



## Epizootological and aetiopathogenetic aspects of mycobacterioses

### Volodymyr Busol\*

Doctor of Veterinary Sciences, Professor  
National Scientific Center "Institute of Experimental and Clinical Veterinary Medicine"  
61023, 83 Pushkinska Str., Kharkiv, Ukraine  
<https://orcid.org/0000-0002-9618-0493>

### Petro Boiko

Doctor of Veterinary Sciences, Associate Professor  
Lesya Ukrainka Volyn National University  
43025, 13 Voli Ave., Lutsk, Ukraine  
<http://orcid.org/0000-0003-1418-1159>

### Michał Bednarski

Doctor of Veterinary Medicine, PhD in Veterinary Sciences  
Wroclaw University of Environmental and Life Sciences  
50-375, 25 C.K. Norwida Str., Wrocław, Poland  
<https://orcid.org/0000-0003-0292-7929>

### Viktor Shevchuk

PhD in Veterinary Sciences, Associate Professor  
National University of Life and Environmental Sciences of Ukraine  
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine  
<https://orcid.org/0000-0002-5937-3333>

### Olha Panivska

Postgraduate Student  
Lesya Ukrainka Volyn National University  
43025, 13 Voli Ave., Lutsk, Ukraine  
<http://orcid.org/0000-0002-1280-4458>

**Abstract.** Animal mycobacterioses, unlike those in humans, are not in the focus of veterinary science and practice for various reasons. This fact, as well as some others, including the growing incidence of human mycobacteriosis caused by non-tuberculous mycobacteria involved in the

### Suggested Citation:

Busol, V., Boiko, P., Bednarski, M., Shevchuk, V., & Panivska, O. (2024). Epizootological and aetiopathogenetic aspects of mycobacterioses. *Ukrainian Journal of Veterinary Sciences*, 15(2), 9-26. doi: 10.31548/veterinary2.2024.09.

\*Corresponding author



sensitisation of productive animals, is an objective, albeit indirect, indication of the existing problem of mycobacteriosis in veterinary medicine. This study employed the comparative geographical and epizootological methods of analysis. The findings obtained from the publications of scientists from around the world helped to summarise and objectively assess the severity of the epizootic situation regarding mycobacteriosis in animals in the world and in Ukraine, to identify a range of features of the infectious and epizootic processes, and to establish the dominant aetiopathogenetic criteria for this infection in animal populations. Animal mycobacteriosis is the subject of detailed scientific research in most countries of the world, as this disease is widespread among productive and unproductive (domestic and wild) animals, as well as the fish fauna of sea and river waters. It was found that the most common causative agents of mycobacteriosis are nontuberculous mycobacteria such as *Mycobacterium avium complex*, *M. abscessus complex*, *M. kansasii*, and *M. fortuitum*, and some others. In Ukraine, animal mycobacteriosis is not given due attention, even though parallergetic reactions to tuberculin in cattle lead to complications in the diagnosis of tuberculosis infection. They cause considerable losses in dairy farming due to the culling and slaughter of highly productive cows. Identification of aetiopathogenetic patterns of paraallergic reactions to tuberculin in productive animals is a key to effective control and management of the epizootic process of animal mycobacteriosis and reduction of biohazards of human infection with non-tuberculous mycobacteria through food of animal origin

**Keywords:** tuberculosis; tuberculin; allergen of atypical mycobacteria; epizootic process; infectious process; allergic reactions; diagnostics

---

## Introduction

Animal mycobacterioses, among other well-known problems of modern veterinary medicine, have become an objective issue in many countries. According to O.A. Zhurylo *et al.* (2020) and the World Health Organisation (2022), mycobacterioses of cattle – animals that are the main producers of milk and dairy products – are of the greatest epizootological and biomedical significance. The findings from L. Varela-Castro *et al.* (2022) also support this. The detection of nonspecific (paraallergic) reactions to tuberculin, primarily in cows from dairy farms that are free of tuberculosis, is a common phenomenon in many countries, including Ukraine. However, such para-allergic reactions to tuberculin in cattle are not usually recorded by specialists of state veterinary institutions, as they are deeply rooted in the opinion that non-tuberculous mycobacteria (NTMB) do

not cause an infectious process in animals, but only cause sensitisation of the animal body.

Based on this postulate, developed back in the 1950s, a misconception is being built that animal sensitisation is not the result of a latent infectious process caused by NTMB, but a permanent, harmless phenomenon that is not related to the infectious process. Thus, if there is no infectious process, then there can be no question of an epizootic process. Mycobacteriosis is an infectious disease caused by NTMB, which has its own aetiopathogenesis, inherent pathological and specific histomorphological changes, and is characterised by a predominantly asymptomatic, permanent form with sensitisation and chronic course. And as indicated by P.K. Boyko *et al.* (2021), the presence of an infectious process in one third of the dairy cows in the herd of a dairy farm is indisputable

evidence of the functioning of the epizootic process of mycobacteriosis in the herd.

The epidemiological monitoring of diseases caused by ATMB can become the basis for creating an information base for in-depth investigation of the epidemiology of mycobacterioses and the ecology of the causative agents of these infections to develop further concepts for the control and management of infectious and epizootic processes of mycobacterioses in animals. This, as pointed out by V.O. Busol *et al.* (2014), will allow to consider milk and dairy products not only as dietary foods, but also as a potential factor of NTMB transmission from AMB-infected cows to the public. Monitoring for the presence of NTMBs in raw milk may eventually become a mandatory requirement of the DSTU as one of the criteria for preventing biohazards to human health from milk and dairy products. Therefore, the purpose of this review was to analyse the literature on the specific features of the epizootic process and the dominant aetiopathogenetic criteria of mycobacteriosis in animal populations at the global level.

To fulfil this purpose, the comparative geographical and statistical methods, as well as the method of epizootological analysis, were used. Furthermore, in processing the scientific literature data, generally accepted research methods and techniques were employed, namely, scientific search, systematic approach, observation, generalisation, and description of published experimental data of other researchers, etc. The authors summarised and provided their own assessment of the main conclusions of the researchers of each of the scientific sources.

### **Environmental mycobacteria – potential causative agents of mycobacteriosis in animals**

Mycobacteriosis is an infectious disease of humans and animals caused by representatives of a large group of NTMBs. V.N. Dahl *et al.* (2023) found an increasing role of NTMB in

the incidence of pneumonia in Denmark, while I. Pavlik *et al.* (2021) established the clinical manifestation of mycobacteriosis in fish, animals, and humans caused by *M. fortuitum*.

According to F. Jamal & M. Hammer (2022), in the early years, according to the introduced classification system for non-tuberculous mycobacteria, they were also called atypical mycobacteria (AMB). Presently, according to J.O. Falkinham (2013), they have been given another name – environmental mycobacteria. K.H. Schroder *et al.* (1992) report that ATMBs were identified shortly after they were found to cause human lung disease in the 1950s. According to Ž. Cvetnić *et al.* (2018), in 1954, A. Timple and E. Runyon proposed a classification of NTMBs, which is now called the Runyon classification. According to this classification, mycobacteria are divided into 4 main groups based on growth rate, colony morphology, and pigmentation ability. According to O.S. Shevchenko *et al.* (2019), the group of NTMBs most commonly encountered in the clinical practice of humane medicine doctors includes *M. avium-intracellulare complex (MAC-complex)*, *M. kansasii*, *M. fortuitum*, *M. abscessus*, *M. chelonae* and a range of others. They are often released from water, soil, and other environmental objects.

On the other hand, the unique structure of the mycobacterial cell wall, which contains many fatty and waxy compounds, substantially increases both the adaptive properties of mycobacteria to changing environmental conditions and their resistance to phagocytosis. This, according to D.T. Armstrong *et al.* (2022), provides mycobacteria with the ability to survive in the environment for a long time and is thus one of the determining factors in the considerable spread of mycobacteria among farm and wild animals.

Given the widespread distribution of ATMB in biotic and abiotic environmental objects, confirmation of their aetiopathogenic role in a particular case, detection of signs of sensitisation of the organism by them, and even

isolation and identification of the mycobacteria themselves requires the establishment of an infectious process in animals. Therefore, the available criteria for this may include the results of bacteriological and biological studies, which can be used to establish the presence of pathogenicity factors in the identified mycobacteria, or to detect pathological or pathomorphological changes in the organs and tissues of animals suspected of having the disease.

According to T.K. Marras *et al.* (2017), the American Association of Thoracic Surgeons has developed microbiological, clinical, and molecular genetic criteria to establish the aetiological role of NTMB in HIV-positive and HIV-negative patients. Unfortunately, such criteria have not yet been developed in veterinary medicine.

The results of the monitoring of scientific literature on the persistence of AMB in animal organisms suggest that a wide range of different animal species inhabiting the territories of countries on all continents are infected with them. The list of animals from which NTMBs have been isolated that have caused mycobacterioses includes productive agricultural, domestic, and wild animals, poultry, fish, amphibians, reptiles, and insects. The present review focused on those animal species and those types of NTMBs that can or do pose a biohazard to public health, both as evident and potentially pathogenic microorganisms.

Thus, according to K. Röltgen & G. Pluschke (2022), *M. ulcerans* infection, or Buruli ulcer, is a mycobacterial disease of humans in West and Central Africa, as well as Australia and Oceania, and is closely associated with tropical wetlands where *M. ulcerans* is found in water, marshes, fish, and insects. Experimental infections with *M. ulcerans* have been reproduced in lizards, amphibians, chicken embryos, opossums, armadillos, rats, mice, and cattle. Natural infection in animals has been observed only in Australia, specifically in captive koalas,

ring-necked possums, and alpacas. The lesions were clinically analogous to those observed in humans. From this review, it can be concluded that the parasitism of *M. ulcerans* on amphibians and warm-blooded animals, as well as humans, is optional, while the ecology of the pathogen itself indicates a saprophytic mode of life as the main one. That is, in the evolution of this AMB species, a gradual transition from saprophyticism to pronounced parasitism is observed, which suggests considering it a potential pathogen of a dangerous infectious disease of animals and humans.

Analysing the epidemiological features of mycobacterioses, O.A. Zhurylo *et al.* (2020) report that up to 80% of human mycobacterioses are caused by *M. avium complex*. They believe that the main reservoir of *M. avium* is open water. *M. avium* is transmitted from water to humans by aerosolisation as a result of the natural formation of aerosols above the water surface. Sick poultry are often the source of *M. avium*. Therefore, it can be argued that the infection caused by *M. avium complex* is sapronotic or zoonotic. This report raises the question: if open water is a reservoir of *M. avium*, then what is the source of this mycobacterium species from which it enters open water? Could water bodies be a habitat for mycobacteria? Scientific research on the ecology of *M. avium* may provide answers to these questions.

### **Infectious and epizootic processes in mycobacteriosis in Ukraine**

Mycobacteriosis as a nosological unit of infectious pathology in veterinary medicine does not yet have the recognition and even definition that infections caused by mycobacteria of the tuberculosis complex (*M. tuberculosis*, *M. bovis*, *M. africanum*) have. The World Organisation for Animal Health (OIE) does not include animal mycobacterioses in epizootic monitoring. Therefore, it is impossible to give an objective

assessment of the spatial and temporal dynamics of the intensity of the epizootic process of mycobacteriosis in the world and in Ukraine specifically. Therefore, to fulfil this purpose, the materials of scientific publications related to this issue were used. The findings of these studies were obtained using different methods and did not always have the same purpose, which also bears the imprint of non-uniformity of the data being compared.

To assess the severity of the epizootic situation with mycobacteriosis in Ukraine objectively, it was necessary to first investigate the spatial and temporal features of the manifestation of mycobacteriosis in animals. The period of scientific observation included the years from 2000 to 2023. There are a range of reasons for the complexity of the task of assessing the epizootic situation in Ukraine. The objective reasons include a considerable reduction in the number of productive animals, the complete elimination of certain livestock industries (horse breeding, sheep breeding, rabbit breeding), and a considerable reduction in the period of keeping cows on dairy farms due to changes in milk production technology. The subjective reasons include the unsatisfactory level of diagnosis by veterinary practitioners and the lack of interest of specialists from state veterinary institutions in diagnosing new infectious pathologies, which adversely affected the reflection of the real state of the epizootic situation with mycobacteriosis, and hence the reduction in demand for the development of modern diagnostic methods and means of preventing infections caused by atypical mycobacteria (AMB).

B.M. Yarchuk *et al.* (2002) note that, as with any factor infection, the epizootic process of mycobacteriosis in animals is characterised by the interaction of three links – the source of the infectious agent, the mechanism of transmission of the pathogen, and the susceptible organism. This interaction takes place against

the backdrop of various environmental factors. Therewith, the latter in most cases play a decisive role in the manifestation of the infectious process of all factor infections, including mycobacteriosis. There is currently no consensus on the source of the causative agents of animal mycobacteriosis. However, P.K. Boyko *et al.* (2021) suggest that animals infected with AMB, including those that respond positively to AMA, are the main source of the infectious agent, because mycobacteria in their bodies are not just indifferent microorganisms, but also cause an active, albeit clinically latent, infectious process. Once in the body of animals, AMBs increase their pathogenicity and, when excreted into the environment in faeces, milk, or other secretions, infect other animals, which we observed in the cows of the dairy farm we studied.

However, considering that the problem of mycobacteriosis in animals is at the initial stage of its development, we believe that the first link of the epizootic chain, namely the characteristics of the source of the infection agent, has been understudied. V.M. Gorzheev *et al.* (2004) emphasise that the investigation of the ecology of different mycobacterial species in animals and in environmental objects allows determining the degree of activity of the pathogen in the manifestation of the epizootic process. Such a theoretical substantiation can be used for a comprehensive study of the epizootic process in both tuberculosis and other mycobacterioses.

L. Heifets (2004) believes that little attention is paid to the study of microbiological characteristics of AMB. This is explained by a range of reasons. As reported by L.M. Feazel *et al.* (2009), mycobacterioses do not have a tuberculosis-like clinical course, and therefore are difficult to detect by clinical diagnostic methods. They often form a mix of infections with tuberculosis, which is why diagnosticians overlook them. However, possessing a wide range

of resistance, AMBs can survive in the environment for a long time and infect susceptible animals for a considerable period of time, causing sensitisation or infection, which is determined by the virulence of mycobacteria.

According to E.M. Lipner *et al.* (2017), the source of pathogens in animal mycobacterioses is sick animals and bacterial carriers, as well as various environmental objects (feed, water, soil, manure), where mycobacteria can not only survive but also multiply, increasing their population, but also have certain ways of entering susceptible organisms, which from the standpoint of epizootology is the basis for classifying them as saprophytic. However, considering the genetically determined pathogenicity factors (cord factor; specific feature of the cell wall structure, which provides resistance to phagocytosis; ability to form L-forms; availability of mechanisms to overcome and inactivate adverse environmental factors, which puts them in second place after spore-forming microorganisms in the bacterial domain), R.A. Mercaldo *et al.* (2023) argue that a considerable number of *Mycobacterium* species evolve towards complete pathogens such as *M. avium*, *M. intracellulare*, *M. kansasii*, *M. fortuitum*, *M. abscessus*, *M. vaccae*, etc.

According to V.M. Gorzheev (2005) and A.I. Zavgorodnyi (2014), in Ukraine, during routine allergic studies, 200–280 farms annually detect reactive animals in which no lesions inherent in tuberculosis are found in organs and tissues during diagnostic slaughter. Bacteriological tests of biomaterial from such animals do not isolate the tuberculosis pathogen. However, non-tuberculous mycobacteria (NTMB) are isolated from the lymph nodes and submucosal layer of the cranial colon, including *M. fortuitum*, *M. scrofulaceum*, *M. xenopi*, etc. The studies of such Ukrainian scientists as V.M. Gorzheev (2005), G. Dyachenko *et al.* (2006), B. T. Stegnyy *et al.* (2014) proved that

over the past 30 years, the isolation of AMB, specifically *M. smegmatis*, *M. fortuitum*, *M. phlei*, *M. vaccae*, etc. has increased significantly (up to 86.2% of the total number of all isolated and identified mycobacteria) from tuberculin-reactive cattle.

The isolation of AMB adversely affects diagnosis and health promotion activities, especially in the case of recurrent tuberculosis. G. Dyachenko *et al.* (2006) note that the use of a comprehensive method of tuberculosis testing allows differentiating the nature of reactions to tuberculin in cattle during two cycles of diagnostic tests. Farms in which cattle are sensitised by AMB should be considered TB-free, as atypical mycobacteria in healthy animals do not cause the development of the TB process.

However, the question of how to deal with animals that tested positive for the atypical mycobacterial allergen (AMA) is still open. According to B.T. Stegnyy *et al.* (2014), these animals, as well as those that have shown allergic reactions to tuberculin, are considered free of TB and can stay in the herd without any restrictions. In this regard, the question stays as to the mechanism of sensitisation – whether it is a physiological or pathological reaction of the immune system in response to permanent or permanent ingestion of AMB into the body of animals or the result of an infectious process caused by AMB. The answers to this, as well as to many other related questions, can be obtained in a detailed investigation of the ways of infection of animals with AMB, their interaction at the cellular, tissue, organ, and organismal levels of infected animals.

A.I. Zavorodnyy & O.V. Kotlyar (2014) found that among cattle in TB-free farms in Ukraine, reactions to tuberculin (purified protein derivative) for mammals were caused by 13 species of atypical mycobacteria, including *M. gordone*, *M. scrofulaceum*, *M. avium*, *M. terrae*, *M. xenopi*, *M. peregrinum*, *M. fortuitum*,

*M. smegmatis*, *M. vaccae*, *M. phlei*, *M. flavescens*, *M. diernhoferi*, *M. thamnophaeos*. The researchers proved that some isolated species of atypical mycobacteria caused in guinea pigs an increased delayed-type sensitivity to mammalian tuberculin (PPD) but did not cause pathological and anatomical changes inherent in tuberculosis.

However, the scientists do not mention the presence of histomorphological changes in the experimental animals. According to V.O. Busol et al. (2014), histological studies and bacteriological examination of regional lymph nodes in infected guinea pigs for the presence of AMB would provide a broader view of the mechanism of sensitisation, and therefore the nature of paraallergic reactions in both experimental animals and animals from which these mycobacteria were isolated. The data obtained by the researchers suggest that a considerable number of AMBs circulate among the cattle population in Ukraine, which complicate allergic diagnosis of tuberculosis in herds of productive animals and pose a threat of human infection through food of animal origin.

This review suggests that none of the Ukrainian scientists has addressed the underlying mechanisms of AMB-induced sensitisation in animals. It is unclear at what stage of interaction between a microorganism and a macroorganism sensitisation occurs, whether it is a result of a latent infectious process caused by AMB, or whether infection with AMB is a purely mechanical process of their penetration into the body with the subsequent activation of a delayed hypersensitivity reaction, which is detected by allergic testing. In the end, the mechanisms of extinction of this process are still unexplored, because paraallergic reactions to tuberculin are permanent, i.e., they can disappear after a certain period of time and then reappear.

The detection of nonspecific (paraallergic) reactions to tuberculin, primarily in cows from dairy farms free of tuberculosis, is a common

phenomenon in many countries. Thus, according to G. Dyachenko et al. (2006), A.I. Zavorodniy et al. (2018), in the United States, 10-15% of animals with paraallergic reactions to tuberculin are detected in routine allergic tests of cattle for tuberculosis, in France – 15-30%, in Latvia – 35.8%, in Lithuania – 81.8-98.3%, in Estonia – 92-95.1%.

These facts are indirect, but objective evidence that AMB circulate in cattle herds around the world, which are the main factors in the occurrence of non-specific reactions to tuberculin. On the other hand, it can be argued that the problem of infection of productive animals with AMB is relevant not only from a scientific standpoint, specifically, a deeper investigation of the aetiopathogenesis, but also from a practical standpoint – how to reduce “spontaneous” outbreaks of paraallergic reactions in a particular herd. The question persists whether these reactions are based on sensitisation of the body as a physiological reaction of the immune system in response to the ingestion of AMB, or sensitisation of the body as a result of an infectious process caused by these bacteria.

According to A.I. Zavorodniy et al. (2018), as of 1 January 2017, there were no more TB-affected locations in Ukraine. However, according to the World Organisation for Animal Health (OIE), Ukraine is currently not in a good situation regarding animal tuberculosis. This is evidenced by allergic reactions of cattle to tuberculin, which are constantly detected in many farms in Ukraine. Reports by V.Yu. Kassich et al. (2010), A.I. Zavorodniy et al. (2018) on the epizootic situation of tuberculosis and other mycobacterioses of cattle in Ukraine at the beginning of the 21st century indicates that the average annual number of dairy farms where reactive animals to tuberculin and allergen of atypical mycobacteria are detected is about  $250 \pm 30$ , (1.47%) of all medium and large dairy farms in the country. The absence of a unified

reporting system of the State Service of Ukraine for Food Safety and Consumer Protection on existing cases of mycobacteriosis in animals does not allow for an objective characterisation of the spatial and temporal dynamics of the epizootic process of mycobacteriosis and the identification of epizootic features of this infection. Therefore, for the above reasons, it is not possible to show the distribution of mycobacteriosis foci by regions of Ukraine, and therefore to establish the territorial confinement of mycobacterial infections in each region.

### **Features of the manifestation of infectious and epizootic processes of mycobacteriosis of animals in countries around the world**

To identify trends in the development of the epizootic process of mycobacteriosis on different continents, the study first analysed scientific publications related to the isolation and identification of AMB from productive animals, and more concretely from cattle in different countries of the world. The next step was to analyse the epidemiological situation regarding mycobacteriosis in other animal species, including amphibians, fish, and poultry.

A group of Brazilian scientists S.A. Bolaños *et al.* (2018) in 08.2014-08.2015 tested 4,766 cows with an intradermal simultaneous tuberculin test in 15 districts of the state of Paraná (Brazil) using PPD-tuberculin and an allergen from *M. avium*. 142 (2.98%) animals were positive. Most often (71%), cows aged 5-10 years were positive. 14 strains of mycobacteria (8.4%) were isolated from 12 cows, including *M. engbaekii* (n = 5), *M. nonchromogenic* (n = 3), *M. arupense* (n = 4), and *M. heraklionense* (n = 2). Despite the absence of *M. tuberculosis* complex mycobacteria in the milk samples, the results highlight the risk of transmission of pathogens from cattle to humans through milk, as some mycobacterial species identified in milk have

been identified as aetiological agents in pulmonary and extrapulmonary diseases in immunocompromised individuals.

In Brazil, where there are more than 220 million heads of cattle, the study of the ecology of mycobacterial pathogens is receiving due attention. Thus, R.B. Pardo *et al.* (2001) identified *Mycobacterium* spp. most frequently (78.95%) out of 780 raw milk samples from 52 cows with a positive simultaneous sample (Stormont test), followed by *M. fortuitum* (10.52%), *M. bovis* and *M. avium* (5.26% each). This is evidenced by scientific publications by C.Q. Leite *et al.* (2003), S.A. Sgarioni *et al.* (2014), which, among other things, even reported the isolation of NTMBs from pasteurised milk samples. Considering that Brazil is the largest country in Latin America, it can be argued that the prevalence of mycobacteriosis among productive animals, especially cattle, is high in other countries of the continent. This requires further research to develop effective measures to prevent mycobacteriosis in herds of productive animals.

NTMB in cow's milk was detected in Asian countries, specifically, M.F. Qamar *et al.* (2013) in Pakistan; F. Aydin *et al.* (2012) in Turkey, and R.R. Kazwala *et al.* (1998) in the African continent – Tanzania. According to C. Chang *et al.* (2002), NTMBs are widespread on dairy farms, being isolated from manure, feed, plants, and water. NTMB infection in cattle occurs nutritionally through the consumption of contaminated water and feed, and aerogenously. However, few studies have been devoted to the elimination of mycobacteria from the body of cows, especially those with positive tuberculin test results. In this case, the reports of G.S. Pandey *et al.* (2013), I. Ben Kahla *et al.* (2011) on the detection of *M. bovis* in milk samples from cows that reacted positively to tuberculin are of great interest. M.M. Franco *et al.* (2013) found that the majority of mycobacteria are eliminated by the intramammary route.

Thus, AMBs are widespread on the territory of dairy farms in many countries on different continents of the world – they are isolated both from abiotic environmental objects and from the body of cows. Therewith, they are identified in the milk of both clinically healthy cows and in the milk of cows that react positively to tuberculin and AMA, which suggests that they are not just transient in the body of cows, but actively multiply in it with all possible manifestations of this form of interaction, which is inherent in a clinically latent or chronic course of the infectious process, and not just sensitisation.

According to scientific publications, NTMBs are widespread among both domestic and wild-life animals. Thus, a group of Polish scientists Ł. Radulski *et al.* (2022) found that mycobacteriosis in animals is often caused by *M. avium* ssp. *hominissuis*. Many species of animals are susceptible to infection with this bacterium, even those in zoos. Therefore, another group of Polish scientists, M. Bruczyńska *et al.* (2023), investigated zoo animals for paratuberculosis (PTB). Out of 131 faecal samples collected from different animal species of eight zoos in Poland, 7 isolates of mycobacteria were bacteriologically isolated, including 5 – *M. avium*, 1 – *M. fortuitum*, and one unidentified species of *Mycobacterium*. PCR confirmed the presence of PTB in faeces from 9 animals. These data also suggest that the paratuberculosis pathogen circulates in animal populations in Polish zoos.

The Australian team of scientists C.R.O'Brien *et al.* (2014) investigated the spread and manifestation of the infectious process caused by *M. ulcerans* among wildlife (common, ringed, mountain, and brushtail possums). The mode of transmission and reservoirs of the bacterium in the environment is still unknown. Real-time PCR studies have detected *M. ulcerans* DNA in a variety of environmental samples, including faeces from local opossums with and without clinical signs of infection. In 27 clinical cases

of *M. ulcerans* infection in adult opossums, single or multiple ulcerative skin lesions were observed, mainly in the head, limbs, and tail, while in 4 cases, pathological examination revealed systemic disease. The natural course of the disease is still unknown, but some easily affected possums (common brush-tailed and mountain possums) can spontaneously overcome the infection, while in other animals (common and ringed possums) the infection can be potentially fatal. The authors believe that further work is needed to determine whether *M. ulcerans* infection poses a potential threat to opossum populations and whether these animals can act as reservoirs of the pathogen.

A group of Italian scientists A. Vetere *et al.* (2022) described a fatal case of systemic mycobacteriosis caused by *M. goodii* in a Kenyan sand boa (*Eryx colubrinus loveridgei*) captured in the wild. Histological examination of the whole organs confirmed systemic mycobacteriosis. *M. goodii* was identified by real-time PCR. South American scientists D.H. Morais *et al.* (2021) pay great attention to infectious diseases of wild animals, which are a potential source of human infectious agents. A total of 1,306 amphibian specimens belonging to 6 families, 12 genera, and 21 species were subjected to a comprehensive study. Of these, 17 samples (0.76%) showed petrified nodules in the intestinal cavity, kidneys, liver, lungs, intestines, and pancreas. The nodules were examined histologically and by PCR. As a result, *M. gordonae* was identified. This is the first report of *M. gordonae* infection in these amphibian species in the wild, while histopathology confirmed a typical mycobacterial lesion in amphibians in northeastern Brazil.

As the results of studies conducted by scientists from different countries suggest, mycobacteriosis is widespread in wild populations of both warm- and cold-blooded animals. Therewith, clinical manifestations of this infection were observed in animals in all countries where

comprehensive (clinical, pathological, bacteriological, histomorphological, and molecular genetic) studies of biomaterials were conducted. The most commonly identified aetiological agents include *M. ulcerans*, *M. gordonae*, *M. avium*, *M. fortuitum*, and many unidentified species. This suggests that animal mycobacteriosis is a widespread phenomenon in the wild fauna and requires a deeper and broader study of the specific features of both infectious and epizootic processes, as well as the establishment of the species composition of pathogens and their ecology. The findings obtained will be of both general biological and health and veterinary significance, as the data will be used to develop an effective system for controlling epizootic and epidemic processes of mycobacteriosis.

The monitoring of scientific studies on avian mycobacteriosis has shown that this subject has received considerable attention from scientists from around the world. Thus, a group of scientists from European universities R.K. Hoop *et al.* (1993) investigated six cases of mycobacteriosis caused by *M. genavense* in three budgerigars (*Melopsittacus undulatus*), one orange-winged amazon (*Amazon amazonica*), one blue-and-white flycatcher (*Cyanoptila cyanomelana*), and one Sunda zebra finch (*Taeniopygia guttata*). Pathological changes caused by NTMB included muscle wasting (5 cases), hepatomegaly (4 cases), and thickening of the small intestine wall (4 cases), as well as granulomas in the lungs and subcutaneous tissue (1 case each). Acid-fast bacilli were found in the liver of all 6 birds. *M. genavense* was isolated only on acidic BACTEC medium, while the pathogen was not isolated on egg medium. These findings suggest the significant role of the environment as a reservoir for *M. genavense*.

German scientists V. Schmidt *et al.* (2022) investigated mycobacteriosis of domestic and some wild birds and the factors contributing to their occurrence. A total of 50 birds diagnosed

with mycobacteriosis based on pathological changes were examined. It was found that the causative agents of mycobacteriosis in birds were *M. avium subsp. avium* (identified in 20 out of 50 birds), *M. genavense* (in 16 out of 50), and *M. avium subsp. hominissuis* (in 3 out of 50). Co-infections (psittacosis, virions, bacteriosis, mycosis, and endoparasitosis) had no effect on the manifestation of mycobacteriosis. Pathological changes of mycobacterial origin were most often (95%) detected in *M. avium* infection, while in *M. genavense* infection – 66%. Pathological changes were detected in the small intestine in 71% of the birds studied and in the lungs in 65%, indicating oral and pulmonary ingestion of mycobacteria. The new strains of *M. avium subsp. hominissuis* that were isolated and identified from birds are of epidemiological significance in terms of their zoonotic role, as this species is of increasing public health concern.

In the 1990s, a group of Czech scientists K. Hejlíček & F. Treml (1994) investigated the occurrence and spread of mycobacteriosis among pigeons, their susceptibility to infection and epizootological significance as a source of *M. avium*. A total of 470 pigeons from seven settlements with different epizootic situations regarding avian tuberculosis were studied. Tuberculosis lesions were detected in 2 birds (0.43%), and mycobacteria were isolated from 5 birds (1.06%). Four out of five isolated strains of mycobacteria were pathogenic to poultry. High resistance of pigeons to *M. avium* was experimentally proved.

A group of scientists from the University of Panama, C. Rengifo-Herrera *et al.* (2019), reported mycobacteriosis in a harpy eagle that showed extreme emaciation with dyspnoea, abnormal changes in the spleen, liver, and air sacs. The biochemical and haematological changes associated with the infection were not initially suspected to be mycobacteriosis. The diagnosis was confirmed by PCR analysis, which

revealed the presence of the *M. avium* complex in the tissue samples. A group of scientists from the United States, G. Pawsat et al. (2023), investigated a unique case of mycobacteriosis in a 32-year-old male salmon crested cockatoo (*Cacatua moluccensis*), which was histologically diagnosed with bilateral ulnar lymphoma. *M. genavense* was identified by PCR. This is an unusual case of simultaneous manifestation of two major diseases – mycobacteriosis and severe degenerative changes in the joints, which could lead to lymphoma.

The analysis of the above publications suggests that infection of birds with NTMB is quite common, and it can be associated with other pathologies and co-infections, which often leads to misdiagnosis. The pH of the medium in which we want to isolate mycobacteria from environmental objects is of particular importance. Clearly, this fact should be borne in mind not only in the microbiological laboratory when isolating mycobacteria from biomaterials and abiotic objects, but also when investigating the specific features of their ecology. Mycobacteriosis in fish is a well-known problem in ornamental fish farming worldwide, as well as in food fish species. Less is known about the prevalence of mycobacteriosis in wild fish species. Norwegian scientists N. Sandlund et al. (2023) described mycobacteriosis in Atlantic mackerel (*Scomber scombrus*) in the form of granulomatous kidney disease. *M. lentiflavum*, *M. stomatopiae*, and *M. montefiorensis* were isolated from 6 samples of mackerel caught in the North Sea.

The freshwater ornamental fish trade is the main source of livelihood for many producers in Trinidad and Tobago. The Aquatic Animal Health Unit of the School of Veterinary Medicine, University of the West Indies, has shown that fish mycobacteriosis is a quite common infection in local ornamental fish. This is based on the findings of studies of 122 fish samples by P. Savage et al. (2022). *Mycobacterium sp.* was

identified by real-time PCR. The prevalence of infection caused by *Mycobacterium sp.* was  $61 \pm 7\%$  (74/122), with positive samples obtained from 54.2% (13/24) of the surveyed farms. Siamese fighting fish (*Betta splendens*) play a significant role in the global aquarium fish trade, but their susceptibility to mycobacteriosis could threaten the long-term sustainability of the industry. Furthermore, N.D. Hung et al. (2023) believe that the emergence of highly pathogenic and multidrug-resistant NTMB strains such as *M. chelonae*, *M. cosmeticum*, *M. farcinogenes*, *M. mucogenicum*, and *M. senegalense* isolated from *Betta splendens* fish has raised concerns both in terms of negative economic impact and public health risks.

Scientists from the University of Baghdad, F. Hussein et al. (2016), investigated the significance and role of *M. marinum* in human and animal infection. *M. marinum* is a species that causes mycobacteriosis in all species of fish (freshwater, brackish, and saltwater), as well as in humans and some animal species. In fish, transmission can occur through the consumption of contaminated food, cannibalism of infected fish or aquatic detritus, or through injury, skin abrasions, or external parasites. The infection in humans mostly occurs in people who keep aquarium fish at home. The infection can be an occupational disease for workers – fish processors or pet shops. Damage to the skin serves as an entry gate for the microorganism during contact with infected fish, during cleaning or maintenance of aquariums, after fin injuries or fish bites. Less commonly, infection can occur through contact with natural water sources while fishing, boating, or swimming. Contact with marine animals and reptiles plays a role in the transmission of the pathogen.

Spanish scientists, E. Montero et al. (2022), described in detail mycobacteriosis in syngnathids that were susceptible to NTMB infection. Clinical manifestations of the disease

ranged from sudden death to non-specific signs (anorexia, depressed general condition, weight loss, severe shortness of breath with increased respiratory rate). Visible ulcers were found on the tail and small white nodules in the liver and inside the eye. The gills, liver, intestines, and mesentery were most often affected. *M. fortuitum*, *M. chelonae*, *M. marinum*, and *Mycobacterium* spp. were identified by real-time PCR. R.S.M. Chong (2022) investigated cases of mycobacteriosis in fish. The first identified pathogen of fish mycobacteriosis was *M. piscium*. Over 200 species of fish found in waters ranging from the cold subarctic to tropical regions have been found to be infected with mycobacteria. Many species of *Mycobacterium* have been identified in fish that do not show clinical signs of disease. However, the most common causative agents of fish mycobacteriosis are *M. marinum*, *M. fortuitum*, and *M. chelonae*. Mycobacteriosis in fish is chronic and is characterised by exhaustion or poor body condition, loss of scales, skin ulcers, reproductive disorders and, rarely, deep haemorrhagic skin lesions. However, the researcher believes that the key takeaway is that fish mycobacteriosis is a zoonotic disease of people who come into contact with affected fish and the water bodies where they are found.

Summarising the above, further investigation of the spatial and temporal parameters of the spread of animal mycobacteriosis in Ukraine and other countries may reveal new patterns of manifestation of the epizootic process of animal mycobacteriosis and its driving forces, which will allow developing effective ways to control this infection not only in populations of different animal species, but will also guarantee food safety and, consequently, human health.

## **Conclusions**

The epidemiological analysis of the spatial and temporal intensity of the epizootic situation regarding mycobacteriosis of animals caused by

AMB in Ukraine and some countries of different continents of the world for 2000-2023 revealed that mycobacterial infections are constantly occurring and are widespread both geographically and in terms of species. In Ukraine, mycobacteriosis was most often recorded in cattle, where it occurs in a latent asymptomatic form and is detected by a simultaneous test in the allergic diagnosis of tuberculosis using PPD-tuberculin and AMA, with additional postmortem bacteriological and histomorphological examination of biomaterial from reactive animals. Every year in Ukraine,  $250 \pm 30$  dairy farms are registered, where AMA-reactive animals are detected, as well as individuals with par allergic reactions to PPD-tuberculin, which indicates the circulation of AMB in Ukrainian dairy cow herds. *M. smegmatis*, *M. scrofulaceum*, *M. fortuitum*, *M. avium*, *M. phlei*, *M. vaccae* and a range of others, including *M. gordone*, *M. terrae*, *M. xenopi*, *M. peregrinum*, *M. flavescens*, *M. diernhoferi*, *M. thamnophis*, were identified as potential causative agents of mycobacteriosis in Ukraine.

On the territory of dairy farms in many countries on different continents of the world, AMBs are widespread, as they are isolated both from abiotic environmental objects and from the body of cows. Therewith, atypical mycobacteria are identified in the milk of both clinically healthy cows and in the milk of cows that react positively to AMA and tuberculin, which suggests that they are not merely transient in the animal body, but also actively multiply in it with all possible manifestations of this form of interaction, which is inherent in the latent course of the infectious process, not just sensitisation.

Mycobacteriosis is widespread in wild populations of both warm- and cold-blooded animals, as well as poultry and fish. Therewith, clinical manifestations of this infection were observed in all countries where comprehensive (clinical, pathological, bacteriological, histomorphological, and molecular genetic) studies

of biomaterials were conducted. The most commonly identified mycobacterial species include *M. ulcerans*, *M. goodnae*, *M. avium*, *M. fortuitum* in animals; *M. avium subsp. Avium*, *M. avium subsp. Hominissuis*, *M. genavense* in poultry; *M. marinum*, *M. fortuitum*, and *M. chelonae* in fish, and many unidentified mycobacterial species. This suggests that mycobacteriosis is a widespread phenomenon in the wild fauna and requires a deeper and broader study of the specific features of both infectious and epizootic processes, as well as the establishment of the species composition of pathogens and their ecology.

The prospect of further research will be to investigate the impact of NTMBs circulating on the territory of a particular dairy farm on the organism of productive animals to establish the ways of infecting animals, pathogenesis, and mechanism of excretion from the body of animals as potential pathogens of human mycobacteriosis.

### Acknowledgements

None.

### Conflict of Interest

None.

### References

- [1] Armstrong, D.T., Eiseemann, E., & Parrish, N.A. (2023). Brief update on mycobacterial taxonomy, 2020 to 2022. *Journal of Clinical Microbiology*, 61(4), article number e0033122. doi: [10.1128/jcm.00331-22](https://doi.org/10.1128/jcm.00331-22).
- [2] Aydin, F., Ulger, M., Emekdaş, G., Aslan, G., & Günel, S. (2012). [Isolation and identification of mycobacterium bovis and non-tuberculous mycobacteria in raw milk samples in Mersin province](#). *Bulletin of Microbiology*, 46(2), 283-289.
- [3] Ben Kahla, I., Boschiroli, M.L., Soussi, F., Cherif, N., Benzarti, M., Boukadida, J., & Hammami, S. (2011). Isolation and molecular characterization of *Mycobacterium bovis* from raw milk in Tunisia. *African Health Sciences*, 11(1), 2-5. doi: [10.4314/ahs.v11i3.70032](https://doi.org/10.4314/ahs.v11i3.70032).
- [4] Bolaños, C.A., Franco, M.M., Filho, A.F., Ikuta, C.Y., Burbano-Rosero, E.M., Neto, J.S., Heinemann, M.B., Motta, R.G., Lechinski de Paula, C., Cordeiro de Moraes, A.B., Guerra, S.T., Alves, A.C., Listoni, F.J., & Ribeiro, M.G. (2018). Nontuberculous mycobacteria in milk from positive cows in the intradermal comparative cervical tuberculin test: Implications for human tuberculosis infections. *Revista do Instituto de Medicina Tropical de São Paulo*, 60, article number e40. doi: [10.1590/S1678-9946201860006](https://doi.org/10.1590/S1678-9946201860006).
- [5] Boyko, P.K., Nychyk, S.A., Boyko, O.P., Tytiuk, O.V., & Shevchuk, V.M. (2021). Mycobacteriosis of cattle – a spontaneous infection in a separate farm or a complex epidemiological problem? *Veterinary Biotechnology Bulletin*, 39, 18-28. doi: [10.31073/vet\\_biotech39-02](https://doi.org/10.31073/vet_biotech39-02).
- [6] Bruczyńska, M., Didkowska, A., Brzezińska, S., Nowak, M., Filip-Hutsch, K., Kalicki, M., Augustynowicz-Kopeć, E., & Anusz, K. (2023). *Mycobacterium avium* subspecies paratuberculosis in asymptomatic zoo herbivores in Poland. *Animals*, 13(6), article number 1022. doi: [10.3390/ani13061022](https://doi.org/10.3390/ani13061022).
- [7] Busol, V.O., Shevchuk, V.M., Mazur, V.M., & Kovalenko, L.V. (2014). [Evolution of intensity of the epizootic process of tuberculosis of cattle in the countries of the world](#). *Scientific Bulletin of Veterinary Medicine (Collection of Scientific Papers)*, 14(114), 74-77.
- [8] Chang, C., Wang, L.Y., Liao, C.Y., & Huang, S.P. (2002). Identification of nontuberculous mycobacteria existing in tap water by PCR-restriction fragment length polymorphism. *Applied and Environmental Microbiology*, 68, 3159-3161. doi: [10.1128/aem.68.6.3159-3161.2002](https://doi.org/10.1128/aem.68.6.3159-3161.2002).

- [9] Chong, R.S.M. (2022). Mycobacteriosis. In *Aquaculture pathophysiology* (pp. 407-415). Cambridge: Academic Press. doi: [10.1016/B978-0-12-812211-2.00031-7](https://doi.org/10.1016/B978-0-12-812211-2.00031-7).
- [10] Cvetnić, Ž., Tuk, M.Z., Duvnjak, S., Reil, I., Mikulić, M., Pavlinec, Ž., Cvetnić, M., & Špičić, S. (2018). Tuberculous and nontuberculous mycobacteria in human and animal infection. *Veterinary Journal of Republic of Srpska (Banja Luka)*, 18(2), 342-369. doi: [10.7251/VETJEN1802342C](https://doi.org/10.7251/VETJEN1802342C).
- [11] Dahl, V.N., Floe, A., & Wejse, Ch. (2023). Nontuberculous mycobacterial infections in a Danish region between 2011 and 2021: Evaluation of trends in diagnostic codes. *Infectious Diseases*, 55(6), 439-443. doi: [10.1080/23744235.2023.2194411](https://doi.org/10.1080/23744235.2023.2194411).
- [12] Dyachenko, G., Kravchenko, N., & Romanenko, V. (2006). The problem of diagnosing tuberculosis of farm animals in modern conditions. *Veterinary Medicine of Ukraine*, 2, 5-7.
- [13] Falkinham, J.O. (2013). Ecology of nontuberculous mycobacteria – where do human infections come from? *Seminars in Respiratory and Critical Care Medicine*, 34(1), 95-102. doi: [10.1055/s-0033-1333568](https://doi.org/10.1055/s-0033-1333568).
- [14] Feazel, L.M., Baumgartner, L.K., Peterson, K.L., Frank, D.N., Harris, J.K., & Pace, N.R. (2009). [Opportunistic pathogens enriched in showerhead biofilms](https://doi.org/10.1073/pnas.0908446106). *Proceedings of the National Academy of Sciences of the United States of America*, 106(38), 16393-16399. doi: [10.1073/pnas.0908446106](https://doi.org/10.1073/pnas.0908446106).
- [15] Franco, M.M., Paes, A.C., Ribeiro, M.G., Pantoja, J.C., Santos, A.C., Miyata, M., Leite, J., Motta, R., & Listoni, F. (2013). [Occurrence of mycobacteria in bovine milk samples from both individual and collective bulk tanks at farms and informal markets in the southeast region of Sao Paulo, Brazil](https://doi.org/10.1186/1745-7575-9-85). *BMC Veterinary Research*, 9, article number 85.
- [16] Gorzheev, V.M., Kassich, Yu.Ya., Zavhorodniy, A.I., Pavlenko, M.S., & Kassich, V.Yu. (2004). Achievements in the fight against tuberculosis of cattle in the farms of Ukraine. *Veterinary Medicine, Interdepartmental Thematic Scientific Collection*, 84, 268-271.
- [17] Heifets, L. (2004). Mycobacterial infections caused by nontuberculous mycobacteria. *Seminars in Respiratory and Critical Care Medicine*, 25(3), 283-295. doi: [10.1055/s-2004-829501](https://doi.org/10.1055/s-2004-829501).
- [18] Hejlíček, K., & Treml, F. (1994). [Epizootiology and pathogenesis of avian mycobacteriosis in domestic pigeons \(Columba livia f. domestica\)](https://doi.org/10.1007/BF01201012). *Veterinary Medicine (Praha)*, 39(10), 615-624.
- [19] Hoop, R.K., Böttger, E.C., Ossent, P., & Salfinger, M. (1993). Mycobacteriosis due to *Mycobacterium genavense* in six pet birds. *Journal of Clinical Microbiology*, 31(4), 990-993. doi: [10.1128/jcm.31.4.990-993.1993](https://doi.org/10.1128/jcm.31.4.990-993.1993).
- [20] Hung, N.D., Dong, H., Senapin, S., Pimsannil, K., Thompson, K., Shinn, A., Soontara, C., Sirimanapong, W., Chatchaipun, S., & Rodkhum, C. (2023). Insight into characteristics and pathogenicity of five rapidly growing non-tuberculous *Mycobacterium* species isolated from the Siamese fighting fish, *Betta splendens*. *Aquaculture*, 575, article number 739822. doi: [10.1016/j.aquaculture.2023.739822](https://doi.org/10.1016/j.aquaculture.2023.739822).
- [21] Hussein, F., Kaayem, S., & Nagham, Al-g. (2016). *Mycobacterium marinum* (mycobacteriosis) in human and animals. Retrieved from <http://surl.li/tsmyg>.
- [22] Jamal, F., & Hammer, M. (2022). Nontuberculous mycobacterial infections. *Radiologic Clinics of North America*, 60(3), 399-408. doi: [10.1016/j.rcl.2022.01.012](https://doi.org/10.1016/j.rcl.2022.01.012).
- [23] Kassich, V.Yu., Fotina, T.I., Berezovskyi, A.V., Fotina, G.A., Kambur, M.D., & Kassich, O.V. (2010). Disinfection of industrial premises of farms unfavorable for tuberculosis using the drug “Brovadez-Plus”. *Bulletin of the Sumy National University*, 8, 42-44.

- [24] Kazwala, R.R., Daborn, C.J., Kusiluka, L.J., Jiwa, S.F, Sharp, J.M., & Kambirage, D.M. (1998). Isolation of Mycobacterium species from raw milk of pastoral cattle of the southern highlands of Tanzania. *Tropical Animal Health and Production*, 30, 233-239. doi: [10.1023/a:1005075112393](https://doi.org/10.1023/a:1005075112393).
- [25] Leite, C.Q., Anno, I.S., Leite, S.R., Roxo, E., Morlock, G.P., & Cooksey, R.C. (2003). Isolation and identification of mycobacteria from livestock specimens and milk obtained in Brazil. *Memórias do Instituto Oswaldo Cruz*, 98, 319-323. doi: [10.1590/S0074-2762003000300005](https://doi.org/10.1590/S0074-2762003000300005).
- [26] Lipner, E.M., Knox, D., French, J., Rudman, J., Strong, M., & Crooks, J.L. (2017). A geospatial epidemiologic analysis of nontuberculous mycobacterial infection: An ecological study in Colorado. *Annals of the American Thoracic Society*, 14(10), 1523-1532. doi: [10.1513/AnnalsATS.201701-081OC](https://doi.org/10.1513/AnnalsATS.201701-081OC).
- [27] Marras, T.K., Campitelli, M.A., Lu, H., Chung, H., Brode, S.K., Marchand-Austin, A., Winthrop, K.L., Gershon, A.S., Kwong, J.C., & Jamieson, F.B. (2017). Pulmonary nontuberculous mycobacteria-associated deaths, Ontario, Canada, 2001-2013. *Emerging Infectious Diseases*, 23(3), 468-476. doi: [10.3201/eid2303.161927](https://doi.org/10.3201/eid2303.161927).
- [28] Mercaldo, R.A., Marshall, J.E., Cangelosi, G.A., Donohue, M., Falkinham, J.O., Fierer, N., French, J., Gebert, M., Honda, J., Lipner, E., Marras, T., Morimoto, K., Salfinger, M., Stout, J., Thomson, R., & Prevots, R., (2023). Environmental risk of nontuberculous mycobacterial infection: Strategies for advancing methodology. *Tuberculosis*, 139, article number 102305. doi: [10.1016/j.tube.2023.102305](https://doi.org/10.1016/j.tube.2023.102305).
- [29] Montero, E., Rojo-Solis, C., Castro, N., Fernández, M., Perez, V., Corpa, J., & Ortega, J. (2022). Clinical and pathological findings associated with mycobacteriosis in captive syngnathids. *Animals*, 12, article number 3259. doi: [10.3390/ani12233259](https://doi.org/10.3390/ani12233259).
- [30] Morais, D.H., Vaz Rodrigues, M., Ávila, R., & Silva, R.J. (2021). Visceral mycobacteriosis in amphibians from Brazilian Caatinga Region. *Diseases of Aquatic Organisms*, 145, 139-144. doi: [10.3354/dao03604](https://doi.org/10.3354/dao03604).
- [31] O'Brien, C.R., Handasyde, K.A., Hibble, J., Lavender, C.J., Legione, A.R., McCowan, C., Globan, M., Mitchell, A.T., McCracken, H.E., Johnson, P.D., & Fyfe, J.A. (2014). Clinical, microbiological and pathological findings of *Mycobacterium ulcerans* infection in three Australian Possum species. *PLoS Neglected Tropical Diseases*, 8(1), article number e2666. doi: [10.1371/journal.pntd.0002666](https://doi.org/10.1371/journal.pntd.0002666).
- [32] Pandey, G.S., Hang'ombe, BM, Mushabati, F., & Kataba, A. (2013). Prevalence of tuberculosis among southern Zambian cattle and isolation of *Mycobacterium bovis* in raw milk obtained from tuberculin positive cows. *Veterinary World*, 6(12), 986-991. doi: [10.14202/vetworld.2013.986-991](https://doi.org/10.14202/vetworld.2013.986-991).
- [33] Pardo, R.B., Langoni, H., Mendoca, L.J., & Chi, K.D. (2001). Isolation Mycobacterium spp. in milk from cows suspected or positive to tuberculosis. *Brazilian Journal of Veterinary Research and Animal Science*, 38, 284-7. doi: [10.1590/S1413-95962001000600007](https://doi.org/10.1590/S1413-95962001000600007).
- [34] Pavlik, I., Ulmann, V., & Weston, R.T. (2021). Clinical relevance and environmental prevalence of *Mycobacterium fortuitum* group members. Comment on Mugetti *et al.* Gene sequencing and phylogenetic analysis: Powerful tools for an improved diagnosis of fish mycobacteriosis caused by *Mycobacterium fortuitum* group members. *Microorganisms*, 9(11), article number 2345. doi: [10.3390/microorganisms9112345](https://doi.org/10.3390/microorganisms9112345).
- [35] Pawsat, G., Hoggard, N., Duvall, A., & Flatland, B. (2023). Bilateral cubital lymphoma and mycobacteriosis in a salmon-crested cockatoo (*Cacatua moluccensis*). *Journal of Avian Medicine and Surgery*, 36(4), 406-413. doi: [10.1647/22-00006](https://doi.org/10.1647/22-00006).

- [36] Qamar, M.F., & Azhar, T. (2013). [Detection of Mycobacterium from bovine milk in Lahore, Pakistan](#). *Science International (Lahore)*, 25(2), 353-357.
- [37] Radulski, Ł., Kalicki, M., Krajewska-Wędzina, M., Lipiec, M., & Szulowski, K. (2022). Pulmonary mycobacteriosis of sitatunga antelope caused by *M. avium* ssp. *hominissuis*. *Annals of Agricultural and Environmental Medicine*, 29(2), 220-223. doi: [10.26444/aaem/145158](#).
- [38] Rengifo-Herrera, C., Reyes, H.J., Reyes, H., Chong, M.A., Acosta, F., Ponder, J., & Goodridge, A. (2019). Avian mycobacteriosis in a rescued harpy eagle from Darien Forest, Panama. *Acta Scientiae Veterinari*, 47, 33192-4177. doi: [10.22456/1679-9216.96502](#).
- [39] Röltgen, K., & Pluschke, G. (2022). Overview: Mycobacterium ulcerans Disease (Buruli Ulcer). *Methods in Molecular Biology (Clifton, N.J.)*, 2387, 3-6. doi: [10.1007/978-1-0716-1779-3\\_1](#).
- [40] Sandlund, N., Skår, C., & Karlsbakk, E. (2023). First identification of mycobacteriosis in Atlantic mackerel (*Scomber scombrus*). *Journal of Fish Diseases*, 46(5), 527-533. doi: [10.1111/jfd.13765](#).
- [41] Savage, A.C.N.P., Blake, L., Suepal, R., McHugh, O., Rodgers, R., Calvern, T., Oura, C., & Soto, E. (2022). Piscine mycobacteriosis in the ornamental fish trade in Trinidad and Tobago. *Journal of Fish Diseases*, 45(4), 547-560. doi: [10.1111/jfd.13580](#).
- [42] Schmidt, V., Köhler, H., Heenemann, K., & Möbius, P. (2022). Mycobacteriosis in various pet and wild birds from Germany: Pathological findings, coinfections, and characterization of causative mycobacteria. *Microbiology Spectrum*, 10(4), article number e0045222. doi: [10.1128/spectrum.00452-22](#).
- [43] Schroder, K.H., Kazda, J., Muller, K., & Muller, H.J. (1992). Isolation of mycobacterium simiae from the environment. *Zentralblatt für Bakteriologie*, 277(4), 561-564. doi: [10.1016/s0934-8840\(11\)80482-2](#).
- [44] Sgarioni, S.A., Hirata, R.D., Hirata, M.H., Leite, C.Q., Prince, K.A., Leite, S.R., Filho, D.V., Siqueira, V.L.D., Caleffi-Ferracioli, K.R., & Cardoso, R.F. (2014). Occurrence of Mycobacterium bovis and non-tuberculous mycobacteria (NTM) in raw and pasteurized milk in the northwestern region of Paraná, Brazil. *Brazilian Journal of Microbiology*, 45, 707-711. doi: [10.1590/s1517-83822014000200046](#).
- [45] Shevchenko, O.S., Todoriko, L.D., Poteyko, P.I., & Pogorelova, O.A. (2019). [Questions of diagnosis and treatment of nontuberculous mycobacteriosis](#). *East European Journal of Internal and Family Medicine*, 1, 36-53.
- [46] Stegnyy, B.T., Zavorodnyi, A.I., & Kalashnyk, M.V. (2014). [Determination of the nature of reactions to tuberculin in cattle](#). *Veterinary Medicine, Interdepartmental Thematic Scientific Collection*, 99, 86-89.
- [47] Varela-Castro, L., Barral, M., Arnal, M.C., Fernández de Luco, D., Gortázar, C., Garrido, J. M., & Sevilla, I.A. (2022). Beyond tuberculosis: Diversity and implications of non-tuberculous mycobacteria at the wildlife-livestock interface. *Transboundary and Emerging Diseases*, 69(5), e2978-e2993. doi: [10.1111/tbed.14649](#).
- [48] Vetere, A., Bertocchi, M., Pagano, T., Di Ianni, F., & Nardini, G. (2022). First case of systemic fatal mycobacteriosis caused by *Mycobacterium goodii* in a pet Kenyan sand boa (*Eryx colubrinus loveridgei*). *BMC Veterinary Research*, 18, article number 291. doi: [10.1186/s12917-022-03351-z](#).
- [49] World Health Organization. (2022). *Global tuberculosis report 2022*. Retrieved from <https://apps.who.int/iris/handle/10665/363752>.
- [50] Yarchuk, B.M., Verbytskyi, P.I., Lytvyn, V.P., Kornienko, L.E., Dombrovskiy, O.B., Tirsin, R.V., & Kornienko, L.M. (2002). *General epizootology*. Bila Tserkva: Bila Tserkva National Agrarian University.

- [51] Zavhorodniy, A.I., & Kotlyar, O.V. (2014). Study of cultural-morphological, biochemical and biological properties of atypical mycobacteria isolated from cattle in farms of Ukraine. *Veterinary Medicine, Interdepartmental Thematic Scientific Collection*, 98, 124-127.
- [52] Zavhorodniy, A.I., Bilushko, V.V., Kalashnyk, M.V., Pozmogova, S.A., & Kalashnyk, N.V. (2018). [Pseudoallergic reactions to tuberculin in cattle](#). *Veterinary Biotechnology*, 32(2), 176-184.
- [53] Zhurylo, O.A., Barbova, A.I., & Sladkova, L.M. (2020). Mycobacterium avium is the causative agent of human mycobacteriosis. *Ukrainian Pulmonology Journal*, 1, 50-58. [doi: 10.31215/2306-4927-2020-107-1-50-58](https://doi.org/10.31215/2306-4927-2020-107-1-50-58).

## Епізоотологічні та етіопатогенетичні аспекти мікобактеріозів

### Володимир Бусол

Доктор ветеринарних наук, професор  
Національний науковий центр «Інститут експериментальної і  
клінічної ветеринарної медицини»  
61023, вул. Пушкінська 83, м. Харків, Україна  
<https://orcid.org/0000-0002-9618-0493>

### Петро Бойко

Доктор ветеринарних наук, доцент  
Волинський національний університет імені Лесі Українки  
43025, просп. Волі, 13, м. Луцьк, Україна  
<http://orcid.org/0000-0003-1418-1159>

### Міхал Беднарські

Доктор філософії, кандидат ветеринарних наук  
Вроцлавський університет наук про навколишнє середовище та життя  
50-375, вул. Норвіда, 25, м. Вроцлав, Польща  
<https://orcid.org/0000-0003-0292-7929>

### Віктор Шевчук

Кандидат ветеринарних наук, доцент  
Національний університет біоресурсів і природокористування України  
03041, вул. Героїв Оборони, 15, м. Київ, Україна  
<https://orcid.org/0000-0002-5937-3333>

### Ольга Панівська

Аспірант  
Волинський національний університет імені Лесі Українки  
43025, просп. Волі, 13, м. Луцьк, Україна  
<http://orcid.org/0000-0002-1280-4458>

**Анотація.** Мікобактеріози тварин, на відміну від таких у людей, внаслідок різних причин не перебувають в полі уваги ветеринарної науки і практики. Цей факт як і низка інших, зокрема зростання захворюваності людей на мікобактеріози, збудниками яких виступають нетуберкульозні мікобактерії, які причетні до сенсibiliзації організму продуктивних тварин, є об'єктивним, хоча й непрямим свідченням існуючої проблеми мікобактеріозів у

ветеринарній медицині. В процесі виконання роботи використано порівняльно-географічний та епізоотологічний методи аналізу. Результати, отримані з публікацій науковців різних країн світу, дали змогу узагальнити та об'єктивно оцінити напруженість епізоотичної ситуації щодо мікобактеріозів тварин у світі та в Україні, виявити низку особливостей інфекційного та епізоотичного процесів, а також встановити домінуючі етіопатогенетичні критерії цієї інфекції в популяціях тварин. Мікобактеріози тварин є предметом детальних наукових досліджень у більшості країн світу оскільки це захворювання має значне поширення серед продуктивних і непродуктивних (домашніх і диких) тварин, іхтіофауни морських і річкових водойм. Встановлено, що найчастіше як збудники мікобактеріозів виступають такі види нетуберкульозних мікобактерій як *Mycobacterium avium complex*, *M. abscessus complex*, *M. kansasii*, і *M. fortuitum* та низка інших. В Україні мікобактеріозам тварин не приділяється належна увага, не зважаючи на те, що параалергічні реакції на туберкулін у великої рогатої худоби призводять до ускладнення діагностики туберкульозної інфекції. Вони є причиною значних збитків в молочному скотарстві через вибраковку та забій високопродуктивних корів. Виявлення етіопатогенетичних закономірностей параалергічних реакцій на туберкулін у продуктивних тварин – запорука ефективного контролю та управління епізоотичним процесом за мікобактеріозу тварин та зменшення біоризиків інфікування людей нетуберкульозними мікобактеріями через продукти харчування тваринного походження

**Ключові слова:** туберкульоз; туберкулін; алерген атипичних мікобактерій; епізоотичний процес; інфекційний процес; алергічні реакції; діагностика