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REVIEW ARTICLE

Influence of mosquito-borne biological agents on health risks among soldiers and military personnel

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Abstract

Introduction. Mosquitoes are the most important vector group for humans, and three genera – *Aedes*, *Anopheles* and *Culex*, are of greatest significance in the transmission of pathogens to humans and animals. The geographical expansion of vectors can lead to the spread diseases into new regions. Soldiers exercise in the field, participate in missions, or are stationed in Military Contingents located in different climatic conditions, which is directly related to exposure to mosquito-borne diseases.

Objective. The aim is to describe the role of mosquitoes in the transmission of selected pathogens of medical and epidemiological importance, which pose a new threat in Europe, pointing to soldiers and other military personnel as particularly vulnerable occupational groups.

Review Methods. PubMed and other online resources and publications were searched to evaluate scientific relevance.

Brief description of the state of knowledge. In recent years in Europe, attention has been drawn to emerging infectious diseases transmitted by mosquitoes, including malaria, Dengue fever, West Nile fever and Chikungunya fever. West Nile virus infections were recorded in many European countries, including Greece, Italy, Germany and Austria. Soldiers, due to their tasks, are particularly vulnerable to vector-borne diseases. In order to reduce the exposure of soldiers to mosquito-borne diseases various protection measures are used.

Summary. Some of vector-borne diseases belong to emerging infectious diseases and may pose a threat to public health. The burden on soldiers with these diseases can be significant, which is the reason why methods of surveillance and the control of vectors are being developed.

Key words
soldiers, pathogens, military, mosquitoes, vector-borne diseases

INTRODUCTION

Vector-borne diseases are diseases that are mainly or exclusively transmitted by invertebrates, primarily mites and insects. Ticks and mosquitoes are the most common vectors, whereas these diseases account for 17% of all infections worldwide [1]. Recently, there have been increasing reports in the literature about emerging infectious diseases (EIDs), i.e. infectious and invasive diseases the prevalence of which has increased in recent years, and may increase in a given area in the near future. These diseases include those caused by emerging or newly discovered pathogens, as well as pathogens with a new spectrum of drug resistance, or caused by the spread of a previously unknown pathogen. It is worth mentioning that 12% of known human pathogens are etiological agents of newly the fact emerging diseases [2, 3]. Research has highlighted that interactions between pathogens, hosts and the environment play a key role in the emergence or re-emergence of these diseases. In addition, social and demographic factors, such as human population growth, urbanisation, globalisation, trade, and travel, influence the emergence of vector-borne diseases [4, 5, 6]. Global warming and associated climate change, characterised by extreme weather events, such as increased temperatures, droughts, rainfall or more frequent and stronger tornadoes and hurricanes, will also affect the emergence and re-emergence of pathogens, especially tropical diseases in some countries in Europe and North America [5, 7, 8, 9]. Between 2010 – 2015, the National IHR (International Health Regulations) Focal Point received notifications from the WHO (World Health Organization) and ECDC (European Centre for Disease Prevention and Control) on emerging infectious diseases that occurred in the WHO European Region, which included malaria, Dengue fever, West Nile fever and Chikungunya fever, among others, also presented in this study [2]. This framing is congruent with the One Health approach which aims to promote global health security by improving collaboration and communication across human-

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animal-environmental domains to jointly address health threats such as zoonotic diseases, antimicrobial resistance, and food safety, for example [10, 11, 12]. Taking into account all these aspects, it is necessary to undertake actions aimed at counteracting the effects of these diseases, and therefore, among others, to monitor vectors and the pathogens they transmit, first of all in particularly endangered areas, which in turn will become useful not only for local populations, but also for civilian employees of the army and national and allied soldiers often exercising in the field, undertaking missions, or stationed in Polish Military Contingents. The Polish Armed Forces have been participating in international missions since 1953 and since that time, more than 120,000 soldiers and other military personnel have taken part in more than 89 operations. As a participant in international relations, Poland contributes to the strengthening of international peace and building a stable security environment. At present, the Polish Army directly participates in 12 Military Contingents, which are located on several continents in different climatic conditions [13], which is directly related to exposure to mosquito-borne transmission diseases, as well as for other vector-borne diseases.

OBJECTIVE

The aim of this review article is to present the role of mosquitoes in the transmission of selected pathogens of medical and epidemiological importance, with particular emphasis on the threat they may pose to soldiers and other military personnel. The work focus mainly on the occurrence of pathogens and induced clinical symptoms. The article also rises the issue of surveillance and vector control regarding soldiers and military contingents which can be deployed in different locations worldwide.

REVIEW METHODS

A literature review using PubMed and other online resources, using combinations of selected key words including 'pathogens in mosquitoes', 'West Nile fever', etc., was undertaken and the articles were reviewed in terms of relevance and scientific merit. The more important literature, both from earlier works and from recent publications was analyzed, additionally enriching it with information obtained from the websites of units dealing with public health issues.

DESCRIPTION OF THE STATE OF KNOWLEDGE

Mosquitoes as vectors of pathogens. Mosquitoes (*Culicidae*) can transmit a range of pathogens belonging to viruses, bacteria, fungi, nematodes, or protozoa. Worldwide, about 3,500 species of mosquitoes have been described, 101 in Europe, while in Poland there are 47 species of mosquitoes, classified in 6 genera: *Aedes*, *Culex*, *Culiseta*, *Anopheles*, *Ochlerotatus* and *Coquillettidia*. For many viruses, pets, rats, and free-living birds are the reservoirs and amplification hosts that can be the source of mosquito infections [14, 15]. Of these vectors, 3 genera (*Aedes*, *Anopheles* and *Culex*) (Tab. 1) play the most important role in the transmission of pathogens to humans and animals. One species of mosquito (e.g. *Aedes albopictus*) can transmit at least 22 different types of arboviruses in addition to parasitic diseases [9, 16]. Arboviruses are arthropod-borne viruses with a worldwide distribution, and most of them have a ribonucleic acid (RNA) genome that has higher mutational rate. Flaviviridae belongs to one of the 4 arbovirus groups, and mosquito-borne flaviviruses are assumed to be the most important neurotropic flaviviruses [17].

Table 1. Most important diseases caused by mosquito-borne pathogens based on [20]; modified

Vector	Disease	Pathogen
Aedes	Chikungunya fever	Chikungunya fever virus (Togaviridae)
	Dengue	Dengue virus (Flaviviridae)
	dirofilariosis	*Dirofilaria* (Onchocercidae, nematodes)
	yellow fever	yellow fever virus (Flaviviridae)
	Zika	Zika virus (Flaviviridae)
Anopheles	dirofilariosis	*Dirofilaria* (Onchocercidae, nematodes)
	malaria	*Plasmodium* (Plasmodiidae, spores, protozoa)
Culex	Japanese encephalitis	Japanese encephalitis virus (Flaviviridae)
	dirofilariosis	*Dirofilaria* (Onchocercidae, nematodes)
	West Nile fever	West Nile virus (Flaviviridae)

A. albopictus is an example of a particular global expansion facilitated by human activity and the transport of used tyres. It is currently on the list of the 100 most invasive species and is considered the most invasive mosquito species. The success of its expansion is due to several factors, including ecological plasticity, strong competitive capacity, and lack of effective control. Climate change suggests that this vector will spread further, beyond its current geographical range limits, and, moreover, it is also showing signs of adapting to cooler climates. *A. albopictus* is native of the tropical forests of Southeast Asia, but has already been reported in 25 different countries in Europe – Albania, Austria, Belgium, Croatia, Czech Republic, France, Germany, Greece, Italy, The Netherlands, Russia, Slovakia, Slovenia, Spain, and Switzerland. It has also been found in South America, Australia, North America, and Africa [16, 18, 19].

Selected transmissible diseases associated with etiological agents transmitted by mosquitoes. Mosquitoes are the most important pathogen vector group for humans, followed by ticks [20, 21]. In recent years, several diseases threatening human health have emerged in Europe due to the geographical expansion of their vectors, such as dengue fever, West Nile fever, Chikungunya fever and malaria, for example, and this worrying phenomenon should not be underestimated [9, 22, 23].

West Nile Fever. The West Nile virus (WNV) is an RNA virus and belongs to the Flaviviridae family. The primary reservoir of the pathogen is tropical and migratory birds, while mammals are accidental hosts. WNV vectors include blood-sucking flies as well as midges and deer flies, with mosquitoes (especially of the genus *Culex*) playing the largest role in transmission to humans. *C. pipiens*, which is widespread in both Europe and North America, feeds on the blood of birds and humans, and additionally overwinters in the imago stage, making it a potentially very dangerous WNV vector. Human-to-human transmission is also possible, and there are known cases of infection by blood transfusion via transplanted organs, intrauterine infection, or breast milk [24, 25, 26, 27, 28, 29]. There are at least 2 genetic lineages of the virus: lineage 1 is found in Europe, Africa, North America, Australia and India, and lineage 2, which is found primarily in Africa. The incubation period for the disease caused by this pathogen, West Nile Fever, is 3 – 15 days, with most cases being asymptomatic. The mild form of the infection is characterised by flu-like symptoms, and the severe form by meningitis and encephalitis, muscle weakness or stroke [25, 26, 28, 30].

In Poland, WNV antibodies have been found in humans, horses, and wild birds, therefore it can be considered that the virus is already present in the country, which, due to the warming climate and more convenient conditions for mosquitoes, is associated with the need for monitoring studies of vectors, as well as birds, horses, and humans [24]. Molecular mosquito surveys in Poland to date have not demonstrated the presence of this virus, indicating the need for further research in this area [31].

According to the ECDC [32], so far in 2021, 139 human cases of West Nile virus infection have been registered in Europe: 57 in Greece, 55 in Italy, 7 in Hungary, 7 in Romania, 6 in Spain, 4 in Germany and 3 in Austria. There were also 9 deaths: 7 in Greece, 1 in Spain and 1 in Romania. In neighbouring countries of the European Union, 18 cases and 3 deaths were reported in Serbia. Cases of WNV infection were found in 7 European Union countries where seasonal circulation of the virus had already been recorded.

Dirofilariosis. Nematodes of the genus *Dirofilaria* cause dirofilariosis, a zoonosis usually carried by dogs or cats, while mosquitoes, e.g. *Culex*, *Anopheles* and *Aedes*, are the vectors of invasive forms (bloodborne microfilariae). The pulmonary form of dirofilariosis in humans is caused primarily by *Dirofilaria immitis*, while the subcutaneous form is most commonly caused by *D. tenuis* and *D. repens* [33, 34]. In Poland in 2007 – 2008, cases of subcutaneous dirofilariosis were described for the first time in 5 Polish patients, but in the absence of data on the occurrence of *D. repens* in animals, it is not certain whether the recorded cases are native infections [33]. Soon afterwards, Cielecka et al. [35] described the first cases of autochthonous, subcutaneous *D. repens* infection in humans in Poland, indicating the introduction of this species into the country and the effective spread of the parasite. Between 2007 – 2011, altogether 18 *D. repens* infections were recorded in humans in Poland, with parasitic lesions located in various parts of the body [36]. In Europe, most human cases of *D. repens* have been reported in Italy and Ukraine. On the other hand, Masny et al. [37] estimated the frequency of *D. repens* infections in mosquitoes in Poland (based on PCR results) to range from 0 – 1.57%. The mosquitoes were collected from the Mazowian Province where 12 – 20% of dogs were infected with *D. repens*, and autochthonous human dirofilariosis was also found. It is worth mentioning that polymorphisms of DNA sequences within primer binding sites used in *D. repens* detection methods in European studies were identified, and non-specific amplification of DNA of another nematode, *Setaria tundra*, also occurred. The authors highlighted the need to develop a standardised test kit for sensitive and specific detection of *D. repens* [37, 38].

Dengue. The dengue virus (DENV) belongs to the RNA viruses, Flaviviridae family, and has 4 serotypes, and infection with 1 type confers weak immunity against other types. The pathogens are transmitted mainly by the mosquito *Aedes aegypti*, but also *Aedes albopictus* and *scutellaris*, and the second link in the dengue epidemic chain includes humans and some species of monkeys as reservoirs and carriers. The mosquito, after a single suck of infected blood, retains the ability to infect for its entire life. DENV loses its pathogenic capacity at ambient temperatures below 20 °C, which causes epidemics to die out in the colder seasons. The disease occurs in 3 forms: classical, haemorrhagic and shock, with an incubation period of 5 – 10 days. The classic form has a flu-like course, in the haemorrhagic form there are symptoms of haemorrhagic diathesis, and a rash appears on the skin. In the shock form, which if untreated has a 20% mortality rate, there is a sudden deterioration in the patient's condition, a drop in blood pressure, loss of consciousness, shock and disseminated intravascular coagulation (DIC) syndrome [39, 40, 41]. DENV infections occur from the South East Asian region, through Middle Eastern countries, Central and South America, Africa, and Western Pacific countries. In Europe in 2010, local disease transmission occurred in Croatia and France in which the vector was *A. albopictus*, which also tolerates colder climates. In Poland, a few cases of the disease, associated with people travelling mainly to India, have also been reported [42].

Malaria. Malaria (marsh fever) in humans is caused by 5 species of parasitic protozoa of the genus *Plasmodium*: *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi*, with *P. falciparum* and *P. vivax* posing the greatest risk to humans. Mosquitoes of the *Anopheles* species are the pathogens' vector. Since 1957, no cases of indigenous malaria transmission have been found in Poland, and since 1963 the country has been considered free of the disease. However, there are still cases imported from other countries, mainly Africa and Asia [43, 44, 45]. The most common course of malaria is fever, which recurs at intervals. The disease is also often characterised by non-specific symptoms, such as vomiting, diarrhoea, shortness of breath or muscle and joint pain. Tropical malaria, which is caused by *P. falciparum*, usually presents with more severe symptoms, where typical symptoms are accompanied by symptoms of multi-organ failure, such as hypoglycaemia, acidosis, jaundice, disseminated intravascular coagulation syndrome or acute respiratory distress syndrome [44, 45]. In Poland, 141 cases of malaria were reported between 2014 – 2018. All cases were imported from countries endemic for the disease, mainly from Africa, and 78% of the invasion was by *P. falciparum*. Recorded data indicate an increase in the number of malaria infiltrations in Poland in recent years compared to previous years, although the total number of cases remains low [46, 47].

Yellow fever. Yellow fever is an infectious disease caused by a virus belonging to the Flaviviridae family. In the urban form of infection, the virus reservoir is man, and the vector is the *Aedes aegypti* mosquito, while in the forest (classical) form, the pathogen reservoir are monkeys and the vectors are mosquitoes of the genera *Haemagogus*, *Sabethes*, and other *Aedes* species. The disease starts suddenly and is accompanied by non-specific symptoms such as fever, malaise and headache. The severe course of the infection occurs in 3 periods: 1) a period of general, non-specific symptoms, 2) a period of remission in which the body temperature reaches normal values, 3) return of fever, usually accompanied by jaundice and, in more severe cases, by signs of haemorrhagic diathesis. Although the disease can be fatal, in most cases it has a benign course and survival provides immunity for life [48, 49, 50]. Vectors carrying the pathogen are collectively found in more than 40 countries in Africa and about 15 countries in South America, with an estimated 206,000 people in 12 African countries contracting the disease in 2005, of whom 52,000 died [51, 52].

Zika. The Zika virus (ZIKV) is an enveloped arbovirus of the Flaviviridae family, possessing a single strand of RNA with positive polarity. The disease caused by this pathogen is usually asymptomatic or mild, a short-lived febrile illness, but autoimmune and neurological complications such as the Guillain-Barré syndrome as well as cases of microcephaly in the foetuses and newborns of mothers exposed to the infection, have been observed [53, 54, 55, 56]. The virus is transmitted to humans by mosquitoes during blood sucking, mainly *Aedes albopictus*, but also other *Aedes* species. Transmission of the virus is also possible through the placenta, via breast milk or sexually and during blood transfusions [53, 54, 55, 56, 57]. The pathogen is the cause of major epidemic outbreaks in Africa and Asia, and more recently in previously infection-free areas of the Pacific, South America, and the Caribbean. In 2015, local transmission of the virus was confirmed in several countries in Central and South America, the Caribbean, Mexico and Cape Verde, single cases were also reported in Europe – Germany, France, Italy, the UK, Ireland, Denmark, Spain, Austria and Finland, as well as in the USA, Israel, Canada, Japan, and Australia, which were imported from endemic areas [53]. Recently, it has been indicated that the first locally acquired infections were recorded in southern France in 2019 [58].

Chikungunya fever. The Chikungunya fever virus (CHIKV) is an RNA virus of the Togaviridae family. It causes the Chikungunya fever (CHIK), and is transmitted by the *Aedes* species of mosquitoes (*A. aegypti*, *A. albopictus*). The disease usually manifests itself with a sudden onset of fever, severe pain that limits the mobility of many joints, a maculopapular rash, headache, and general weakness. Blood-borne transmission of the virus and maternal-foetal transmission have also been reported. CHIK is endemic in many countries in Africa, Asia and the Indian and Pacific Oceans, but in late 2013, local transmission were found in the Americas and the Caribbean islands [59, 60, 61, 62, 63]. Local transmission of Chikungunya fever in Europe was first reported in 2007 in Italy. Approximately 200 cases have been confirmed, which shows the transmissibility of *A. albopictus* also in Europe. In 2010, France experienced the second indigenous transmission of this virus in Europe [61, 63, 64].

Japanese encephalitis. Arboviruses Flaviviridae cause Japanese encephalitis, a disease of the central nervous system. The viruses are transmitted by mosquitoes of the *Culex* genus. The species *C. tritaeniorhynchus* is the main vector in most endemic areas and is associated with rice production, as watery rice fields provide the best habitat for the development of these mosquito larvae. Furthermore, the pathogen has been isolated from about 30 species of mosquitoes belonging to different genera, but the presence of the virus does not determine their ability to transmit. It should also be added that viraemia is detected in many vertebrates, but only pigs and birds have sufficiently high levels of the virus in their blood to allow infection by mosquitoes. In humans, the infection predominantly manifests with flu-like symptoms, while about 1% of patients develop a severe form accompanied by encephalitis (mortality rate up to 30%). The disease occurs mainly in Southeast Asia, as well as Pakistan, India, Sri Lanka, Nepal, Papua New Guinea, and Australia [51, 65, 66, 67, 68].

Risks to soldiers and military personnel from exposure to mosquitoes. Over the centuries, epidemics during wars have significantly reduced the combat power of armies, caused the suspension or abandonment of military operations, and additionally wreaked havoc on the civilian population. Until World War I, infectious diseases rather than injuries associated with military action were the leading cause of morbidity and mortality among soldiers [69]. In those days, of the 12 'war pestilences', 5 were transmitted by vectors: plague, yellow fever, malaria, typhoid, and relapsing fever [70]. Since the Russo-Japanese War (1904–1905) and World War I, partly due to weapons development and advances in military hygiene and disease control methods (e.g. vaccination, chemoprophylaxis, antibiotics, medical treatment, personal protection, and vector control measures), there has been a steady decline in the incidence of infectious diseases among soldiers and civilians [71]. During World War II, vector-borne diseases posed a persistent threat to warring armies [72]. Today, infectious diseases continue to be of key importance in developing countries in terms of morbidity and mortality among the population [73]. Military activities in areas of hitherto isolated ecological niches, the destruction of human and animal habitats, the migration of human populations, and the destruction of local infrastructure, all provide conditions conducive to the development in nature transmissible diseases [74].

Vectors and the diseases that accompany them have changed their geographical range over the centuries, qualitatively and quantitatively, and, among other things, are a growing problem for military contingents deployed outside the home country [75]. The armed forces brought together under the NATO (North Atlantic Treaty Organisation), which are engaged around the world, are constantly being forced to develop new strategies to control infectious disease vectors for the deployment of military contingents. The vector-borne disease burden on armed forces can be significant, and most Western armies have developed vector control strategies [76]. Mosquito surveillance data allows risk assessment before implementation and planning of preventive countermeasures. Entomological and epidemiological data collected from mosquito surveillance at military installations are crucial to forecast changes in the mosquito population and the monitoring of mosquito-borne diseases in these areas [77]. Preventive countermeasures and unit protection measures are used to reduce soldiers' exposure to mosquito-borne diseases. Preventive measures include proper use (manner of wearing) of uniforms, application of repellent to exposed skin, use of repellents, such as permethrin, to impregnate uniforms and the use of mosquito nets, curtains, tents, and insecticide-treated nets. Collective protection measures, on the other hand, include site selection for military bases, environmental management, spraying in spaces that may be mosquito habitats, and indoor spraying. In a combat environment, personal countermeasures are often the last line of protection for soldiers. To be effective, collective protection measures require knowledge of the entomological situation regarding mosquitoes, and the presence of appropriate personnel competent to implement the chosen vector control methods. Many of the tools now used worldwide for vector control and personal protection come from military research. Most of the repellents and insecticide spraying systems currently in use were designed and introduced for use by the armed forces. During World War II, the United States Armed Forces worked on new repellents, such as dimethyl phthalate and indalone, in addition, the repellent DDT (dichlorodiphenyltrichloroethane) was developed [78, 79, 84]. Additionally, the effectiveness of permethrin-impregnated field uniforms against arthropod stings has been evaluated in a field studies. Most of these recently developed measures are now being used to effectively protect refugee and displaced human populations exposed to vectors. Other protective measures, which include, for example, impregnated tents, are or will be adapted for wider military use [79].

To design an effective vector control strategy, it is necessary to acquire knowledge of the entomological situation in areas of military deployment. Entomological research is a common tool in assessing health risks during deployment for most western armies [80, 81]. For example, the information obtained on malaria transmission and the area of distribution of the vector of this disease with confirmed carriage, makes it possible to determine the level of risk depending on the distribution of troops and the susceptibility of vectors to insecticides. A study on the Ivory Coast (Côte d'Ivoire) of West Africa, found that the risk of malaria for soldiers living in barracks was very high (high chance of being bitten by parasite-infected mosquitoes) [82]. Military research strategies are of particular interest not only to the military community. The data obtained may influence, among other things, the expansion of information on the exposure of military contingent personnel, the public health exposure assessment, vector-borne disease epidemiology, and trends for local populations, such as a report of malaria transmission in central Dakar and the epidemiology of leishmaniasis in Egypt [81, 83].

At the same time, bearing in mind the health security of the armed forces of NATO countries, actions have been initiated concerning the reduction of soldiers' exposure to the threat of infectious diseases in the area of broadly understood prophylaxis. The US Army has responded to the threat from vector-borne infectious diseases since the early part of the 20th century. This is the area by the study of Major Walter Reed and other researchers investigating the transmission routes of the yellow fever virus [84].

These initial successes in the field of medical entomology prepared the ground for subsequent efforts by the US Army to control vectors and prevent vector-borne diseases, which expanded during World War II. The US combat experience led to the appointment of military entomologists and the establishment of vector-borne disease control units [84, 85]. When Poland joined NATO in 1999, it committed itself to adopting common principles of the organisation, including in the area of medical security. The area of preventive medicine during military operations, including surveillance and vector control of infectious diseases [86], plays an important role in NATO standardisation documents on medical security. In the course of work at NATO level, a standardisation document and a manual governing the implementation of such surveillance and control during the execution of military operations [87, 88] have been prepared. The document has been ratified and implemented by Poland. At the present time, on the basis of the aforementioned regulation, an applicable instruction is being prepared. In addition, according to legal regulations, information on threats of infectious diseases should be transmitted to allied troops staying temporarily or permanently on the territory of Poland.

Since 2017, as part of its preventive medicine activities, the Epidemiological Response Centre of The Polish Armed Forces has been carrying out an assessment of the exposure of soldiers and military personnel to tick-borne diseases. From 2022, the assessment will be extended to another infectious disease vectors – mosquitoes. The result of the assessment will be a report indicating the level of health risk estimated for each of the sites covered by the surveillance and ways of appropriate prevention. The report will forwarded to the various commands, including those of allied troops stationed in Poland.

Thanks to commercially available vaccination programmes, some diseases no longer pose a risk to military personnel and military operations (e.g. yellow fever and Japanese encephalitis). On the other hand, known re-emerging diseases and newly emerging diseases continue to cause concern due to the lack of specific and effective prevention. Scientific advances have brought a reduction in the impact of arthropod-borne diseases on the armed forces, but the threat is still present, and limitations in vector control or in the use of personal protective equipment could result in these diseases having the same impact on military operations as in the past.

SUMMARY

The most current public health threats include newly emerging infectious diseases among people. In Europe, between 2010 – 2015, cases caused by hitherto unknown etiological agents were reported, as well as the re-emergence of diseases that had already occurred in previous years in other European countries, making it important for people travelling in Europe to be aware of the risk. Treatment for transmissible diseases is limited, therefore prevention is an important point in their development, and those exposed should be advised that minimising risk is mainly about avoiding vectors. The risk of infection with mosquito-borne pathogens is generally greatest from dusk to dawn, although *A. albopictus* feeds both during the day and night. To highlight vector-borne infectious diseases, it is important to mention that they have been the cause of dangerous pandemics, an example being the plague, which caused the deaths of 25 – 40 million people [6]. In this area, a whole cross-section of vulnerable occupational groups should not be forgotten, such as farmers, breeders, or soldiers and other military personnel who, while on missions or in military contingents, are directly exposed to new infectious diseases. In many regions of the world, including

Poland, soldiers are the most numerous professional group who perform their duties in areas with different climatic and sanitary conditions, where they stay in a specific place and time for a period of many months. Soldiers importing infectious and parasitic diseases, including tropical diseases, into Poland are entering civilian health care, therefore the national health service should also be aware of the risks associated with newly emerging pathogens.

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REFERENCES

1. Huntington MK, Allison J, Nair D. Emerging Vector-Borne Diseases. Am Fam Physician. 2016;94(7):551–557.
2. Henszel Ł, Janiec J, Izdebski R, et al. Emerging infectious diseases not covered by routine vaccination in Europe in 2010–2015 – the review of WHO and ECDC notifications for the National IHR Focal Point in Poland. Przegl Epidemiol. 2015;69:679–686.
3. McArthur DB. Emerging Infectious Diseases. Nurs Clin N Am. 2019;54(2):297–311. https://doi.org/10.1016/j.cnur.2019.02.006
4. Weaver SC, Charlier C, Vasilakis N, et al. Zika, Chikungunya, and Other Emerging Vector-Borne Viral Diseases. Annu Rev Med. 2018;69:395–408. doi:10.1146/annurev-med-050715-105122
5. Sigfrid L, Reusken C, Eckerle I, et al. Preparing clinicians for (re-) emerging arbovirus infectious diseases in Europe. Clin Microbiol Infect. 2018;24(3):229–239. http://dx.doi.org/10.1016/j.cmi.2017.05.029
6. Chala B, Hamde F. Emerging and Re-emerging Vector-Borne Infectious Diseases and the Challenges for Control: A Review. Front Public Health. 2021;9:715759. doi: 10.3389/fpubh.2021.715759
7. Semenza JC, Suk JE. Vector-borne diseases and climate change: a European perspective. FEMS Microbiol Lett. 2018;365(2):fnx244. doi: 10.1093/femsle/fnx244
8. Kuna A, Gajewski M, Biernat B. Selected arboviral diseases imported to Poland – current state of knowledge and perspectives for research. Ann Agric Environ Med. 2019;26(3):385–391. doi: 10.26444/aaem/102471
9. El-Sayed A, Kamel M. Climatic changes and their role in emergence and re-emergence of diseases. Environ Sci Pollut Res. 2020;27(18):22336–22352. https://doi.org/10.1007/s11356-020-08896-w
10. Faburay B. The case for a 'one health' approach to combating vector-borne diseases. Infect Ecol Epidemiol. 2015;5:28132. http://dx.doi.org/10.3402/iee.v5.28132
11. Paternoster G, Tomassone L, Tamba M, et al. The Degree of One Health Implementation in the West Nile Virus Integrated Surveillance in Northern Italy, 2016. Front Public Health. 2017;5:236. https://doi.org/10.3389/fpubh.2017.00236
12. Sinclair JR. Importance of a One Health approach in advancing global health security and the Sustainable Development Goals. Rev Sci Tech Off Int Epiz. 2019;38(1):145–154. doi: 10.20506/rst.38.1.2949
13. Ministry of National Defence website https://www.gov.pl/web/obrona-narodowa/misje (access: 2021.06.07).
14. Kowalska-Ulczyńska B, Giłka W. Mosquitoes (*Diptera: Culicidae*) of the vicinity of Wyskok in the Masuria. Wiad Entomol. 2003;22(2):91–100. Article in Polish.
15. Krasoń K, Larska M. The risk of diseases transmitted by insect vectors in animals in Europe. Post Mikrobiol. 2018;57(4):385–397. doi: 10.21307/PM-2018.57.4.385
16. Lwande OW, Obanda V, Lindström A, et al. Globe-Trotting *Aedes aegypti* and *Aedes albopictus*: Risk Factors for Arbovirus Pandemics. Vector Borne Zoonotic Dis. 2020;20(2):71–81. doi: 10.1089/vbz.2019.2486
17. Abdullahi AM, Sarmast ST, Singh R. Molecular Biology and Epidemiology of Neurotropic Viruses. Cureus 2020;12(8):e9674. doi: 10.7759/cureus.9674
18. Medlock JM, Hansford KM, Versteirt V, et al. An entomological review of invasive mosquitoes in Europe. Bull Entomol Res. 2015;105:637–663. doi:10.1017/S0007485315000103
19. Reinhold JM, Lazzari CR, Lahondère C. Effects of the Environmental Temperature on *Aedes aegypti* and *Aedes albopictus* Mosquitoes: A Review. Insects. 2018;9(4):158. doi:10.3390/insects9040158
20. World Health Organization Vector-borne diseases https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases (access: 2021.11.30).
21. Mansfield KL, Jizhou L, Phipps LP, et al. Emerging tick-borne viruses in the twenty-first century. Front Cell Infect Microbiol. 2017;7:298. doi: 10.3389/fcimb.2017.00298
22. Paixão ES, Teixeira MG, Rodrigues LC. Zika, chikungunya and dengue: the causes and threats of new and re-emerging arboviral diseases. BMJ Glob Health. 2017;3: e000530. doi:10.1136/bmjgh-2017-000530
23. Pierson TC, Diamond MS. The Continued Emerging Threat of Flaviviruses. Nat Microbiol. 2020;5(6):796–812. doi:10.1038/s41564-020-0714-0
24. Niczyporuk SJ. West Nile Virus in Poland – real threat in the light of the reports from the Conference "The current problems concerning bloodborne pathogens" (10 March 2017, Warsaw). J Transf Med. 2017;10(2):54–62. Article in Polish.
25. de Castro-Jorge LA, Lima Siconelli MJ, dos Santos Ribeiro B, et al. West Nile virus infections are here! Are we prepared to face another flavivirus epidemic? Rev Soc Bras Med Trop. 2019;52: e20190089. doi: 10.1590/0037-8682-0089-2018
26. Meyding-Lamadé U, Craemer E, Schnitzler P. Emerging and re-emerging viruses affecting the nervous system. Neurol Res Pract. 2019;1(20). https://doi.org/10.1186/s42466-019-0020-6
27. Vonesch N, Binazzi A, Bonafede M, et al. Emerging zoonotic viral infections of occupational health importance. Pathog Dis. 2019;77(2):ftz018. doi:10.1093/femspd/ftz018
28. Zannoli S, Sambri V. West Nile Virus and Usutu Virus Co-Circulation in Europe: Epidemiology and Implications. Microorganisms. 2019;7(7):184. doi:10.3390/microorganisms7070184
29. Vilibic-Cavlek T, Savic V, Klobucar A, et al. Emerging Trends in the West Nile Virus Epidemiology in Croatia in the 'One Health' Context, 2011–2020. Trop Med Infect Dis. 2021;6(3):140. https://doi.org/10.3390/tropicalmed6030140
30. Moniuszko-Malinowska A, Czupryna P, Dunaj J, et al. West Nile virus and USUTU – a threat to Poland. Przegl Epidemiol. 2016;70(1):7–10;99–102.
31. Kubica-Biernat B, Kruminis-Łozowska W, Stańczak J, et al. A study on the occurrence of West Nile virus in mosquitoes (Diptera: Culicidae) on the selected areas in Poland. Wiad Parazytol. 2009;55(3):259–263. Article in Polish.
32. European Centre for Disease Prevention and Control. Communicable Disease Threats Report, week 45, 7–13 November 2021. https://www.ecdc.europa.eu/en/publications-data/communicable-disease-threats-report-7-13-november-2021-week-45 (access: 2021.12.04).
33. Żarnowska-Prymek H, Cielecka D, Salamatin R. *Dirofilariasis – Dirofilaria repens* – first time described in Polish patients. Przegl Epidemiol. 2008;62(3):547–551. Article in Polish.
34. Capelli G, Genchi C, Baneth G, et al. Recent advances on *Dirofilaria repens* in dogs and humans in Europe. Parasit Vectors. 2018;11(1):663. https://doi.org/10.1186/s13071-018-3205-x
35. Cielecka D, Żarnowska-Prymek H, Masny A, et al. Human dirofilariosis in Poland: the first cases of autochthonous infections with *Dirofilaria repens*. Ann Agric Environ Med. 2012;19(3):445–450.
36. Fuehrer HP, Morelli S, Unterköfler MS, et al. *Dirofilaria spp.* and *Angiostrongylus vasorum*: Current Risk of Spreading in Central and Northern Europe. Pathogens. 2021;10(10):1268. https://doi.org/10.3390/pathogens10101268
37. Masny A, Sałamatin R, Rożej-Bielicka W, et al. Is molecular xeno-monitoring of mosquitoes for *Dirofilaria repens* suitable for dirofilariosis surveillance in endemic regions? Parasit Res. 2016;115(2):511–525. doi: 10.1007/s00436-015-4767-6
38. Rydzanicz K, Gołąb E, Rożej-Bielicka W, et al. Screening of mosquitoes for filarioid helminths in urban areas in south western Poland – common patterns in European *Setaria tundra* xenomonitoring studies. Parasitol Res. 2019;118(1):127–138. https://doi.org/10.1007/s00436-018-6134-x
39. Pathak VK, Mohan M. A notorious vector-borne disease: Dengue fever, its evolution as public health threat. J Family Med Prim Care 2019;8(10):3125–3129. doi:10.4103/jfmpc.jfmpc_716_19
40. Harapan H, Michie A, Sasmono RT, et al. Dengue: A Minireview. Viruses. 2020;12:829. doi:10.3390/v12080829
41. Roy SK, Bhattacharjee S. Dengue virus: epidemiology, biology, and disease aetiology. Can J Microbiol. 2021;67(10):687–702. dx.doi.org/10.1139/cjm-2020-0572
42. Pancer K, Szkoda MT, Gut W. Imported cases of dengue in Poland and their diagnosis. Przegl Epidemiol. 2014;68(4):651–655.
43. Walczak A. About the needs of anti-malarial prophylactics among Polish travellers. Probl Hig Epidemiol. 2014;95(1):1–5. Article in Polish.

44. Malchrzak W, Rymer W, Inglot M. Imported malaria caused by *Plasmodium falciparum* – case report. Przegl Epidemiol. 2018;72(3):363–370. doi:10.32394/pe.72.3.12
45. Kulawiak N, Borys S, Roszko-Wysokińska A, et al. Challenges in the diagnosis and treatment of malaria in Polish workers returning from Africa: a case series and review of literature. Int Marit Health. 2022;73(1):46–51. doi: 10.5603/IMH.2022.0006.
46. Sadkowska-Todys M, Zieliński A, Czarkowski MP. Infectious diseases in Poland in 2016. Przegl Epidemiol. 2018;72(2):129–141.
47. Stępień M. Malaria in Poland in 2014–2018. Przegl Epidemiol. 2019;73(2):201–209. https://doi.org/10.32394/pe.73.19
48. Korzeniewski K. Viral haemorrhagic fevers. Forum Med Rodz. 2012;6(5):205–221. Article in Polish.
49. Sacchetto L, Drumond BP, Han BA, et al. Re-emergence of yellow fever in the neotropics – quo vadis? Emerg Top Life Sci. 2020;4(4):411–422. https://doi.org/10.1042/ETLS20200187
50. Socha W, Kwaśnik M, Larska M, et al. Vector-Borne Viral Diseases as a Current Threat for Human and Animal Health – One Health Perspective. J Clin Med. 2022;11(11):3026. https://doi.org/10.3390/jcm11113026
51. Cholewiński M, Derda M, Klimberg A, et al. Vectors carrying parasitic, bacterial and viral diseases in humans. I. Flies (Diptera). Hygeia Public Health 2017;52(2):96–102. Article in Polish.
52. Chippaux JP, Chippaux A. Yellow fever in Africa and the Americas: a historical and epidemiological perspective. J Venom Anim Toxins Incl Trop Dis. 2018;24:20. https://doi.org/10.1186/s40409-018-0162-y
53. Gańczak M. Zika – an emerging infectious disease. The risk assessment from Polish perspective. Przegl Epidemiol. 2016;70(1):1–6, 93–97.
54. Agumadu VC, Ramphul K. Zika Virus: A Review of Literature. Cureus 2018;10(7):e3025. doi: 10.7759/cureus.3025
55. Kazmi SS, Ali W, Bibi N, et al. A review on Zika virus outbreak, epidemiology, transmission and infection dynamics. J of Biol Res-Thessaloniki. 2020;27:5. https://doi.org/10.1186/s40709-020-00115-4
56. Sharma V, Sharma M, Dhull D, et al. Zika virus: an emerging challenge to public health worldwide. Can J Microbiol. 2020;66(2):87–98. dx.doi.org/10.1139/cjm-2019-0331
57. Gliński Z, Kostro K. Can domestic animals get infected with Zika virus? Życie Wet. 2016;91(4):228–231. Article in Polish.
58. Masmejan S, Musso D, Vouga M, et al. Zika Virus. Pathogens. 2020;9(11):898. doi:10.3390/pathogens9110898
59. Walczak A, Milona M. Potential threat for Polish travellers – Chikungunya fever. Probl Hig Epidemiol. 2015;96(2):329–334. Article in Polish.
60. Silva LA, Dermody TS. Chikungunya vius: epidemiology, replication, disease mechanisms, and prospective intervention strategies. J Clin Invest. 2017;127(3):737–749. https://doi.org/10.1172/JCI84417
61. Moizéis RNC, de Medeiros Fernandes TAA, da Matta Guedes PM, et al. Chikungunya fever: a threat to global public health. Pathog Glob Health. 2018;112(4):182–194. https://doi.org/10.1080/20477724.2018.1478777
62. Silva JVJ, Ludwig-Begall LF, de Oliveira-Filho EF, et al. A scoping review of Chikungunya virus infection: epidemiology, clinical characteristics, viral co-circulation complications, and control. Acta Trop. 2018;188:213–224. https://doi.org/10.1016/j.actatropica.2018.09.003
63. Tjaden NB, Cheng Y, Beierkuhnlein C, et al. Chikungunya Beyond the Tropics: Where and When Do We Expect Disease Transmission in Europe? Viruses 2021;13:1024. https://doi.org/10.3390/v13061024.
64. World Health Organization, Fact sheet – Chikungunya in the WHO European Region. https://www.euro.who.int/en/media-centre/sections/fact-sheets/2014/03/fact-sheets-world-health-day-2014-vector-borne-diseases/fact-sheet-chikungunya-in-the-who-european-region (access: 2021.12.04).
65. Pearce JC, Learoyd TP, Langendorf BJ, et al. Japanese encephalitis: the vectors, ecology, and potential for expansion. J Travel Med. 2018;25, Suppl 1:S16-S26. doi: 10.1093/jtm/tay009
66. van den Hurk AF, Pyke AT, Mackenzie JS, et al. Japanese Encephalitis Virus in Australia: From Known Known to Know Unknown. Trop Med Infect Dis. 2019;4(1):38. doi:10.3390/tropicalmed4010038
67. Mulvey P, Duong V, Boyer S, et al. The Ecology and Evolution of Japanese Encephalitis Virus. Pathogens. 2021;10(12):1534. https://doi.org/10.3390/pathogens10121534
68. Caldwell M, Boruah AP, Thakur KT. Acute neurologic emerging flaviviruses. Ther Adv Infect Dis. 2022;9:1–19. doi: 10.1177/20499361221102664
69. Smallman-Raynor MR, Cliff AD. Impact of infectious diseases on war. Infect Dis Clin North Am. 2004;18(2):341–368. doi: 10.1016/j.idc.2004.01.009
70. Prinzing F, Westergaard H. Epidemics resulting from wars. Oxford: Clarendon Press, 1916.
71. Hoeffler DF, Melton LJ 3rd. Changes in the distribution of Navy and Marine Corps casualties from World War I through the Vietnam conflict. Mil Med. 1981;146(11):776–779.
72. Mc Coy OR. Incidence of insect-borne diseases in US Army during World War II. Mosq News. 1946;6(4):214.
73. Gayer M, Legros D, Formenty P, et al. Conflict and emerging infectious diseases. Emerg Infect Dis. 2007;13(11):1625–1631. doi: 10.3201/eid1311.061093
74. Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis. 1995;1(1):7–15. doi: 10.3201/eid0101.950102
75. Zapor MJ, Moran KA. Infectious diseases during wartime. Curr Opin Infect Dis. 2005;18(5):395–399. doi: 10.1097/01.qco.0000182102.50430.2c
76. Pages F. Vector control for armed forces: a historical requirement requiring continual adaptation. Med Trop. (Mars) 2009;69(2):165–172.
77. Britch SC, Linthicum KJ, Anyamba A, et al. Satellite vegetation index data as a tool to forecast population dynamics of medically important mosquitoes at military installations in the continental United States. Mil Med. 2008;173(7):677–683. doi: 10.7205/milmed.173.7.677
78. Machault V, Orlandi-Pradines E, Michel R, et al. Remote sensing and malaria risk for military personnel in Africa. J Travel Med. 2008;15(4):216–220. doi: 10.1111/j.1708-8305.2008.00202.x
79. Faulde MK, Uedelhoven WM, Malerius M, et al. Factory-based permethrin impregnation of uniforms: residual activity against *Aedes aegypti* and *Ixodes ricinus* in battle dress uniforms worn under field conditions, and cross-contamination during the laundering and storage process. Mil Med. 2006;171(6):472–477. doi: 10.7205/milmed.171.6.472
80. Coleman RE, Hochberg LP, Putnam JL, et al. Use of vector diagnostics during military deployments: recent experience in Iraq and Afghanistan. Mil Med. 2009;174(9):904–920. doi: 10.7205/milmed-d-00-2509
81. Hanafi HA, Fryauff DJ, Modi GB, et al. Bionomics of phlebotomine sandflies at a peacekeeping duty site in the north of Sinai, Egypt. Acta Trop. 2007;101(2):106–114. doi:10.1016/j.actatropica.2006.12.005
82. Girod R, Orlandi-Pradines E, Rogier C, et al. Malaria transmission and insecticide resistance of *Anopheles gambiae* (*Diptera: Culicidae*) in the French military camp of Port-Bouët, Abidjan (Côte d'Ivoire): implications for vector control. J Med Entomol. 2006;43(5):1082–1087. doi:10.1603/0022-2585(2006)43[1082:mtairo]2.0.co;2
83. Pagès F, Texier G, Pradines B, et al. Malaria transmission in Dakar: a two-year survey. Malar J. 2008;7:178. doi: 10.1186/1475-2875-7-178
84. Kitchen LW, Lawrence KL, Coleman RE. The role of the United States military in the development of vector control products, including insect repellents, insecticides, and bed nets. J Vector Ecol. 2009;34(1):50–61. doi: 10.1111/j.1948-7134.2009.00007.x
85. Lang JT. Contributions of military pest management to preventive medicine. Mil Med. 1988;153(3):137–139.
86. NATO Allied Joint Publication AJP-4.10, Edition C, Version 1, Allied Joint Doctrine for Medical Support, 2019.
87. Allied Medical Publication AMedP-4.2, Edition A, Version 2, Deployment Pests and Disease Vectors Surveillance and Control, 2017.
88. Standards Related Document AMedP-4.2-1, Edition A Version 1, Contingency Pest, and Vector Surveillance, 2018.