Technology, Management

Introduction

India is a nation where raising livestock is one of the primary sources of income for the rural population, and the livestock sector contributed 4.35% of the total gross value added (GVA) in 2019–20 of the Indian economy (Chauhan et al. 2021). As per the 20th Livestock Census conducted in 2019, the total livestock population in India was 535.82 million, including 192.52 million cattle, 109.85 million buffaloes, 74.26 million sheep, 148.88 million goats, 9.06 million pigs, 851.81 million poultry and 0.85 million other livestock (Vandeplas et al. 2013).

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Economically and socially, infectious diseases affecting domestic animals lead to production losses and loss of livelihood of the farmers. Diseases affecting livestock and poultry are prioritized for control based on prevalence, mortality and morbidity rate, zoonotic significance, and economic loss (Kumar et al. 2021). Among all, the prevalence of disease is an important parameter that requires the collection of statistically defined sample numbers and testing of the samples (Messam et al. 2008).

The first step in the animal disease prevalence study in a population is the determination of a statistically defined random sample number and sampling frame. Execution of the sampling plan in the field requires liaison with local veterinarians and village heads, meticulous planning of sample collection, sample storage in the field, and careful transportation, labeling, and storage in the laboratory. Biological sample collection from domestic animals in the field can be performed with ease and efficiency with proper management practices and advanced technological tools. Management practices and use of advanced technologies are equally important as the determination of sample number and sampling frame for efficient field sampling for animal disease prevalence. Management practices with regional touch considering the local cultural, socioeconomic, and political conditions in mind are a vital part of any animal and human disease prevalence studies. The quality of the biological samples collected in the field has a direct bearing on the integrity of the data generated, prevalence estimates and subsequent policy decisions on disease control. Hence, compromising the quality of biological samples collected in the field could potentially undermine the priority setting principles in disease control (Migliavaca et al. 2020). In India, regulatory approvals such as the Institutional Animal Ethics Committee (IAEC) and Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA) are required for performing animal experimentation in field conditions. For handling hazardous microorganisms, Institutional Bio-Safety Committee (IBSC) approval was necessary (Race and Hammond 2008). Prior to sampling, regulatory approvals had to be acquired.

Several factors influence the quality of samples in epidemiological studies, including environmental conditions, sample collection methods, handling samples in the field, mode of sample transport, duration of sample transport and storage conditions (Holland et al. 2003), which in turn impact the test results. Good management practices are very important not only to ensure the quality of samples but also to shorten sampling time, to collect samples effortlessly, to manage public relations, to build trust with local veterinarians and farmers, and to collect samples in an ethical and professional manner.

Sampling of animals in field conditions and data collection can be greatly improved using advanced technologies, viz. GPS instrument, voice recorders, online data collection forms, muzzle printing device, handheld label printers, temperature and motion data loggers and digital cameras.

Several papers reviewed the study design, search strategy, data sources, study selection, data extraction, sample size determination, sample frame and data analysis for disease prevalence studies in animals and humans (Messam et al. 2008; Detering et al. 2019; Akbarpour et al. 2022), but to our knowledge, few papers have been published on the management practices in sample collection and quality of assessment of prevalence data in humans (Peplies et al. 2010; Migliavaca et al. 2020). This paper is the first to compile management practices and technological tools for efficient field sampling of domestic animals under Indian field conditions.

Steps in management practices for sample collection from domestic animals in field conditions

There are no defined number of steps in executing biological sample collection from domestic animals in the field. The following management steps are based on our experience in animal sampling in field conditions in different Indian states (Fig. 1).

1. Paper planning
2. Preparation of standard operating procedures for field sampling of animals
3. Liaison with field veterinarians, animal handlers and village heads
4. Packaging the materials for sample collection
5. Sample collection under field conditions
6. Labeling the samples under field conditions
7. Storage of samples in field conditions
8. Packaging of biological samples collected in the field
9. Transportation/shipment of samples
10. Aliquoting the samples and relabeling in the laboratory
11. Laboratory storage of samples
12. Biomedical waste disposal

Paper planning

The first step in the management of field sampling of animals is proper planning on paper. Written or printed documents carrying the fine details of the entire sampling process should be prepared. Planning for field-level animal sampling should be based on the objectives of the study, target animal species,

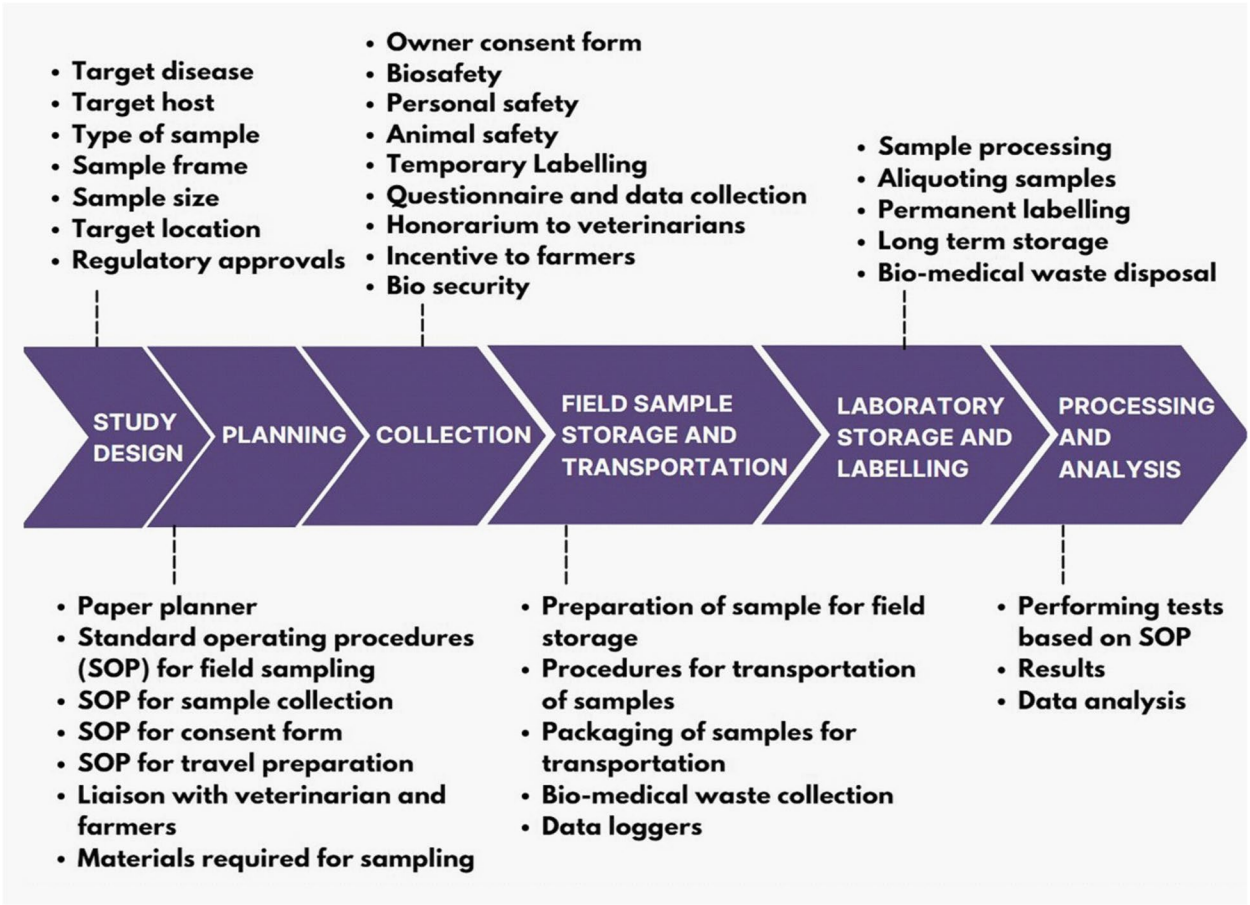

Fig. 1 Flow diagram explaining details of management practices involved in sample collection in animals in the field

target diseases, type of biological samples, sample collection techniques, transport and storage of samples, data collection, method of analysis, and other practical implications. The plan should be pragmatic and workable in field conditions so that the plan is executed without major hurdles. The planning starts with preparing a planner table that includes location, date of sampling, time of sampling, number of animals in each species, number of different types of biological samples and sampling frame, contact details of the local veterinarian/village head/animal handlers, location of the closest veterinary dispensary/hospital, availability of refrigeration storage facility in the hospital, availability of Travis or animal restraining facility, number of farmers to be contacted and interviewed, number of farmers to be given with incentives, number of questionnaire copies to be taken, number of sampling consent forms to be taken, information on vaccination of animals in the location especially against the target disease (e.g., Brucella vaccine) and information on disease outbreak in the location especially the target diseases (Table 1).

Table 1 Model planner for biological sample collection in animals in the field

a. Spatiotemporal and contact details of the sampling location								
S.No	**Date, Month and Year of sample collection**	**Timing of sample collection**	**State**	**District**	**Taluk**	**Village**	**Location of the veterinary hospital/clinic/laboratory**	**Contact information—veterinary hospital/office or veterinarian**
b. Details of animal species, sample number, target group and incentives								
Number of animals to be sampled							**Number of farmers to be contacted**	**Number of incentives to be given**
Cattle		**Buffalo**		**Sheep**	**Goat**	**Pig**		

When planning a prevalence study, it is crucial for researchers to specify the proper inclusion and exclusion criteria but also consider how those choices will affect the validity of the sampling and testing results. Exclusion criteria are characteristics of prospective study participants who meet the inclusion criteria but have additional traits that could hinder the study's success or increase the risk for a negative result or unfavorable outcome. Factors such as vaccination and disease outbreaks will significantly affect sero-prevalence and molecular prevalence studies. Sample collection should not be done in areas where outbreaks of the target disease are going on and in areas where vaccination against the target disease is being done. Samples collected during target disease outbreaks and vaccination are not considered random samples and yield a higher prevalence rate for the target disease in that region. Animals vaccinated against the target disease and animal herds suffering from target disease outbreaks should not be included in the sampling plan. Additional care should be taken while collecting samples from pregnant animals, nursing animals, sick animals, aggressive animals, and debilitated animals. The animals that were injured while collecting samples in the field should have been compensated appropriately.

Informed owner consent forms for animal sampling need to be prepared in advance, preferably in the local language, which should clearly state the purpose of sampling along with the volume of blood or other samples to be collected from each animal (Porteri and Borry 2008; Manti and Licari 2018). The owner of the animal should be made aware of the purpose of sampling, testing, expected benefits, risks, dangers, consequences and need to sign the consent form before proceeding with sample collection. Early morning sample collection is preferred because farmers usually take their cattle, sheep, and goats out for grazing in the morning in India. The local veterinarian should be made aware of the purpose of the sampling, objective of the study and sampling details with the planner. Once the veterinarian agreed and confirmed the date and time of the sampling, the itinerary and sample frame details were communicated. The date and month of sample collection must be finalized based on the availability of local veterinarians and farmers. The weather forecast for the sampling location must be referred to avoid the dates predicted with rain, thunderstorms, and cyclones. A round trip via train/bus/flight should be booked based on the date of sample collection. A staying place preferably nearest to the local veterinary dispensary/laboratory should be prebooked, which should have a refrigeration facility to store samples and to freeze the ice/gel packs.

Before initiating field sample collection in animals, the personnel involved in the study should be appropriately trained on all the SOPs pertaining to the sample collection and certified through online or offline examinations. The field study project should have a built-in budget to train the personnel and support the certification process.

Preparation of SOP for field sampling of animals

SOP is a written instruction to help facilitate successful completion of the project or study. SOP will provide uniformity in biological sampling in animals throughout the sampling process, ensuring that the sample collection, transportation, and storage would be in the same manner throughout the sample collection process. Even a small difference in either the sample collection or storage step in an SOP would yield different results between the groups (Peplies et al. 2010). For efficient field sample collection, SOP should consist of all the key points about the various methods and techniques involved in sample collection, materials needed, liaison, consent, incentives/honorarium details, sample storage conditions, transportation procedures, animal information, data collection, sample quality maintenance, biomedical-waste disposal, biosafety, precautions, and safety of personnel (Table 2).

Table 2 SOPs required in various stages of biological sampling in animals in field conditions

Planning	Collection	Post-sampling	Sample handling and storage
SOP for contacting the veterinarian and fixing the date and time of collection	SOP for sample collection in the field	SOP for sample labeling after collection	SOP for transportation of samples
SOP for travel preparation	SOP for biosafety in field sampling	SOP for field storage of samples	SOP for storage condition of samples during transportation
SOP for material preparation and packaging	SOP for personnel safety in field condition	SOP for questionnaire survey	SOP for sample labeling, aliquoting and laboratory storage
SOP to obtain informed consent form from animal owners	SOP for animal safety during sample collection	SOP for distribution of incentives to farmers	SOP for sample separation (centrifugation procedures)
	SOP for biosecurity in field sampling	SOP for giving honorarium to veterinarian	SOP for biomedical waste disposal

Contingency plans for sample storage in the field and return travel in the case of extended sampling time should also be in place.

Liaison with field veterinarians, animal handlers and village heads

Working in close partnership with field veterinarians, animal handlers, farm managers and village heads is essential for successful and efficient biological sample collection from domestic animals in the field. This collaboration enables us to obtain valuable information on the diversity and number of different animal species in the selected village/location. Not only does this practice ensure that the samples are collected with utmost safety and accuracy, but it also helps to protect animals from any harm. Sample collection consent forms ensure that there is no miscommunication between the sampling team and farmers and are essential for hassle-free sample collection. The project or study should have an inbuilt budget for providing honorarium to local veterinarians and animal handlers for helping in the collection of biological samples from animals. Incentives in the form of veterinary healthcare products for animals can be given to farmers for providing the animal samples. Liaison allows us to establish trust between the collection team and the farming community, maintain accurate records of our activities, and provide a safe and comfortable environment for both animals and personnel.

Packaging the materials for sample collection

Prepare and pack the necessary items required for sample collection a day before the start of travel toward the sampling location. Check whether materials such as syringes, needles, and collection tubes are in sufficient quantity as per the number of animals to be sampled. Based on the study plan, appropriate vacutainers were chosen for serum samples, lipid profiles, therapeutic drug monitoring (using red capped vacutainers), plasma, hematological examinations such as complete hemogram (using EDTA vacutainers), glucose estimation, toxicology studies (using gray color vacutainers), arterial blood gas analysis, bone marrow studies, lymphocyte immunotherapy (using dark green vacutainers), trace elements such as Cu and Zn, and toxicology and nutrient determination (using royal blue vacutainers).

Materials required for sampling should be categorized into materials required for presampling, sampling, and postsampling (Table 3). Depending on the type of sample collection, material requirements will vary for each step. A check list should be made to ensure that all the necessary materials are packed a day before reaching the sampling village/location.

The number of materials required for each sample collection varies according to the number of animals to be sampled in a location as per the sample frame. A checklist should be prepared for biological sampling in a specific location, and materials should be packed and verified using the checklist (Table 4). The minimum number of syringe, needle and collection containers required should always be at least 10–20% greater than the actual number of materials needed, which ensures that even in case of damage or inadvertent loss of materials, sample collection can be successfully completed. After reaching the veterinary dispensary,

Table 3 Materials required for presampling, sampling, and postsampling of animals in the field

Presampling materials	Sampling materials	Post-sampling materials
First Aid kit	PPE Kit	Vacutainer holding tray/rack
Travel tickets	Face masks and head caps	Labels, pens and marker pens
ID cards	Latex and transparent gloves	Zip-lock covers
Permission letter for sample transportation	Syringes and needles	Shock absorbent materials: polyurethane foam, bubble wrap, paper pads
Sample collection consent forms	Cotton and surgical spirit	Ice box and ice/gel packs
IAEC and IBSC certificates	Vacutainers	Temperature and motion loggers
		Bio waste collection bags
	Swabs	Shrapnel collection containers
	Gum boot	Biohazard waste collection box
	Zip lock covers	Questionnaire
	Sterile swabs	Voice recorders
	Sterile containers (100 mL), Containers with formalin, Containers with transport medium	Incentive materials for farmers
		Honorarium for veterinarian/animal handlers

Table 4 Checklist of materials to be packed for biological sample collection in animals

Number of materials required															
PPE Kit	Gumboot	Cotton	Disinfectants	Syringe	Needle	Vacutainers	Sterile Containers	Cotton swabs	Questionnaire and sample collection consent forms	First aid kit	Labels and marker pens	Ice box	Ice/gel packs	Biowaste disposable bags	Sharp objects collection container

Table 5 Biomedical waste management guidelines

Category	Type of waste	Bag/container to be used	Disposal methods
Yellow	Soiled waste contaminated with blood and body fluids, cotton swabs and discarded blood and its components	Yellow colored nonchlorinated plastic bags	Incineration or plasma pyrolysis or deep burial (only allowed in rural areas where incineration facilities is not available). In absence of above facilities, autoclaving or microwaving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Waste sharps sent for final disposal to iron foundries (having consent to operate from the State Pollution Control Boards or Pollution Control Committees) or sanitary landfill or designated concrete waste sharp pit
Red	Contaminated waste (Recyclable) including syringes (without needles and fixed needle syringes), vacutainers with their needles cut and gloves	Red color nonchlorinated plastic bags or containers	
White—Translucent	Waste sharps such as needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades, or any other contaminated sharp object that may cause puncture and cuts	Puncture proof, leak proof, tamper proof containers	

ice packs/gel packs should be frozen in the freezer for transportation of the samples collected from the location.

Sample collection under field conditions

Collection of blood samples

Make sure to carry enough frozen gel packs to store samples soon after collection in the field. After reaching the location of the farm/household/herd, randomly choose the animal for sampling. The needle size was chosen as 16 or 18 gauge for cattle and buffalo, 20–22 gauge for sheep and goat, and 19–21 gauge for pigs, and a suitable syringe (1/2/5/10/20 mL) was used for the exact volume of samples. Before handling the animals, the sampling team wore a face mask, gloves, disposable apron, and gumboots. Once the animal was identified, the animal was restrained in travis in a proper position suitable for blood collection from the jugular vein with the help of the owner/farmer. Travis may not be available in all farms or in field conditions, and in that case, the animal needs to be restrained with the help of animal handlers and farmers using locally available make-shift travis (World Organization for Animal Health (WOAH, OIE (2018)). Sheep and goat tend to be calm and exhibit significant flocking behavior. If isolated from the herd, they may become highly anxious. They usually remain dormant after being trapped. To prevent any harm to the animals, handlers should always exercise caution. Head or horn butting may occur during blood collection. The animal was gently restrained in a lateral recumbency position. The animal was held firmly, and the neck was tilted to find the jugular vein. If needed, trim the area of blood collection to remove hairs (WOAH, OIE (2018)). The pig needs to be restrained using a snare or casting rope against a wall or corner securely. Small pigs can be held or placed using a v-trough. The cranial vena cava, ear vein or external jugular vein can be chosen depending on the volume of sample required (WOAH, OIE (2018)). Free-range pigs are generally difficult to restrain in field conditions and require more manpower. Alternatively, blood can be collected from the marginal ear vein directly in the slaughterhouse before slaughtering restrained pigs.

Collection of fecal samples

For the collection of fresh fecal samples, the animals were firmly held in a standing position. Wear long disposable plastic sleeves to collect the sample directly from the rectum. Do not collect fecal samples on the ground, as they are potentially contaminated with soil organisms and parasites. Collect samples based on the amount of fecal sample needed. Place the collected fecal sample in a screw cap sterile collection container and secure the container properly. Label the container and store in an ice box. The sample containers were transferred to the laboratory within 24 h of collection on dry ice and stored at -20°C. For long-term storage, the fecal samples need to be stored at -80°C (Santiago et al. 2014). Based on the test to be performed, the storage temperature and viability of fecal samples may vary (WOAH, OIE (2018)).

Collection of milk, urine, and swabs

Animals should be restrained before milking, and proper sterile procedures should be followed to prevent contamination due to surface microorganisms. Teat was cleaned thoroughly with gauze pads soaked in 70% ethyl alcohol. After the teat dried completely, the first milk was discarded to prevent contamination. To minimize contamination, sterile containers should be used for collection. After the collection of milk, the containers were labeled, sealed tightly and stored at 4°C. The volume of milk collected depends on the animal species and type of testing (Quinn et al. 2002; Yohannis and Molla 2013; Cabral et al. 2015).

Before collection of urine, the urogenital region was cleaned thoroughly. Mid-stream urine can be collected using the free capture method in a labeled sterile container with a tight lid. Collected urine should be processed immediately or stored at 4°C for 24 h (Neumann et al. 2020). The volume of urine collected depends on the animal species and type of testing (Kurien et al. 2004).

In general, oral, nasal, wound and rectal swabs were taken from the animals depending on the target disease. The animal was restrained if needed before inserting the swab. Ensure that the swab does not damage the animal or draw blood. The process was repeated until the desired amount of sample was acquired. Place the swab in a leakproof container with or without medium based on the test (Bourbeau 2005; VanderLey et al. 2011; Osová et al. 2018).

Biomedical waste segregation and collection in field

Once the sample collection is done, the materials used for the collection need to be segregated and collected in appropriate colored biomedical waste collection bags. Biomedical waste materials should not be disposed of in the field to avoid contamination and transmission of diseases. A biodisposable bag (yellow, red and white colored) should be used to collect materials such as cotton, syringe and needles, and PPE from the field to the laboratory for safe disposal. The used shrapnel, such as blades and needles, should be collected in a separate shrapnel collection container. All biomedical waste materials should be autoclaved and handed over to the biomedical waste disposal agency for proper disposal or as mentioned in Table 5. The same syringe and needle

should not be used for other animals. The PPE used in a farm/herd/village should not be used in the next farm/herd/village. Sampling of multiple farms and villages on the same day should be avoided to prevent transmission of diseases. In the case of sampling in multiple villages and farms on the same day, take a shower and wear new PPE set before moving to the next village and farm.

Labeling the samples under field conditions

Under field conditions, the labeling process should be quick and readable. Temporary labeling with markers or direct marking on vacutainers/containers will be sufficient to identify the sample. Permanent labeling with proper ID can be performed after reaching the laboratory, which will minimize the time taken during sample collection. Details such as farmer/owner name, address and contact details, animal ear tag, age, breed, sex, and medical history should be noted separately and tagged with the sample ID as per the label.

Storage of samples in field conditions

After adequate labeling was performed, the samples needed to be stored temporarily in an airtight container or ice box with frozen gel packs to preserve the samples. The frozen gel pack should be able to provide a consistent temperature until the samples are transported from the sample collection location to a nearby veterinary dispensary/hospital or laboratory. An ice box with gel packs will be ideal for maintaining the samples at 4–8°C and will be easy to carry around during field sample collection.

Packaging of biological samples collected in the field

Packaging the biological samples collected in the field for transportation is a critical step of sampling, as it helps to maintain the integrity of the sample and ensures that the quality remains the same. The packaging materials should be chosen in such a way that they absorb the impact made during the journey and protect it from contamination. These materials need to be lightweight and disposable, allowing for easy transportation. Some of the commonly used materials for packaging include absorbent materials, leak-proof containers, gel packs and ice boxes or thermocol boxes. Package should contain a primary container (a vacutainer rack/stand or thermocol with place holders or zip-lock covers), a secondary leak-proof packaging container (plastic containers or thermocol box) to seal the primary container and to avoid spillage and an outer container to carry the materials. The sample vials first need to be arranged in a blood collection rack/stand or zip-lock covers to securely hold the vials in place. Before packaging, ensure that the sample containers/vials are labeled properly and sealed with parafilm. The containers need to be placed in a secondary leak-proof container. The materials then need to be packed with absorbent materials and gel packs in an outer container, such as an ice box, thermocol box or hard-board box, for easy transportation (Fig. 2). Airtight and waterproof packing tape was used to seal the outer container to minimize the temperature loss during transportation.

Absorbent materials should be able to absorb any moisture or liquid from samples and help maintain a consistent temperature. They are also used to cushion the samples, reducing the risk of breaking or damaging the container during transport. Shock absorbent materials, such as polyurethane foam, paper pads, and bubble wrap, are ideal for transportation purposes. Once the sample was securely placed in a secondary container, using gel packs and shock absorbent materials, the outer containers could be packed properly. Many containers come with premade slots for the samples, providing additional protection against unexpected shocks to the container. They can also provide insulation from extreme temperatures or vibrations. Hence, three levels of protection can be achieved by using these packaging methods, which will ensure that biological samples reach the laboratory under the same conditions as they were collected in the field.

For transportation of biomedical waste disposal materials, separate packaging should be used. Materials such as PPE, cotton and syringes should be tightly packed in biohazard bags. Sharp object collection containers with lock facilities should be used for disposing needles and sharp objects.

Transportation/shipment of samples

It is critical to have the biological samples transferred to the laboratory as quickly as possible to maintain quick turnaround times and sample quality (Zaninotto et al. 2012). When transporting biological samples, a variety of rules and laws must be followed. The awareness of potential risks during the transport of biologic materials has increased, not only among scientists but also among the public. In the case of shipping blood samples from a different region, various regulations need to be followed since they pose a very high risk of infectious disease transmission. International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA) laws and federal regulations (Department of Transportation, DOT) govern the transport of potentially infectious and other hazardous materials, and specific regulations are in place regarding the packaging, labeling, and documentation of shipped goods according to their classification (Snyder 2002).

There are various regulations in Asia that were derived from WHO and WOAH guidelines. These regulations were modified based on country-specific requirements, such as Singapore (https://www.moh.gov.sg/biosafety/

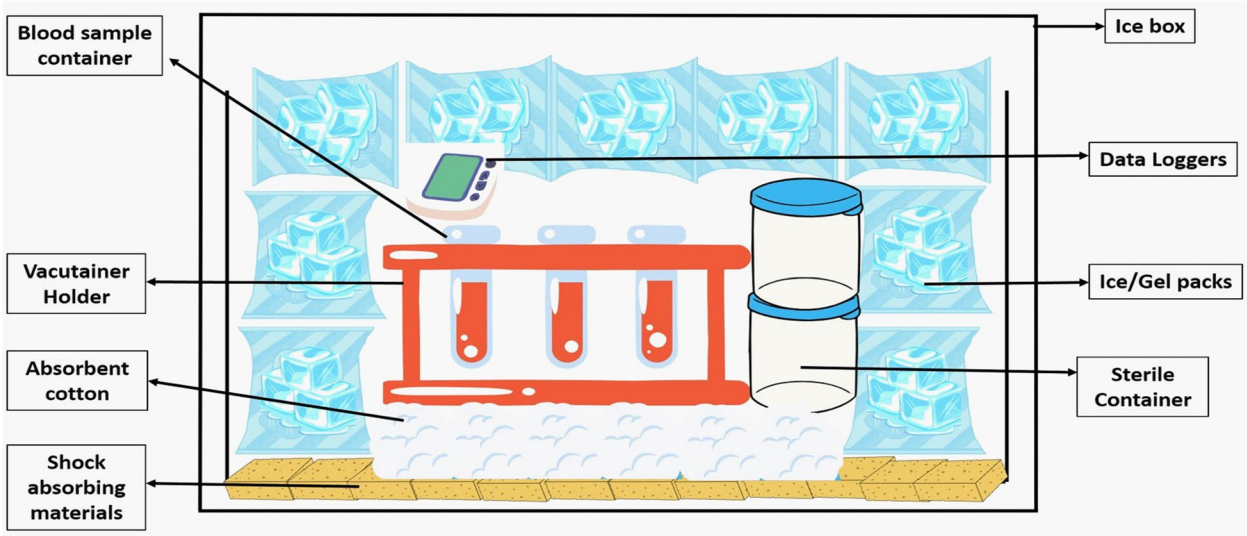

Fig. 2 Cross-sectional view of the packaged sample collection box

common/transportation), China (http://www.caac.gov.cn/en/ZCFG/MHFG/201509/P020160226465217721446.pdf) and Thailand (https://kris.kmitl.ac.th/wp-content/uploads/2019/12/2.-PATHOGENS-AND-ANIMAL-TOXINS-ACT-B.E.25582015.pdf). In India, there are guidelines/regulations for the transportation of human biological samples issued by ICMR (https://main.icmr.nic.in/content/download-guidelines-transfer-biological-material) that can be adopted for animal sample transportation.

From a more laboratory-specific point of view, the requirements stated in the Clinical Laboratory Standards Institute (CLSI) guidelines on procedures for the handling and processing of blood specimens for common laboratory tests and the ISO 20658:2017 on requirements for collection, transport, receipt, and handling of samples should be followed by any accredited laboratory (Nybo et al. 2019).

Aliquoting the samples and relabeling in the laboratory

After reaching the laboratory, samples need to be aliquoted and properly relabeled for long-term storage and analysis. Based on the quantity of sample collected and the intended testing, the sample must be aliquoted into small tubes and sealed using parafilm. Aliquoting helps preserve the samples from repeated freeze/thaw cycles. After the samples are aliquoted, they need to be labeled with appropriate sample IDs using permanent markers, barcode labeling, RFID or label printers (Peplies et al. 2010). Labels should be chosen in such a way that they are nonerasable and frost-resistant. A labeling format should be chosen that should represent information of the sample collected. The first three letters should consist of the state, district, block/taluk, and village information followed by animal species and animal number, e.g., APKRNUPACa001 (AP-Andhra Pradesh state, KR – Krishna district, NU – Nunna taluk, PA – Pathapadu village and Ca—cattle). Ensure that the temporary labeling done in the field matches the labeling in the laboratory for each sample.

Laboratory storage of samples

When samples are stored for short and long periods of time, as well as during the time between sample collection and processing, temperature may have an impact on the quality of the samples. Isolated DNA is typically kept at 4°C for a few weeks, -20°C for a few months, and -80°C for a few years (Matange et al. 2021). Isolated RNA should be stored at -80°C to maintain its integrity (Seelenfreund et al. 2014). Serum should be at -20°C for short-term storage and -80°C for long-term storage (Tuck et al. 2009). Fecal samples can be stored at room temperature for immediate analysis or parasite culture. Fecal samples should be stored at 4–8°C for short-term storage and analysis and at -20°C for long-term storage.

Cleaning and disinfection of soiled gumboots

Cleaning and disinfecting the soiled gumboots after field sampling are important to prevent the dissemination of infectious organisms. Personnel involved in cleaning the soiled gumboots should wear proper PPE, including face masks, eye protection (goggles/face shields), head caps, water-resistant gowns and double gloves (inner gloves: latex or nitrile gloves; outer gloves: rubber gloves). All

visible dirt should be removed properly with detergent and water by using a disposable brush before disinfection. Then, the cleaned gumboots were disinfected by immersion in 0.5% bleaching solution for at least 10 min. The disinfected boots were rinsed with water and then air dried (WHO 2014; Reidy et al. 2017).

Biomedical waste disposal

The most neglected aspect of field sampling is biomedical waste management. Waste materials such as soiled syringes, needles, vacutainers, gloves, masks, aprons, and PPE need to be disposed of properly to avoid disease transmission and environmental contamination. Biomedical waste should be disposed based on the Bio-Medical Waste Management Rules, 2016 (Datta et al. 2018) implemented by the government of India (Table 5). Rules are defined based on the category of waste, such as human anatomical waste, animal anatomical waste, soiled waste, contaminated waste, etc. For each type of waste, the container to be used and the treatment and disposal options vary. Methods of treatment and disposal of waste required only for animal field sampling are listed in Table 5.

Personnel safety and biosafety

Maintaining personnel safety is extremely challenging in field sampling processes that involve livestock. Safe practices should be followed at all times to minimize occupational risk. Personnel must be knowledgeable about the animal species, animal behavior and zoonotic diseases of animals. Implementing restraints and other control measures while handling animals should be a priority. In the absence of proper travis, shift animal restraints should be identified in the field. PPE, face masks, gloves, gumboots and other necessary protection are required when in direct contact with animals. Other factors, such as weather and landscape, also present challenges in personnel safety (Richmond et al. 2003; Phippen 2008).

To prevent the unintentional or accidental release of biologically hazardous agents or toxins, biosafety guidelines must be followed when collecting field samples. These procedures protect the environment, personnel, animal handlers, and veterinarians. Biosafety guidelines include hand washing after handling animals and potential hazardous materials, avoiding hand-to-face contact during sample collection, proper training for handling samples during transportation, always wearing PPE, disposal of sharps, nonsharps, solid and liquid waste in their respective disposal bags, and avoiding reusing gloves, masks, and cotton when handling different animals (Burnett et al. 2009).

Animal safety

Safety of animals during sample collection is as important as personnel safety. Animal health and stress should be monitored during sample collection. Loud noise and quick movements tend to increase the stress of animals; hence, animal handlers should handle animals gently during sample collection. Animals were restrained properly to avoid any injury to animals while collecting the samples. Sample collection was performed by experienced persons under the supervision of veterinarians to minimize any injuries to the animals.

Biosecurity

Biosecurity is a way of preventing pathogens from entering or exiting any area where they can affect people or domestic animals. There is no specific biosecurity guideline for the biological sampling of animals under field conditions. The standard principles of biosecurity should be practiced in the field to prevent the dissemination of disease from sample collection locations to other locations. The fomites and personnel involved in biological sampling can potentially act as carriers of disease agents and transmit diseases from one place to another. Sampling the animals in multiple locations on the same day should be avoided to prevent potential dissemination of disease agents. In the case of multiple animal sampling on the same day, taking a shower before moving to a new location and wearing a new set of PPE and gumboots in the new location are highly recommended. After sample collection was completed on a farm, the used PPE was discarded, and the gumboot was properly washed and disinfected. If the same vehicle is used in the sample collection of multiple locations/farms, it is recommended to clean and disinfect the tires of the vehicles before entering the new location (Morley 2002).

Technologies used to enhance efficient field sampling

There is a potential application of various technologies in animal sample collection in field conditions that can improve the efficiency of sampling and the quality of samples collected from animals. The use of technological tools can significantly reduce the amount of time required to collect data and improve accuracy by minimizing human error. Technologies specifically used for increasing the efficiency of field sampling are listed below:

1. GPS Tracker
2. Digital voice recorder
3. Digital camera
4. Muzzle print
5. Data loggers
6. Online data collection forms
7. Handheld label printers
8. Portable battery-operated cooler box

GPS tracker

The Global Positioning System (GPS) can deliver incredibly precise location data. Location data are crucial for the final analysis of the results. Implementation of government policies and other beneficiary activities will be done based on the location data obtained. During field sampling, it will be harder to obtain the specific location along with latitude and longitude using the smartphone since it depends on cellular coverage and signal strength. Smartphones use assisted GPS technology, which is a combination of networks and GPS antennas and is significantly less accurate than conventional GPS devices (Merry and Bettinger 2019). To overcome this, compact GPS tracking devices can be used that provide accurate and real-time location tracking. GPS trackers are portable and have a long battery life compared to mobile phones. With a GPS tracker, one can track the amount of time spent at a particular location along with geographic data. GPS can also be used in real-time monitoring of the sampling and the location of samples during transportation.

Digital voice recorder

Under field sampling conditions, voice recorders can be used to record interactions between farmers/veinarians and sampling personnel. Information gathered during sample collection should be either in a written or audio format. It will be challenging to collect data in written format during sample collection, as it is time consuming and requires separate manpower. It will be easy if the researcher handles the transcription of audio to a written format to avoid any inaccuracy. All recordings can be replayed to gather any missing information, such as farmer details, animal breeds and medical history. A digital voice recorder is portable, and the data recorded can be retrieved by connecting to a mobile/laptop via USB or Wi-Fi.

Digital camera

Digital cameras are devices used to capture high-quality photos and video at various resolutions. Documenting the entire process of sample collection via a digital camera will be useful in reviewing the data and for future analysis. During sample collection, it is necessary to take photos and videos of the animal to examine the process and identification of animals. Photos and videos of animals, muzzle, dental anatomy, farmers, farm location, animal housing, landscapes, and vegetation of the location can be recorded. Using the animal photos and dentition, the breed and age of the animals can be reconfirmed.

Muzzle print

Muzzle or nose prints are unique to cattle and consist of various distinct features, such as skin patterns, ridges, and grooves. Muzzle print technology is developed to identify the cattle using its muzzle print pattern. It is a fast and accurate identification system that uses image algorithms to detect every single variation in a muzzle print. For cattle identification, a muzzle image of cattle is taken and uploaded into a database that acts as a primary template (Awad 2016). For identifying the cattle, new live images will be taken, which will then be matched with primary template images in the database. The cattle will be tagged to its muzzle image and can be identified by matching its live image to its database image. Mobile apps are developed specifically for the identification of cattle through muzzle print (Awad 2016). It can be operated remotely via a phone, and no additional devices are needed. It aims to replace methods such as RFID tagging and ear tagging. It will be a useful tool in population analysis, prevalence studies, insurance claims, and the implementation of government schemes and policies.

Data loggers

Data loggers are devices used to record raw live data from the environment, such as temperature, humidity, moisture, sound, and vibrations. Depending on the use, different data loggers can be used to monitor those parameters. Manual logging of each data point will be less accurate, unreliable and challenging to perform during transportation. Hence, data loggers can be used while transporting samples to monitor necessary parameters. In case of any change in set conditions, the data loggers will notify the person, and the issue can be addressed accordingly. For sample transportation, two main data loggers, temperature and motion loggers, can be used to monitor the quality of the sample.

Temperature data loggers The primary way to ensure the quality of samples is to measure the temperature during transportation. Temperature data loggers are designed to monitor even slight changes in temperature in the environment. Most of the temperature loggers recorded the temperature from -40°C to 70°C. It will constantly record the temperature data as set by the user either by second or hour and provide the raw data. Most temperature data loggers will measure not only temperature but also other key parameters, such as humidity. Data loggers come with LCD displays, alarms to notify when set temperatures are reached, good battery life, USB interfaces and software to view the data captured and with water-resistant built quality. The temperature loggers are fixed inside the sample box, and once the sample reaches the destination, the temperature for the entire journey can be viewed in a graphical or numerical representation. Based on the temperature data of the samples obtained from data loggers, a decision can be

made whether to accept or reject the samples. Ice boxes equipped with inbuilt temperature and humidity loggers are available on the market; however, they are expensive and heavy when compared to standalone data loggers (Lippi et al. 2011; Kartoğlu et al. 2010). Whole blood in anticoagulant or serum tubes stored for 10 h at 21 ± 1°C may be used for routine analysis without restrictions for all investigated analytes except folate and phosphate (Henriksen et al. 2014). The integrity of specimens and consequently the quality of the results deteriorate above 35°C, and when stored longer than 24 h, 2 to 8°C is the optimal temperature range for specimen transport, especially if delays in analysis are anticipated (Kaur et al. 2019). Raw fecal and urine samples were transported at 4–8°C within 24 h. Whole blood can be stored at 4–8°C for up to 24 h before the serum is separated, but it must not be frozen (World Health Organization (WHO) 2007).

Motion data loggers Motion loggers are used to detect shock and vibrations during the transportation of samples. The accelerometer associated with the motion logger measures the subtle changes in vibration and shock. They are also capable of measuring temperature and humidity; hence, a single motion data logger will be sufficient to monitor all the necessary parameters. They are portable, battery operated, and display or store data that can be viewed later via USB. Sudden changes in motion and impulsive vibrations might exert excessive shear stress on the RBCs and cause hemolysis in the whole blood samples. Hence, it is essential to measure the changes in shock and vibrations during transportation to ensure that the sample quality is not compromised (Klose et al. 2010). Impulse vibration was shown in vitro to cause damage to RBCs. It is suggested that the damage to RBCs depends on both the peak acceleration and exposure duration of impulse vibration. The higher the peak acceleration and the longer the exposure duration, the greater the proportion of RBC lysis. Peak accelerations lower than 200 km/s^2 and less than 10 min exposure time were found to be the acceptable level of motion or vibration for transporting whole blood samples and RBCs (Ando et al. 2005).

Online data collection forms

Online data collection forms/survey tools provide a more reliable and inexpensive process, while paper-based surveys are challenging to complete in field conditions and are not suitable for long-distance travel. Some of the commonly used online forms are Google Forms, Microsoft Forms, Jot Forms, etc. Google Forms are more user-friendly than other cloud-based forms and are mainly used for creating questionnaires and submitting responses easily. For animal sample collection, the questionnaire should mainly focus on animal details such as age, sex, breed, health information, vaccination details, feeding details and the environment in which animals are housed and fed. Apart from the frequently asked questions, the questionnaire needs to be tailored carefully based on the type of information needed for the sampling plan. A large amount of data can be gathered, analysed, and visualized using this tool. Google Forms has the option to add or modify questions, add video- or audio-based questions and customize themes. The responses will automatically be saved in a Google spreadsheet, which is also cloud-based. Later, it can be visualized in different graphical representations (Mondal et al. 2018; Farmer et al. 2016). Data collection and sample collection should occur simultaneously to save time and to collect valid on-site information.

Portable handheld label printers

Conventional label stickers can be used for labeling the sample containers; however, there is an enormous risk of getting erased or damaged during storage and transportation. Furthermore, human errors such as mismatching of labels, wrong labeling and missing of labeling a container might occur. Labels and label markers might be damaged if exposed for a long time in moisture or in high/low temperature conditions. To avoid these possible problems, a portable-battery operated label printer can be used in the sampling of animals in the field. The label printer is smaller in size and lightweight and can be easily carried out during field sampling. Based on the sample container, the label size will be determined, and the required ID can be entered on the device. Once the details are entered, the device will generate a sticky label that can be pasted onto the container. Labels can also be printed with QR codes or barcodes containing traditionally needed information. The label format can be stored in the printer's available storage and can be instantly used in the field. Some of the commonly used label printers available on the market are the Brady M210 printer, SUPVAN label printer and Brother PT-H105 printer.

Portable battery-operated cooler box

In field conditions and in long-distance transportation of biological samples, consistent maintenance of the temperature of ice packs is a challenging task and sometimes requires replacement of discharged ice packs with ice packs. For long-distance transportation of biological samples, portable battery-operated ice boxes can be one of the most suitable options to store samples at the

required temperature. A portable battery-operated ice cooler box allows the storage of samples at the desired temperature under field conditions. The portable design will be ideal for long distance travel during sample collection. The ice box provides an on/off switch with a red/green LED light indicator, which enables the temperature to be maintained consistently. It can be easily charged using conventional 12 V DC and 22 V AC power outlets.

Conclusion

The aim of the epidemiology study is the control and eradication of major epidemic diseases in livestock in any region of the world, which requires coordinated and regional approaches. The quality of biological samples collected from domestic animals in field conditions is of paramount importance in animal disease prevalence studies. This paper discussed various steps and the importance of management practices in biological sample collection in domestic animals under Indian field conditions to ensure the quality of samples. The use of advanced technologies in field sampling would also improve the sample quality, accuracy of data, and efficiency of the sampling process. Region-specific management practices and guidelines for the collection of biological samples from domestic animals that encompass the local social, cultural, and political scenario are needed to ensure the quality of the samples and highly reliable test results.

Abbreviations

AC	Alternating Current
CLSI	Clinical Laboratory Standards Institute
Cu	Copper
DOT	Department of Transportation
DC	Direct Current
EDTA	Ethylenediaminetetraacetic acid
G	Gauge
GPS	Global Positioning System
IAEC	Institutional Animal Ethics Committee
IBSC	Institutional Biosafety Committee
ISO	International Organization for Standardization
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
ID	Identity Document
LCD	Liquid–crystal display
LED	Light-Emitting Diode
PPE	Personal Protective Equipment
QR	Quick Response
RFID	Radio-frequency identification
SOP	Standard Operating Procedure
USB	Universal Serial Bus
V	Volt
WHO	World Health Organization
WOAH	World Organization for Animal Health
Wi-Fi	Wireless Fidelity
Zn	Zinc

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Authors' contributions

Conceptualization: AP, TKG, ABRP; writing: AP, GKR, PS, DM; reviewing: SC, DRG, KK; funding acquisition: AP, ABRP. All authors have read and approved the manuscript.

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The authors declare that they have no competing interests.

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