

## Review articles

# Hygiene pests as vectors for parasitic and bacterial diseases in humans

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**ABSTRACT.** Diseases transmitted by hygiene pests remain a very serious problem in spite of fast developments in science and medicine. The present study focuses on pests carrying germs that pose a threat to human health and life. The quick pace of life, the need to satisfy human needs and mass production of food sometimes result in flagrant sanitary, hygienic and epidemiological deficiencies. These irregularities are conducive to hygiene pests, which, when not held in check by proper control measures, may act more efficiently and quickly.

**Key words:** Diptera, Hemiptera, flies, ticks, parasitic diseases, vectors

Hygiene pests are defined as living organisms causing sanitary, epidemiological and economic losses at the place where they live. A pest may also be very troublesome for other organisms with which it co-exists, including humans. Usually, pests are organisms from the insect and arachnid groups, but they also include birds and rodents [1]. They are passive carriers of germs from one organism to another, for example from animals to people. The most dangerous diseases transmitted by these organisms are present in developing countries, but they can also pose a major health risk in developed countries. Today, increased vulnerability to infections in humans depends on many factors such as a considerable rise in the number of international tourists, immigration, imports of food products, lack of knowledge about parasites, failure to comply with basic hygiene requirements, a growing number of people with impaired immune systems and lifestyle diseases.

In spite of rapid developments in science and medicine, diseases transmitted by pests are still a very serious problem. Pests contaminate their environment with excrements and the microorganisms they carry. Their presence near humans is a health hazard. Pests also contribute to the deterioration of stored raw materials, feed,

wooden objects and other products. This study concerns pests acting as vectors transmitting pathogens that pose a threat to human life and health.

## Diptera

The order Diptera includes over 124,000 insect species present worldwide. According to the literature, there are 7,000 such species in Poland, but it is estimated that the figure may well exceed 10,000. Among the more widely known there are flies, gadflies, bumble bees, mosquitoes, gnats, black flies and others. Even though many Diptera species are useful, they are not well liked. The aversion people feel towards some of them is partly justified, as their bites can be very painful and the insects themselves can be a real nuisance when flying in groups. The order is characteristic for having just one pair of wings.

A commonly known family of Diptera is the Muscidae, which play a major role in carrying bacteria. About 4,000 species belonging to over 100 genera have so far been described worldwide, with around 300 species found in Poland [2].

The Muscidae include the *Musca* (fly) genus, represented by a synanthrope which has

accompanied man for a long time – the housefly (*Musca domestica*) – as well as the African flies of the *Glossina* genus (tse-tse) which feed on mammal blood and carry protozoa of the *Trypanosoma* genus.

The housefly (*M. domestica*) often feeds on human and animal faeces, which makes bacteria accumulate on their hairy bodies. Flies may transmit these onto food products, which may lead to people becoming infected with dangerous bacteria or viruses, causing various diseases. Houseflies may transmit such diseases as salmonellosis, typhoid fever, dysentery, typhus, tuberculosis and polio [3]. They may also carry parasites and fungi. The largest amounts of bacteria are to be found in fly faeces and crop content. For example, *Mycobacterium tuberculosis* is able to survive in the digestive tract of the fly for 16 days and another 13 days in the insect's faeces. Typhus bacteria survive for up to 6 days in the insect's intestines and 2 days in its droppings.

Preventive measures aimed at combating pathogens consist in deterring flies from coming into contact with food. It is therefore safe practice to store food in closed containers and/or a refrigerator. One of the key rules to observe to avoid spreading diseases carried by the housefly is to take care of hand hygiene and the cleanliness of kitchen utensils. Repellents and mosquito nets offer additional protection.

The trypanosomiasis-carrying flies of the *Glossina* genus are to be found in tropical and subtropical Africa [4]. The genus includes about 20 insect species. Otherwise known as tse-tse, the flies inhabit fields, forests, savannas and river basins. The risk of infection is highest in rural areas. The flies can survive and breed in temperatures ranging from 16°C to 38°C and air humidity of 50–80% [5]. They bite during the day.

Tse-tse flies carry 2 species of disease causing *Trypanosoma*. These are *Trypanosoma brucei gambiense* and *T. brucei rhodesiense* [6].

Bites of the tse-tse fly infect the circulatory system of the host (various mammals including man) with trypomastigote forms which reproduce asexually. They may be found in blood plasma, bone marrow, lymph nodes and the cerebrospinal fluid [7]. People may be infected for many months, even years, without presenting the characteristic symptoms of the disease. Once symptoms are noticed, it is often too late for any treatment, as trypanosomiasis is already too advanced. Typical

symptoms include ulceration in the area of the bite, high fever with shivering, headache and insomnia [8]. After the parasites enter the nervous system, the patient becomes comatose and usually dies.

Infection can be prevented by using insecticides, mosquito nets, repellents, traps and special screens attracting tse-tse flies. There is no vaccine against the *Trypanosoma* flagellate.

The Diptera order also subsumes the subfamily of Phlebotominae made up of about 300 species. They are small, thermophile insects measuring from 1.2 to 4 mm. They have very delicate bodies covered with thick hair as well as long feelers and long legs. Females feed on the blood of vertebrates. When feeding, they may transmit various diseases. Among others, they carry the *Leishmania donovani* parasites causing visceral leishmaniasis, the *Bartonella bacilliformis* bacteria which cause Carrion's disease, and Rift valley fever.

Leishmaniasis is transmitted by two types of mosquitoes – *Lutzomyia* and *Phlebotomus* [9]. The former is present mainly in forest areas of Central and South America. *Phlebotomus* flies, on the other hand, come from the African and Asian savannas. It is estimated that there are 350 million people (88 countries) living in the areas where leishmaniasis is prevalent. The disease has three varieties – visceral, cutaneous and mucocutaneous [10].

Most diseases in this group are transmitted only among animals, but some may also be transferred from animals to people or among people (through mosquitoes). Out of the total number of 30 species present in animals, 21 are pathogenic for people.

In Poland, leishmaniasis is diagnosed in tourists who have visited exotic countries and the Mediterranean region (the disease occurs in southern Europe) [11]. Infection can be prevented by using repellents and mosquito nets as well as wearing clothing offering protection from Diptera bites.

Carrion's disease is an infectious disease in the bartonellosis group, transmitted by black flies and caused by the *Bartonella bacilliformis* bacteria. The species is present only in South America. In justified cases, imported infections also need to be taken into account. During the initial phase, symptoms including paleness, muscle pain and malaise are acute and are known under the name of Oroya fever. The infection is opportunistic and often fatal (40–88% of cases) if left untreated. Quickly administered treatment, however, reduces the percentage of deaths to about 9%. The acute phase

is followed by the asymptomatic phase, after which about 10% of those infected present atrophic inflammatory changes of the skin [12].

Rift valley fever occurs in Sub-Saharan mosquito habitats. Its course is usually benign with rare complications. The etiological factor is the RNA virus (RVFV) from the genus *Phlebovirus*, in the Bunyaviridae family. After a 4–6 day incubation period, patients suffer from fever, acute headache, muscle and joint pain, photophobia, occasional dizziness, nausea, vomiting, fatigue and hallucinations. The disease lasts several days, but fevers may reoccur. Most patients recover fully. Infection must, however, be treated as imported.

The most frequent complication is viral damage to the retina, including the macula. As the disease progresses, central vision becomes impaired. In the most acute form of the disease, patients present haemorrhagic symptoms and suffer from meningitis. After a few days, jaundice sets in and patients experience blood vomiting, tarry stools, bleeding gums and petechiae. Meningeal signs appear from 5 to 15 days after the fever period. Post mortem examination shows necrotic foci in the liver [13].

The order Diptera also encompasses the family Culicidae (mosquitoes). Culicidae are present throughout the world. We know over 40 genera and about 3,500 species. The habitats of Culicidae range from the Arctic to the tropics.

Adult mosquitoes have piercing and sucking mouthparts. Females feed on the blood of homeothermic animals, some of them also feeding on the blood of insects. Their larvae develop in water.

The number of people suffering from diseases transmitted by these insects is growing at a tremendous pace. Mosquito species present in Poland currently pose no danger to human life and health as they do not carry dangerous viruses or bacteria. Still, the bite itself is unpleasant and painful, especially when it provokes a severe immune reaction with allergic symptoms on the skin.

There are about 48 mosquito species in Poland, which accounts for only a small percentage of the 3,500 species present worldwide [14]. Some of these insects hunt only birds or other mammals such as hares. Only females need food in the form of blood to ensure that the eggs they will lay will develop correctly. The reason is that blood contains protein which is necessary for their offspring to

grow [15].

There are many factors which contribute to the attacks of mosquito females on their hosts. These include high air humidity, the time of day such as evening or early morning, lack of wind and little sun, ammonia and lactic acid in the sweat of hosts acting as a factor of attraction, as well as carbon dioxide the hosts exhale [16,17]. In addition, according to studies, the blood type preferred by mosquito females is 0 [18]. Females are also guided in their choice of hosts by the size of the body, height, strong perfume, dark clothes and high-pitched sound, specifically with the frequency of 300–800 vibrations per second, which suggests they prefer naturally higher feminine voices [19].

Humans are the most attractive hosts for mosquito females, as studies show that human sweat is much more appealing than the sweat of animals including gorillas and chimpanzees. As it is sucking blood, a female will secrete a pheromone which attracts other females, informing them about available food and causing more bites.

The victim whose skin is pierced with a proboscis is not always in a position to feel it, as the specialised ending of the mouthparts may bypass the nerve endings located in the skin tissue. The saliva introduced into the ensuing wound contains anticoagulants [20]. These are the substances which cause irritable itching. When satiated, females do not look for other victims but go looking for a water reservoir where its offspring will develop. Interestingly, should the water dry out, the eggs can survive in the ground for a period of up to several years. One female is able to lay as many as one thousand eggs.

Mosquitoes are best kept off by nets, repellents, adequate clothing and various substances such as camphor, bergamot, cinnamon, cloves, lavender, eucalyptus, geranium, thyme and myristica oils. Even though they are efficient, oils work for a rather short period of time and in high concentrations may not be well tolerated. Their synthetic equivalents are available at shops and pharmacies.

Mosquito species present in subtropical and tropical zones transmit a number of dangerous microorganisms causing such diseases as yellow fever, dengue, filariasis, malaria, viral encephalitis and Rift valley fever.

Yellow fever is a disease caused by viruses from the flavivirus group. The viruses are transmitted by *Aedes aegypti* mosquitoes [21].

Symptoms may vary from benign to very severe,

which may even prove fatal. In total, mosquitoes carrying the virus are present in over 40 African and 15 South American countries [22].

The onset of the disease is accompanied by sudden symptoms such as high temperature of up to 40°C, malaise, shivering and headaches. Yellow fever may lead to jaundice (hence the name), haemorrhages and renal disorders [23]. It can be fatal.

Vaccination against yellow fever lasts for 10 years [24]. Additional preventive measures include avoiding contact with mosquitoes, wearing adequate clothing as well as using repellents and mosquito nets. It is obligatory to get vaccinated before going to some countries, and the fact needs to be registered in the International Certificate of Vaccination.

Dengue is an infectious tropical disease caused by the dengue virus. This viral disease is also spread by *Aedes aegypti* and *A. albopictus* species [25].

It is the most common disease in tropical countries, especially those of Africa and South-East Asia. Its symptoms include enlarged lymph nodes and liver, nausea, fever, joint pain, headache, vomiting, haemorrhage, and even coma [26]. Preventive measures consist in using repellents, mosquito nets, adequate clothing, etc. There is no vaccine against the disease.

Japanese encephalitis is a disease caused by arboviruses from the family Flaviviridae. The disease is spread by mosquitoes of the *Culex* genus [27]. Japanese encephalitis is a viral disease of the central nervous system. It is present mainly in South-East Asia, Pakistan, India, Sri Lanka, Nepal, Papua New Guinea, but also in northern Australia [28].

Symptoms largely resemble those of influenza. About 1% of patients suffer from the acute form of the disease accompanied by encephalitis. The mortality rate in such cases is about 30%.

Vaccination against Japanese encephalitis lasts for 3 years [29].

Dirofilariosis is transmitted by mosquitoes of the *Anopheles*, *Aedes* and *Culex* genera. It is triggered by two species of nematodes – *Dirofilaria immitis* and *D. repens* [30]. Outbreaks are located in southern Europe, North America, Australia and South-East Asia. The disease usually affects people living in foreign countries, occurrences in Poland being rare [31]. Man can serve as an incidental host.

Nematodes may spend up to several months looking for a suitable place to live in the human

body. A characteristic sign of their presence is a lump under the skin with a diameter of 2 cm. They can only be removed surgically.

In Poland, dirofilariosis is most common in dogs which have been infected abroad. As it progresses, larvae settle under the skin or in the tissue surrounding the heart, the heart itself or the lungs. This is where they move on to the next phase in their life cycle. An adult parasite may reach up to ca. 30 cm [32].

The disease develops over a period lasting for several months to even several years with such accompanying symptoms as drowsiness and aversion to physical activity, reduced body weight and tiresome bouts of coughing.

Tests for the presence of the parasite and later diagnostic activities in dogs consist in performing an ultrasound scan of the pulmonary artery or serological tests. Treatment of this exotic disease in dogs is complicated and may put the animal's life in danger. Left untreated, the disease may be fatal.

Malaria, otherwise known as paludism, is an acute or chronic tropical disease caused by protozoa of the *Plasmodium* genus [33]. There are 5 species of *Plasmodium* present in humans in various tropical countries. The parasites are transmitted by a number of mosquito species of the *Anopheles* genus. The approximate number of species serving as disease vectors is 30–40 [34]. Transmitted unicellular organisms live in red blood cells of intermediary hosts – humans and other mammals as well as reptiles and birds. Their definitive host is the mosquito, in whose body they go through their sexual cycle.

Various water reservoirs are used by mosquitoes as convenient breeding grounds. These can even include puddles or boggy and damp rice fields. Mosquito numbers are very much dependent on rain intensity, temperature and humidity. Mosquito development and transmission of malaria are best helped by air temperature of 17–33°C and average relative humidity over 60%. The mosquitoes bite their victims and feed off them from dusk to dawn.

The insects are characterised by different feeding preferences. Some species prefer human blood (anthropophilic), while others prefer the blood of animals (zoophilic) such as cattle or birds. Both play a major role in the transmission and spread of malaria [35].

The course of the disease is accompanied by twitching, shivering and increased body temperature of up to 40°C. Additional symptoms include nausea,



drowsiness, severe headache, vomiting, occasional diarrhoea, coughing as well as muscle and bone pain. The disease may lead to very serious complications and damage to internal organs [36].

Diseases transmitted by insects from the Diptera order pose a great problem. They are mainly present in the tropical zones of Africa, Asia and Central and South America, but they are also a threat in Europe.

Infection can be prevented by avoiding contact with insects as well as by using repellents and mosquito nets.

## Hemiptera

Hemiptera are a group of insects whose number worldwide is estimated at around 80,000 species. They comprise two suborders – Homoptera and Heteroptera [37].

One of the major representatives of the type is the bed bug. Fond of unhygienic conditions and feeding on human blood at night, this small insect can be a great everyday nuisance for its victims. Their preferred habitat is bedrooms and especially bed sheets, floor or bed cracks as well as linen drawers [38].

Bed bug bites may provoke strong allergic irritation and swelling of the skin, which may be very unpleasant for people suffering from allergies.

It used to be believed that the insect is not dangerous to human health, the only problem it may pose being an allergic reaction to its bite of varying intensity. We now know, however, that it can carry germs causing such diseases as tularemia, Chagas disease, tuberculosis and the plague [39]. In addition, in one hospital, Canadian doctors discovered bed bugs which carried dangerous bacteria such as drug-resistant strains of *Staphylococcus aureus* and *Enterococcus* which may provoke sepsis in patients with impaired immunity [40].

Chagas disease, otherwise known as American trypanosomiasis, is a tropical parasitic infectious disease. It affects both people and animals. Incidence is highest in both Americas. Its course may be acute or chronic.

The disease is caused by the protozoan *Trypanosoma cruzi* carried by blood-sucking Hemiptera. In the majority of cases, infection results from a bite [41]. Hemiptera which are vectors of the disease belong to the Triatominae subfamily and the *Triatoma*, *Panstrongylus* and *Rhodnius* genera [42]. People may sometimes become infected with

trypanosomiasis following blood transfusion and ingestion of contaminated food products. It may also happen during pregnancy when the disease is passed from mother to children [43].

The initial phase during which protozoa reproduce in the system is called acute. There is only a relatively small swelling visible in the location of the bite with such potential additional symptoms as fever, muscle pain and headache. If the bite is in the eye area, the so-called Romana's sign may appear [44] – the vicinity of the eye and pupil will swell up, the conjunctiva will become inflamed and lymph nodes located near the ear will become enlarged. It is very important to be able to identify the disease properly and administer treatment because, even though patients do not report any unpleasant or uncomfortable symptoms, the disease may trigger serious system changes such as damage to the heart muscle or plexuses of the digestive tract muscle coat, mainly the oesophagus and the large intestine [45].

The first symptoms of *Trypanosoma cruzi* infection appear after about 8–10 days. This is not true for infections following blood transfusion as symptoms appear after about 20–40 days. In most patients, the acute phase of the disease persists for up to six weeks, after which the disease enters the chronic phase. The chronic phase is incurable.

## Oriental and German cockroaches

Oriental and German cockroaches (the order Blattodea) are very fond of contaminated and dirty places. This is probably why we think it is best to avoid them, as they can potentially transmit different diseases. Many of the microorganisms they carry are resistant to antibiotics. About 12% of hospitals in Poland face the problem of infestation, a considerable number of hospital infections being due to contacts with Oriental or German cockroaches [46].

In the main, Oriental and German cockroaches may infect people with such infectious diseases as dysentery, salmonellosis, polio and typhoid [47]. This is chiefly the result of food products becoming contaminated with either faeces or remains of dead insects which get into the human body through the digestive system. The same may happen at home.

Dysentery is caused by the bacilli of the *Shigella* genus bacteria. The disease is mainly caused by the following *Shigella* species: *S. sonnei*, *S. flexneri*, *S. dysenteriae* and *S. boydii* [48].

The disease takes the form of an acute infectious condition and mainly affects the large intestine. Symptoms manifest as very frequent diarrhoeas with blood and mucus [49]. Left untreated, the disease is very dangerous for the health and even life of patients. Most frequently, infection takes place along the faecal-oral and food routes by transferring pathogens from the hands into our digestive system. Otherwise, it is transmitted by insects. Treatment requires antibiotics.

Salmonellosis is a group of infectious diseases caused by Gram-negative bacilli of *Salmonella* with such serotypes as *S. enterica*, *S. enteritidis* and *S. typhimurium* [50]. The spread of the disease is greatly facilitated by insects such as cockroaches which serve as passive vectors, the main source of infection being food contaminated with excrements of infected animals, people and insects including Oriental and German cockroaches.

The most frequent symptom is gastro-intestinal catarrh. Unfortunately, the reservoir of bacteria causing the disease is not limited to insects but extends to a wide range of animal species, including mammals and birds. Other symptoms are acute and debilitating diarrhoea, headaches, vomiting and high fever [51].

In some patients, germs break through the intestinal barrier to induce an infection of the circulatory system. Once in the system, the microorganisms may cause blood poisoning, meningitis, pneumonia, bone inflammation and endocarditis. A percentage of patients become asymptomatic hosts.

Polio is caused by the poliovirus from the Picornaviridae family. It is an infectious disease transmitted by cockroaches and via the faecal-oral route. The virus replicates in the intestinal epithelium with an incubation period lasting from 9 to 12 days. Subsequently, it affects lymph nodes and the circulatory system. If antibodies are produced quickly, the infection may be contained. If not, it leads to so-called secondary viraemia which spreads the virus throughout the body. Among other sites, the virus attacks the central nervous system and especially the anterior horns of the spinal cord, the medulla and the pons. The course of the disease may be benign, but it can also be fatal or induce disability and paralysis [52].

Symptoms are similar to those of influenza, including muscle pain, fever, respiratory problems and diarrhoea. Fortunately, the acute form of the disease called paralytic polio is very rare. Its

primary consequence is paralysis of the extremities concerning primarily the lower limbs (less often the upper limbs) and leading to dystrophy and deformation of the affected parts of the body [53].

The disease may be prevented through vaccination.

Typhoid is caused by *Salmonella typhi* bacilli. Infection takes place through contact with food and water contaminated with insect excrements [54]. Its course is acute and involves the following symptoms: high fever which builds up slowly to reach a peak point at 40°C, lack of appetite combined with headaches and general fatigue, strong pain in the abdominal area, diarrhoea or constipation, and rash in the area of the chest or the epigastrium. The bacteria secrete a specific toxin which induces inflammatory and necrotic changes in the intestines. The disease may also trigger serious complications such as blood poisoning, intestinal perforation and peritonitis [55]. Left untreated, typhoid may be fatal. The disease has a global distribution, with the highest risk of infection in Africa, South America and South Asia. It can be combated with vaccines and antibiotics. Preventive measures consist in washing the hands before eating as well as washing fruit and vegetables.

## Fleas

Roughly speaking, the planet is inhabited by about 2,500 species of fleas [56], several dozen being present in Poland. They are parasites of homeothermic animals, which means that they live directly on their hosts, but also in their immediate vicinity. Some fleas stay on the definitive host animal while others usually remain in the host's bedding or resting places.

The group of fleas causing health problems for living organisms includes the dog flea (*Ctenocephalides canis*), cat flea (*C. felis*), human flea (*Pulex irritans*) and rat flea (*Xenopsylla cheopis*). The creatures move about by both jumping and crawling, although those that jump are in the great majority. They are extremely agile. Thanks to a springy substance in their muscles called resilin, they can make 30,000 jumps without resting [57].

The insects can wait motionless for their potential host for even one year. The amount of blood ingested during one meal can exceed their body weight by a factor of fifteen.

Fleas pose a threat to animal and human health

not only because they provoke allergic reactions, but also because they transmit infectious and parasitic diseases such as bartonellosis, tularemia, typhus, tungiasis, the plague and others.

Bartonellosis (cat-scratch disease) is caused by bacteria of the *Bartonella* genus. The medical literature differentiates between several types of the disease depending on the vector which contributed to their transmission. If it is the flea, we may talk of cat-scratch disease.

The species which is the most common vector of the disease is *Bartonella henselae*, a microorganism present in flea droppings. Cats become infected by transferring the germ onto damaged skin tissue together with insect faeces [58]. This, unfortunately, is a frequent occurrence aggravated by cats' propensity to scratch during a flea invasion.

Humans become infected by being scratched by cats, bitten by insects or scratching themselves. As a result, microorganisms enter the body through the wound. Initial symptoms may start to appear only after several or a dozen days from the moment of infection. The area around the wound may come out in a rash after which the skin reddens and swells up. Subsequent stages involve pimples, abscesses or skin ulceration.

The erythema is painful and itchy. Changes to the skin disappear over time without leaving scars. Unfortunately, bacteria enter the circulatory system and consequently spread throughout the body, attacking and inflaming the lymph nodes [59]. The disease often presents symptoms similar to those of influenza such as general fatigue, muscle and joint pain, shivering, fever, malaise, apathy and lack of appetite [60]. In time, the temperature increases. Enlarged lymph nodes may even undergo suppuration. Severe cases, which are fortunately rare, involve complications such as peliosis hepatis, inflammation of the eyeball and conjunctiva, pneumonia and meningitis. The disease and its symptoms often subside spontaneously within about 2–3 weeks. However, given the fact that incomplete treatment may lead to the bacteria becoming dormant to be reactivated in the future, it is recommended to administer antibiotics.

Tularemia, a disease transmitted by fleas, among other vectors, is caused by the *Francisella tularensis* bacteria. As they replicate, the bacteria cause swelling of the lymph nodes and may even lead to blood poisoning [61].

People become infected mainly as a result of being bitten by rodents such as rats or mice as well

as insects such as fleas. Bacteria spread throughout the system, reaching various organs together with blood and lymph.

In the cutaneous form of tularemia, a lump develops and becomes ulcerated over time. The lump is painful and the neighbouring lymph nodes are enlarged. It is the most common type of the disease, experienced by 75–85% of patients. The lung type is different, as it has mortality rates of over 30% if left untreated [62]. Patients experience high fever, headache, coughing, inflammation of the conjunctiva, shivering, vomiting and muscle pain. The disease is treated with antibiotics.

Murine typhus is caused by *Rickettsia prowazekii* and *R. typhi* bacteria and is transmitted mainly by rats and mice infested by infected fleas [63]. The rat flea is the most common vector. Insect faeces contains *Rickettsia*, and the pathogen enters the body when flea bites are scratched. *Rickettsia* bacteria trigger pathological changes of blood vessels, the nervous system, endocrine glands and the heart.

Symptoms include fever, a feeling of helplessness, quickened breathing, migraine, swellings, enlarged liver and spleen, possible impaired consciousness and insomnia. In addition, the heart becomes enlarged and there is partial atony of the muscles [64]. After one month, neurological symptoms gradually subside. The disease may lead to very serious complications such as hypostatic pneumonia, parotid gland inflammation, encephalitis, meningitis, nephritis, phlebitis and arterial inflammation.

The disease is treated with antibiotics. Prevention measures require observing personal hygiene requirements and using vaccines.

Tungiasis is caused by the sand flea *Tunga penetrans* [65]. It is mainly present in tropical regions of Central Africa, South America and India. Sand fleas are often to be found in large number on beaches, in neglected stables or houses with poor hygiene standards. Females lay eggs from which larvae will develop under the skin of the host. Eggs are laid on the feet and in the area of the toes [66]. Symptoms include skin changes, strong and irritable itching as well as ulceration of the feet and toes. The disease can lead to such serious complications as tetanus and gas gangrene.

The plague, which used to be called the „black death”, no longer kills as many people as in the past. It is still present, however, in South Asia and African countries [67,68,69]. Annually, about 3,000

cases are reported worldwide. The disease is caused by the *Yersinia pestis* bacteria and is transmitted mainly by rats, with the rat flea as the intermediary vector.

As a characteristic symptom of this acute infectious disease, dark necrotic changes appear on the skin in the area of the flea bite and in other places.

There are three types of the plague [70], the most common of which is the bubonic plague. It is characterized by the following symptoms: pronounced dilation of blood vessels, severe headaches, serious general weakness, sweating and convulsive shivers. Patients also experience very strong swelling of the lymph nodes, especially in the groin. The rapidly progressing infection affects successive lymph nodes. Death occurs within several days.

The two other types of the plague are pneumonic and septicemic. In the case of the former, the infection is airborne, with bacteria entering the lymph nodes via the circulatory system. Severe pneumonia is accompanied by haemoptysis, cyanosis and shortness of breath. Death occurs within two to three days. Septicemic plague, on the other hand, is characterised by severely impaired consciousness and sepsis. Its course is very acute, with patients dying within several hours.

Preventive measures consist in maintaining hygiene standards, avoiding contact with wild rodents, using insect repellents and regularly de fleaing domestic pets.

## Ants

Ants are insects which always establish large colonies. They are usually associated with hard work, devotion and usefulness. Unfortunately, not all the ants are useful, and the qualities mentioned above do not quite fit them.

Some ants carry diseases which are dangerous for humans. One of the species carrying various germs is the pharaoh ant (*Monomorium pharaonis*), which, apart from the already mentioned salmonellosis, transmits a wide range of other microorganisms [71].

The ant came to Europe from India about 100 years ago and can now be found in many Polish cities, where they live in residential buildings, hospitals and canteens [72]. Nests are set up in warm, moist places. They like nesting under floors, in wall crevices, next to stoves, near sinks and bath

tubs as well as under flower pots. They feed day and night on practically all plant and animal origin products. Among other germs, the ants carry *Pseudomonas aeruginosa*, *Klebsiella* bacteria and other pathogens.

*Pseudomonas aeruginosa* is a bacterium which lives mainly in water and soil. The organism is opportunistic, which means it causes diseases in patients whose immune system is already deficient. In such people, it can cause a number of diseases such as inflammation in the area of the middle and outer ear, sepsis, wound infection, dysfunctions of the respiratory system as well as infections of the urinary tract, joints, bones and the eyeball [73]. Treatment is difficult due to high resistance of the bacteria to antibiotics.

*Staphylococcus* is a genus of Gram-positive bacteria. They are quite common on the skin and mucous membranes, but can prove pathogenic in people with compromised immune function due to various diseases and ailments. This relates mainly to two species – *S. epidermidis* and *S. aureus* [74]. Infection can occur via skin lesions, blood and contaminated food products.

The large group of disorders caused by *Staphylococcus* includes infections of subcutaneous and skin tissues such as abscesses, styes and lichens; inflammation of the trachea and the urinary tract, pneumonia, meningitis and vasculitis; and staphylococcal food poisoning.

*Klebsiella pneumoniae* is a bacterium which is found in the normal flora of the skin, mouth, respiratory tract and the digestive system. Under some conditions, it may cause pneumonia as well as inflammation of the urinary and digestive tracts. The bacteria are opportunistic and resistant to antibiotics. They activate their pathogenic functions mainly in the case of people with compromised immunity [75] or children. Infection occurs after ingesting infected food or exposure to saliva. Symptoms are similar to those of influenza including fever, coughing and occasional shivers. Large amounts of thick mucus are secreted.

## Ticks

Ticks are arachnids which prefer forests, meadows, pastures and lake areas. Today, they are also becoming increasingly present in municipal parks and greens. The group is divided into hard ticks (Ixodidae) which are partly covered with a hard scutum, and soft ticks (Argasidae), which do



not have a scutum. About 800 species of ticks have been identified. They are external parasites of vertebrates.

Depending on the specific species, ticks transmit different infectious diseases. Ticks of the *Ixodes*, *Dermacentor*, *Amblyomma* and *Rhipicephalus* genera carry the *Rickettsia rickettsii* bacterium, which causes Rocky Mountain spotted fever [76]. It is an acute disease with a reservoir in dogs and wild rodents living in South America. The onset is sudden with strong shivering, and the resulting fever is similar as in the case of typhoid. As the disease progresses, the skin erupts in a rash which changes into a haemorrhage on days three to five.

Another rickettsiosis caused by the *R. conorii* bacterium is Conor and Bruch disease. In the great majority of cases, the role of the vector is played by the tick *Rhipicephalus sanguineus*. The disease takes its toll in the Mediterranean region [77]. Its course is characterised by high fever, headaches and pain in the lumbosacral section of the spine, also affecting the lower extremities. A red rash appears at the site of the bite [78]. The liver and spleen become enlarged. The rash on the skin may take different forms, appearing on the third and fourth day of the disease. Fever persists for a dozen or so days (14–17). The disease usually subsides with no complications.

Borreliosis is also known as Lyme disease or Lyme arthritis. It is caused by the bacterium *Borrelia burgdorferi*, discovered in 1982 and transmitted mainly by *Ixodes* ticks. The bacterium may appear in several forms, i.e. as spirochaetes or endospores – cysts [79]. As spirochaetes they are very agile, whereas cysts, while not being very active, are resistant to some antibiotics which destroy spirochaetes.

The disease has been recognised and diagnosed since the second half of the 1980s, which makes it a relatively recent discovery [80]. Unfortunately, more and more cases are being reported.

*Borrelia* sp. can penetrate different cells such as macrophages, fibroblasts and lymphocytes. There are different forms of borreliosis causing various joint and neurological symptoms, sometimes accompanied by skin changes.

The disease affects three types of tissues: connective, nervous and muscular [81]. From the moment of biting, the disease develops over a period of 1–3 weeks. One of its potential symptoms is erythema migrans. It appears near the site of the bite. It may resemble a blister or an irregularly

shaped petechia. It is usually a swollen, reddened spot with a diameter from several to a dozen centimetres which may be slightly protruding, rather warm and painful to the touch. A typical tick-related erythema is brighter in the middle, its shape resembling a ring. Erythematous changes of the skin are accompanied by successive symptoms which are specific for tick bites. These are skin stinging, itching, concentration problems, muscle and joint pain and even circulation problems [82].

Borreliosis is not the only disease transmitted by ticks. USA doctors warn against a much more dangerous disease which can develop after tick bites – the Powassan virus [83].

The Powassan virus is spread by ticks just like borreliosis. Doctors claim, however, that the disease is much more dangerous – first, because it causes permanent neurological damage; and second, because there is no cure for it.

The virus is named after the Canadian town of Powassan, Ontario, located east of the Great Lakes of North America. It is in the North-West of the USA that doctors observed an increased number of cases of this tick-borne disease. As many as 10% of cases are fatal, whereas in half the patients the nervous system is left permanently damaged.

Doctors point out that the symptoms are very similar to those typical of borreliosis. What is different is their intensity, as in the case of the Powassan virus they are more acute. It only takes a few minutes from the bite to the onset of fever, vomiting and fatigue.

The disease is all the more dangerous as no optimal cure has been developed to combat it.

Other very dangerous tick-borne diseases are those caused by flaviviruses. The *Flavivirus* genus includes the West Nile virus, dengue virus, tick-borne meningitis, yellow fever virus and Zika virus. Diseases are spread primarily by the tick species *Ixodes ricinus* and *I. persulcatus* [84]. Consequences of infection may be more serious than in the case of borreliosis, including death or disability, especially if the disease is not adequately treated in good time.

Babesiosis is another disease transmitted by ticks. It occurs rarely and resembles malaria. It is most often diagnosed in people living in Africa, Southern Europe and New England.

Babesiosis is caused by the protozoan *Babesia* carried by ticks of the Ixodidae family [85]. They attack red blood cells of vertebrates, triggering their degradation. The best described, and also the most dangerous, are two species – *Babesia divergens* and

*B. microti*. The former is especially dangerous and more widely present in Europe. If the disease it causes is identified too late, it may be fatal [86].

Symptoms are much more benign in the case of the species *B. microti*, which is mainly present in the USA and has its reservoir in rodents. Infection is followed by fatigue of the patient and fever, which quickly subsides by itself [87].

The disease is difficult to treat. In patients with a fully functional immune system, it resembles influenza and usually subsides spontaneously within 8 weeks. Additional symptoms include shivering, sweating, headaches and general fatigue. If immunity is too weak, babesiosis may cause death.

## Birds

Infection with avian pathogens is either food-borne (for example following ingestion of infected meat) or air-borne. People become infected by ingesting water or food contaminated with pathogens or else through contact with dirt or dust containing pathogens, bird excrements or contaminated objects. Among other diseases, birds transmit salmonellosis, campylobacteriosis, tuberculosis, avian influenza and allergies.

Salmonellosis is caused by the bacterium *Salmonella enterica*. The bacteria are present throughout the world and are a very common cause of food poisoning in people and animals [88].

Birds usually become infected by salmonella bacilli from contaminated feed and then excrete them in their faeces. Poultry, and consequently poultry eggs, provide a reservoir for the bacteria [89]. People become infected due to a general lack of hygiene (including not washing fruit and vegetables before eating [90] and not washing hands before preparing meals), re-freezing products, eating undercooked and under-grilled food, eating raw meat or having contact with raw poultry eggs.

Specific symptoms of salmonellosis mainly include vomiting and severe diarrhoea as well as a subfebrile condition often evolving into higher temperatures [91]. Infection may lead to dehydration, weakening and even death in the case of children and old people. In some cases, patients may experience strong headaches and pain in the spleen which becomes enlarged. The heart, kidneys and motor organs may also suffer from pathological changes.

Campylobacteriosis is an acute infectious disease which ranks second on the list of the most

important zoonoses in Central Europe. It is caused by *Campylobacter* bacteria, the two species which are most often responsible for infections being *C. coli* and *C. jejuni* [92].

Bird excrements play a major role in the spread of germs, especially in the case of breeding farms, but also when it comes to wild birds such as ducks or poultry [93]. However, mammals living in the wild may also serve as hosts. Microorganisms are present in the digestive tract and excrements of animals. People become infected by drinking water contaminated with bacteria and, for example, by eating poultry meat which has not been thermally treated in a proper fashion.

Dominating symptoms in people are diarrhoea, inflamed intestines and stomach inflammation. Diarrhoea may be bloody. Other symptoms often include fever and abdominal pain as well as enlarged spleen and liver. Pain in the joints is also a common occurrence, as is meningitis [94]. These symptoms usually subside spontaneously, but if they persist for over a week, relevant treatment must be implemented.

Tuberculosis is caused by several *Mycobacterium* species such as the human *M. tuberculosis*, *M. bovis* and *M. avium*. They occur commonly worldwide. Diseases in birds and people are mainly caused by *M. avium* [95]. Infection occurs through contact with an infected person or animal. The route of transmission is chiefly airborne, pathogens being expelled by sneezing or coughing. Only a negligible amount of cases result from microbes transmitted through food.

Bird species which may have a significant impact on the spread of the disease include pheasants, cuckoos, ducks, cranes and songbirds [96]. *Mycobacterium tuberculosis* may wait dormant in the human body for years with no pathogenic activity, only to attack when the immune system is weakened. The following symptoms occur during the course of the disease: general fatigue, fever, coughing, diarrhoea, minimal appetite and weight loss [97]. The body becomes progressively exhausted, which may even cause death. Treating people consists in administering antibiotics, which is far from easy given the great resistance of mycobacteria to antibiotic treatment.

Influenza (avian influenza) is a disease which is mainly present in wild birds, but cases in people have also been reported. Influenza germs are carried mainly by wild fowl and especially hens, turkeys and ducks.

Avian influenza is caused by viruses from the Orthomyxoviridae family [98]. People may become infected by eating meat which did not undergo proper thermal treatment or from prolonged contact with infected birds involving long exposure to dirt or dust containing germs, bird faeces as well as contaminated feed, water or equipment.

Even though human cases are rare, the disease must not be ignored.

When infection does happen, the virus causes a lot of damage, proving fatal in about 60% of patients. Symptoms suggesting infection are very similar to those of common influenza, involving muscle and joint pains, sore throat, fever and in some cases breathing problems and pneumonia [99].

The basic precaution to take in order to avoid the disease transferring to people is to observe hygiene requirements and stay away from potential hosts of avian influenza.

Allergic alveolitis is caused by contact with bird feathers, dandruff-like epidermis or airborne fragments of bird excrements. These animal-origin substances are full of allergens which may trigger inflammation of the alveoli, primarily in people who have become vulnerable to bird allergens over time [100]. The disease is common in bird breeders and especially those keeping pigeons or parrots. In such cases, specific symptoms are triggered by a mucin compound which is present in bird faeces and easily airborne.

Excessive exposure to specific allergens is manifested by breathing problems, shivering, fever, coughing and weight loss.

The disease is often diagnosed as a chronic or frequent cold, which leads to inadequate treatment. In chronic forms, it may result in calcinations in the lungs, significantly reducing the capacity and efficiency of respiratory organs.

People diagnosed with allergic alveolitis must avoid contact with birds.

## Rodents

Rodents, which belong to the mammal class, have great potential to host various parasites and microorganisms causing diseases in people and certainly contribute greatly to the process. They may carry over 60 dangerous microbes [101]. Among rodents, rats and mice account for the largest share in the transmission of diseases.

Fond of living in water supply networks, rats

have contact with a whole range of germs and microorganisms, the great majority of which can be transmitted to people. They are often present in flats with very poor furnishing and hygiene standards as well as densely populated buildings. They can infest kitchens and cellars. The fact that they share their lives with people increases the likelihood of getting bitten and infected with different pathogens.

Some diseases transmitted by rodents are also transmitted by other pests mentioned in this study. The nature of those diseases has already been explained above when describing microorganisms carried by other pests. They include tularemia, murine typhus, salmonellosis and the plague. Beside these, rodents also transmit other diseases described below.

Important examples of such pests include the brown rat (*Rattus norvegicus*), black rat (*R. rattus*), house mouse (*Mus musculus*) and field mouse (*Apodemus agrarius*).

Trichinosis is a disease caused by the nematode *Trichinella spiralis*, a dangerous parasite in humans and many animals. Wild rodents are its important reservoir [102]. This is greatly facilitated by the fact that such rodents are prone to eat slaughterhouse waste, pet food leftovers and waste from rubbish bins. In addition, their diet also includes many kinds of dead animals such as fox carcasses, martens, raccoon dogs, cats, dogs, rats and mice. The carcasses they eat are also often infected with *Trichinella* larvae, which contributes to the spread of the disease to unaware rodents.

Rats are sometimes eaten by pigs or wild boars. If this happens, invasive forms of *Trichinella* penetrate the pig intestines. They are then released by gastric acids from their characteristic capsule where they were preserved in the rodent's body, which allows them to grow, achieve sexual maturity and replicate in the intestine. The new generation of larvae penetrate the intestinal wall, enter the blood stream, circulate through the entire body and settle in striated muscles. Most often, larvae penetrate the intercostal, tongue, diaphragm, larynx and back muscles. They then encyst in a characteristic capsule, become calcined and wait to be eaten by the next predator, including man [103]. Encysted larvae can survive from 20 to 40 years.

People become infected by ingesting undercooked or raw pig or wild boar meat. Symptoms suggesting the presence of larvae in the body include aversion to eating, nausea, diarrhoea, abdominal pain, headache combined with dizziness,

insomnia and itching. As the larvae migrate around the organism and settle in different muscles, the patient feels pain in the forehead, eyes and the base of the nose. Common additional symptoms manifest as swelling and heaviness of the eyelids and face as well as stiffness in the neck, nape, thighs and the head [104]. Beside potential complications concerning the heart and lungs, the disease can also be fatal.

Rat-bite fever is caused by the bacteria *Streptobacillus moniliformis* and *Spirillum minus* [105], which are mainly carried by rats, mice and gerbils. Infection occurs following a bite. Symptoms include permanent, recurrent pain in the joints and, additionally, recurrent fever, rash, nausea and vomiting. There may be complications such as pneumonia, endocarditis, myocarditis and meningitis [106]. Left untreated, the disease is fatal in about 10% of cases [107].

Leptospirosis is a disease caused by corkscrew-shaped *Leptospira* bacteria, the species most often responsible for diseases in people and animals being *Leptospira interrogans*, *L. icterohaemorrhagiae* and *L. grippityphosa* [108]. In addition to the great number of animals which can carry the microbe, the main culprits as regards transmission are rodents and especially sick or host rats, which excrete the bacteria in their urine. The most important reservoir of microorganisms related to human diseases is the species *Rattus norvegicus* [109].

People become infected through contact with contaminated soil and water or by ingesting infected food. Lesions to the skin, mucous membrane or the conjunctiva may lead to leptospirosis infection [110]. Benefiting from damage to these structures, the leptospira enter different organs such as the lungs or kidneys with blood. In the first phase of the disease, symptoms include high temperature of 39–40°C, pain in the conjunctiva, increased sensitivity to light, muscle and joint pains and a rash. In the second phase, these symptoms are joined by abdominal pain and enlargement of the spleen and liver as well as possible meningitis and jaundice [111]. The course of the disease may be very acute and lead to death.

Toxoplasmosis is a disease caused by the protozoan *Toxoplasma gondii*, whose definitive host is the domestic cat and other Felidae species [112]. The parasite reproduces sexually in the host's body, which leads to the creation of oocysts excreted together with the host's faeces to the environment. Oocysts represent an invasive stage involving a

wide range of intermediary hosts, including a number of mammals such as rats and mice. The group of intermediary hosts also includes man, who may be infected by, for example, ingesting food or water contaminated with cat excrement.

Cysts can survive many years in the body of the intermediary host, including man. They settle in the muscles, eyeballs and the central nervous system through the agency of the circulatory system. Many people remain unaware that they have been infected, as there are no symptoms from the parasite encapsulated in cysts.

The disease may, however, manifest in characteristic symptoms and two forms – innate and acquired [113]. In the case of acquired toxoplasmosis, symptoms include high temperature, pneumonia, myocarditis, headache, enlarged lymph nodes, liver and spleen, encephalitis and meningitis. Innate toxoplasmosis affects the child during pregnancy. Unfortunately, it may lead to various congenital diseases of the child or pathological consequences of the disease in the future. Common disorders include hydrocephalus, eyeball inflammation and hemorrhagic necrosis of the brain.

Rickettsial pox is a disease caused by the bacterium *Rickettsia akari*, which lives in the body of the mite *Allodermanyssus sanguineus*, found on mice [114]. Infection in people is triggered by a mite bite. The first sign is a lump which changes into a blister filled with serum, to become covered with a scab. Related symptoms include photophobia, muscle pain, fever, shivering, a rash resembling chickenpox and profuse sweating [115].

Intensive studies are being carried out worldwide to contain diseases transmitted by hygiene pests acting as vectors. The problem persists, however, in spite of technological advances and new products introduced today to better control the spread of diseases.

Unfortunately, the quick pace of life, the need to satisfy human needs and mass production of food sometimes result in flagrant sanitary, hygienic and epidemiological deficiencies. These irregularities are conducive to hygiene pests which, without being held in check by proper control measures, may act more efficiently and quickly.

Other factors contributing to the spread of diseases transmitted by pests are mass migration of people and tourism. This is because many tropical and exotic diseases are brought to Poland from different parts of the world.



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