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Analysis of the epidemiological and epizootic situation of alveolar echinococcosis in the world

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Abstract

This review article presents literature data on the distribution of alveolar echinococcosis cases across the world over the past 30 years (1993-2023), statistical data from the WOAH for the past 5 years (2020-2024), and the research results reported by domestic scientists.

Alveolar echinococcosis, also known as multilocular echinococcosis, is one of the most dangerous zoonotic parasitic infections. The causative agent, the cestode Echinococcus multilocularis, infects carnivorous animals, small rodents, and humans. Humans, as accidental intermediate hosts, are at high risk for severe complications, including liver and other organ damage. This infection has been recorded in Canada, the USA, Germany, France, Switzerland, Austria, Belgium, the Netherlands, the Czech Republic, Slovakia, Sweden, Denmark, the UK, China, India, Pakistan, Nepal, Bhutan, Iran, Iraq, Mongolia, Lithuania, Latvia, Estonia, Russia, Belarus, the Kyrgyz Republic, and the Republic of Kazakhstan.

The World Health Organization classifies this infection as one of the 17 neglected diseases requiring control and elimination by 2050.

Keywords: alveolar echinococcosis; definitive host; epidemiological situation; epizootiological monitoring; intermediate host; WOAH.

Introduction

Alveolar echinococcosis (AE) is one of the most dangerous zoonoses prevalent in countries with temperate and cold climates. The disease poses a particular threat in regions of Europe, Asia, and North America, where high morbidity rates are detected among wild and domestic animals.

Echinococcus multilocularis has a complex life cycle involving definitive and intermediate hosts. Wild carnivores, such as foxes and raccoon dogs, are the primary carriers, and dogs can become infected by consuming infected rodents. The feces of infected animals contain the parasite eggs, which contaminate the environment and can infect intermediate hosts. Humans serve as intermediate hosts and a biological dead end for *E. multilocularis*.

Human infection occurs through the following three major routes:

- Direct exposure to wild carnivores (such as Arctic foxes and foxes) through contact with their pelts and ingestion of oncospheres present on their fur;
- Consumption of wild plants, berries, or water from sources used by wild carnivores; and
- Exposure to dogs, which become actively infected by feeding on wild rodents. In this case, human infection occurs under the same conditions as in echinococcosis.

High infection risks (within endemic areas) are found among hunters and their families, fur trappers, taxidermists, and rural residents, where dogs play a significant role in daily life and farming. In such cases, children are at particularly high risk.

The most comprehensive analysis of the global distribution of AE cases was conducted by *P.R. Torgerson, K. Keller, M. Magnotta* and *N. Ragland.* In 2010, they published an article using publications from authors worldwide and a stochastic approach to uncertainty modeling. They stated that AE is highly endemic in Sichuan, Gansu, Qinghai, and Ningxia provinces in China, although the actual incidence in the Tibet Autonomous Region may be much higher than the estimated incidence. AE is also found in the USA, Canada, Switzerland, southern Germany, eastern France, and Russia, which is a major endemic zone for AE. Unlike China, Russia lacks publications on mass ultrasound screenings of the population; however, several serological studies confirm the possibility of a high number of cases, especially in Siberia [1].

In China, the majority of human AE cases have been confirmed in Tibet, Xinjiang, Sichuan, Qinghai, and Gansu. In Japan, the endemic zone for AE is Hokkaido Island, where approximately 20 human cases are confirmed annually [2-4]. Studies by *X. Wang, J. Liu* and *Q. Zuo* have demonstrated that voles are probably more important natural intermediate hosts for both *E. multilocularis* and *E. shiquicus* in Shiqu County on the eastern Tibetan Plateau. Therefore, they recommended that future studies on human AE epidemiology should include small mammals as a vital component for research and control purposes [5].

AE foci are generally associated with the habitats of definitive hosts involved in the life cycle of the parasite. In the USA and northern Canada, foci are related to the habitats of the Arctic fox; in Austria, Switzerland, and southern Germany, foci are related to the habitats of the red fox; and in Japan, foci are related to the habitats of other fox species. In Russia, the largest infection foci are found in Chukotka and Kamchatka [6].

A high prevalence of AE has been reported in Kyrgyzstan [7]. According to statistical reports from medical institutions and regional disease prevention centers of the Kyrgyz Republic from 1996 to 2018, the average long-term incidence rate of AE per 100,000 population was 2.2, with a minimum of 0.4 (1996) and a maximum of 3.9 (2015) [8].

An isolated AE case was reported in India in a man from the mountainous regions of Kashmir; however, no animal reservoir has yet been identified [9].

Data regarding AE cases are lacking in Afghanistan. However, the literature reports a case of an Afghan patient treated in the UK [10], suggesting potential future cases, particularly in the north of the country. Between 1948 and 1993, 37 cases of AE were recorded in Iran, or fewer than 1 case per year. One case of AE has been reported in northern Iraq [11].

Data on human AE cases in Belarus are scarce, with reports of only two patients with AE, one from Brest and the other from the Mogilev region. The actual situation concerning AE in Ukraine and Moldova remains unknown due to the lack of published data. AE has been diagnosed in patients from across the Baltic region. In Lithuania, 178 patients were recorded between 1997 and 2014, and the incidence of AE was found to increase from 0.03 in 2004 to 0.57 in 2009 and 0.74 in 2012. To date, only 13 patients with echinococcosis have been registered in Estonia; however, the specific Echinococcus species was not identified [12]. In Latvia, 29 AE cases were reported between 1996 and 2010 [13].

In France, a large-scale study of foxes revealed *E. multilocularis* in 36 of 44 administrative units in the northeastern part of the country. Furthermore, 26 new endemic areas were identified, with prevalence rates of 7% (3/41) and 17% (1/6), respectively [14, 15].

According to the WOAH [16], *E. multilocularis* was detected in domestic and wild animals in regions of America, Asia, and Europe between 2020 and 2024 (Figures 1, 2).

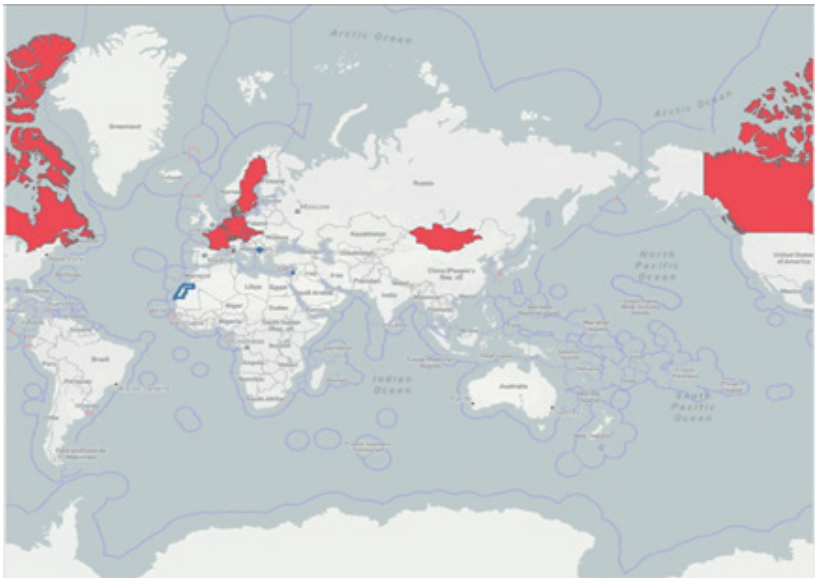

Figure 1 – Map of *Echinococcus multilocularis* occurrence in wild animals according to WOAH data for 2020-2024

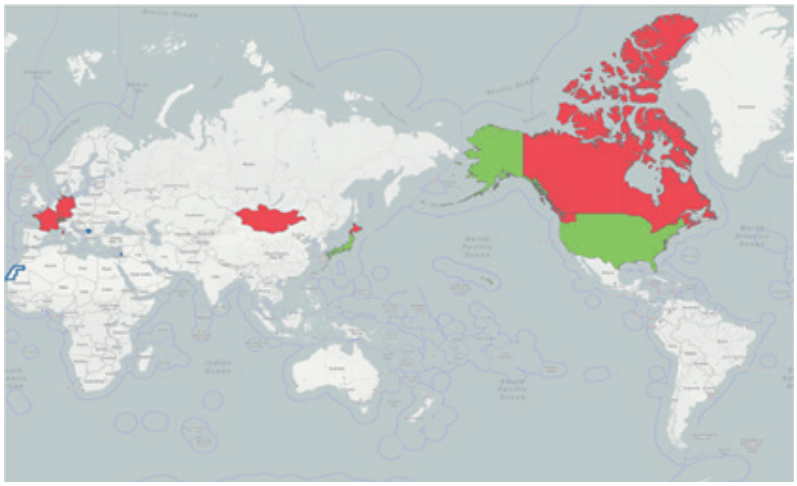

Figure 2 – Map of *Echinococcus multilocularis* occurrence in domestic animals according to WOAH data for 2020-2024

In 2020, AE was recorded among domestic and wild animals in regions of Europe, America, and Asia. Furthermore, *E. multilocularis* was recorded in wild and domestic animals in Canada, Mongolia, France, Germany, and Switzerland; in wild animals in Belgium, the Czech Republic, the Netherlands, and Sweden; and in domestic animals only in Japan. In 2021, E. multilocularis was recorded in wild and domestic animals in Canada, Mongolia, Germany, France, and Switzerland and only in wild animals in Austria, Belgium, the Czech Republic, the Netherlands, Slovakia, and Sweden. In 2022, AE was registered in wild and domestic animals in Canada, Mongolia, Germany, Switzerland, and France and only in wild animals in the Czech Republic, Slovakia, and Sweden. In 2023, AE was recorded among animals only in regions of Europe and Asia. In Sweden and the Czech Republic, it was detected in wild animals, and in Switzerland and Mongolia, it was detected in both wild and domestic animals. In 2024, AE was recorded among animals only in regions of Europe and America. AE was recorded in wild animals in Austria, Belgium, the Czech Republic, Denmark, the Netherlands, Slovakia, and Sweden; only in domestic animals in the USA; and in both wild and domestic animals in Germany, Switzerland, and Canada.

Among neighboring countries sharing land borders with Kazakhstan, AE showed a wide distribution in the Russian Federation and the Kyrgyz Republic [7, 17]. This study investigated *Echinococcus*

granulosus s.l. and *Echinococcus multilocularis* in dog feces and the environment in two Kyrgyz districts. In dog feces, E. granulosus s.l. eggs were found in ~4.2% of samples in Alay and ~3.5% in Kochkor; E. multilocularis eggs in 2.8% and 3.2%, respectively. Environmental contamination was also similar: 8.3 vs. 7.5 eggs/m² for E. granulosus s.l. and 4.4 vs. 5.0 eggs/m² for E. multilocularis. Despite higher human AE incidence in Alay (162 vs. 21 cases per 100,000), no clear association was found between human cases and egg contamination, though contamination increased in autumn after dogs returned from pastures. [18]. In the Russian Federation, *E. multilocularis* was detected in the Taymyr Peninsula in 64.1% of examined Arctic foxes and in one of two red foxes, whereas it was less frequent in dogs and wolves. In Magadan oblast, the parasite was detected in 25.4% of Arctic foxes but not in dogs (>800 examined). Significant infection rates were recorded in Chukotka and Yakutia [19, 20]. In Central Asia, Kyrgyzstan shows the highest burden of alveolar echinococcosis with 140–200 cases annually (AIR 2.62/100,000). Kazakhstan reported 135 cases in 1996–2019 (AIR 0.037/100,000), while Uzbekistan, Iran, Armenia, and Tajikistan had very low AIRs (≤0.1/100,000). In Turkey, 641–918 cases were recorded from 1939–2018, averaging ~20 new cases annually (AIR 0.023/100,000) [21]. In the Kyrgyz Republic, *T.A. Abdyzhaparov* [22] reported the highest percentage of infected animals among gray (4.0%) and red (2.4%) marmots, ground squirrels (3.8%), and forest dormice (2.6%). Moreover, studies by *C.A. Alvarez Rojas, P.A. Kronenberg, S. Aitbaev* et al. [23] in Kyrgyzstan reported that of 43 examined dog fecal samples, *E. multilocularis* was confirmed by PCR in 23 (53.48%) samples, and *E. granulosus* was detected in 20 samples (46.51%). In the Russian Federation, according to data from FBUN «Omsk Research Institute of Natural Focal Infections» of Rospotrebnadzor in Omsk oblast, intermediate hosts (small mammals) with *E. multilocularis* showed an infection rate of 2.2%, whereas definitive hosts (foxes) exhibited infection rates of 30.6%–53.6% [20]. There was 1 case of human disease registered in 2014 (the diagnosis was made posthumously), the disease was characterized by a malignant course for more than 10-15 years, the affected organ was the liver, with characteristic metastases of the mesentery, intestines and peritoneum. Over the past five years, during the mandatory medical examinations of the population, 996 patients with echinococcosis were registered, in the regions of the Arctic zone, 25 people (2.51%) were identified with alveococcosis. [24].

Among the population of the Republic of Kazakhstan, AE was recorded in certain regions but significantly less frequently than cystic echinococcosis. According to data reported by *M.A. Seisembaev, D.S.Toksanbaev, Zh.B. Baimakhanov* [25], over a period of 15 years (1996–2010), 102 patients were diagnosed with hepatic AE and its various complications at the Liver Surgery Department of the National Scientific Center of Surgery named after *A.N. Syzganov,* including 9 (8.8%) patients who had undergone previous ineffective (exploratory) surgeries, 38 (37.3%) men and 64 (62.7%) women, aged 19-69 years, and young and working-age individuals comprising 76.5%.

From 2011 to 2019, 17 cases of human AE were recorded in different regions of the Republic of Kazakhstan. For instance, in 2016, four cases were recorded in Almaty, East Kazakhstan, Karaganda, and Kostanay oblasts, and in 2017, five cases were recorded (one case each in Almaty, West Kazakhstan, and Pavlodar oblasts and two cases in North Kazakhstan oblast). In 2018, two patients with AE were operated in Akmola oblast, three patients with AE were reported in Almaty oblast, and one patient each in Kostanay, Pavlodar, and North Kazakhstan oblasts. In 2019, one resident of Almaty oblast and two residents of North Kazakhstan oblast were operated [26].

In 2020, one AE case was recorded in Almaty and Kostanay oblasts. In 2021, four patients from Almaty oblast and one each from Karaganda, Kostanay, and North Kazakhstan oblasts and Almaty city were operated with an AE diagnosis. In 2022, five patients from Almaty oblast, two patients from East Kazakhstan, one patient from Pavlodar, one patient from Zhetysu oblast, and one patient from North Kazakhstan oblast were operated. In 2023, one patient from Abay oblast, three patients from Almaty oblast, two patients from Zhetysu oblast, and one patient from Pavlodar oblast were operated. In 2024, human AE cases were reported in Almaty, Zhetysu, Zhambyl, North Kazakhstan, Kostanay, Akmola, and Pavlodar oblasts. A total of 10 AE cases were recorded, including 2 in Zhambyl oblast, 3 in Zhetysu oblast, and 1 each in the other abovementioned regions.

Therefore, according to data from the National Center of Public Health of Ministry of Healthcare of RK, 37 patients were operated in Kazakhstan with an AE diagnosis over the past 5 years (2020-2024) (Figure 3).

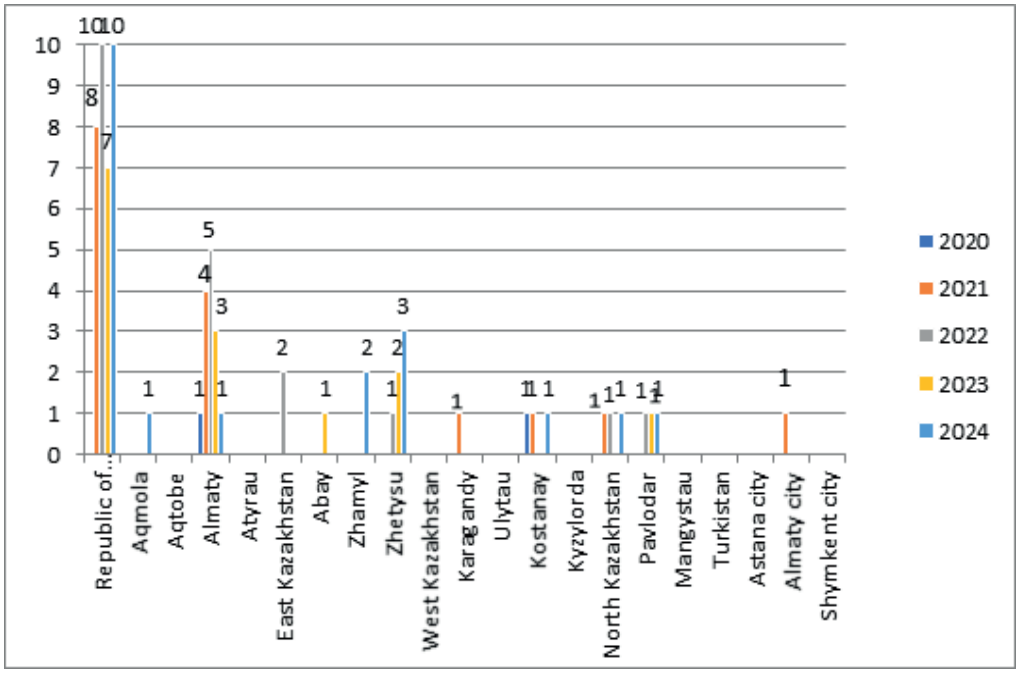

Figure 3 – Absolute incidence rates of alveolar echinococcosis in the population of the Republic of Kazakhstan for 2020-2024

As shown in Figure 3, the number of infected individuals increased in Almaty and Zhetysu oblasts, with the first cases of the disease being recorded in Zhambyl oblast. In North Kazakhstan and Pavlodar oblasts, human AE infections are reported annually.

In the life cycle of the parasite, carnivores (e.g., dogs, foxes, and Arctic foxes) serve as definitive hosts, i.e., carriers and disseminators of mature helminth forms. *R. Uakhit, A. Smagulova* et al. [27] analyzed the sequences of the genes cox1 and nad1 and identified two echinococcosis species, viz., *E. granulosus* in red foxes and wolves and *E. multilocularis* in corsac foxes. Sequencing of mitochondrial genome segments revealed seven pathogen haplotypes in the examined *E. granulosus samples.* Molecular analysis of *E. multilocularis cox1* and *nad1* genes revealed three new haplotypes that exhibited significant variability compared with other investigated Asian haplotypes. Hence, corsac foxes must be included among the definitive hosts that participate in the life cycle of *E. multilocularis* in Kazakhstan. Previous studies had reported the tapeworm form of *E. multilocularis* in foxes and domestic dogs in Kazakhstan [28, 29].

As mentioned earlier, intermediate hosts include small rodents and humans. In Kazakhstan, according to Professor *B.Sh. Shaikenov* [30], *E. multilocularis* larvae were identified in examined highland areas rodent species. The gray and red voles, muskrats, zokors, and great gerbils play the most significant role in forming infection foci. During 2019-2020, *E. multilocularis* larval cysts were detected in the liver and lungs of three common voles in Kostanay oblast among 148 dissected rodents of various species (ground squirrels, great gerbils, wood mice, common voles, harvest mice, field mice, narrow-skulled voles, steppe lemmings, jerboas, and tamarisk gerbils) captured in Mangystau, Kostanay, North Kazakhstan, East Kazakhstan, and West Kazakhstan oblasts [31].

Therefore, based on the literature analysis, the definitive hosts in the life cycle of *E. multilocularis* include dogs, foxes, corsac foxes, and Arctic foxes, and in Kazakhstan, they include dogs, foxes, and corsac foxes. More than 40 species of small mammals have been identified as potential intermediate hosts [32, 33], with 18 species participating in the life cycle of this helminth within our country.

Domestic dogs, foxes, corsac foxes, and Arctic foxes become infected by consuming wild rodents that harbor *E. multilocularis* larvae, and rodents become infected by consuming wild plants, berries, or soil contaminated with helminth eggs. Humans acquire the infection during hunting, carcass dressing, and gathering of wild berries and mushrooms contaminated with E. multilocularis oncospheres.

Conclusion

This review has shown that alveococcosis is a complex parasitic disease, the circulation of which depends on the interaction between definitive hosts (dogs and wild canids) and numerous species of small mammals serving as intermediate hosts. The epidemiological situation in Kazakhstan is determined by the presence of both domestic and wild reservoirs, which maintain the natural foci of *E. multilocularis.* Therefore, according to the epizootiological principle of continuous transmission cycles, it is important to consider the following risk factors:

- Human contact with infected wild carnivores. Foxes are the primary disseminators of helminth eggs in natural biocenoses, whereas dogs (domestic, stray, and feral) play this role in anthropogenic zones. Stray and feral dogs that feed on rodents may play a major role in spreading invasive elements in the environment. When infection rates in domestic dogs increase, the risk of infection spread among the population of the country increases.

- Migration of infected dogs. When dogs are imported into the country from endemic regions where the infection is prevalent, the risk of infection spread increases in anthropogenic zones (rural areas and cities).

- Agricultural lands may become contaminated with E. multilocularis eggs because irrigation water is obtained from canals and open reservoirs inhabited by wild carnivores. This increases the risk of infection for people involved in crop production who do not follow sanitary hygienic guidelines when handling environmental objects (e.g., soil and plants).

The key risk factor for the mass spread of AE is the increasing population of small rodents and foxes, including their appearance in urban and rural areas; however, the most dangerous factor is the inclusion of stray, feral, and domestic dogs in the infection transmission cycle.

Authors contribution

AZh, SB, SK, EK: Conceptualized and designed the study, conducted comprehensive literature searches, analyzed collected data, and prepared the manuscript. AA, ZS: Performed final editing and proofreading of the manuscript. All authors have read, reviewed, and approved the final version of the manuscript.

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