A RETROSPECTIVE AND CROSS-SECTIONAL STUDY OF DOGS RABIES, VACCINATION COVERAGE AND BARRIERS IN ADDIS ABABA

MSc Thesis

BY

KIRUBEL BEFEKADU

(DVM)

Addis Ababa University College of Veterinary Medicine and Agriculture

Department of Veterinary Microbiology, Immunology and Veterinary Public Health

JUNE, 2024

BISHOFTU, ETHIOPIA

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A thesis submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Veterinary Science (MVSc) in Veterinary Public Health

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Department of Veterinary Microbiology, Immunology and Veterinary Public Health

As MVSc research advisors, we here by certify that we have read and evaluated this thesis prepared under our guidance by Kirubel Befekadu

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A RETROSPECTIVE STUDY OF DOGS RABIES, VACCINATION COVERAGE AND CHALLENGES IN ADDIS ABABA

Kirubel Befekadu	___________________	_________________
Name of Student	Signature	Date

We recommend that it can be submitted as fulfilling the MVSc thesis requirement.

Dr. Biruhtesfa Asrade	___________________	_________________
Major Advisor	Signature	Date
Dr. Zerihun Assefa	___________________	_________________
Co-advisor	Signature	Date

Addis Ababa University

College of Veterinary Medicine and Agriculture

Department of Veterinary Microbiology, Immunology and Veterinary Public Health

As a member of examining board of the final MVSc, open defence we certify that we have read and evaluate the thesis prepared by Kirubel Befekadu

Entitled:

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Kirubel Befekadu	___________________	_________________
Name of Student	Signature	Date

We recommend that it can be submitted as fulfilling the MVSc thesis requirement.

Dr. ___________________	___________________	_________________
Chairman	Signature	Date
Dr. ___________________	___________________	_________________
External Examiner	Signature	Date
Dr. ___________________	___________________	_________________
Internal Examiner	Signature	Date

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Name: Kirubel Befekadu

Signature: _________________

Date of Summation

Advisors

Biruhtesfa Asrade (DVM, MSc, Associate professor)

Signature: _________________

Zerihun Assefa (DVM, MVSc, Assistant professor)

Signature: _________________

Addis Ababa University College of Veterinary Medicine and Agriculture, Bishoftu

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LIST OF ABBREVIATIONS

CDC	Centres for Disease Control
CNS	Central Nervous System
DALYs	Disability-adjusted Life Years
ELISA	Enzyme-linked Immunosorbent Assay
EPHI	Ethiopian Public Health Institute
ERA	Evelyn Rokitniki Abelseth
FAT	Fluorescent Antibody Test
NGOs	Non-governmental Organizations
NOHSC	National One Health Steering Committee
OIE	World Organization for Animal Health
PEP	Post-exposure Prophylaxis
PPE	Personal Protective Equipment
RABV	Rabies Virus
RIG	Rabies Immunoglobulin
RNA	Ribo-nucleic Acid
STATA	Statistics and Data
USD	United States Dollar
WHO	World Health Organization

ABSTRACT

A retrospective and cross-sectional study about the incidence of rabies and the coverage and barriers of rabies vaccination was conducted in Addis Ababa city from October 2023 to April 2024. The objective of this study was to assess the general condition of rabies and its vaccination coverage within Addis Ababa. Data was collected through surveys of dog owners and interviews with veterinarians in various sub-cities across Addis Ababa. Additionally, retrospective analysis of dog bite records from the Ethiopian Public Health Institute and canine vaccination data (2020-2023) from the Farmers and Urban Agriculture Development Commission were employed. Out of the 206 dog owners who participated in the survey, the majority (66.5%) indicated that their dogs were fully vaccinated. Some of the significant barriers for dog vaccination acknowledged by respondents were poor knowledge of rabies, unrestricted dog movement, and lack of mass vaccination campaign. Interviewed veterinary professionals identified lack of equipment, coordination with other agencies and inadequate long-term planning as the major barriers for vaccination coverage. In Addis Ababa, 3,123 individuals were reported to be bitten by a suspected dog from 2019 to 2023 and overall incidence rate was found to be 12.45. In the same period 92.7% of the victims were reported to have received post-exposure prophylaxis. According to records from the Farmers and Urban Agriculture Development Commission, a total of 96,319 dogs received rabies vaccination in Addis Ababa during the period spanning from 2020 to 2023. In the present study, there was a significant increase in the number of human cases of dog bites receiving post-exposure anti-rabies vaccination. Additionally, this research revealed a lack of awareness regarding rabies vaccination, particularly notable in sub-cities like Arada and Lemi Kura. This study recommends for the scaling-up of periodic mass vaccination campaigns for dogs, coupled with one health initiatives and targeted restrictions on canine movement, as a comprehensive strategy for rabies control.

Key Words: *Addis Ababa, EPHI*, *mass vaccination*, *Rabies, Retrospective*

1. INTRODUCTION

Rabies is a deadly zoonotic illness that affects people worldwide and is mostly spread by carnivores. Each year, it is known to significantly increase the morbidity and death rates in both humans and animals (Barecha *et al.*, 2017). According to estimates, rabies causes roughly 31,000 and 24,000 human fatalities per year in Asia and Africa, respectively. Additionally, it causes 8.6 billion USD in economic losses globally year and 3.7 million disability-adjusted life years (DALYs) (Gebru *et al.*, 2019).

Any mammal is susceptible to contracting the viral disease known as rabies. However, it is primarily transmitted to humans through bites from rabid domestic dogs, accounting for more than 99% of all human fatalities caused by rabies. Many developed nations have successfully eradicated rabies from domestic dog populations. However, in most developing countries, rabies continues to be prevalent among domestic dogs and is inadequately controlled (Hampson *et al.*, 2015).

Animal productivity is at risk due to the development of dog-borne rabies in rural areas. For safety, dogs in these areas are frequently housed close to other animals. A cycle of transmission and persistence within the animal population may be established by the virus moving from dogs to cattle as a result of this close contact (Yizengaw *et al.,* 2018).

Several investigations have indicated a concurrent rise in both human and dog populations globally, particularly in Africa. This expansion appears to provide favourable conditions for the transmission of numerous significant zoonotic infectious diseases from dogs to humans (Baneth *et al.*, 2016).

The majority of rabies-related deaths in humans take place in impoverished Asia and Africa. Ethiopia is among those most severely impacted by this. As documented by Asfaw *et al.* (2024), an analysis of rabies fatalities in Ethiopia revealed a significant geographic disparity. The regions of Amhara and Oromia bore the brunt of the disease burden, accounting for 38.4% and 22.2% of the 297 reported human deaths from 2018 - 2022, respectively. In contrast, Addis Ababa city reported a lower fatality count of 11 during the specified timeframe.

In Ethiopia, domestic dogs are the main carriers of rabies. Dogs are poorly managed, and only owned dogs living in cities are frequently vaccinated against rabies. The high endemicity of canine rabies in the nation is a result of both a large dog population and inadequate dog management (Gebru *et al.*, 2019).

Human rabies poses a significant public health challenge in Ethiopia, particularly in the large cities of developing countries characterized by extensive borders, high dog populations, unrestricted dog movement and impoverished conditions. The prevalence of human deaths due to rabies, along with the associated economic losses and public health burden, further emphasize the urgency of addressing this issue. Dogs, cats, and other wild animals have all been found to be capable of spreading the rabies virus to both people and livestock (Ali, 2022).

There have also been claims of a chronic lack of record keeping and underreporting of human rabies cases in Ethiopia. As a result, the disease's real impact has been underestimated and given less priority for control and prevention. In addition, a sizable portion of those who have been exposed to rabies favour visiting traditional healers for medical care as opposed to going to hospitals (Kabeta *et al.*, 2015).

In developing countries, rabies represents a significant urban health concern, characterized by its prevalence among household pets such as cats and dogs (Shite *et al.*, 2015). Several investigations have indicated endemic spread of rabies across Addis Ababa. The majority of confirmed cases of animal rabies in Addis Ababa over the past two decades were found in dogs, which correlates with the high incidence of confirmed cases (Ali *et al.*, 2010; Deressa *et al.*, 2010). It is closely linked to the existence of a sizable stray dog population.

Rabies prevention and control necessitate a collaborative effort across various sectors. Key strategies include: Strict Quarantine Measures: Implementing regulations to prevent the spread of rabies through animal movement. Stray Dog Control: Addressing stray dog populations to reduce transmission risks. Educational Outreach: Organizing extension programs to raise public awareness about rabies and prevention methods. Wildlife Rabies Management: Developing strategies to control and prevent rabies in wild animals. Dog Registration and Vaccination: Implementing dog registration systems and conducting mass dog vaccination campaigns. For humans, prompt post-exposure prophylaxis (PEP) after animal bites can prevent rabies deaths almost entirely. Ethiopia's current strategy (Integrated Rabies Control and Elimination Strategy, 2018-2030) emphasizes mass dog vaccination as a cornerstone for achieving rabies elimination by 2030 (Asfaw *et al.*, 2024).

Rates of dog vaccination coverage in Addis Ababa have previously been reported to range from 1.8 to 26.9%, well below the continuous coverage of 70% required to eradicate canine rabies. Previous rabies immunization campaigns in Addis Ababa have been hampered by a number of factors, including a lack of vaccines, high vaccination costs, low community involvement in companion dog vaccination programmes, and a lack of a veterinary workforce trained in canine mass vaccination strategies or safe dog handling techniques (Yoak *et al.*, 2021).

Optimizing rabies control programs in Ethiopia necessitates a comprehensive cost-effectiveness analysis grounded in the principles of One Health. This framework requires expanding the analysis beyond the direct human health costs to encompass the economic impact of rabies on livestock, particularly in cattle-rearing communities (Beyene *et al.,* 2019).

In 2016, four key Ethiopian Ministries joined together to establish the National One Health Steering Committee (NOHSC) with the support of the government of Ethiopia and other partners. One of the NOHSC's primary goals is to strengthen zoonotic disease prevention, detection and response through a long-term and collaboration at the national and sub-national level. The responsibilities of the Committee's leadership are to ensure balance and overcome previous problems with multi-sectoral coordination as well as promoting One Health goal. The Steering Committee received financial and technical support from partners, local non-governmental organizations (NGOs); and Ethiopian universities (Erkyihun *et al.*, 2022).

Ethiopia has adopted the WHO goal of rabies elimination by 2030. However, assessing progress towards this objective within Addis Ababa remains challenging due to a scarcity of robust scientific studies. Specifically, limited data exists to comprehensively evaluate vaccination coverage and potential obstacles associated with mass dog vaccination campaigns and post-exposure prophylaxis in humans, critical interventions for rabies control. To address this knowledge gap, the present study aimed to assess the general condition of rabies and its vaccination coverage within Addis Ababa.

Therefore, the specific objectives of this study were:

- To access the incidence of rabies within the region of Addis Ababa;
- To ascertain the vaccination coverage rates for both canine and human rabies in Addis Ababa.
- To identify barriers to vaccination and recommend possible solutions to address these challenges.
- To analyse the spatial distribution of suspected rabies cases in Addis Ababa.

2. LITERATURE REVIEW

2.1. Etiology of Rabies

Humans and animals are both affected by the zoonotic infectious disease rabies. It is a lethal illness that is spread by the bite of an infected animal. The disease is caused by a bullet-shaped, single-stranded, enveloped RNA virus belongs to the *Lyssavirus* genus of the *Rhabodviridae* family (Kumar *et al.*, 2023). When the disease was originally reported in 2300 B.C., it was already known to be terrible in nature (Rajasekaran *et al.*, 2022).

All warm-blooded species can contract the multi-host rabies virus, although dogs, wild predators, raccoon, badgers, and bats are thought to be the virus' primary natural reservoirs. In more than 150 nations and territories, including Ethiopia, the disease is a significant public health issue. Canines, particularly dogs, serve as the main infection reservoir in developing countries, whereas in developed countries, wildlife species serve as hosts and present a greater risk of infection transmission to people and animals (Kumar *et al.*, 2023).

The rabies virus exhibits dimensions approximately measuring 180 nm in length and 75 nm in width. The genomic content of the RABV encompasses only five proteins, namely nucleoprotein (N), phosphoprotein (P), matrix protein (M), glycoprotein (G), and the sizeable protein (L), also recognized as RNA-dependent RNA polymerase (RdRp) (Albertini *et al.*, 2011) (Fig. 1). Within viral transcription and replication processes, the involvement of N is indispensable. The neuropathogenicity of RABV is significantly influenced by G, which plays a pivotal role in receptor engagement and accessing the nervous system through the endosomal transport pathway via a membrane fusion process triggered by low pH (Gaudin, 2000). The cytoplasm of the Negri body, acting as a specialized "virus factory," serves as the exclusive site for every transcription and replication event (Lahaye *et al.*, 2009).

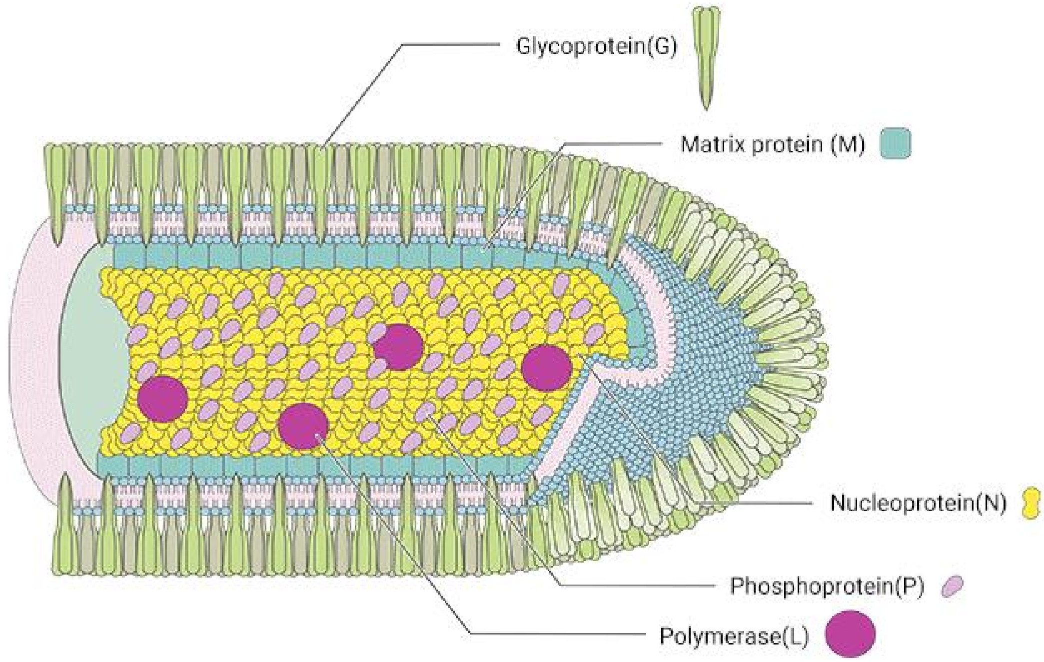

Figure 1. Structure of Rabies Virus (Source: https://www.cusabio.com/infectious-diseases/rabies-virus.html Accessed on 30 March 2024)

2.2. Epidemiology and Transmission

Rabies remains a lethal disease capable of causing fatalities in both humans and animals, notwithstanding advancements in vaccine campaigns and diagnostic methods. Its prevalence spans globally, with the exception of select countries characterized by stringent quarantine regulations, intensive eradication initiatives, or natural barriers such as mountain ranges and rivers. In resource-limited nations, particularly those in Asia and Africa, rabies persists as a significant public health challenge. This circumstance stems from the endemicity of canine rabies, which is primarily transmitted among dogs and poses a persistent risk to human populations through dog bites (Blanton *et al.,* 2010).

The three primary rabies hotspots globally can be categorized as follows: rabies-free countries, predominantly comprising islands such as England, Australia, and Japan; countries where canine rabies has been effectively managed, yet wildlife rabies remains the predominant form of the disease, encompassing regions across Asia, Latin America, and Africa; and countries where enzootic canine rabies continues to persist. (Barecha *et al.*, 2017).

Rabies is typically maintained and spread by certain animal reservoir hosts in a specific geographic area. In North America, racoons, skunks, foxes, and bats are significant rabies virus reservoirs. The red fox, however, is the most significant reservoir in continental Europe. The major source of the virus throughout Central and South America as well as the Caribbean islands is the vampire bat. RABV is reported in most countries worldwide and has been registered everywhere, with the exception of Australia (where rabies was only found in bats), New Zealand, the United Kingdom, Japan, the Scandinavian and Caribbean nations, and Antarctica, where the main vectors are absent. Rabies is a common and well-known disease among domestic dog populations in Ethiopia (Ali, 2022).

Rabies virus (RABV) is transmitted from the central nervous system to the salivary glands via the facial and glossopharyngeal nerves. Subsequently, the virus is excreted into saliva, thereby facilitating transmission to another host. Dogs and cats, owing to their frequent interactions with humans, are recognized as primary vectors, responsible for approximately 90% of documented cases of rabies transmission (Blanton *et al.*, 2010). Domestic and wild animals may potentially spread the illness to people by biting. Although scratching and licking can sometimes spread viruses, bites are the most common way for them to spread. Although fresh saliva can contaminate skin wounds, the infection always originates from an infected animal, and the bite of such an animal is typically the mode of transmission. The virus can persist in the saliva for up to five days before symptoms appear. Because the virus is not consistently present in saliva, bites from rabid animals do not always lead to infection. Additionally, clothing can sometimes keep the virus from entering the wound by wiping saliva from the teeth (Quinn *et al.*, 2011).

Since man-dog interaction is so widespread in Ethiopia, rabies is largely a dog illness, putting many people at risk for exposure. Ethiopia is one of the countries most severely impacted by rabies, with an estimated 10,000 deaths each year (Moges, 2015). Another retrospective research in Addis Ababa between 1990 and 2000 found that 2,200 people on average were treated with anti-rabies after exposure, whereas 95% of dog bites were the cause of fatal human instances. (Oyda and Megersa, 2017).

2.3. Pathogenesis

When the rabies virus enters the central nervous system (CNS), it produces lethal inflammation of the brain due to its great affinity for nerve tissue. When an animal bites someone who is infected with the virus, their saliva contaminates the wound. It then spreads to neighbouring motor and sensory neurons, where it can either attach itself directly to a nerve or multiply in neighbouring muscle cells. The virus moves slowly (5–100 mm/day) backwards up the nerve fibres to the CNS after invading peripheral nerves (Barecha *et al.*, 2017).

After entering the CNS, the rabies virus replicates massively on the membranes of nerve cells, or neurons as depicted in Figure 2. After that, it leaves CNS by slowly riding motor neurons in a flow that goes backward. The virus enters the ventral roots and nerves as a result. Starting in the dorsal root ganglia, which are sensory neuron clusters close to the spine, the virus also affects sensory axons. This enables it to move along the sensory neurons that supply different tissues, such as skin, hair follicles, muscle spindles, and even salivary glands, heart muscle, lungs, and abdominal organs (Hemachudha *et al.,* 2013).

The central nervous system (CNS) is where rabies mostly causes damage. The only way the virus can get there is by ascending peripheral neurons from the original site of infection. Frequently, this results in a progressive paralysis that begins in the rear legs and moves up. The virus causes erratic behaviour, anxiety, and seizures by irritating key brain regions as it spreads throughout the body. Other symptoms include loss of bladder/bowel control, strange desires, excessive drooling, and digestive issues, which indicate the virus may also be impacting the autonomic nerve system and possibly hormone glands. Because rabies paralyses the respiratory system, it usually results in death (Barecha *et al.*, 2017).

There are five basic stages of rabies infection in humans: incubation, prodromal, acute neurological, coma, and death. The incubation period, during which there are no symptoms, can be as little as one week but often lasts between one and three months. The location of the bite greatly influences the time it takes for symptoms to manifest. Bite sites with high densities of nerves, such as the face, neck, hands, and particularly the fingertips, result in quicker infection rates and shorter incubation times. Generally, bites to the upper limbs or chest take longer to show symptoms, unless they are close to important nerves (Shite *et al.,* 2015).

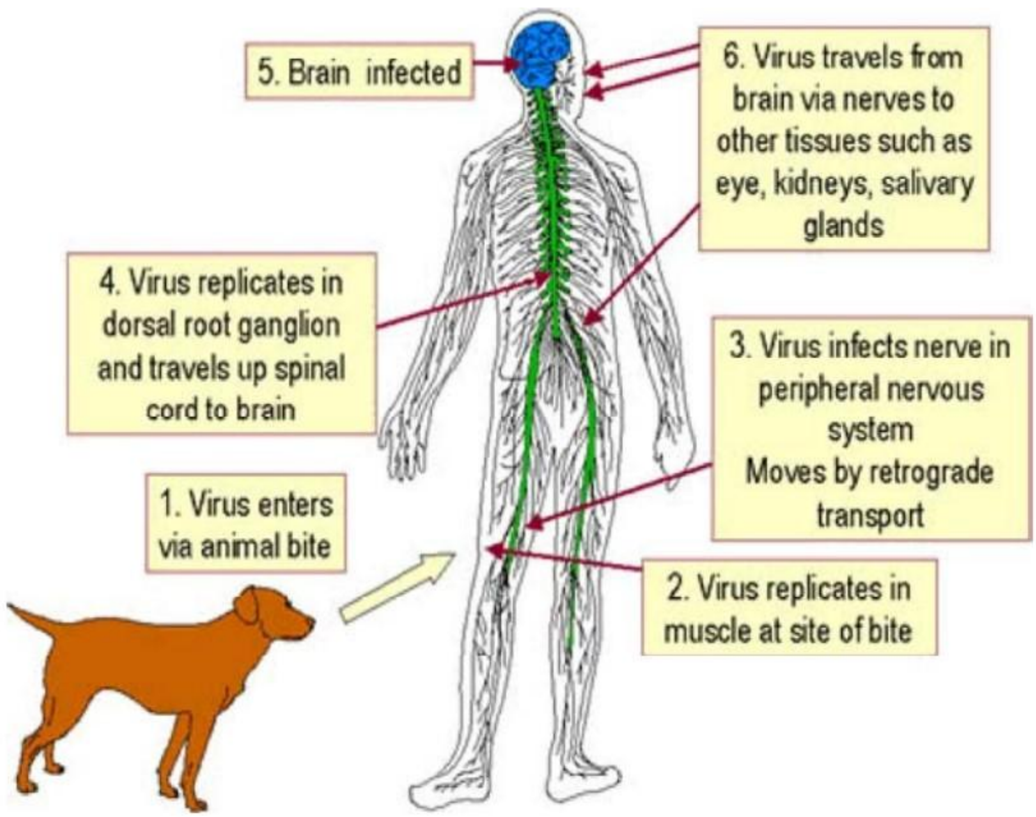

Figure 2: The overall pathogenesis and spread of rabies virus from the site of bite (Source: Shite *et al.* (2015))

2.4. Clinical Signs and Diagnosis

The rabies virus infection, which primarily occurs when a rabid animal attacks another animal or a person, causes an acute viral sickness of the central nervous system that affects humans and other mammals. Once clinical signs start to show, infected animals invariably die from the illness. The virus may be found in clinically sick animals' saliva, and it spreads through the bite of infected animals that one may come across. The dog serves a crucial role as a reservoir and transmitter of the illness to people, making rabies a serious public health concern in many developing regions. It is widely recognized to result in a significant number of human and animal deaths each year (Ali, 2022).

In most species, the clinical signs of rabies are similar, although there is a lot of individual diversity. The incubation time following a bite by a rabid animal is typically between 14 to 90 days, although it can be much longer. Which the incubation period is determined by: the quantity of viral inoculums, the route, the location, the degree of exposure, the separation between the lesion and the spinal cord or brain, and the state of vaccination (Ali, 2022).

Initial clinical symptoms are frequently vague and may include anxiety, restlessness, anorexia or an increased appetite, nausea, vomiting, diarrhoea, a mild temperature, dilated pupils, hypersensitivity to stimuli, and excessive salivation (Oyda and Megersa, 2017).

The two main symptoms of rabies are "furious" or "paralytic." When rabies manifests in its furious form, which accounts for around 70% of cases in dogs and cats, it is easy to diagnose. The symptoms of this illness include irritability, aggressiveness, excessive salivation, indiscriminate biting of inert items, and damaged and irritated oral tissues. The clinical appearance resembles a number of different illnesses, including canine distemper and human ascending paralysis. If rabies is detected in the responsible mammal, it is better to start PEP as soon as possible in an exposed person. It is okay to stop the immunization if the suspicious dog is still alive. Rabid canines, according to studies, will not live longer than ten days following clinical signs (Wilde *et al.*, 2013).

The so-called "furious" form frequently coexists with a neurological phase that alternates between periods of agitation, violence, and cohesive tranquillity. Additionally, there can be a sense of approaching disaster. If aggressive cardiopulmonary care is not provided, respiratory failure and coma set in within a few days, resulting in quick death. There have been a few examples of humans surviving rabies, but they are the exception rather than the rule. Prior to the beginning of a coma, hydrophobic convulsions may occasionally occur in the diaphragm and neck, though they do not necessarily present simultaneously. (Wilde *et al.*, 2013).

Although it may begin before the neurological phase, autonomic dysfunction typically emerges with excessive salivation, erratic blood pressure, cardiac arrhythmias, pupillary dysfunction, and neurogenic pulmonary oedema. In patients with dog rabies, hallucinations and seizures are uncommon, but they can happen (Hemachudha *et al.*, 2013).

The paralytic type of rabies manifests in one-third of cases. Without expertise and advanced laboratory assistance, the paralytic type of rabies is challenging to identify (Wilde *et al.*, 2013). Progression of paralysis is a hallmark of this strain of rabies. The paralysis of the masseters and throat muscles, together with excessive salivation and difficulty swallowing, are the earliest signs of hydrophobia. A change in vocalization, such as an aberrant bellow in cattle or a raspy howl in dogs, facial paralysis, or a dropping of the lower jaw, can be brought on by laryngeal paralysis. Ruminants have the potential to disperse from the herd and exhibit depression or somnolence. Also present are ascending spinal paresis or paralysis, ataxia, and lack of coordination (Chernet and Nejash, 2016).

To administer post-exposure prophylaxis in a timely manner, rabies in humans and animals must be diagnosed in a laboratory. Although hydrophobia is a very suggestive symptom, rabies does not have any pathognomonic clinical symptoms. Lab-based assays have been developed to definitively prove infection since rabies diagnosis may be done either in vivo or post-mortem (Chernet and Nejash, 2016).

2.4.1. Laboratory Diagnosis

Currently, multiple diagnostic assays exist, and the techniques for detecting rabies are internationally standardized. The principal methods historically utilized for rabies diagnosis encompassed histological examination and the discovery of Negri bodies within cerebral smears. However, due to their restricted sensitivity and the widespread availability of contemporary techniques distinguished for their precision and sensitivity, these methods are no longer widely practiced. Few of these techniques include:

1. Florescent Antibody Test (FAT)

The Fluorescent Antibody Test (FAT) stands as the most frequently employed diagnostic assay for rabies. The FAT enables precise and exceptionally sensitive identification of rabies virus antigens within brain smears, sections of salivary glands, and cultures of infected cells (Warrell *et al.*, 1988). In approximately 95–99% of cases, the FAT yields precise results on fresh specimens within a short time frame (OIE, 2008).

Smears generated from a collective sample of brain tissue, encompassing the brain stem, undergo fixation using high-quality cold acetone, followed by staining with a specialized conjugate to facilitate direct rabies diagnosis. Laboratory synthesis of anti-rabies fluorescent conjugates is feasible, with the fluorescence emitted by individual nucleocapsid protein aggregates serving as the basis for identification in the FAT. Prior to application, it is imperative to validate the specificity and sensitivity of the locally prevalent viral types for the anti-rabies fluorescent conjugates (OIE, 2008).

2. **Enzyme-Linked Immunosorbent Assay (ELISA) Test**

A variant of immunochemical testing designed to detect the rabies antigen is referred to as an enzyme-linked immunosorbent assay (ELISA), which proves beneficial for comprehensive epidemiological surveys. Prior to its implementation, rigorous validation against a multitude of samples across diverse laboratory settings is imperative. It is crucial to ascertain the specificity and sensitivity of the anti-rabies enzyme conjugates against prevalent virus types in the region before employing this test. Furthermore, integration of this test with viral isolation or confirmation via FAT is essential for reliable results (Xu *et al.*, 2007).

3. **Cell culture test**

Standard rabies diagnosis entails the utilization of neuroblastoma cell lines, which are cultured in Dulbecco's Eagle's medium modified with 5% fetal calf serum, and maintained at 36°C with 5% CO2. This cell line exhibits sensitivity to street isolates without necessitating an adaptation phase; however, it is imperative to assess its susceptibility to locally prevalent viral variants prior to usage. The Fluorescent Antibody Test (FAT) confirms the presence of the rabies virus within the cells, with the test typically concluding within 18 hours, and the incubation period extending for 48 hours, or up to 4 days in certain laboratory settings (OIE, 2008).

4. Serological tests

Because of delayed sero-conversion and the restricted number of animals that survive the disease and subsequently develop post-infection antibodies, serological tests are infrequently utilized in epidemiological investigations. The main application of serology lies in evaluating vaccination responses among wildlife populations following oral immunization of rabies reservoirs or in domestic animals before international travel (Cliquet *et al.,* 2000).

2.5. Public Health Importance

Despite being preventable, rabies remains a neglected zoonotic disease with significant public health implications. In Ethiopia, the primary mode of rabies transmission is through bites inflicted by rabid canines or through contact of saliva with broken skin. In many poor nations, domestic dogs are the main source of the rabies virus, which helps spread to other domestic animals through secondary transmission. While there have been no documented instances of rabies transmission through the consumption of products (meat or milk) from infected animals, it is strongly discouraged to consume raw product from potentially exposed animals (Kabeto *et al.*, 2021).

The outcome of rabies exposure is influenced by factors such as the extent of infection, the site of the bite, and the concentration of rabies virus present in the saliva of the rabid animal. Various isolates of the rabies virus demonstrate differing degrees of virulence depending on the mode of inoculation. For instance, bat-derived virus isolates exhibit greater virulence compared to those from canine sources when introduced topically into the epidermis, attributed to their accelerated replication in non-neuronal cells at lower temperatures. Instances of non-bite exposure to rabies in humans have been rare, with only a limited number of cases reported over the past five decades. Aside from bites, alternative routes of rabies transmission encompass inhalation of concentrated aerosolized rabies viruses, transmission via organ and corneal transplants, and contamination of compromised skin with rabies antigen present in the saliva or brain tissues of a rabid animal (Deressa *et al.*, 2015).

To interrupt the disease cycle, comprehensive surveillance measures are essential for acquiring accurate data necessary to enhance community awareness regarding the gravity of rabies. Such efforts are imperative for fostering political determination and collaborative endeavours aimed at instigating revisions in rabies-related policies (Kabeta *et al.*, 2015).

488 human fatalities were recorded between 1964 and 1975, according to the yearly reports of the Ethiopian Public Health Institute (EPHI) (Oyda and Megersa, 2017). A total of 9593 post-exposure cases and 153 fatal human rabies cases were reported between 1996 and 2000. According to Yimer

et al. (2002), the instances were first reported in Addis Ababa, its surrounds, and other parts of the nation. Similar to this, research by Moges (2015) revealed that from 1990 to 2000, Ethiopia saw up to 322 lethal rabies cases. Rabies poses a significant risk to humans and other animals due to low vaccination rates and the high prevalence of dogs in both urban and rural areas (Oyda and Megersa, 2017).

2.6. Control and Prevention

2.6.1. Canine Vaccination

The origins of anti-rabies vaccines may be traced back to the 19th century, when Louis Pasteur introduced the first vaccine. He showed that dogs who were given a preparation made from the nerve tissue of infected rabbits were protected from rabies when they were later inoculated with the live virus (Starodubova *et al.*, 2015).

Even though rabies is an incurable and deadly disease, it can be avoided by receiving vaccinations and avoiding contact with rabid wildlife (Ali, 2022). Implementing mass dog vaccination programs emerges as the most viable and cost-effective approach to eradicating canine rabies, thereby safeguarding both human and animal populations from the threat of mortality (Barecha *et al.*, 2017).

Irrespective of age, weight, or general health status, it is crucial for all dogs to undergo vaccination as part of mass vaccination programs. While the primary objective is to vaccinate as many dogs as possible, achieving herd immunity necessitates immunizing at least 70% of the population. For effective rabies prevention, it is recommended that dogs receive their initial rabies vaccination at three months of age, followed by a booster shot after one year, and subsequently every three years. Similarly, cats should also be vaccinated against rabies at three months of age, with yearly booster shots thereafter. Moreover, in regions where clinical cases of rabies are prevalent among agricultural animals, it is advisable to administer vaccinations to ensure their protection (Barecha *et al.*, 2017).

In cases where animals encounter a rabid animal and have not received prior vaccination, immediate euthanasia is recommended. Adhering to pre-exposure immunization requisites, the administration of the rabies vaccine is advised either upon entering isolation or within 28 days before release. In instances where a healthy dog exposes a human to potential rabies, regardless of their vaccination status, the animal should be confined indoors and closely monitored for ten consecutive days following the exposure (Tepsumethanon *et al.*, 2004).

2.6.2. Pre- and Post-exposure Prophylaxis (PEP) for Humans

Pre-exposure vaccination should also be extended to individuals engaged in high-risk occupations, such as rabies researchers, laboratory personnel, veterinarians, their staff, and animal handlers. Furthermore, individuals involved in activities that involve frequent contact with potentially rabid animals, including bats, raccoons, skunks, dogs, cats, or other carriers of the rabies virus, should also be considered for pre-exposure vaccination. By proactively providing pre-exposure vaccines to these at-risk groups, a heightened level of protection can be established against potential rabies infections (Manning *et al.*, 2008).

Following a potential rabies exposure, a standardized post-exposure prophylaxis (PEP) regimen is implemented to prevent the development of clinical rabies. This regimen consists of a multifaceted approach, including thorough wound decontamination, administration of rabies vaccine, and potential utilization of rabies immune globulin (RIG), tailored to the specific exposure category (Figure 3). As outlined by the World Health Organization (WHO), immediate wound washing with soap and water is the cornerstone of initial PEP. This is followed by the intramuscular injection of cell-culture rabies vaccine at designated intervals: 0, 3, 7, 14, 30, and 90 days post-exposure. The rabies vaccine stimulates the host immune system to generate a protective antibody response against the rabies virus. This process typically requires 7-14 days following the initial vaccination. Notably, for individuals who have completed a successful PEP regimen within the preceding three months and experience a subsequent rabies exposure, only local wound management is necessary. In such cases, repeat rabies vaccination and RIG administration are not warranted (Kabeto *et al.*, 2021).

Rabies immune globulin (RIG) is a crucial component of PEP for rabies. This engineered molecule acts as a "passive immunity" booster, specifically targeting a defined region of the rabies virus' G protein. RIG demonstrates high efficacy in neutralizing the virus in vitro or before it reaches the CNS. This is particularly important during the early stages of infection, when the body's own immune response is still developing in response to the rabies vaccine. However, a significant limitation of RIG is its inability to effectively cross the blood-brain barrier, a protective mechanism that shields the CNS from foreign substances. While the theoretical possibility of administering RIG directly into the brain exists, it is not a practical therapeutic approach (Beyene *et al.*, 2018).

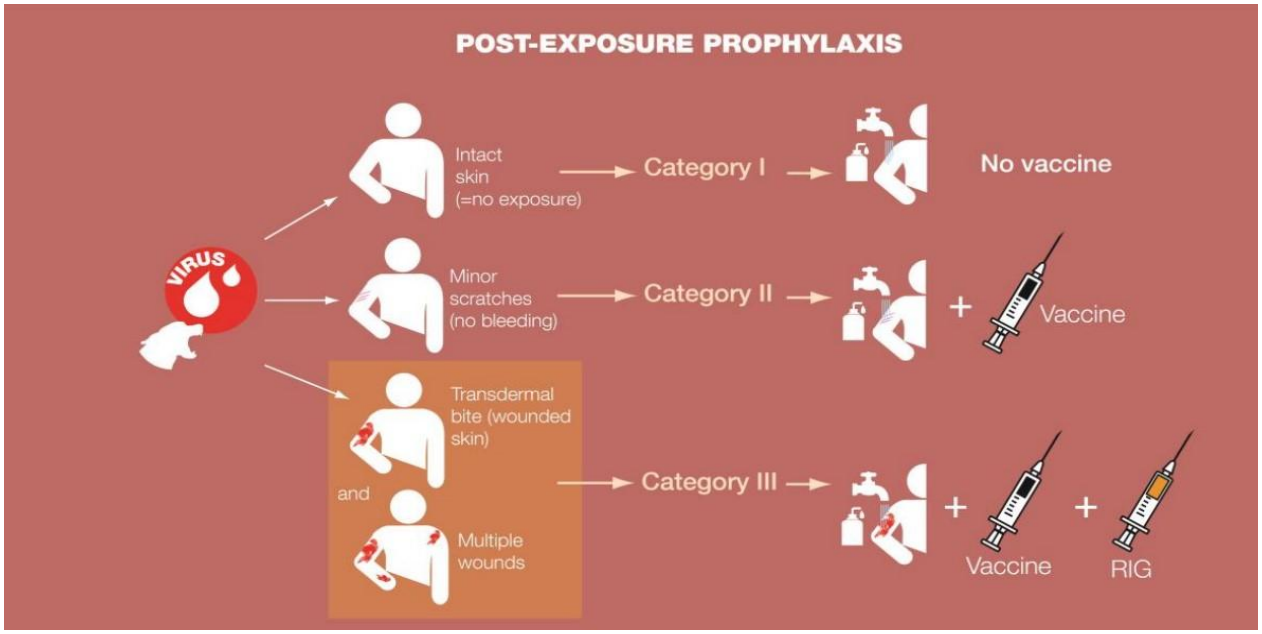

Figure 3: Categories of rabies exposure (Source: https://msrmh.com/blog/the-silent-terror-understanding-rabies-and-the-vital-role-of-post-exposure-prophylaxis/ Accessed on 30 March, 2024).

2.7. Status of Rabies in Ethiopia

Ethiopia has been one of the developing nations with one of the highest rabies cases, with reports of the first significant dog epidemic in several regions of Ethiopia in 1884 especially in the former province of Tigre, Begemder, Gojjam, Wollo and the present Eritrea and documentation in and around Addis Ababa in August 1903 (Ali *et al.*, 2010).

In Addis Ababa, canine rabies has been identified as a well-established disease, as indicated by retrospective data collected at EPHI between 1990 and 2000. Notably, there has been no observed decline in the annual count of confirmed rabies cases during this period (Aklilu *et al.*, 2021).

Based on the evaluation of the rabies situation, a total of 2,172 confirmed cases of animal rabies were recorded in the vicinity of Addis Ababa from 1990 to 2000. Among these cases, dogs constituted 89.83% and had an incidence rate of 73.2% (Yimer, 2002).

Mesfin (2022) reported that between 2015 and 2019, the Ethiopian Public Health Institute Public Health Emergency Management received reports of a total of 1,772 potential cases of human rabies exposure resulting from dog bites. The results showed that there has been a steady increase in the yearly number of likely human rabies exposure cases brought on by dog bites during the previous five years. This indicates a concerning escalation in the incidence of human rabies exposure in Ethiopia during the specified time period.

In alignment with Ethiopia's commitment, a comprehensive national strategy for rabies control and eradication is anticipated to be completed by 2030. Following its approval in 2018, a series of activities have been undertaken to address this goal. These activities encompass various aspects, including the enhancement and integration of the surveillance system, expansion of laboratory facilities, implementation of integrated dog bite management protocols, production of vaccines, large-scale dog vaccination campaigns, provision of post-exposure prophylaxis (PEP) to individuals exposed to rabies, and capacity-building initiatives (Abdella *et al.*, 2022).

In comparing the immunisation status of dogs engaged in biting occurrences in Addis Ababa, Abdella *et al.* (2022) found a worrying trend of protracted rabies attacks. Only two of the 10 canines that were brought to the EPHI for a rabies examination turned out to be vaccinated, according to their findings. Furthermore, seven out of the ten dogs diagnosed with rabies were identified as infected. These findings emphasize the prevalence of rabies among dogs in Addis Ababa, with a rapid upward trend observed from 2016 to 2020. These results underscore the urgent need for enhanced rabies control measures, including improved vaccination coverage, in the region.

Brain tissue obtained from sheep The Fermi kind of rabies vaccine has been continuously produced and used since 1944 for most of the patients exposed to rabies at the institution, which is now known as the Ethiopian Public Health Institute (EPHI). However, it is important to note that the World Health Organization (WHO) has discouraged the use of this vaccine (EHNRI, 2012). The primary barrier to replacing Fermi type vaccine has been the exorbitant expenses associated with tissue culture vaccine.

Produced domestically, the nerve tissue vaccine (NTV) serves as the primary rabies vaccine in Ethiopia. It addresses a substantial 88% of the country's PEP vaccine needs, particularly in the capital city of Addis Ababa. However, this dominance may lessen in outlying regions due to limited access to and affordability of imported cell culture-based vaccines (Kabeto *et al.*, 2021).

NTV used in the conventional post-exposure prophylaxis (PEP) regimen for rabies requires a multi-dose schedule. For the first 14 days, there are 17 daily injections given in succession during the first phase. Three more booster doses are administered at 10-day intervals on days 24, 34, and 44 after this rigorous treatment. This PEP regimen is recommended for everyone who may have come into contact with a suspected or confirmed rabid animal (Kabeto *et al.*, 2021).

The Ethiopian Public Health Institute (EPHI) is currently focused on enhancing the manufacture of anti-rabies vaccines by transitioning from the neural tissue vaccine (NTV) to a cell culture-based vaccine. The vaccine utilizes the Evelyn Rokitniki Abelseth (ERA) fixed rabies virus seed strain, which was acquired from the CDC gift and grown on the Vero cell line. The substance is rendered inactive using a solution of 5% formalin, which is in a liquid state (Hurisa *et al.*, 2013).

Ethiopians who have been in contact with the rabies virus frequently see traditional healers for a diagnosis and course of treatment. Ethiopians, both in urban and rural areas, employ traditional medicine extensively because it is more accessible, affordable, and culturally acceptable than contemporary medical care. Traditional approaches to addressing rabies cases are believed to impede the timely acquisition of Post-Exposure Prophylaxis (PEP) (Moges, 2015). In Ethiopian traditional medicine, healing is not solely focused on curing diseases but also on promoting and supporting various aspects of human well-being, including physical, spiritual, social, mental, and material health (Admassu *et al.*, 2014).

Rabies is not just a disease of domestic animals; it can also infect wild species. This is concerning for endangered populations like the Ethiopian wolf. A study examining rabies in these wolves found that 13 out of 15 brain samples sent to a diagnostic centre in the US were positive for the virus. Notably, the study highlighted a specific outbreak that occurred in the Bale Mountains between the years 2003 and 2004 regarding the wolves (Randall *et al.*, 2004).

3. MATERIAL AND METHODS

3.1. Study Area

The study was conducted in Addis Ababa, the capital and largest city of Ethiopia, and its surrounding areas from October 2023 to April 2024. Addis Ababa is located at coordinates 9°1′48″N latitude and 38°44′24″E longitude. It is situated at an altitude ranging between 2326 and 3000 meters above sea level. The city experiences an average annual rainfall of 1089 mm. The average relative humidity throughout the year is 60.7%. The mean maximum temperature is 20°C, while the mean minimum temperature is 12°C. The City Administration of Addis Ababa has a population density of 165.1 people per square kilometres. The total area of Addis Ababa is 540 km², which is sub-divided into 11 sub-cities and 118 woredas (districts) (Fig. 4). According to the UN population projection, Addis Ababa had a total population of 5,461,000 inhabitants (Mesfin, 2022). Addis Ababa is estimated to have a dog population ranging from 250,000 to 350,000. Significantly, approximately only 30% population is comprised of owned dogs (Gebremedhin *et al.*, 2020).

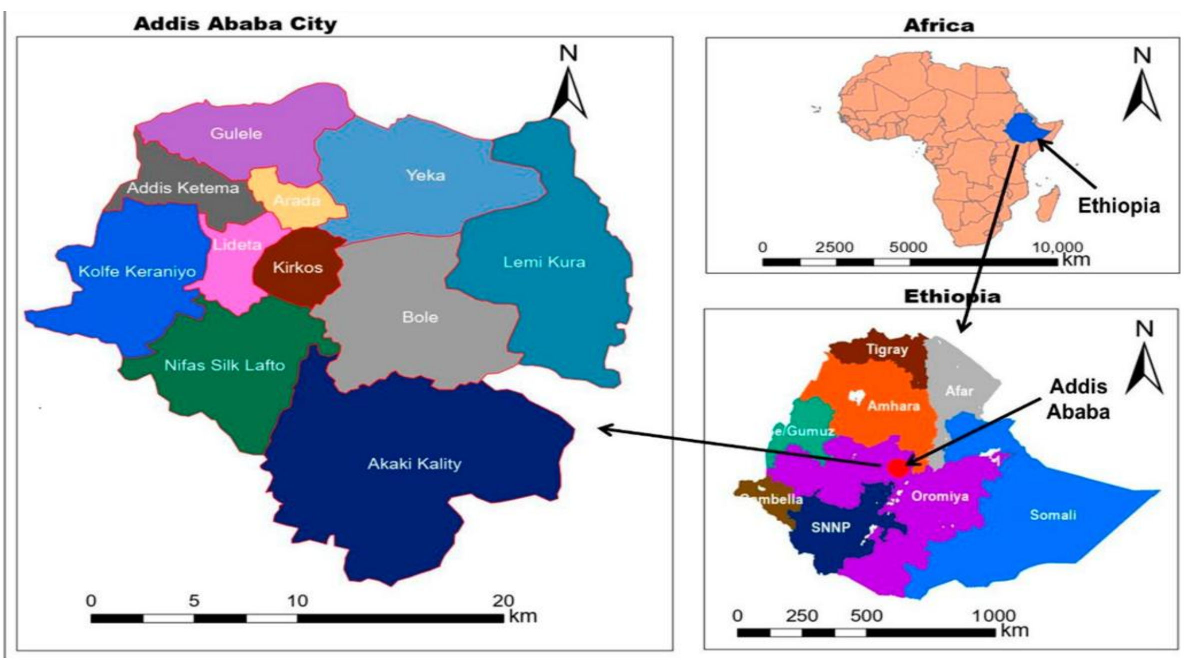

Figure 4. Map of the study area, Addis Ababa. (Source: Addis *et al.*, (2023))

3.2. Study Design

A cross-sectional and retrospective investigation was conducted between October 2023 and March 2024 in Addis Ababa, Ethiopia, with the primary objectives of assessing the extent of rabies vaccine coverage, identifying potential obstacles to vaccination, and clarifying the incidence of rabies cases over the preceding five-year period.

This study adopted a semi-structured questionnaire survey as the primary approach for data collection. 206 individuals from 5 sub-cities and 11 veterinary professionals representing all sub-cities of Addis Ababa were interviewed to determine rabies vaccination coverage and potential obstacles.

Additionally, secondary data were obtained through a comprehensive examination of various data records housed within both the Ethiopian Public Health Institute (EPHI) and the Farmers and Urban Agriculture Development Commission.

3.3. Data Collection

3.3.1. Retrospective Data

The analysis of registers was maintained at the zoonoses laboratory of the Ethiopian Public Health Institute (EPHI) covering the years 2019 to 2023 provided valuable insights into the incidence of rabies infection in humans. These registers included the number of suspected human cases after a dog bite, human demography and distribution of these cases, and the number of samples that were confirmed positive after a laboratory test.

The EPHI also carries out post-exposure anti-rabies therapy and conducts diagnostic tests for rabies using samples obtained from both animals and humans, specifically from the brain. By examining these registers, the study was able to gather important data and information related to the occurrence and distribution of rabies infections.

The zoonoses laboratory's involvement in post-exposure anti-rabies therapy highlights its role in providing crucial medical interventions to individuals who have been exposed to the rabies virus.

The number of people that received post exposure anti rabies treatments during the same period was obtained by reviewing the records of people that came to the Institute being bitten by rabid or suspected rabid animals and sent mainly to the St. Paul hospital that provide post exposure treatment for humans.

The retrospective data pertaining to canine vaccination records within each sub-city of Addis Ababa from 2020 to 2023 was acquired through the meticulous examination of archives maintained by the Farmers and Urban Agriculture Development Commission. This commission, formerly under the purview of the Ministry of Trade prior to its integration into the Ministry of Agriculture, is entrusted with the aggregation of comprehensive reports from various sub-cities. These reports encompass vital information including, the annual number of both owned and stray dog vaccinations, issuance of vaccine cards to owners, and other pertinent metrics, thereby facilitating the assessment of rabies vaccine coverage across Addis Ababa.

3.3.2. Questionnaire Survey

A semi-structured questionnaire survey was employed to assess the vaccination status of domestic animals, serving as an indicator of the coverage of the mass vaccination campaigns conducted in the Akaki Kality, Arada, Gulele, Kirkos and Lemi Kura sub-cities of Addis Ababa. The questionnaire was administered to volunteer respondents, selected through a convenience sampling method. This involved collaborating with local veterinary professionals to conduct door-to-door visits. During these visits, potential participants were approached and their willingness to participate in the questionnaire survey was assessed. The survey encompassed inquiries regarding the occurrence of the disease and the vaccination history of the animals.

3.3.3. Interview with Veterinary Professionals

As part of this study's endeavour to assess the prevailing status of rabies vaccination and identify associated barriers, interviews were conducted with 11 veterinary professionals representing all sub-cities of Addis Ababa. These interviews were conducted through direct engagement of each professional which was facilitated either through regional Farmers and Urban Agriculture offices or by visiting local veterinary clinics.

3.4. Sample size determination

The questionnaire survey sample size is calculated by using formula (Arsham *et al.*, 2007):

$$n=0.5/SE^2$$

Where: n=sample size, SE (Standard error) =5%. The sample size required for questionnaire survey as per the above formula was 200.

3.5. Data Management and Analysis

3.5.1. Statistical Analysis

Data from EPHI report, interview of veterinary professionals and questionnaire survey was collected and recorded on a Microsoft Excel spreadsheet 365. Then, the data collected was analyzed by using statistical software (STATA version 14) and descriptive statistics for associations was analysed using the Chi- square test (χ 2) and Linear regression analysis methods.

3.5.2. Spatial Distribution

To analyse the spatial distribution of rabies exposure in the study area, QGIS software (version 3.34.6) was used. First, a table containing rabies exposure data (including location coordinates) was imported. These points were then overlaid onto a shapefile representing the study area. Both the point data and the shapefile were ensured to have the same coordinate system (geo-referenced) for accurate spatial analysis. Finally, after visualizing the rabies exposure points on the map, QGIS's built-in hotspot analysis tool was employed to identify areas with concentrated rabies occurrences.

4. RESULTS

4.1. General Information of Study Participants

4.1.1. Socio-Demographic Attribute

A total of 206 people from selected sub-cities of Addis Ababa selected through convenience sampling technique were questioned about their knowledge of rabies vaccine coverage (Table 1). During the study, male participants accounted for 65% (134/206) of the interviewees, while females constituted 35% (72/206). The educational attainment of the study participants was documented, revealing that the majority (109 individuals, accounting for 52.9%) had achieved a secondary education or higher. Conversely, 53 participants (25.7%) had received no formal education, and 44 participants (21.4%) had completed primary-level education.

Table 1. Distribution of study participants by Sub city

Sub-cities	No. Of study participants	Percentage (%)
Akaki Kality	51	24.8
Arada	64	31.1
Gulele	32	15.5
Kirkos	11	5.3
Lemi Kura	48	23.3

4.1.2. General Dog Information

Among the 206 dog owners surveyed in this study, a substantial majority, comprising 145 individuals (70.4%), reported ownership of a single dog. From the remaining participants, 43 individuals (20.9%) indicated ownership of two dogs, 17 individuals (8.2%) possessed three dogs, while only one individual (0.5%) reported ownership of five dogs (Fig. 5).

The age distribution of the dogs owned by study participants exhibited notable diversity. A majority of participants (148 individuals, constituting 71.8%) reported ownership of adult dogs, falling within the age range of 1 to 8 years. Additionally, 41 owners (19.9%) indicated possession of young dogs, aged between 6 months and 1 year, while 10 owners (4.9%) reported ownership of elderly dogs, aged 8 years or older. Notably, a smaller proportion of participants (7 individuals, or 3.4%) stated ownership of puppies, defined as dogs younger than 6 months old.

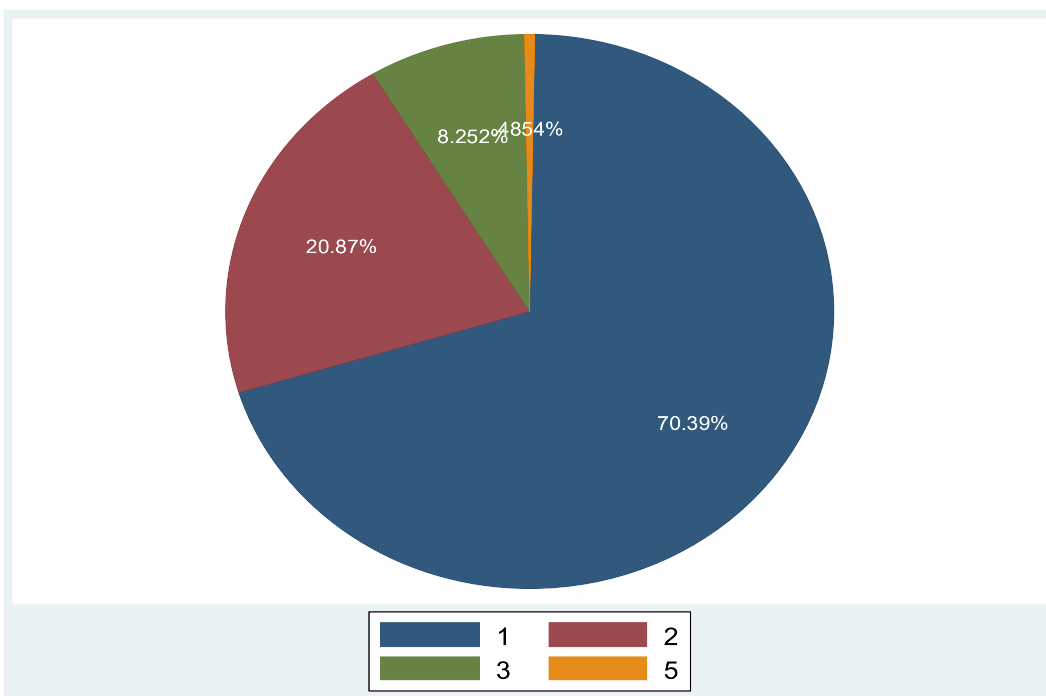

Figure 5. Pie chart of the number of dogs owned by a participant

4.2. Vaccination Status According to Survey

Among the 206 respondents surveyed in this study, 137 individuals (66.5%) affirmed that their dogs were deemed fully vaccinated, denoting compliance with the recommended vaccination regimen within the past year. On the other hand, 24 participants (11.7%) indicated that although their dogs had been vaccinated previously but it had been over a year since their last vaccination. Additionally, 45 participants (21.8%) reported that their dogs had never received any form of vaccination (Fig. 6).

As illustrated in Figure 6, it is evident that only 6 respondents (12.5%) asserted full compliance with current-year vaccination protocols for their dogs within the Lemi Kura Sub-city. Specifically, half of the participants (25 out of 48) acknowledged that their dogs had never been vaccinated against rabies. Furthermore, an additional 17 respondents (35.4%) indicated that their dogs' vaccinations were not up-to-date, lacking vaccination within the year preceding the survey.

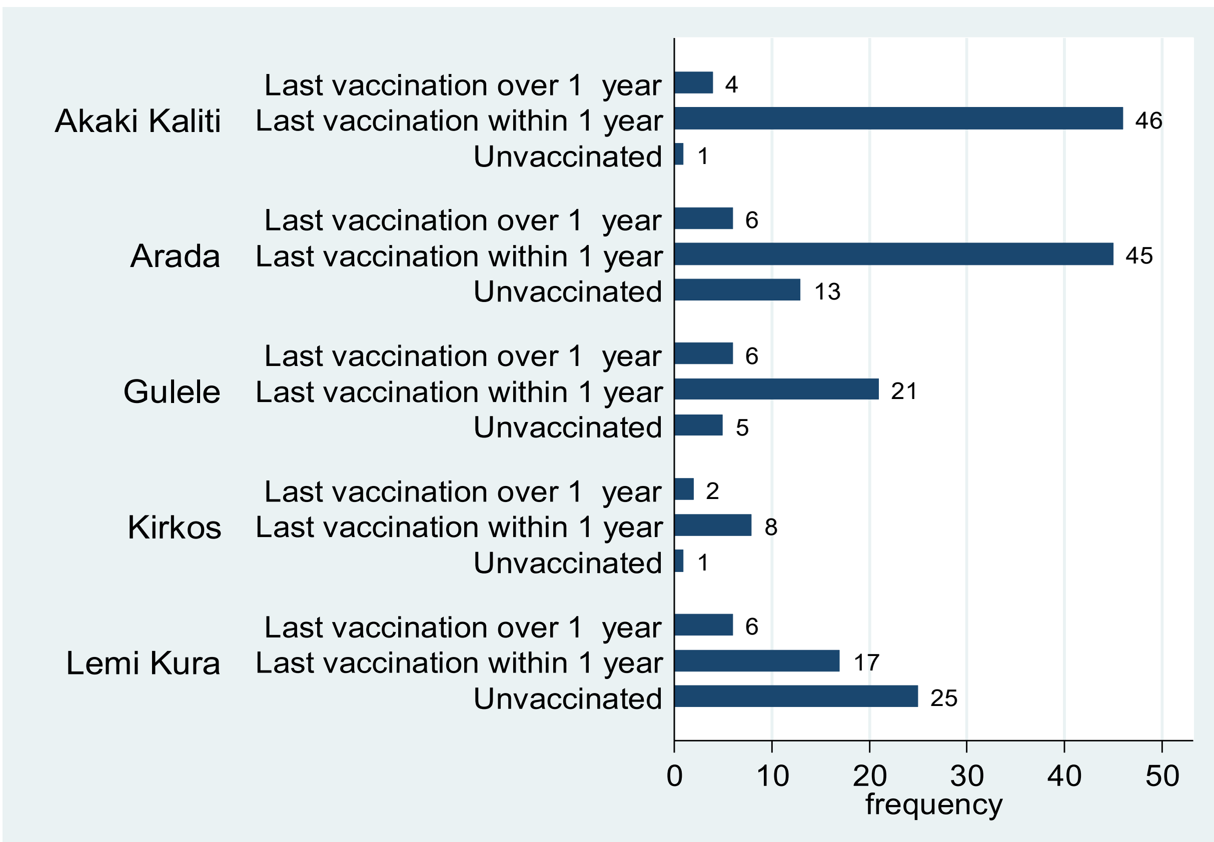

Figure 6. Distribution of Vaccination Status by Sub city.

In the sub-city of Arada, 20.3% (13 out of 64) of respondents reported non-compliance with dog vaccination. The primary barriers identified by participants hindering dog vaccination included prohibitive travel expenses due to distant vaccination centers and a belief that confining dogs indoors would eliminate the risk of rabies transmission. Additionally, some respondents expressed challenges in seeking veterinary care for vaccination due to concerns about their dog's aggressive behavior.

In contrast, respondents from other sub-cities exhibited a more favorable vaccination rate. Specifically, 46 out of 50 participants (92%) from Akaki Kality, 21 out of 32 participants (65.6%) from Gulele, and 8 out of 11 participants (72.7%) from Kirkos sub-cities reported full vaccination coverage for their dogs.

4.3. Factors Affecting Rabies Vaccination Rate

The majority of respondents (about 94.2%) had knowledge of rabies, indicating awareness of the disease among the surveyed population. Furthermore, the data shows that 66% of dog owners surveyed vaccinated their dogs against rabies within a year. Only 44.2% of dog owners reported vaccinating their dogs during government-led vaccination campaigns.

In this survey, several factors influencing the vaccination rate were investigated. Among these factors, statistically significant associations were observed with the participants' general knowledge regarding rabies, the confinement status of their dogs, the recency of the dog's last vaccination, the age at which the dog received its first vaccination, and the presence or absence of mass vaccination campaigns in the area. Conversely, the participants' reported witnessing of a prior rabies case within their vicinity was found to be statistically insignificant.

Table 3 illustrates that factors including prior knowledge of rabies, age at first vaccination, and the presence of mass vaccination campaigns exhibit a strong association (p-value < 0.05) with the vaccination status of the dogs. Conversely, factors such as the sex and education level of the owner, restrictions on dog movement, the age of the dog, and the date of the last vaccination do not demonstrate a significant association (p-value > 0.05) with the vaccination status of the dogs studied.

Table 2. Factors affecting the vaccination rate reported by study participants

Variables	No. Of study participants	Percentage	χ^2	p-value
Dog Movement			15.9665	0.000
Allowed to Roam	77	37.4		
Restricted	129	62.6		
Knowledge of Rabies			29.3258	0.000
Yes	194	94.2		
No	12	5.8		
Last Vaccination Date			132.0348	0.000
Within a Year	137	66.2		
Over a Year Ago	69	33.8		
First Vaccination Age			202.6936	0.000
Younger than 1 yr old	89	43.2		
Older than 1 yr old	72	35		
Unknown	45	21.8		
Mass Vaccine Campaign			17.6609	0.000
Yes	91	44.2		
No	115	55.8		
Witness a Rabies Case			0.1256	0.939
Yes	52	25.2		
No	154	74.8		

Table 3. Linear regression of strong association between risk factors and vaccination status

Risk Factors	p-value	[95% Conf. Interval]	
Education Status	0.342	-.151723	.0529184
Sex	0.698	-.1938313	.1301029
Age of dogs	0.051	-.0004617	.2588617
Dog Movement	0.862	-.1805735	.1513812
Knowledge of Rabies	0.015	.0898527	.8213463
Last Vaccination Date	0.137	-.3793791	.052639
First Vaccination Age	0.000	-.6766208	-.4040711
Mass Campaigns	0.039	.0080766	.3114721

4.4. Barriers to Vaccination in Addis Ababa

As part of this study's attempt to assess the status of rabies vaccination in Addis Ababa and identify associated barriers, interviews were conducted with 11 veterinary professionals representing all sub-cities of Addis Ababa. These interviews were conducted through direct engagement with each professional, facilitated either through regional Farmers and Urban Agriculture offices or by visiting local veterinary clinics.

Table 4. Factors affecting the vaccination rate reported by veterinary professionals

Variables	Frequency	Percentage (%)
Is rabies epidemic		
Yes	0	-
No	11	100
Equipment		
Adequate	1	9.1
Lacking	10	90.9
Annual Campaign		
Yes	11	100
No	0	-
Public Awareness		
Good	7	63.6
Poor	4	36.4
Collaborations		
Exist	5	45.5
Lacking	6	54.5
Use of current Innovations		
Yes	3	27.3
No	8	72.7
Long term plan		
Adequate	3	27.3
Lacking	8	72.7

4.5. Secondary Data Analysis Results

4.5.1. Retrospective Data of Dog Bites and PEP

A total of 3,123 individuals sought medical care at the Ethiopian Public Health Institute (EPHI) subsequent to sustaining dog bites between 2019 and 2023 (Table 5). The highest numbers of cases were concentrated in Kolfe Keranio (917 cases, 29.4%), Gulele (313 cases, 10.02%), and Yeka (308 cases, 9.9%). Conversely, sub-cities like Akaki Kality (116 cases, 3.7%), Arada (144 cases, 4.6%), and Bole (210 cases, 6.7%) reported substantially lower numbers of suspected bite cases.

Table 5. Distribution of suspected rabies cases from EPHI by sub city 2019-2023

Sub city	**Year**					
	2019	**2020**	**2021**	**2022**	**2023**	**Total**
Addis Ketema	4	27	28	102	124	285
Akaki Kality	3	21	19	31	42	116
Arada	10	24	28	36	46	144
Bole	8	47	34	64	57	210
Gulele	13	32	50	120	98	313
Kirkos	174	22	13	24	23	256
Kolfe Keranio	549	102	55	112	99	917
Lemi Kura	-	-	-	28	60	88
Lideta	86	13	18	63	34	214
Nifas Silk Lafto	2	77	38	97	58	272
Yeka	27	81	59	55	86	308
Total	876	446	342	732	727	3123

Among these bite victims, 2,073 individuals (66.4%) were male, while the remaining 1,050 individuals (33.6%) were female (Table 6).

Table 6. Distribution of suspected rabies cases from EPHI by sex 2019-2023

Sex	Year					
	2019	**2020**	**2021**	**2022**	**2023**	**Total**
Male	537	371	271	425	469	2073 (66.4%)
Female	339	75	71	307	258	1050 (33.6%)
Total	876	446	342	732	727	3123

Following laboratory diagnosis, 710 dogs (22.7%) tested positive for the rabies virus, with the remainder yielding either negative results or possessing an unknown confirmation status (Table 7).

Table 7. Distribution of lab confirmation of suspected dogs from EPHI 2019-2023

Confirmation	Year					
	2019	**2020**	**2021**	**2022**	**2023**	**Total**
Positive	133	185	145	102	145	710 (22.7%)
Negative/Unknown	743	261	197	630	582	2413 (77.3%)
Total	876	446	342	732	727	3123

According to data obtained from the Ethiopian Public Health Institute (EPHI), a total of 68 individuals succumbed to injuries inflicted by suspected dogs in Ethiopia. Of these fatalities, 16 individuals (23.53%) were recorded in Addis Ababa city over the period spanning 2019 to 2023.The year 2019 accounted for the highest number of fatalities, with 6 cases (37.5%), followed by 2022 with 5 cases (31.25%) (Table 8). Conversely, there were no reported fatalities in Addis Ababa in 2020.

Table 8. Human fatal rabies cases report in Addis Ababa according to EPHI from 2019 - 2023

Sex	Year					
	2019	2020	2021	2022	2023	Total
Male	2	0	2	5	3	12 (75%)
Female	4	0	0	0	0	4 (25%)
Total	6	0	2	5	3	16

From the 3,123 victims who sought treatment, 2,887 (92.4%) received adequate post-exposure prophylaxis (PEP), mainly from St. Paul hospital located nearby. The remaining cases either demonstrated non-compliance due to the absence of rabies in the animals (as per the practice where initiation of post-exposure prophylaxis occurs for bites around the face, head, or upper body, with discontinuation if the animal remains alive after a ten-day observation period).

Table 9. Distribution of PEP recipients by sub city 2019-2023

Sub city	Year					
	2019	2020	2021	2022	2023	Total
Addis Ketema	3	27	26	96	110	262
Akaki Kality	3	21	19	26	40	109
Arada	10	24	25	33	42	134
Bole	8	46	30	59	55	198
Gulele	13	32	45	103	86	279
Kirkos	156	20	13	22	23	234
Kolfe Keranio	501	93	52	102	99	847
Lemi Kura	-	-	-	26	60	86
Lideta	82	13	16	57	29	197
Nifas Silk Lafto	2	71	31	89	53	246
Yeka	26	81	53	53	82	295
Total	804	428	310	666	679	2887

Seasonal Distribution of Suspected Rabies Exposure in Addis Ababa

Of the total cases of suspected human rabies exposure from dog bites, 660 (29.8%), 540 (24.03%), 538 (23.9%) and 509 (22.65%) were reported during Winter, Autumn, Spring, and Summer seasons, respectively.

Table 10. Seasonal distribution of suspected human rabies cases in Addis Ababa (2020 - 2023)

	Winter (Bega)			Spring (Tsedey)			Summer (Kiremt)			Autumn (Meher)		
	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
	200	227	233	184	180	174	157	167	185	201	162	177
Total	660			538			509			540		

Spatial Distribution of Suspected Rabies Exposure in Addis Ababa

An examination of data from the EPHI for the period 2019-2023 revealed a potential spatial trend in suspected rabies cases within Addis Ababa. As illustrated in Figure 7, the majority of cases appear to be concentrated in the city's northern and northwestern regions.

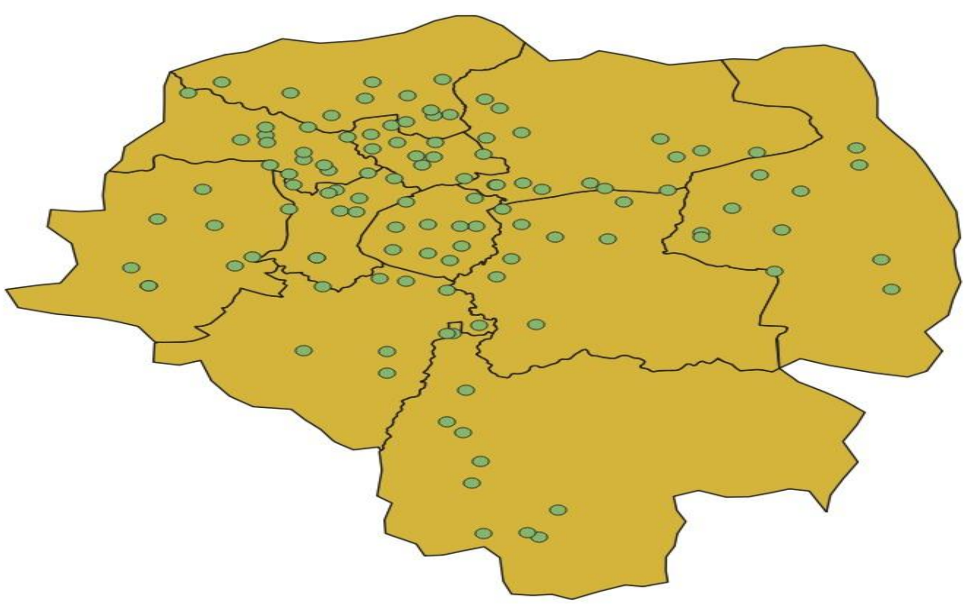

Figure 7: Spatial Distribution of Suspected Rabies Cases Recorded in EPHI, from 2019-2013 in Addis Ababa

The spatial interpolation analysis (Figure 8) yielded significant results, highlighting the presence of geographic clusters of rabies cases within specific sub-cities of Addis Ababa. These sub-cities were identified as Addis Ketema, Gulele, Kolfe Keranio, and Yeka. Specifically, it was found that at the connection between adjacent sub city boundaries of Addis Ketema, Gulele, Kolfe Keranio, and Yeka were high-risk areas for rabies occurrence. This spatial clustering suggests a non-random distribution of rabies cases within the city, warranting further investigation into potential risk factors associated with these specific areas.

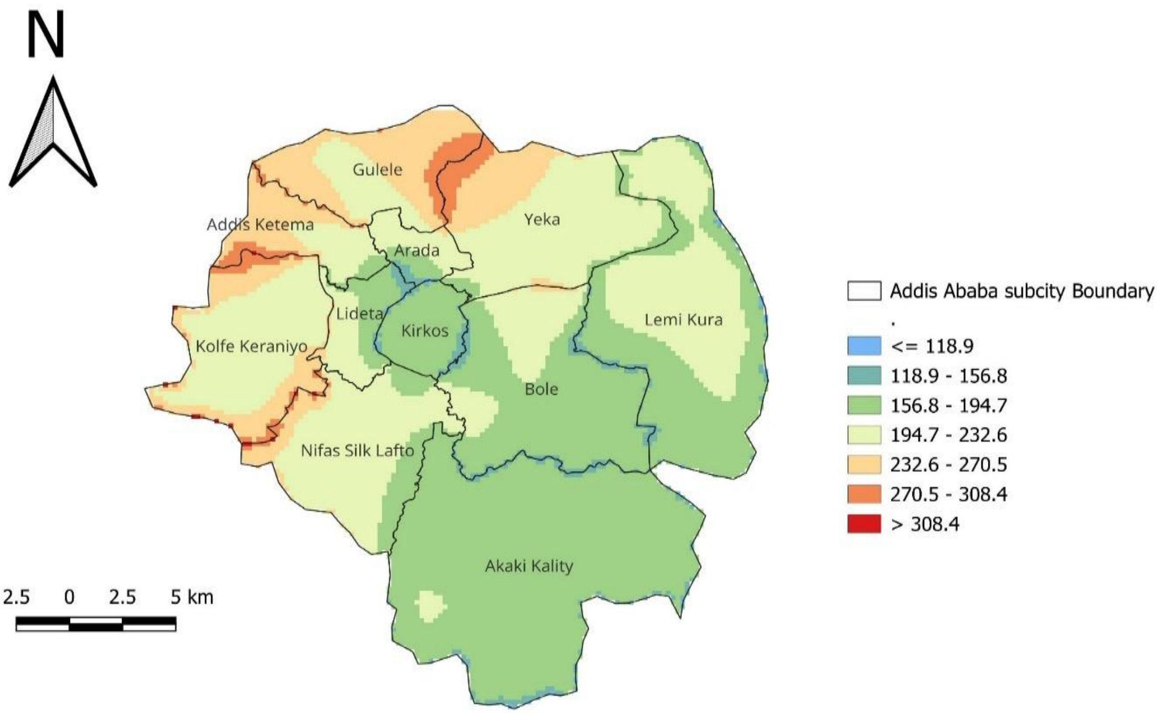

Figure 8: Interpolation of Spatial Distribution of Suspected Rabies Cases in Addis Ababa

Incidence of Suspected Human Rabies Exposure Cases and Deaths

The overall incidence rate of suspected human rabies exposure cases by dog bites were 12.45. The highest incidence of suspected human rabies exposure was reported in 2019 (19.08 per 100,000), followed by 2022 (13.84 per 100,000), while the lowest incidence was recorded in 2021 (6.83 per 100,000) (Table 11). Additionally, the highest incidence of death resulting from suspected human rabies exposure cases in Addis Ababa was reported in 2019 (0.13 per 100,000), followed by 2022 (0.095 per 100,000).

Table 11. Incidence of suspected human rabies exposure cases and deaths by dog bite in Addis Ababa, Ethiopia (2019-2023)

Year	Population at risk	Suspected Rabies Cases	Incidence per 100,000	Number of Deaths	Deaths per 100,000
2019	4592000	876	19.08	6	0.13
2020	4794000	446	9.3	0	0
2021	5006000	342	6.83	2	0.04
2022	5288000	732	13.84	5	0.095
2023	5461000	727	13.31	3	0.055

4.5.2. Dog Vaccination Distribution

According to records from the Farmers and Urban Agriculture Development Commission, a total of 96,319 dogs received rabies vaccination across all 11 sub-cities of Addis Ababa during the period spanning from 2020 to 2023. Among these sub-cities, Bole exhibited the highest vaccination coverage, with 12,775 dogs (13.3%) reported as vaccinated, closely followed by Yeka (9,888 dogs, 10.3%), Gulele (9,656 dogs, 10.02%), and Kirkos (9,632 dogs, 10%). Conversely, the lowest vaccination coverage was observed in Lideta sub-city (6,214 dogs, 6.5%), followed by Akaki Kality (6,745 dogs, 7%), and Addis Ketema (7,597 dogs, 7.9%) (Fig. 10).

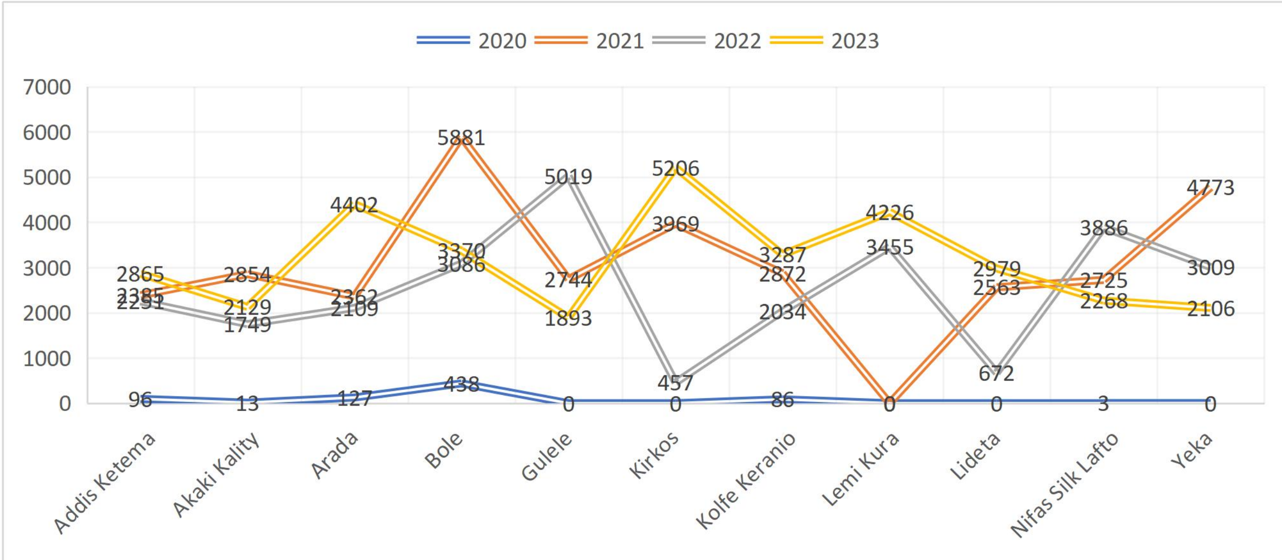

Figure 9: Distribution of Dog Vaccinations by Sub-city 2020-2023

The records also show a noteworthy disparity in vaccine coverage between stray dogs and owned dogs. In 2022, out of 27,727 reported dog vaccinations, only 13,300 (47.9%) were attributed to owned dogs, with the remaining 52.1% represented by stray dogs. Conversely, in 2023, the reported dog vaccinations from sub-cities amounted to 34,731, with dogs under ownership accounting for the majority (20,199, 58.2%), while stray dogs constituted 14,532 (41.8%) of the total.

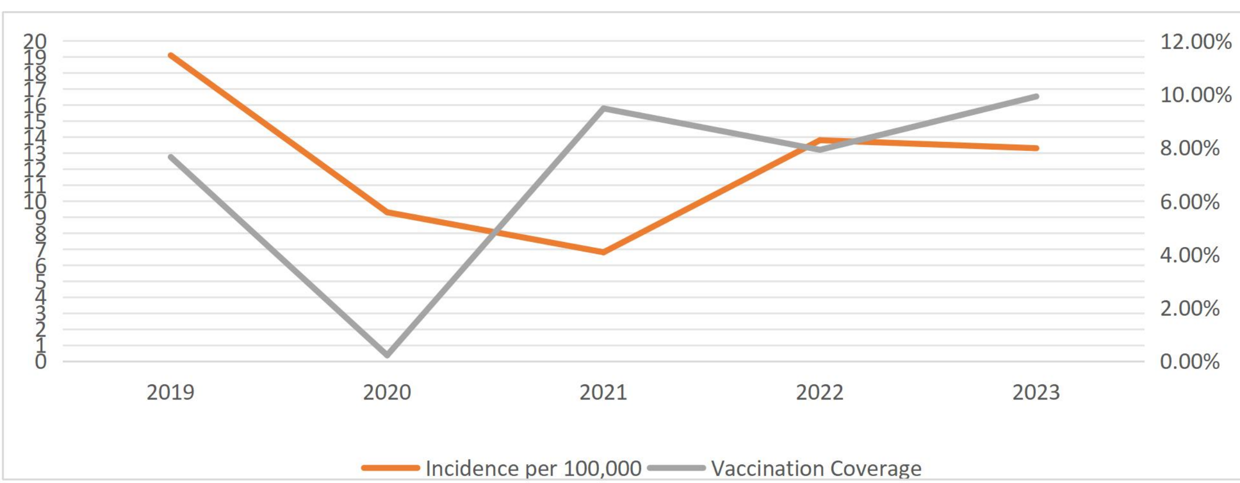

Figure 10: Rabies incidence in correlation to rate of vaccine coverage in Addis Ababa, from 2019 to 2023.

5. DISCUSSION

In this study, 66.5% of participants reported that their dogs had been vaccinated within the past year (2023/2024 GC). While this figure falls below the WHO's recommended coverage of 70%, it notably surpasses the estimated 5% coverage reported by the East Africa Rabies Network (Pieracci *et al.*, 2017). Comparatively, this result is closer to findings from certain studies conducted in Addis Ababa, which reported vaccination coverage ranging between 62.4% and 81.4% (Yoak *et al.*, 2021; Kamero, 2021), yet exceeds the reported coverage levels in other studies such as, 1.8% and 33.3%, in Ethiopia; 8.7% in Zambia and 25% in Tanzania (Ali *et al.*, 2010; Yimer *et al.*, 2012; Mulipukwa *et al.*, 2017; Bardosh *et al.*, 2014). Few of the reasons for the difference in vaccination coverage could be the areas studied, availability of private vaccinators, limited knowledge about rabies awareness level and strategies of stray dog control employed by the professionals in the particular area.

From the sub-cities included in this study, Lemi Kura showed the greatest number of unvaccinated dogs. Among the owners who had not vaccinated their dogs in Lemi Kura, various barriers were cited as impediments to vaccination compliance. Predominantly, a lack of access to vaccination services was identified as the primary obstacle by the majority (17/24 or 70.8%) of owners. This challenge stemmed from residing in relatively remote areas where vaccination facilities were limited, resulting in owners either being unaware of vaccination sites or facing logistical challenges in reaching them due to distance.

This finding aligns with the observations of Yoak *et al.* (2021), who noted that a significant proportion of respondents exhibited limited willingness to travel long distance for rabies vaccination. Specifically, the study reported that the majority of respondents were only willing to travel a median distance of 1 km, with approximately 41.5% of owners expressing unwillingness to travel at all for a rabies vaccine. However, the above conclusion was in opposition to the observation of a study in Malawi who found that 75% of dog owners are willing to travel up to 1.5 km to find vaccination centers (Mazeri *et al.*, 2018).

The study revealed a high level of rabies awareness among the surveyed dog owner population, suggesting a general understanding of the disease. Encouragingly, data indicated that 66% of respondents reported vaccinating their dogs against rabies within the past year. However, only

44.2% of dog owners specifically mentioned utilizing government-led vaccination campaigns. This discrepancy suggests several possibilities: some dog owners may be unaware of or uninformed about these campaigns, or they might prefer alternative methods of pet vaccination outside of government initiatives.

Additional barriers to rabies vaccination uptake were identified through the survey. These included a lack of awareness regarding the benefits associated with rabies vaccination and logistical challenges arising from occupational commitments. Moreover, one participant expressed apprehension regarding the vaccine's quality, citing a personal observation wherein a neighbor's dogs purportedly succumbed shortly after receiving vaccination, thereby instilling doubt and reluctance. Furthermore, the perceived costliness of for-profit vaccinators was highlighted as a deterrent, contributing to suboptimal vaccination coverage in the area.

The aforementioned results are consistent with the observations made by Mazeri *et al.* (2018), who similarly identified lower socio-economic status and limited public awareness as significant barriers to effective rabies vaccination campaigns. However, in the report by Yoak *et al.* (2021), a contrasting finding emerged, with 95% of respondents expressing willingness to pay for vaccination. Such disparities in attitudes could potentially be attributed to variations in socio-economic status across the study areas.

In this study, 62.6% of participants reported implementing restrictions on their dogs, preferring to keep them confined rather than allowing free roaming, which some participants perceived as a viable method for rabies prevention. This finding contrasts with the report by Yoak *et al.* (2021), who documented that 65.9% of dogs were allowed to roam freely in Addis Ababa. Additionally, studies conducted by Mulipukwa *et al.* (2017) in Zambia and Barbosa Costa *et al.* (2020) in Haiti similarly reported that the majority of dogs in their respective communities were not restrained and were allowed to roam freely. The difference result may be due to the difference of public awareness in the respective study populations.

All interviewed veterinary professionals unanimously confirmed the absence of known rabies epidemic areas within their purview therefore not affecting the vaccination strategy. Furthermore, they provided assurance regarding the annual implementation of comprehensive mass vaccination campaigns targeting both stray dogs and owned dogs, underscoring the systematic efforts undertaken to mitigate the spread of rabies.

Numerous barriers to achieving optimal vaccination coverage were presented during discussions with veterinary professionals. Foremost among these obstacles, as highlighted by the majority of respondents, was the deficiency in essential equipment, including personal protective equipment (PPE), restraining poles, and dog muzzles. Moreover, professionals emphasized the shortage of pre-exposure vaccines, posing significant risks for individuals involved in vaccine administration. This result agrees with the findings of Bardosh *et al.* (2014) and Dreyfus *et al.* (2024), who documented similar challenges faced by veterinary professionals in Tanzania and Madagascar. These studies revealed a shortage of government funding, resulting in inadequate provision of essential equipment and protection for veterinary professionals.

Another notable barrier emphasized by professionals pertained to the escalating population of stray dogs throughout the city. Respondents underscored that the majority of rabies infections resulting from dog bites are attributed to stray dogs. They explained that prior to the year 2010 EC (2018 GC), these stray dogs would have been subject to eradication efforts. However, following condemnation of this practice by the World Health Organization (WHO) and directives to prioritize vaccination initiatives, professionals encountered challenges in capturing and vaccinating these stray dogs.

While a few respondents acknowledged collaboration with select foreign non-governmental organizations (NGOs), resulting in the provision of vaccines and equipment that extended vaccine coverage, the prevailing sentiment among the majority highlighted the absence of collaboration with other health organizations, including human clinics, NGOs, and government agencies, as well as the lack of access to contemporary equipment and innovative techniques, which were identified as potential barriers to achieving broader vaccination coverage. This finding corroborates the conclusions drawn by van de Burgwa *et al.* (2017), who identified a deficiency in innovative solutions as a significant challenge faced by veterinary practitioners. This observation was based on insights gathered through interviews with key opinion leaders within the veterinary field.

Although many respondents noted a commendable level of public awareness regarding the disease within their respective areas, attributed to collaborative efforts by professionals through the dissemination of brochures, home visits, and utilization of mass media, a common concern expressed was the absence of long-term strategic planning for the eradication of the disease nationwide.

A total of 3,123 individuals sought medical care at the EPHI subsequent to sustaining dog bites between 2019 and 2023. Notably, the findings of this study revealed a lower incidence of dog bites compared to other studies conducted in Addis Ababa. Specifically, previous research reported figures ranging from 6,001 over the period 2016 to 2020, 6,100 between 2012 and 2016, and 13,361 from 1990 to 2000 (Abdella *et al.*, 2022; Lombamo *et al.*, 2018; Yimer *et al.*, 2002). However, it is noteworthy that the current study's findings indicate a higher number of dog bites in comparison to research conducted by Mesfin *et al.* (2022), which documented 1,772 cases from 2015 to 2019 and Ali *et al.* (2010), who reported 2,261 cases from 2003 to 2009 in Addis Ababa, and Yibrah and Damtie (2015), which reported 261 cases in Gonder from 2011 to 2013. One possible justification for this disparity is the increase of vaccination in Addis Ababa.

This study revealed that among the suspected rabies cases brought to the EPHI, the majority (66.4%) were male victims. This finding is consistent with the observations made by Yibrah and Damtie (2015) in Gonder and Gizachew *et al.* (2023) in Woliso, who similarly reported that male victims accounted for 62.8% and 59.4% of suspected rabies cases, respectively. This gender disparity may be attributed to the differential engagement in activities, with males typically participating in more nocturnal and outdoor pursuits, while females are more inclined to remain indoors due to cultural and religious considerations.

Through an examination of records at the Ethiopian Public Health Institute (EPHI), this study identified a total of 710 cases confirmed positive for rabies via laboratory testing spanning the years 2019 to 2023. These findings contrast with previous observations by Ali *et al.* (2010), who reported 1,724 positive rabies cases among dogs from 2003 to 2009; Deressa *et al.* (2010), who documented 2,458 positive rabies cases among dogs from 2001 to 2009; and Yimer *et al.* (2002), who reported 1,951 positive rabies cases among dogs from 1990 to 2000.

In this study, it was observed that 16 out of the 68 individuals (23.53%) who succumbed to injuries inflicted by suspected dogs during the period spanning 2019 to 2023 were from Addis Ababa city. This finding closely aligns with the report by Mesfin (2022), who documented 8 deaths in Addis Ababa from 2015 to 2019, and Yimer *et al.* (2002), who reported that 21.1% of the 322 deaths recorded from 1990 to 2000 in Ethiopia were from Addis Ababa city. Conversely, reports by Aklilu *et al.* (2021) and Deressa *et al.* (2010) revealed 87 deaths in Ethiopia from 2015 to 2019 and 386 deaths (with an annual range of 35 to 38) from 2001 to 2009, respectively. This phenomenon could be attributed to the administration of anti-rabies post-exposure treatment to individuals who have been exposed to rabies.

This study revealed that 92.4% of dog bite victims had received post-exposure prophylaxis (PEP), predominantly administered at St. Paul Hospital. This observation aligns with similar findings from other studies conducted in Ethiopia (Deressa *et al.*, 2010; Reta *et al.*, 2014). However, the proportion of victims seeking PEP in this study was notably higher compared to the findings of Yimer *et al.* (2002), who reported a PEP utilization rate of 66.1% among victims in Addis Ababa.

In examining the seasonal distribution of rabies cases, this study found that the summer season had the fewest instances (22.65%, N=509), while the winter season had the highest number of cases (29.38%, N=660). The majority of bites were found to occur in the autumn and winter, which coincides with the breeding season for dogs, during which male dogs tend to gather around a female in estrus for mating purposes. This finding is consistent with the findings reported by Yibrah and Damtie (2015) in Gonder, Kabeta *et al.* (2014) in Jimma, and Gebru *et al.* (2019) in Northwestern Tigray. However, it contradicts the findings of other studies such as Mesfin (2022), who reported the majority of cases occurring in the autumn, and Abubakar and Bakari (2012) in Nigeria, who reported the highest incidence of cases during the spring season. The variance could stem from the extended incubation period of rabies, as well as geographical and seasonal disparities.

The spatial interpolation analysis identified a significant spatial clustering of suspected rabies exposures within Addis Ababa. The northern and northwestern regions exhibited the highest concentration of cases. Specifically, sub-cities of Addis Ketema, Gulele, Kolfe Keranio, and Yeka emerged as hotspots, indicating areas with a substantially elevated risk of rabies exposure. Conversely, sub-cities like Lemi Kura, Bole, Kirkos, and Akaki Kality were designated as cold spots, suggesting a lower likelihood of exposure. This observed spatial heterogeneity warrants further investigation into potential contributing factors. Possible explanations for the clustering of cases in the hotspots could include a higher density of stray dogs and human populations; Lower vaccination rates, encompassing both owned and stray dogs; or dog migration patterns, either from rural to urban areas or between sub-cities within Addis Ababa.

The incidence rate of suspected human rabies exposure cases by dog bite was 19.08, 13.84, 13.31, 9.3 and 6.83 in 2019, 2022, 2023, 2020, and 2021, respectively, with the overall incidence rate being 12.45. This result is higher than another study performed by Mesfin (2022) in Addis Ababa, and Yigzaw *et al.* (2018) Northwestern Amhara, and Jemberu *et al.* (2013) North Gonder who reported an overall incidence rate of 8.4, 7.01 and 2.33 respectively. This might be due to the presence of many stray dogs and no adequate vaccination coverage at the study area during the study period. On the other hand, the findings of this study were lower than the reports of Tenzin *et al.* (2011) in Bhutan, Mazigo *et al.* (2014) in Tanzazia, Adomako *et al.* (2018) in Ghana and Ngugi *et al.* (2018) in Kenya, whose overall incidence rate was, 482.8, 58, 172, 289, respectively. The differences could be attributed to population size, socio-cultural factors such as the relationship between human and animals.

According to records from the Farmers and Urban Agriculture Development Commission, a total of 96,319 dogs received rabies vaccination across all 11 sub-cities of Addis Ababa during the period spanning from 2020 to 2023. This finding is comparable to Yimer *et al.* (2002) who reported 95,160 in Ethiopia between the years of 1996 to 2000. However, the findings of the study were higher than the studies by Ali *et al.* (2010) who reported 45217 vaccinated dogs in Addis Ababa between 2003 and 2009, and Deressa *et al.* (2010), who reported 85,055 dogs were vaccinated in various regions of Ethiopia from 2001 to 2009.

6. CONCLUSION AND RECOMMENDATIONS

Rabies stands as one of the most significant and detrimental public health concerns for both animals and humans across various regions of the developing world, including Ethiopia, where dogs serve as prominent reservoirs and transmitters of the disease to humans and other animals. Although there is a general trend of slight decrease in rabies incidence in Addis Ababa compared to previous decades, it remains one of rabies foci in the country. Particularly noteworthy is the high incidence rate documented in Kolfe Keraniyo sub-city, with 971 cases reported over a five-year period. In the current investigation, over the five years, a notable rise in the number of human cases of dog bites receiving post-exposure anti-rabies vaccine was observed. Although there are differences among sub-cities, there has been an increase in canine vaccinations over the five years. Furthermore, while this study unveiled a good level of awareness regarding rabies vaccination, some dog owners show a lack of some basic knowledge about rabies vaccinations, particularly evident in sub-cities such as Arada and Lemi Kura, where a significant proportion of respondents reported that their dogs were not vaccinated, citing various barriers. Through interviews with dog owners, potential barriers to vaccination, including unrestricted dog movement, limited awareness of rabies, absence of mass vaccination campaigns, and long distance to vaccination sites, were identified to have a statistically significant association with vaccine coverage rates. Furthermore, veterinary professionals highlighted challenges such as inadequate equipment, limited collaboration in innovation efforts, and insufficient long-term planning as the primary barriers affecting rabies vaccination rates.

Therefore, based on the above conclusions, the following recommendations should be considered:

- Scaling up and conducting periodic mass vaccination campaigns for dogs, including stray dogs.
- Increasing awareness among all stakeholders through a One Health approach, which includes veterinary and human medicine professionals, as well as dog owners, about the prevalence and potential public health impact of rabies in the city.
- Integrated efforts should be pursued for disease and dog population control, including vaccination and restriction of dogs' free movement by implementing legal requirement for dog owners.

- Integration of education on canine health and behavior into an overarching strategic plan for rabies elimination. This initiative may enhance individuals' ability to handle dogs over time and consequently increase willingness to vaccinate, particularly regarding traveling to vaccination clinics.
- To optimize rabies control efforts in Addis Ababa, further research is warranted to explore the utility of spatial modelling approaches. By explaining the spatial distribution of rabies risk, such models can inform the development of targeted and geographically specific control strategies.

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ANNEXS

Annex 1: Questionnaire for Dog Owners

Thank you for taking the time to complete this questionnaire. The purpose of this survey is to gather information about the vaccination status of domestic dogs in our community. Your responses will help us assess the coverage and effectiveness of dog vaccination campaigns. Please provide accurate and complete information. Your participation is greatly appreciated.

1	Owners' Information	Name:
		Address: Region _______________, District/ ______________ Mobile No. _________________
		Age (years):_____________ , Sex: A) Male B) Female
		Educational status: Basic writing & reading /No education/ Primary level/ High school level/Diploma/University level
		Occupation:Farmers/Dependants/housewife/Businessman/Student/Employee/other
2	Have you witnessed any cases of rabies disease in animals within your community?	a) Yes b) No c) Not sure
3	If you have witnessed cases of rabies disease, please provide the following details for each case	a) Approximate date of occurrence: b) Location (specific area or region):
4	Do you keep dogs?	Yes/No. If Yes How many_________
5	What is the age of your dog?	Puppy(0-6mon) Young (6 – 12 month) Adult (12 month-10 Years) Aged (more than 10 Years)

6	Why do you keep them? Purpose	As pet/ To guard house/ Love and affection/Other purposes (please specify)__________________________________
7	Do you restrict your dog's outside home movement?	Yes/No
8	Have you heard about rabies?	Yes/No. If the answer is No, do not ask some questions in the next section
9	Where did you hear it?	Professionals/mass media/community/friends/Religious institutions/ others (specify)____________________
10	Will you inform/report to the health/veterinary authorities if there is a suspected rabies outbreak in your area/community?	Yes/No/Not sure
11	Do you believe that rabies can be transmitted to humans from a dog/cat/other animals	Yes/No/Not sure
12	Has each of your dogs received any vaccinations? Please select the appropriate option for each dog:	Dog 1: i) Fully vaccinated ii) Partially vaccinated iii) Not vaccinated iv) Unsure/Unknown
		Dog 2: i) Fully vaccinated ii) Partially vaccinated iii) Not vaccinated iv) Unsure/Unknown
		Dog 3: i) Fully vaccinated ii) Partially vaccinated iii) Not vaccinated iv) Unsure/Unknown

13	If your dog(s) have been vaccinated, please provide the following details for each dog:	Dog 1: i) Date of the last vaccination: ii) Type of vaccine administered:
		Dog 2: i) Date of the last vaccination: ii) Type of vaccine administered:
		Dog 3: i) Date of the last vaccination: ii) Type of vaccine administered:
14	If any of your dogs are not vaccinated or their vaccination status is unknown, please briefly explain the reasons or circumstances.	
15	Do you know what age is recommended for a dog's first rabies vaccination?	3month/6-month/1 year/2 year
16	Do you believe it is important to vaccinate dogs against rabies every year?	Yes/No/Not sure
17	Do you believe that rabies outbreaks can be prevented by regular vaccination of dogs?	Yes/No/Not sure
18	Have you encountered any	

	challenges or difficulties in accessing veterinary services for dog vaccinations? Please elaborate if applicable.	
19	Are you aware of any local dog vaccination campaigns or initiatives in your community? If yes, please provide details if possible.	
20	Do you have any suggestions or recommendations to improve dog vaccination coverage in our community?	
21	Have you or a family member been bitten by a dog?	Yes/No/Not sure. If yes whom bitten? My wife/husband, Son, daughter, worker, relatives, others (specify)_______________
22	Have you taken Post-Exposure vaccine?	
23	Which dog bit you or your family member?	Owned dog/stray dogs/both
24	Which parts of your body were bitten by the dog?	Hands/limbs/neck/shoulder/head/face/buttock/others (specify)_____________________________________
25	Are you aware that a dog bite wound should be washed with soap and water?	Yes/No.
26	Have you attempted to consult a medical practitioner immediately after being bitten by a dog?	If yes, what factors contributed to your decision? ____ __

27	What do you recommend measures to control/prevention of rabies?	

Thank you for participating in this questionnaire.

Annex 2: Interview Questions for Veterinary Professionals

1. How frequently do you encounter cases of rabies in domestic animals within your area and how has this data influenced vaccination priorities and strategies?
2. How would you assess the current rabies vaccine coverage among domestic animals in your area?
3. In your experience, what challenges do veterinary professionals face in achieving optimal rabies vaccination rates in your area, and are there specific areas or communities with lower coverage?
4. Can you provide insights into the efficiency of existing rabies vaccination programs in terms of reaching target populations and ensuring long-lasting immunity in animals?
5. How has the collaboration between veterinary professionals, government agencies, and local communities contributed to the overall effectiveness of rabies vaccination campaigns in your area?
6. What advancements or innovations in rabies vaccine technology have been adopted in the region, and how have they impacted the vaccination efforts and outcomes?
7. Are there any specific strategies or interventions being implemented to address challenges related to vaccine accessibility, awareness, or acceptance within the community?
8. How do veterinary professionals monitor and evaluate the success of rabies vaccination campaigns, and what metrics are used to assess the impact on both animal and human health?
9. What role do education and public awareness campaigns play in promoting rabies vaccination, and are there any notable successes or lessons learned in this regard?
10. In terms of rabies eradication efforts, what long-term goals and strategies are being pursued in your area, and how can the veterinary community contribute to achieving these objectives?