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Patterns of Epidemiology and Epizootiology of Toxocariasis Across the Russian Federation

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ABSTRACT

The article reviews the incidence of toxocariasis in both humans and dogs in different regions of the Russian Federation, taking into account variations by age and gender. The article discusses the routes of transmission of the parasite to potential hosts and assesses the extent of environmental contamination by infected animals shedding *Toxocara* eggs in urban and rural areas. The clinical manifestations of the disease, along with hematological characteristics in affected individuals, are also analyzed. Toxocariasis is common in numerous countries worldwide, including Russia, Africa, Europe, the United States, and Southeast Asia. The infection is most often detected in stray dogs and cats, which contribute to environmental contamination by excreting large quantities of helminth eggs in inhabited areas. On average, approximately 16% of dogs and cats carry the infection, though in special cases, the prevalence can increase to 90%. In 2020, helminth infections accounted for 87.5% of all parasitic diseases. In that year, 871 cases of toxocariasis in humans were reported, corresponding to an incidence rate of 0.59 per 100,000 people. This represented a 2.25-fold decline from 2019 and a 3.9-fold decrease since 2011. Among children under 17 years of age, 353 cases were recorded (1.17 per 100,000 in this age group), marking a decrease of 1.9 times compared to 2019 and a 4.9-fold drop from 2011 levels.

Keywords: Soil, Spread, Human, Dog, Morbidity, Seropositivity

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Introduction

Toxocariasis is a significant parasitic disease affecting both animals and humans, caused by the nematodes *Toxocara canis* and *T. mystax* (or *T. cati*), which primarily parasitize canines and felines, although humans can also be infected. Since the formal tracking of this disease began in 1991, the incidence of toxocariasis in the Russian Federation has notably risen, from 0.03-2.19 per 100,000 population by 2014. Between 1991 and 2015, the incidence of toxocariasis among the population increased significantly, from 0.03-1.72 per 100,000 population. Urban residents are more affected by this disease than those living in rural areas, with urban cases representing 57% and rural cases 43% of the reported cases, respectively [1]. Approximately 40% of toxocariasis cases are in children under fourteen years old. The highest morbidity rates were observed in the Ural and Siberian Federal Districts (FDs). In the Ural Federal District, the average annual incidence rate was 6.3 per 100,000 population, fluctuating between 3.4 (2005) and 9.0 (2012). In the Siberian Federal District, the incidence ranged from 1.3 (2005) to 3.4 (2014), with an average of 2.9 per 100,000 population [1, 2].

Toxocariasis presents a serious concern, especially in large cities. Estimating the total number of individuals infected with *Toxocara* is challenging, as this parasitic disease belongs to the group of larval helminthiasis, which is often not recorded [3, 4]. Among invasive diseases, helminthiasis accounts for 87.5% of cases. Compared to 2011, the distribution of parasitic infections has shifted, with helminthiasis now making up 10.3% more cases. In recent years, the incidence of toxocariasis, particularly in large urban areas, has been a growing issue. In 2020, 871 human cases were reported (0.59 per 100,000 population), which was a 2.25-fold decrease compared to 2019 and 3.9 times lower than in 2011. Of these, 353 cases involved children under 17 years of age (1.17 per 100,000 in this age group), which was 1.9 times fewer than in 2019 and 4.9 times fewer than in 2011. In 2020, parasitic pathogens were found in the soil of various areas: livestock complexes (0.8%, compared to 1.71% in 2019 and 4.5% in 2011), crop farms (1.9%, compared to 0.77% in 2019 and 2.0% in 2011), residential areas (0.81%, compared to 0.88% in 2019 and 1.5% in 2011), including in children's organizations and playgrounds (0.52%, compared to 0.57% in 2019 and 1.1% in 2011), and the sanitary protection zones of water supply sources (1.3%, compared to 1.04% in 2019 and 1.4% in 2011). The high number of dogs in urban areas and the lack of proper sanitation measures, including the absence of disinfection for excrement, contribute to the wide circulation of the toxocariasis pathogen in the environment (soil) and increase the risk of human infection [5, 6].

The research aims to evaluate the prevalence of toxocariasis among both dogs and humans in the Russian Federation, categorized by age group and sex. The selection of scientific papers was based on their scientific value relative to the research topic **(Figure 1)**. A total of one hundred seventy-five publications were analyzed, with 50 of them containing data on the spread of toxocariasis in humans and animals. Publications from the E-Library database were prioritized, as the review focuses on research within the Russian Federation. State Reports from the Federal Service for Supervision of Consumer Rights Protection and Human Welfare on the state of sanitary and epidemiological welfare of the population in the Russian Federation were also used.

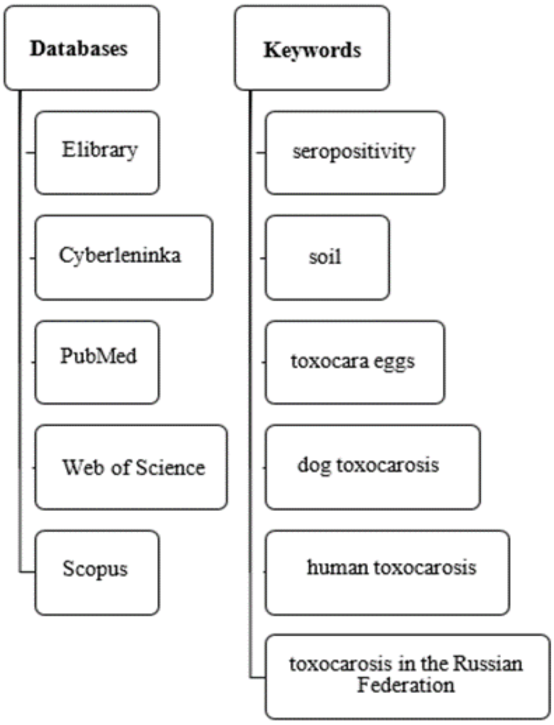

Figure 1. A comprehensive analysis of available studies on the prevalence of toxocariasis in the Russian Federation.

Prevalence of toxocariasis in animals and humans

Toxocariasis in dogs

The prevalence of toxocariasis in dogs varies across different urban areas, with an average of 40%, but it is notably higher in rural regions, where it can reach up to 100%, particularly in puppies during their early months of life [7]. Dogs can contract helminths through intrauterine transmission when larvae migrate from the mother to the fetus via the placenta or through direct contact with contaminated water, food, soil, or intermediate hosts [8]. The incidence of toxocariasis is significantly high, driven by the large dog population and their increased susceptibility to infection. One gram of dog feces can contain up to 15,000 *Toxocara* eggs, leading to substantial environmental contamination with helminth eggs [9, 10]. The global prevalence of toxocariasis in dogs ranges from 15-93%, depending on the continent [11, 12].

Between 2011 and 2017, 1,600 fecal samples from domestic dogs and 1,119 from cats were analyzed in Moscow. The overall infestation rate in domestic dogs was 2.43%. The infection rate in adult dogs varied over the years from 1.62-4.16%, while in puppies, it ranged from 2.4-10.8%. Puppies had a significantly higher infection rate, with an overall incidence of 5.39%, which is twice that of adult dogs. In cats, the infestation rate was 3.95%, with the lowest detection rate recorded in 2012 at 0.66%, and the highest in 2017 at 13.43%. Kittens, similar to puppies, exhibited a higher infection rate of 10.03%. The general infection rate in cats was 5.63%, which was double that of dogs in both adult and kitten groups. The consistent infestation of domestic animals with *Toxocara* makes them a persistent source of environmental contamination, posing an ongoing risk to humans [13, 14].

In Krasnodar, from 2018 to 2019, fecal samples from 107 domestic dogs, ranging from birth to nine years old, were analyzed. A positive sample was found in 64 dogs (68.4%). The highest number of infections were detected in the summer (82.9%) and spring (58.6%), while fewer cases were observed in autumn (45.2%) and winter (18.2%). Puppies aged 0 to 2 months were the most susceptible to infection, with 62.6% testing positive, followed by those aged two to six months (25%) and six to twelve months (9.4%). Only 3% of dogs aged one to six years were infected, and no cases were found in dogs over 6 years old [15].

In the Yamalo-Nenets Autonomous Okrug, toxocariasis is commonly found in fur-bearing animals [16]. The rate of infection in these animals with *T. canis* was recorded at 24.3 ± 3.2%, with an abundance index of 14.4 ± 1.10 individuals, or 304.5 ± 20.5 eggs per gram of feces, based on pathoanatomic and coprological studies. The highest incidence was found in silver-black foxes (28.9%), while the lowest was observed in arctic foxes (12.6%). In wild Arctic foxes, *T. sapis* was detected in 32.4% of cases, with an abundance index of 14.2 individuals. Dogs exhibited the highest prevalence of *T. canis* infection at 17.6% [17].

In Tyumen, the invasion rate in dogs ranged from 12.3-44.8%. The highest rate occurred in summer (44.8 ± 3.2%), while it decreased to 26.7 ± 1.3% in autumn. By winter, the rate dropped to a minimum of 12.3 ± 1.4%, before rising again to 32.8 ± 2.3% in spring. The summer peak in toxocariasis is largely attributed to the increase in the number of young animals that are the primary hosts for the mature parasites [18, 19].

In the Altai Territory, the highest levels of invasion intensity were observed among the dogs studied, with more than 40% infected with toxocariasis and more than 39% with toxascaridosis [20, 21].

Toxocariasis in humans

Humans serve as paratenic hosts for *T. canis*. Infection occurs primarily through the ingestion of eggs, which can happen when a person comes into contact with an infected animal or with soil contaminated by *Toxocara* eggs. Children are particularly vulnerable to this infection due to their habit of playing in the sand and interacting with dogs. The likelihood of human contact with *T. canis*-contaminated soil is estimated at 15% for adults, but this risk increases significantly in children who engage in geophagia and in adults who frequently come into contact with such soil [9, 10].

Human infection with *Toxocara* can also occur when ingesting invasive eggs that have contaminated unwashed fruits, vegetables, or berries. Additionally, consumption of raw or undercooked meat from paratenic hosts, such as chickens, lambs, pigeons, and pigs, may lead to infection. There is no evidence to support transplacental or transmammary transmission of toxocariasis from a pregnant or lactating woman [22].

The significance of addressing and preventing toxocariasis is growing due to worsening living conditions, particularly as political and economic crises in various countries have led to declining living standards and inadequate sanitation. Moreover, the spread of toxocariasis is often linked to migration, especially among refugees. This disease is prevalent in many regions, including parts of Africa, Russia, Southeast Asia, Europe, and the United States [14, 19, 23-26].

The symptoms of toxocariasis present a highly inconsistent clinical picture, often leading to confusion even among seasoned practitioners. This is primarily due to a lack of knowledge in parasitology, particularly among general practitioners and pediatricians. Consequently, other diagnoses such as allergic conditions, chronic pneumonia, and dermatitis are frequently made, complicating the patient's treatment [20, 21, 27-29].

The clinical presentation of toxocariasis varies depending on the number of larvae ingested, the specific organs or tissues affected, and the strength of the host’s immune reaction. The disease typically follows a prolonged and recurrent course, which may last from several months to years, with periods of larvae migration. The liver, eyes, lungs, skeletal muscles, heart, and central nervous system are common sites for larval migration. While toxocariasis can occur at any age, it is most frequently seen in children aged 1-6 years. The migration of *Toxocara* larvae triggers a significant immune response, including localized inflammation and eosinophilia. The condition is usually classified into visceral and ocular forms. Determining the incubation period can be challenging, as a single exposure to the parasite can lead to infection. In rare cases, if the timing of exposure is identifiable, symptoms typically appear 2-3 weeks after contact with the pathogen. The acute phase of the visceral form is marked by general symptoms similar to those of other infectious or allergic diseases, alongside varying degrees of organ damage. Common symptoms of visceral toxocariasis include recurrent fever, respiratory issues, liver enlargement, lymph node swelling, eosinophilia, and elevated levels of gamma globulin. If the lungs are affected, patients often experience a dry, non-productive cough at night. During a physical exam, dry wheezing may be heard across the lung fields, and sometimes, wet rales can be detected. Chest X-rays typically reveal eosinophilic infiltrates, either multiple or solitary, along with an altered pulmonary pattern and signs of bronchopulmonary infiltration [7].

Soil plays a central role in the risk of human infection. In a study involving 481 depersonalized dog feces samples from different regions of southern Russia, 29.31% of the samples tested positive. The prevalence of *T. canis* eggs varied between 6.0% in the Krasnodar Territory and 16.7% in the Republic of Adygea. This difference can be attributed to the regular pre-sale deworming of puppies and the routine deworming of adult dogs 3-4 times annually. *Toxocara* eggs were the most common, making up 42.2% of the eggs found in dog feces, contributing significantly to soil contamination. As such, dogs are considered a primary source of soil contamination with *Toxocara* eggs which also play a role in the fecal-oral transmission route for human infections. Stray animals are the primary contributors to the spread of toxocariasis. Immunological testing for *T. canis*-specific antibodies in a generally healthy population in southern Russia revealed a notable proportion of seropositive individuals [30-32]. Seropositivity levels in the examined regions ranged from 19.5-40.9% in the Rostov region, 17.0-25.0% in Astrakhan, 21.78-37.11% in Krasnodar, 22.5-47.0% in Adygea, 34.0-42.27% in Karachay-Cherkess, 13.8% in the Chechen Republic, and 19.9% in Crimea. This data highlights the high frequency of human contact with the causative agent of toxocariasis, as evidenced by the seroprevalence index, which when considering long-term cumulative data on the detection of specific antibodies, averages from 13.8% in the Chechen Republic to 37.2% in Adygea [33].

Studies carried out in Khabarovsk between 2010 and 2019 found immunoglobulin G antibodies against *T. canis* antigens in 1414 individuals (18.7%; 95% DI = 17.83-19.59%) from the Amur region. Seropositivity was detected across all regions studied. The highest seropositivity rates were observed in the Jewish Autonomous Region, with values ranging from 37.3-95%. Specifically, 44.0% of individuals in the Birobidzhan district tested positive. In the Khabarovsk Territory, the highest seroprevalence was found in the residents of the Bikinsky (53.0–95%), Khabarovsk (28.1–95%), and Lazo districts (24.9–95%). These findings highlight the significant presence of antibodies to *Toxocara* antigens, especially among rural populations. This could be attributed to the large number of dogs (both leashed and hunting types) in villages and the frequent soil contact during gardening activities. The majority of participants in the Amur region were from Blagoveshchensk which might have influenced the results. It is generally thought that southern regions of the country provide more favorable conditions for the development of geohelminth eggs compared to the Amur region, likely due to the longer winters and lower temperatures typical of the Far East. Despite the harsher climate in the Amur region, no significant differences in seropositivity rates between the Amur region and southern Russia were observed [30].

Between 2013 and 2017, a total of 17,419 parasitic infection cases were recorded in the Astrakhan region, with helminthiasis accounting for 87.5% of these cases. Toxocariasis in humans was reported in 34 cases (0.22%). The highest number of toxocariasis cases occurred in 2013 and 2017, making up 29.4% and 32.4% of the total cases, respectively. In the other years, toxocariasis cases were still reported, though less frequently: 14.7% in 2014 and 2015, and 8.8% in 2016. The disease was more prevalent among women, who accounted for 64.7% of the cases. Both children and adults were affected by toxocariasis, with adults representing 82.4% of the cases. Among adults, 67.6% were employed in production, 11.8% were pensioners, and 2.9% were unemployed. Children made up 17.6% of the cases, with 11.8% attending preschool and 2.9% attending secondary school. In one instance (2.9%), the child was at home with their parents [34].

Research carried out in the Irkutsk region from 2008-2018 revealed an average incidence rate of toxocariasis of 0.39 ± 0.07 cases per 100,000 people. The highest rate occurred in 2018, with 0.78 cases per 100,000. In addition to this peak, three other notable increases were observed in 2011, 2014, and 2016, with these periods lasting two to three years. Children under fourteen years old were the most affected, with an incidence rate of 0.54 ± 0.15 per 100,000. The rural population experienced the highest average annual morbidity rate at 0.57 ± 0.09 per 100,000, which was 1.5 times higher than the regional average. Over the study period, the incidence increased nearly fourfold (from 0.2 ± 0.03 to 0.78 ± 0.06 per 100,000), with an average annual increase of 14.5%. Rural residents were found to be the most vulnerable to infection. Between 2008 and 2018, 103 cases of toxocariasis were reported in the region. Of these, 68.0% were adults, and 32.0% were children under 17. Among the affected children, those aged seven to fourteen years (44.0%) and three to six years (38.0%) were most frequently diagnosed, while 12% of the cases were in children aged one to two years and 6.0% were in the 15-17 years age group [5, 6].

In Krasnodar, similar studies were conducted from 2013-2016 involving 34 children (17 boys and 17 girls, aged 1-17 years) suspected of having visceral toxocariasis. Among these children, 29.4% were aged one to seven years, and 70.8% were older than seven years, with an equal distribution between genders. The duration of toxocariasis varied, with 50% of the children having the infection for up to 1 year, 5.8% for up to 2 years, 41% for up to 3 years, and 3.2% for up to 5 years. Epidemiological analysis revealed that 41.1% of the affected children had dogs at home, 29.5% had cats, and 17.5% had access to suburban areas during summer. Other potential sources of infection included contaminated food (insufficiently washed vegetables, herbs, and berries), water (from bathing), or household contact [35].

Soil pollution with Toxocara eggs

A comparison of the incidence data of toxocariasis with seroepidemiological findings suggests that the actual morbidity rate of this parasitic infection in southern Russia is considerably higher than the officially reported figures. The seroepidemiological survey results from the southern Russian territories show a strong correlation with soil parasitological studies (correlation coefficient of 0.85 between population seropositivity and soil contamination). Soil contamination with helminth eggs varied from 0-58.0% in the examined regions, with contamination intensity ranging from 0-85 eggs per kilogram of soil. Between 2011 and 2018, the percentage of viable helminth eggs was 21.3% in the Rostov region, 39.6% in the Republic of Adygea, 27.5% in the Karachay–Cherkess Republic, and 8.3% in the Astrakhan region. The Krasnodar Territory showed no viable *Toxocara* eggs throughout the research period, although 9.6% of the samples were positive for *Toxocara* pathogens, suggesting that caution should be exercised when evaluating the epidemiological situation and considering soil contamination levels during regional zoning. *Toxocara* eggs comprised the largest portion of geohelminth eggs in the soils of southern Russia, making up 73.4%, with an average of 3.8% of these eggs being viable. The average viability of *Toxocara* eggs across regions was 5.6% in the Rostov region, 0.5% in the Republic of Adygea, 5.0% in the Karachay-Cherkess Republic, and 8.0% in the Astrakhan region. These findings highlight the persistent risk of toxocariasis infection in the population of southern Russia. The highest soil contamination with *Toxocara* eggs was recorded in the Astrakhan region (30.0%), while the lowest was in the Republic of Adygea (6.7%). Soil contamination intensity ranged from 3.5 eggs/kg in the Krasnodar Territory to 26.8 eggs/kg in the Rostov region [36].

In the Kursk region, *Toxocara* eggs were present in 45.3% of soil samples examined. The highest percentage of helminth-containing samples (90.9%) was found in areas where animals commonly gather, such as near garbage bins and heat stations. Helminth eggs were found in 59.8% of samples taken from parks and squares and 28.0% from playgrounds. Additionally, 117 snow samples revealed the presence of helminth eggs in 47.9% of the samples. The highest proportion of positive snow samples (83.3%) was found in areas where stray animals tend to congregate [8].

In Krasnogorsk, the grass-covered areas surrounding residential buildings were found to have the highest levels of contamination. These areas, often frequented by pets and stray animals, are more prone to contamination due to the frequent defecation of animals in grassy regions. The greater degree of contamination in these areas, as opposed to parks, can be attributed to their proximity to residential areas, making them popular for dog walking [37].

In Kabardino-Balkaria, the soil and water sources of 63 villages and 9 cities pose significant risks due to contamination with *T. canis* eggs, presenting a substantial threat to both humans and animals. The contamination cycle in the North Caucasus follows the pattern “dog – feces – water – soil – livestock and humans,” fostering a high level of infestation with contamination rates reaching 80-100%. In well-maintained household areas, the soil contamination rate with *T. canis* eggs was 33%, while poorly maintained areas had a rate of 92%. In places where dogs are kept or in vegetable gardens, the contamination reached 100%. Additionally, *T. canis* eggs were found in 70-96 % of soil samples from schools and parks. Among agricultural sites, contamination rates were notably high, with 58% of samples from feeders, 93% from floors, and 100% from courtyards showing traces of the eggs. Water from puddles and holes and soil from livestock farms also showed contamination levels between 80-100%. Summer cottages displayed a high contamination level, with *Toxocara* eggs found in 80 % of soil samples. Contamination was also widespread in various crops: 65% of dill, 74% of parsley, 66% of cilantro, 70% of lettuce, 63% of sorrel, 37% of green peas, 44% of tomatoes, 62% of cabbage, and 56% of cucumbers in open fields. On average, *T. canis* eggs were present in 61.7% of the samples, with an average of 16.24 ± 1.56 eggs per 100 grams of sample [38].

In Kirov, the average rate of *Toxocara* infection in dogs was found to be 18.7%. A clear correlation between soil contamination with *T. canis* eggs and the presence of dog excrement was observed, indicating that higher levels of dog feces correspond to increased contamination of the soil with *Toxocara* eggs. The contamination of soil with *T. canis* eggs across three sites in Kirov averaged 36%, with the park and surrounding area showing the highest contamination at 48%. The rate of infection in dogs also mirrored this trend, with a direct link between the level of dog infestations and soil contamination in these areas [39].

In southern Russia, both the seropositivity of the population and the soil contamination with *Toxocara* eggs are notably high, yet these levels do not align with the officially reported incidence of toxocariasis. This discrepancy suggests that the actual prevalence of the disease in the population of these regions is considerably higher than what is officially recognized [9, 10].

Conclusion

Dogs serve as a primary source of soil contamination with *Toxocara* eggs, which poses a significant risk of toxocariasis infection in humans, particularly children. The findings of the seroepidemiological survey align with results from sanitary and parasitological soil studies. Stray animals are identified as a major contributor to the spread of the disease. Toxocariasis remains a major public health concern that requires a collaborative approach between medical and veterinary professionals, alongside support from local authorities.

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Ethics Statement: The research adhered to international ethical standards.

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