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Review Article

Veterinary Parasiticides: Implications for Livestock Health, Parasite Control, and Environmental Risks

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MZM conceived the review concept and developed the data collection protocol. MUF, MS and Hafsa conducted the literature search, reviewed the relevant studies, and prepared the summary. LI, MTF and H wrote initial draft. MZM and LI technically proofread the draft and supervised the work. All authors read and approved the final manuscript.

Key words
Veterinary parasiticides, Livestock health, Parasite control, Anthelmintic resistance, Environmental impacts, Sustainable parasite management, Ecological risks

ABSTRACT

Veterinary parasiticides are indispensable drugs used worldwide to improve livestock health and welfare by effectively managing parasitic infections. These essential medicines contribute significantly to improving livestock production. The effective control of economically threatening parasites in modern livestock farms requires the rational use of essential antiparasitic agents such as anthelmintics, ectoparasiticides and endectocides. Parasiticides are essential tools in modern livestock farming effectively controlling parasites that cause significant economic losses. This review examines how parasitic drugs affect livestock well-being, as well as play a role in parasite control, and their associated environmental hazards. Additionally, this review paper explores the ecological impact of parasiticides, including their persistence in the soil and water and their potential toxicity to beneficial organisms. The use of parasiticides should be coupled with new methods of parasite management and protection of natural ecosystems and should be implemented properly to ensure long term successful, environmentally sound, livestock use of veterinary parasiticides. By synthesizing evidences from recent studies, this paper highlights the need for sustainable practices to minimize the ecological consequences of the use of parasiticides.

INTRODUCTION

Parasitic infestations in livestock constitute an international veterinary problem, more or less, associated with the production areas with increased cultivation operations (Kaminsky and Mäser, 2025). The two main classes of parasites are the internal and external types. There are various parasites that inhabit inside and outside of their host bodies, such as nematodes, trematodes, and protozoa as internal parasites and lice, ticks, and flies as external parasites. Parasitic diseases inflict massive effects on the health of livestock, and their effects either reduce productivity and endanger reproduction or lower overall welfare. The development of veterinary parasiticides has had a profound impact on the control of parasitic infectious diseases, thereby improving the animal health and farmers welfare (Sander *et al*., 2020). In veterinary medicine, parasiticides are important because they do stop and treat animal parasitic infections, thus protecting animal health and productivity. Veterinary parasiticides are usually administered against a number of parasites, including ticks, worms, fleas, and lice that inflict considerable damage to livestock and companion animals (Femi, 2026).

Chemical and biological agents that function as parasiticides in veterinary applications are also used in the management of parasites in livestock. Veterinary

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parasiticides also provide significant control of parasitic diseases in livestock. It creates a crucial matrix that helps in preventing and controlling many parasites that have a drastic impact on cattle and sheep, as well as in goats and domestic animals. Control measures against parasites have been revolutionized by these chemical substances and the death and illness rates from parasite pathogens/diseases have been decreased.

Parasiticides administration to livestock is commonly achieved by several methods such as oral drenching, topical applications, and injections can be used in parasitic administration in livestock animals. For example, cattle drenching is a procedure that delivers anthelmintic solutions for the killing of internal worms inside the gastrointestinal tract for better weight gain and reproduction results, as well as improves overall herd health. But the overuse of parasiticides causes a large amount of damage to the environment. Pastures are used with the veterinary application of macrocyclic lactones; these pastures are becoming scarred by both harming dung insects and slowing down the rate at which the fecal material decomposes in pastures. Parasiticides can pass through the animals to their manure and can harm aquatic and terrestrial ecosystems, thus interfering with natural ecosystem elements.

The unrestricted, indiscriminate, and widespread use of parasiticides in various target populations has led to the development of resistance in parasite populations to these chemicals. There is documented resistance of parasitic worms to typical worm treatments in local populations across different geographical areas, therefore requiring the adoption of integrated parasite management (IPM) strategies. Effective parasite population reduction for certain therapy-specific applications and pasture management practices is integrated in the IPM system, which couples the parasite population reduction procedures with concerns of environmental health. By using risk-based methods of prescribing parasiticides, veterinarians can balance the need for effective parasite control with the motive to protect environmental health (Gregson, 2024).

This review paper explores the importance of sustainable practices and responsible use of parasiticides for conscious parasiticide management as a determinant for sustainable livelihoods towards long-term livestock production sustainability in a healthy environmental state. Key topics include the mechanism of action, effectiveness against prevalent parasites, emerging resistance issues, and sustainable strategies to mitigate resistance and environmental risks caused by the use of these parasiticides.

TYPES OF VETERINARY PARASITICIDES

Classification of parasiticides

Anthelmintics are a pharmaceutical group that destroys internal parasites, such as nematodes (roundworms), cestodes (tapeworms), as well as trematodes (flukes lying inside the body). As for the anthelmintic, veterinary medicine requires it to avert helminth illnesses from bothering the animals. Endoparasiticides are classified into benzimidazoles, imidazothiazoles, macrocyclic lactones, and amino-acetonitrile derivatives (AAD).

Organophosphates and pyrethroids are included in ectoparasiticides; they are also used to control fleas, ticks, mites, and lice. These medications immobilize and kill the parasites because of their reaction to the parasite's nervous system (Baynes, 2018; Anadón *et al*., 2025). These external parasites transmit diseases like Lyme and babesiosis to the livestock. These parasiticides are available in different formulations, including spot-on, sprays, oral tablets, as well as collars for parasite management.

Endectocides are versatile agents effective against both internal and external parasites. The two substances belonging to the class of macrocyclic lactones are highly effective and have extensive parasiticide activity against arthropods as well as nematodes. These work against the protozoa of type parasites, which cause coccidiosis and giardiasis, as well as in other protozoan parasitic conditions. Acaricides are used to define agents that serve to eliminate arachnid organisms, such as ticks and mites. Other than pyrethroids and macrocyclic lactones, acaricides belong to numerous chemical classes that include organophosphates. A standard method of getting rid of flies, lice, and other ectoparasites causing discomfort to animals, which reduces feed efficiency and permits transmission of diseases. Both organophosphates and pyrethroids, as well as insect growth regulators (IGR), are being used as chemical control agents in the veterinary field. As a solution to reduce environmental damage caused by these chemicals, integrated pest control systems are of great importance because of the increasing development of resistant species (Anadón *et al*., 2025).

Modes of action of veterinary parasiticides

Benzimidazoles kill the parasites by attaching to the β-tubulin proteins in helminths that are essential in processes such as promoting the formation of microtubules, cellular division, and nutrient processing. The energy metabolic processes can be damaged by the action of the drug, leading to the mortality of the parasite. Levamisole (an imidazothiazole) acts as an agonist at nicotinic acetylcholine receptors on nematode muscle cells. This muscle stimulation induced by the drug results in the parasitic expulsion by spastic movement of the host parasite (Kotze *et al*., 2014). Glutamate-gated chloride channels are the targets for the action of macrolide antiparasitic drugs such as ivermectin and moxidectin on the nervous and muscle tissue of the parasite. The activation of these channels enhances the chloride ion permeability through these channels that leads the parasite to hyperpolarize and paralyzes leading to death. The pharmaceutical compounds must be of selective toxicity because the components of the host body channels that they target do not exist in the host organism, or if they do, they are not a significant influencing factor (Cully *et al*., 1994). Monepantel action results from its binding to the nematode-specific acetylcholine receptor subunit ACR 23 that belongs to a DEG 3 subfamily. Disrupted neuromuscular function results in the events leading to paralysis and the ultimate death of the parasite. According to Rufener *et al*. (2010), this mechanism proves to be effective against nematodes that are resistant to other anthelmintic classes.

Organophosphates and carbamates are compounds that block the enzyme, acetylcholinesterase (AChE), at synaptic gaps of neurons, resulting in the accumulation of acetylcholine within the synapses (Majeed *et al*., 2025). The large buildup of acetylcholine leads to continuous nerve signal transmission, resulting in spastic paralysis and parasite death eventually (Aroniadou-Anderjaska *et al*., 2022). Synthetic pyrethroids mechanistically block sodium channels in peripheral and central neurons of parasites, resulting in a delay to repolarization, which ultimately causes muscle paralysis (Boller and Silverstein, 2016; Anadón *et al*., 2025; Majeed *et al*., 2025).

Endectocides, however, have desirable activities that turn off the parasites' neurotransmission functions and often result in the death of the parasites after the corresponding endectocide treatment. When endectocides increase glutamate-gated chloride channel activity, there is a lethal effect on parasite neuromuscular function. Inner endectocides that selectively strengthen glutamate-gated chloride channels, allowing an easy entry of chloride ions in muscles and nerves of parasites, causing death by hyperpolarization and paralysis. This is because only parasites have those specific glutamate-gated chloride channels (Yakob, 2016; El-Saber *et al*., 2020).

IMPLICATIONS OF VETERINARY PARASITICIDES ON LIVESTOCK HEATH

Impact on animal health

The use of veterinary parasiticides has helped in combating parasitic diseases affecting animal healthcare positively, therefore improving welfare as well as animal productivity. According to the British Veterinary Association (2020), the adoption of these parasiticides leads to the development of parasite immunity and the consequences of environmental adoption. Parasiticides contribute to improving livestock health in that they control disease outbreaks while livestock continues to have high growth rates and milk production. Due to these agents' effectiveness, parasitic control is effective, which hence leads to improving livestock welfare standards and offering them financial benefits to the animal husbandry operations. The use of parasiticides has improved livestock's health as they can control parasitic load, hence preventing weight loss, milk production reduction, and mortality (Selzer and Epe, 2021). An important part of controlling gastrointestinal nematodes in cattle, which affect cattle's health are macrocyclic lactones.

Since 2010, the animal health market has developed into one of almost €29.4 billion, which still grows by 6% a year. The sales of the antiparasitic sector in the world animal health market are high, with €7 billion or 23% of the market share. As it plays an important role in reducing animal medicine consumption and promoting stable economic operations in the agriculture sector, the pharmacy industry is extremely important to this practice. (Giannelli *et al*., 2024). Parasitic infections, together with helminths, form major health problems that also reduce livestock productivity and overall health. Milk production in Pakistan has been proven to benefit greatly when anthelmintic treatments are administered through drugs like albendazole and ivermectin. According to the research, anthelmintic drug administration increased milk production by 0.8 liters per day in dairy cattle and 0.7 liters per day in buffaloes (Rashid *et al*., 2022).

Effectiveness and resistance

As a tool, veterinary parasiticides reduce zoonotic disease transmission risk through animal-to-human transmission and are of public health importance where people live in proximity to livestock herds. The use of parasitic control chemicals, which are applied excessive leading to resistance in the parasites and hence a reduction of their effect in the future (Selzer and Epe, 2021). However, the existence of multidrug-resistant parasites in farm animals poses serious problems for livestock health as well as productivity and sustainability in parasite prevention. Anthelmintics are widely administered, resulting in the development of resistance in parasite species, making effective management tactics more complex (Kaminsky *et al*., 2008).

Disturbing resistance patterns in gastrointestinal nematodes of sheep and goats had been observed in European research carried out between 1980 and 2020.

Post 2010 data indicated resistance prevalence rate 86% for benzimidazoles, 52% for moxidectin, and 48% for levamisole. Both scientific studies have proven that there are survival rates for all gastrointestinal nematode genera when treated. *Cooperia* and *Ostertegia* species of cattle gastrointestinal nematodes have developed resistance toward multiple classes of anthelmintics. Studies of cattle populations differed in anthelmintic resistance at the level of classes of drugs. Also, the resistance frequency of benzimidazoles and macrocyclic lactone was 0-100%, levamisole had 0–17%, and moxidectin 0–73%. The findings of research prove that no survivability of *Cooperia* and *Ostertagia* parasites was noticed after treatments, as bovine parasite resistance patterns are insignificant. Multidrug resistance in the sheep *Haemonchus contortus* strain is an obstacle in the control of this parasite population (Babják *et al*., 2023). The use of parasiticides has been inspected in dogs and cats through excessive application, which can lead to the development of resistance to these medications, even at a slower pace for infection as compared to livestock infection. Fear of the development of drug resistance to roundworm parasiticides hangs together with pet owners and the veterinary community due to the constant use of such parasiticides.

Role of parasiticides in parasite control

In integrated parasite management (IPM) systems, parasiticides are primarily used to manage parasites at a required chemical level. Because they offer a quick and easy way to reduce the parasite burden, parasiticides are widely used in IPM. The three components of the IPM method, chemical, biological, and managemental treatments, when combined, improve the efficiency and sustainability of parasite control for cattle. According to research, disease monitoring can decrease the need for the use of generalized parasiticide (Read, 2021). The scientific research proves that using selective parasite treatment gives better results than using broad-spectrum continuous treatment all around. According to Gabrielli *et al*. (2011), preventive chemotherapy is the medical use of anthelmintic drugs either as individual formulations or as blend products for helminth disease control. The periods during which the intervention takes place are fixed in order to accomplish the purpose of having a reduced rate of morbidity, as well as reducing the spread of infection. Methods of alternative control, which combine vaccines and biological controls based on dung beetles, make the sustainable control of parasite populations possible (Kaplan and Vidyashankar, 2012). Subsequent to the wide applications of these chemicals, the environment was degraded, especially in livestock farming areas infested with high densities. The persistence of parasiticides in the environment prevents the development of sustainable parasite control strategies.

Environmental implications and risks

The use of veterinary parasiticides for livestock health raises major environmental problems (Wells and Collins, 2022). Indeed, new research reveals that parasiticides, particularly those of an insecticidal nature applied to both pets and cattle, have a bad effect on the environment. Likewise, the chemicals are quite hazardous to land ecosystems as well as aquatic environments. Imidacloprid and fipronil, two chemicals used to treat pet fleas, have recently been found in rivers, harming bug populations and the insects that eat them (Goulson and Luttikhuizen, 2020). The effect of veterinary parasiticides has strongly endangered environmental health because of their widespread implementation. When these chemicals escape from their intended places by flooding or through people's carelessness in disposing of them, they enter both water and soil that makes ecosystems vulnerable to being contaminated. Parasiticides in soil and water systems are among the leading environmental problems since they remain in them and impact other beneficial species, as well as aquatic species and soil-dwelling microorganisms. Studies show that organophosphates, as well as macrocyclic lactones, persist in the environment and accumulate in unintended species (Wells and Collins, 2022).

Veterinary parasiticides used in livestock farming have been linked to the contamination of soil and water resources, raising environmental concerns. According to the studies, the parasiticides coming out in livestock excrement considerably damage the good bacteria that live in the soil. Veterinary drugs are applied as preventative measures, not only for treatment. Sands and Wall (2018) demonstrated that the application of parasiticides in cattle farms on a regular basis alters the treatable dung beetles that congregate in their environment, as these beetles are key players in nutrient management and oxygenating soils. According to the study, significant beetle population declines in places where high amounts of parasiticides were used could impact soil health and ecosystem functioning. Veterinary drugs can lead to aquatic environments through multiple routes, including the drainage of treated fields as well as the disposal of medicines into the drains. According to Boxall *et al*. (2012) review, veterinary pharmaceuticals, including parasiticides, were observed in surface waters and sediments. The contaminants pose a threat to aquatic organisms, a concern of substances that circulate in organisms, as well as ecological systems.

Scientific studies indicate that farm animals treated with anthelmintic drugs often harbor residual drug amounts in their tissues that are subsequently carried to final food products derived from treated animals. The amount of anthelmintic residue accumulation depends especially on the chemical nature of the medication, the dosage, and the animal's breakdown method. Withdrawal periods are needed to ensure milk and meat products are safe to the public before they reach the market. Kinsella *et al*. (2009) developed the analysis technique for verification of flukicide and anthelmintic residues in bovine milk and liver tissue using liquid chromatography–tandem mass spectrometry. It emphasizes that accurate residue detection systems must be implemented to enforce the withdrawal periods of these chemicals to support food safety standards. Anthelmintic drug residues in milk determination were done by the advanced analytical tool known as ultra-high-performance liquid chromatography tandem mass spectrometry with rapid polarity switching (Whelan *et al*., 2010). Research studies show that it is very important to monitor and control anthelmintic residue levels so that people who consume the food are protected. The aim of environmental regulations on parasite product use in agriculture is the reduction of its impact on human health, ecosystems, and non-targeted organisms. There is different legislation for different places from environmental protection units that are concerned about the number of chemical residues and the use of pesticides that are left in the food. The parasiticides are monitored for their impact on water pollution and wildlife by the Environmental Protection Agency using environmental protection standards that have been established per the federal insecticide, fungicide, and rodenticide act (FIFRA) and clean water act (CWA) (Touart, 2020). Food drug and cosmetic act (FDCA) mandate the food and drug administration (FDA) to set the parasiticide residue limits for food animals. USDA's withdrawal period rules define the time frame for preventing the meat and dairy residues. Parasiticides are sold and used under administrations of Australian pesticides and veterinary medicines authority (APVMA) of the Agricultural and Veterinary Chemicals Code Act (1994). The Australian national authorities establish the legal basis under the Agricultural and Veterinary Chemicals Code Act (1994), through which the agricultural and veterinary chemical products are evaluated, registered, and controlled.

Strategies for mitigating environmental risks

The need exists for the development of verified environmental risk management solutions for veterinary parasiticides, as these are important for livestock parasite control. Multiple methods have been presented in research publications to reduce such risks in some particular scenarios. The most significant factor for the effectiveness of environmental risk reduction from veterinary parasiticides lies in its improved methods of application. The guideline of such parasiticides that are veterinary medicinal products are issued by the European Medicines Agency to facilitate Environmental Risk Assessments (ERAs). This guideline states that system evaluation on possible environmental emissions is to be made, and then potential risks are to be assessed before the adoption of feasible mitigation strategies.

However, the reflection papers by the European Medicines Agency (2015) and by the veterinary medicines directorate (Weeks and Stapleton, 2018) suggest their regulatory responsibility of understanding how companion animal parasiticides enter and impact environmental systems. Manufacturers should conduct environmental risk assessments that enable the identification and mitigation of adverse environmental effects.

The application of parasite products use in agriculture is monitored by environmental regulations on the reduction of impacts on ecosystems and human health, as well as on non-target organisms including birds (Wells and Collins, 2022; De Marchi *et al*., 2025; de Montaigu *et al*., 2025). There are different laws for different regions with the idea of keeping the minimal amount of chemicals in food, protecting the environment, and safe usage of parasiticides. The federal insecticide, fungicide, and rodenticide act and clean water act set environmental protection standards for parasiticides organized by the environmental protection agency to monitor water pollution or wildlife impacts (Touart, 2020). Parasiticide residue limitations for consumers' food based on animal products are determined by the food and drug administration (FDA) under the food, drug, and cosmetic act (FDCA). The protocols of the US department of agriculture (USDA) establish meat and dairy residue elimination times. In the Australian Agricultural and Veterinary Chemicals Code Act (1994), parasiticides' sales and use are administered by the Australian pesticides and veterinary medicines authority (APVMA). The Australian national authorities obtain the legal ground to evaluate, register, and control agricultural and veterinary chemical products based on the Agricultural and Veterinary Chemicals Code Act (1994).

Therefore, it is necessary to responsibly develop strategies for managing environmental risks associated with veterinary parasiticides used in agriculture to control cattle parasites. These help manufacturers to identify the possible negative consequences being caused to the environment, and help them to reduce these effects. Suitable application techniques would enable the veterinary professionals to collaborate with pet owners to reduce the environmental impact of parasiticides while enhancing parasite control in pets.

Research gaps and future directions

Parasiticides are still a main weapon against parasites, but more sustainable, safer to the environment, and they still need to be developed and are currently being researched. Novel parasiticides that don't persist in soil and water, and those that are safer to non-target organisms, are needed (Yuskiv *et al*., 2024). Parasiticide resistance becomes more and more serious in veterinary medicine, which makes the problem important enough to develop a mode of resistance management and keep chemical control effective (Wright, 2023).

Efficacy of commonly used parasiticides reduces when parasites survive treatments due to their genetic mutations, resulting in resistance in them (Kaplan and Vidyashankar, 2012). The suggested control strategies are diagnostic testing, targeted treatments, other control options, and compliance with regulations. Routine fecal egg counts and molecular diagnostics can be used to make an early diagnosis of parasite burdens and resistance (Kaplan, 2020). Drug efficacy and treatment choice are defined using larval development assays (Vercruysse *et al*., 2018). Do not blanket deworm but treat high-risk animals only (Charlier *et al*., 2014). Therefore, for refugia-based management and to slow the evolution of resistance, part of the parasite population must remain exposed to no drugs (Besier, 2012). With targeted delivery of parasiticides to livestock, one of the recent improvements is to enhance the drug's efficacy and thus reduce the amount of drug used, as well as reduce side effects. Controlling oxygen delivery was found to be at the forefront, and nanoparticle-based delivery systems were seen to be leading (Swain *et al*., 2015).

Researchers had produced solid lipid nanoparticles (SLNs) consisting of the edible wax made of honeybee, beeswax, to deliver albendazole in the nematode *Haemonchus contortus*. The nanoparticles showed high drug loading efficiency of 83.3 ± 6.5 mg/g, sustained drug release, and led to 50-fold enhancement in the potency of albendazole (Sharma *et al*., 2023). Multifunctional nanomaterials must be updated regarding the control of illness in humans and domestic animals as antiparasitic agents. These nanomaterials have properties with less toxicity by addressing the problems of the existing parasitic disease treatments (González-Fernández *et al*., 2025). The investigation of botanical dewormers, probiotics, and enzyme-based treatment has the potential of reducing the reliance on synthetic parasiticides (Burke and Miller, 2020). It will imply vaccines, genetic selection, and strategic use of drugs. In future research, eco-friendly parasiticides, precision in dosing strategies, and resistance monitoring will be used to mitigate negative impacts on the offspring of the livestock and the environment.

CONCLUSIONS AND RECOMMENDATIONS

The parasiticides used extensively throughout the world have, to a large extent, succeeded in decreasing the morbidity and mortality caused by parasitic infections, and have facilitated better animal welfare and greater human, crop, and economic gains for the farmer. Moreover, targeted delivery systems (nanoparticles and slow-release formulation), improvement in the efficacy of the drug, reducing the dose of the drug, and preventing drug resistance are also being considered. Unfortunately, the increasing trend of parasiticides usage is contributing to environmental contamination and causing adverse effects on non-target fauna, including beneficial arthropods, aquatic biota, and soil microbiota. Persistent residues of such drugs from pastures, water sources, and manure create an imbalance in the ecosystem and spread the anthelmintic resistance between the parasite populations. Moreover, multidrug-resistant parasites have emerged. Hence, there is an urgent need to work out sustainable solutions to attain effective parasite control.

Mitigation of these risks should rely on integrated parasite management strategies. IPM includes rotational grazing, use of parasite-resistant breeding of livestock, use of biological control agents, and proper use of anthelmintics through precision dosing and combination therapies. Additionally, the regulatory policy should monitor drug residues in the environment and further development of eco-friendly substitutes to marketable anthelmintics (plant-based anthelmintics, immunological interventions).

Future work will include further research on the development of new types of parasiticide formulations that can enhance their efficacy and reduce environmental impact. New ways to prospectively control target parasites with minimal interference to native communities have been afforded recently, which will prevent biological invasion by advances in nanotechnology, biotechnology, and genomics. A holistic approach that balances parasite management, livestock productivity, and environmental sustainability can deliver long-term health benefits to livestock while minimizing the adverse consequences that arise as a result of the use of parasiticides by the livestock industry.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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