Melioidosis is an underreported zoonosis in many countries where environmental conditions are favorable for growth of *Burkholderia pseudomallei*, the causative agent.\(^1,2\) The disease is most often detected in tropical areas such as Southeast Asia and northern Australia, where the case fatality rate in humans is estimated to be as high as 50%.\(^3\) Diagnosis is difficult owing to a lack of specific clinical signs and limitations of currently available diagnostic tests. Cases of melioidosis involving animals are sporadically reported, and the global extent of *B pseudomallei* in the environment is not well understood.\(^4\)

*Burkholderia pseudomallei* has been proposed for inclusion on the USDA’s National List of Reportable Animal Diseases\(^5\) and has been classified as a category B bioterrorism agent by the US Department of Health and Human Services. *Burkholderia pseudomallei* is also designated as a tier-1 select agent under the Federal Select Agent Program because it is among “the biological agents and toxins that present the greatest risk of deliberate misuse with significant potential for mass casualties or devastating effect to the economy, critical infrastructure, or public confidence and poses a severe threat to public health and safety.”\(^6\) *Burkholderia pseudomallei* is not known to be present in the continental United States, other than in select research laboratories, but is now considered endemic in Puerto Rico.\(^6\) In addition, the number of human cases diagnosed in the United States has increased in recent years, and not all cases can be attributed to travel outside the United States.\(^7,8\)

The present report describes the epidemiology of *B pseudomallei* infection in domestic animals and assesses the potential for establishment of the organism in the southeastern United States. To minimize the consequences of environmental contamination and the possibility that the organism will become endemic, veterinarians should be aware of the signs of melioidosis in domestic animals and of procedures for diagnosing and reporting the condition.

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**Agent**

*B. pseudomallei* is a gram-negative, bipolar, aerobic, non–spore-forming, motile rod. A soil-borne saprophyte, it can adapt to a range of environments, ecological niches, and hosts because of a diverse array of factors encoded by its genome that aid its survival in harsh or suboptimal environments, such as biofilm-forming capability.\(^9,10\) The adaptability of *B pseudomallei* is demonstrated by its capability of surviving in distilled water for more than 2 years, facilitated by the presence of a lipopolysaccharide outer membrane.\(^11\) These characteristics and an array of virulence factors, including its intracellular replication machinery, enable *B pseudomallei* to avoid host immune responses and become an opportunistic pathogen.\(^10,12,13\) The adaptive ability of *B pseudomallei* is further reflected in the variety of colony sizes, textures, and colors it exhibits.\(^14\) For example, on a complete medium such as Luria-Bertani agar, colonies will typically appear white, but yellow variants can appear under hypoxic growth conditions at low pH.\(^15\) These yellow variants are adapted for colonization of the stomach, whereas the white variants are better suited for survival in environments with normal oxygen conditions.\(^15\)

**Species affected**

Melioidosis has been reported in humans and a variety of other animals, including nonhuman primates, kangaroo, deer, buffalo, camel, rat, parrot, reptiles, and zebra.\(^5\) Among domestic animals, melioidosis is most frequently reported in sheep, goats, and swine. Infection occurs in cats and dogs but may be underreported in endemic areas.\(^16,17\) Infection in pigs has occurred as a result of consume infected carcasses or environmental contamination from infected goats.\(^18,19\) Chronic or acute infection can occur in cattle with underlying immunosuppressive conditions.\(^20–22\) Infection may also occur in horses, although it is infrequently reported.\(^23,24\)
Transmission

Animal-to-animal transmission of *B pseudomallei* is thought to be rare, and the organism does not need an animal host to replicate. Clinically infected individuals can shed the organism in urine, feces, sputum, or purulent material. Fecal shedding may be overlooked in subclinically infected animals, but studies have shown that mice can shed *B pseudomallei* in their feces when chronically infected.

Small doses of aerosolized *B pseudomallei* organisms can result in infection via inhalation. Heavy wind and rain may lead *B pseudomallei* to become aerosolized from the soil and expose more individuals via inhalation, with most cases reported a week after floods or heavy rain.

Although transmission is most often associated with inhalation of contaminated soil particulates, aspiration, ingestion, and cutaneous inoculation have all been documented. Laboratory- and hospital-acquired infections have also been reported. *Burkholderia pseudomallei* can also be transmitted to offspring through milk, as observed in humans and goats. Transplacental transmission has also been observed in goats.

Clinical signs and pathological lesions

The ability of *B pseudomallei* to survive intracellularly and interfere with the host immune response leads to a wide array of clinical manifestations. Melioidosis has been referred to as the great imitator because it can present as almost any disease and affect almost any organ. Common manifestations range from subclinical to abscesses, septicemia, and pneumonia. Infection is triggered by attachment of the organism to epithelial cells and associated inflammation. In humans, acute septicemia is common, and half of all cases of acute septicemia are fatal. The severity of the disease varies by strain, route of transmission, bacterial load, and host characteristics. The incubation period typically ranges from 1 to 21 days, but the organism can remain latent for years within a host. A human case of melioidosis was reported 62 years after initial exposure.

Goats are the most susceptible livestock and may exhibit fever, anorexia, progressive emaciation, nasal discharge, and paresis of the hind limbs. Although melioidosis is considered rare in cattle, abscesses and neurologic signs have been reported. In cats, ocular disease, sepsis, and neurologic disease have been identified. Disease manifestations in these cases may be the result of latent infection triggered by stress rather than acute infection. In dogs, fever, myalgia, abscesses, and epididymitis have been reported.

In Thailand, where melioidosis is endemic, infection in zoo species is considered clinically important because of the high mortality rate. The most common clinical signs among zoo animals reportedly include nonspecific signs of depression, anorexia, generalized lymphadenopathy, pyrexia, and respiratory distress.

Diagnosis

The lack of specific clinical signs means melioidosis may appear like many other diseases, making diagnosis difficult. This difficulty can lead to delayed diagnosis or misdiagnosis, particularly in areas where melioidosis is not considered endemic. An additional complication in the diagnosis of melioidosis is the poor sensitivity and specificity of currently available diagnostic tests. Positive results for current antibody-detection tests may indicate infection with or exposure to *B pseudomallei* or may simply represent cross-reaction with other antigens, although the degree of cross-reaction is debatable. In addition, negative serologic test results have been observed in individuals in which results of bacterial culture of the organism were positive. Bacterial culture is considered the gold standard for diagnosing melioidosis, but the sensitivity of culture ranges from 52% to 69%. Misidentification on culture is also possible owing to the presence of variant colony morphologies and the tendency for the organism to switch between colony morphotypes in the laboratory, which was noted as early as 1930. *Burkholderia pseudomallei* may be misidentified as *Pseudomonas* spp or other gram-negative organisms if melioidosis is not suspected. Further complicating diagnosis is the finding that *B pseudomallei* can exist in a viable but non-culturable state.

*Burkholderia pseudomallei* isolates from horses may be misidentified as *Burkholderia mallei*, the causative agent of glanders, which is also a zoonotic disease. *Burkholderia mallei* is a nonmotile organism that does not persist in the environment outside of the equine host. Oddly enough, *B mallei* has been shown to be a clone of *B pseudomallei* specifically adapted to its equine host. Glanders, as opposed to melioidosis, is listed by the World Organization for Animal Health (OIE) as a disease of importance to international trade.

Treatment

*Burkholderia pseudomallei* is resistant to many antimicrobials, and relapse may occur in both humans and other animals because of antimicrobial resistance. Treatment is often ineffective, but selection of appropriate antimicrobials has been shown to reduce the mortality rate by half. Tetacyclines, sulfonamides, trimethoprim-sulfamethoxazole, and ceftazidime have been reported to be effective. In animals, treatment duration is 8 weeks to 6 months depending on the immune status and responsiveness of the patient. Patients should be monitored by a veterinarian after treatment for signs of relapse.

Disinfection

Sodium hypochlorite (0.5% [bleach]) and a specific multipurpose disinfectant prepared as a 1% solution according to the manufacturer’s directions have been shown to be bactericidal when allowed to remain in contact with *B pseudomallei* for 30 min-

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utes. However, sodium hypochlorite may be less effective for cleaning porous surfaces, if the contact time is not adequate, if organic material is present, or if coverage is not adequate (as can occur with spray application). Chlorine has some growth-inhibiting effects, but they are not considered adequate to kill *B. pseudomallei*, particularly when organic matter such as feces is present.

**Environment**

**Distribution**

*B. pseudomallei* is typically found in tropical areas between latitudes 20° north and 20° south. The organism is considered endemic in Southeast Asia, northern Australia, India, and China, although sporadic cases in humans and animals have been seen in other areas. In endemic areas, the number of reported cases of melioidosis is associated with both the level of pervasiveness of the organism in the environment and the occurrence of extreme weather events. A small number of organisms (e.g., < 30 colony-forming units/g) in the soil may lead to few or no cases, whereas more cases are observed when larger numbers of *B. pseudomallei* organisms are present in the environment (e.g., > 200 colony-forming units/g).

Because of limitations of diagnostic tests, laboratory capacity, and access to medical or veterinary care, melioidosis is likely underdiagnosed in endemic areas and bordering regions where melioidosis has not yet been reported. Importation of infected animals could lead to the establishment of *B. pseudomallei* where environmental conditions are suitable.

**Survivability**

*B. pseudomallei* can survive in sandy soil or clay and is often found deep (25 to 60 cm) in moist clay soil, although it can be found as deep as 70 cm. Replication in the soil may be promoted or antagonized by other soil organisms. *B. pseudomallei* can persist for years in soil and muddy water or within living host reservoirs, including amoebae (e.g., *Acanthamoeba* spp), dinoflagellates (e.g., *Alexandrium minutum*), mycorrhizal fungi (e.g., *Gigaspora dicipiens*), and the roots of various plants, especially grasses.

**Physicochemical properties**

The optimal conditions reported for *B. pseudomallei* survival in soil are pH of 4 to 8, moisture > 10%, and soil temperature between 24°C and 32°C (75°F and 90°F), although it can survive outside of these conditions. In endemic areas, *B. pseudomallei* is a normal inhabitant of water and has been detected in surface water, potable water, rainwater, and purified or distilled water. The organism can survive in a wide range of pH, salinity, and temperature conditions, but optimal conditions are temperatures ranging from 20° to 40°C (68° to 104°F), pH ranging from 5 to 8, and salinity ≤ 2.5% (although the organism has been reported in estuary conditions with salinity ranging from 0.05% to 3.5%).

**Environmental suitability of the southeastern United States**

To assess the similarity of soil characteristics in the United States with soil characteristics of areas in which *B. pseudomallei* is endemic, we constructed a fuzzy system model with data from the USDA's Natural Resources Conservation Services soil survey database. The soil survey database stores data on the soil, landscape, and climatic conditions for the United States and its territories. Fuzzy systems allow multiple attributes to be classified on the basis of degree of truthfulness, rather than as simply true or false. The resulting index is a value from 0 to 1 representing a combination of functions that demonstrates the overlap or relationship in the membership of each attribute.

Each soil attribute from the soil survey database was assigned a membership value on the basis of degree of similarity of that attribute to reported optimal physicochemical properties reflected in the fuzzy membership function. The resulting soil habitat similarity index reflected the degree of similarity of soil pH, moisture, and temperature to optimal conditions by considering the membership values of all 3 characteristics and selecting the lowest, assuming the least suitable condition would be the limiting factor for bacterial growth. An index of 1 suggested all 3 conditions (i.e., soil pH, moisture, and temperature) of the soil in a particular area were very similar to optimal conditions in areas where *B. pseudomallei* is endemic. An index of 0 indicated at least 1 of the 3 conditions was well outside the range expected to be conducive to the growth of *B. pseudomallei*. Our model suggested that soil throughout the southeastern United States, particularly along the Atlantic coast and in most of Florida and Louisiana, had soil attributes similar (index > 0.40) to attributes of soil in areas where *B. pseudomallei* is endemic (Figure 1). These findings were comparable to those of Limmathurosakul et al., who identified regions in the United States that share environmental conditions similar to those seen in some areas where *B. pseudomallei* is endemic.
The burden of melioidosis is likely much greater than currently reported, with the potential for *Burkholderia pseudomallei* to become established in many parts of the world.\(^1\) Our modeling suggested that conditions may be suitable for *B. pseudomallei* to become established in the southeastern United States, substantiating its potential as an emerging zoonosis and threat as a potential bioterrorism agent.

In December 2014, 2 rhesus macaques (*Macaca mulatta*) at the Tulane National Primate Research Center in St Tammany Parish, La, were confirmed infected with *B. pseudomallei*.\(^1\) An investigation found that *B. pseudomallei* was used in research in mice and nonhuman primates in a biosafety level 3 laboratory located across the street from the field cages on the Primate Research Center's north campus. The infected macaques were members of a nonhuman primate breeding colony consisting of > 4,000 animals housed in the outdoor field cages. This incident serves as a reminder that *B. pseudomallei* poses a long-term threat to the region even without intentional release.

Because we found that soil physicochemical properties in the southeastern United States were similar to optimal conditions reported in the literature, it is possible that *B. pseudomallei* would replicate and thrive in the soil if it were introduced to this region. Following establishment, severe weather events, such as tropical storms or hurricanes, could create opportunities for clusters of cases to occur in humans and animals as soil particulates became aerosolized and dispersed over large areas. Sporadic cases could also be seen when soil was disturbed by activities such as gardening, farming, construction, and land development. Veterinarians in the southeastern United States should consider melioidosis as a differential diagnosis for animals exposed to soil that have pneumonia or other illnesses unresponsive to typical antimicrobial treatment.

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**Figure 1**—Map illustrating similarity of soil characteristics in the southeastern United States to soil characteristics in areas where *Burkholderia pseudomallei* is endemic. Habitat similarity indices were constructed with a fuzzy system model. An index of 1 suggests that all 3 conditions (ie, soil pH, moisture, and temperature) of the soil in a particular area were very similar to optimal soil conditions in areas where *B. pseudomallei* is endemic; an index of 0 indicates at least 1 of the 3 conditions was well outside of the range expected to be conducive to the growth of *B. pseudomallei*.
In areas where *B. pseudomallei* is endemic, the prevalence of melioidosis corresponds to the number of organisms in the environment. When only small numbers of organisms are present in the soil, cases are likely to be few and far between, but when large numbers of *B. pseudomallei* organisms are present in the environment, the prevalence of melioidosis may be much higher. Because melioidosis can cause clinical signs commonly seen with a wide variety of diseases, initial or sporadic cases could go undiagnosed for years if practitioners do not consider melioidosis in the differential diagnosis. Hence, the frequency and distribution of melioidosis are likely much greater than reported.10,102

Practitioner awareness of melioidosis could lead to more rapid diagnoses, more frequent use of appropriate treatment, and lower mortality rates.103 State or federal animal health officials should be notified whenever a *Pseudomonas*-like organism resistant to polymyxin E, polymyxin B, and gentamicin is identified, as these are characteristics of *B. pseudomallei*. Samples of blood, urine, sputum, purulent material, and skin lesions should be collected and submitted for diagnostic testing when melioidosis is suspected.

Although animal-to-animal and animal-to-human transmission of *B. pseudomallei* are considered rare, they are possible.104 To minimize the likelihood of transmission to workers and other patients, gloves and a mask and gown should be worn when collecting samples and when treating animals suspected to be infected. A multipurpose disinfectant105 prepared as a 1% solution or sodium hypochlorite (0.5%) should be applied to areas in contact with contaminated body fluids, allowing for a minimum 30-minute contact time.

The CDC has developed a case definition for melioidosis in humans,106 which may help when interpreting test results for domestic animals with suggestive clinical signs. However, clinical signs vary by species, so this definition should not be considered exclusive. In clinically infected animals, the sensitivity of bacterial culture for *B. pseudomallei* can be as low as 60%.107 In addition, owing to its intracellular nature, *B. pseudomallei* can remain latent in animals, so results of serologic testing in exposed or potentially exposed individuals could be misleading in the absence of clinical signs. Positive results of serologic tests for glanders in horses could have international trade implications, and it may be necessary to rule out *B. pseudomallei* even if horses do not have clinical signs of disease.

The challenges in detecting *B. pseudomallei* should not be a reason to leave melioidosis off a differential diagnosis list, particularly in areas where establishment is possible. Practitioners should suspect melioidosis if a cluster of pneumonia cases is seen within the weeks after a major weather event that resulted in aerosolizing of soil particles. Melioidosis should also be considered when abscesses or other infections are unresponsive to standard antimicrobial treatment. Veterinarians will play an important role in detecting and preventing the spread of melioidosis if it is introduced in the United States.

### Acknowledgments

Mention of companies or commercial products does not imply recommendation or endorsement by the USDA over others not mentioned. The USDA neither guarantees nor warrants the standard of any product mentioned.

### Footnotes

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