



P-ISSN: 2788-9890 E-ISSN: 2788-9904

NTU Journal of Agricultural and Veterinary Sciences

Available online at: <https://journals.ntu.edu.iq/index.php/NTU-JAVS/index>



# Evaluating the Environmental and Hygienic Impacts of Veterinary Pharmaceuticals: Investigating Risks and Solutions (Article Review)

1<sup>st</sup> Alaa Shamil Alalaf , 2<sup>nd</sup> Safwan L. Shihab

1,2. Department of Animal production, College of Agriculture and forestry, University of Mosul, Mosul, Iraq

## Article Informations

**Received:** 01-11- 2024,  
**Accepted:** 07-03-2025,  
**Published online:** 28-09-2025

### Corresponding author:

Name: Alaa Shamil Alalaf  
Affiliation : Department of  
Animal production, College of  
Agriculture and forestry,  
University of Mosul, Mosul, Iraq  
Email:  
[alaa.shamil@uomosul.edu.iq](mailto:alaa.shamil@uomosul.edu.iq)

### Key Words:

antibiotic,  
environment,  
Human health,  
Veterinary pharmaceutical,

## ABSTRACT

The veterinary pharmaceutical residues have generated critical ecological and human health risks. including antimicrobial, antiparasitic, nonsteroidal anti-inflammatory drugs, these residues can survive in the environment for decades, veterinary medicines specially the antibiotic considered the primary source for bacterial resistance in humans according to the World Health Organization (WHO) short term health associated effect lead to human allergenicity and toxicity while the long term including sever health issues like disruption of intestinal microflora ,carcinogenicity and teratogenicity. An extensive search related to environmental distribution of veterinary pharmaceuticals was performed through researches online databases like (Google scholar, ScienceDirect, Web of Science, and PubMed), then papers collected, analyzed, and explained. The active drugs and their metabolites have contributed globally to aquatics and land contamination. While knowledge is growing, large information gaps remain on their effects. The impacts of these chemicals in the environment are still largely unknown. This review shows a clear need to extensively track not just presence of veterinary compounds in different areas worldwide, but primary sources as well. Identifying sources is key to shaping regulatory monitoring, as it addressing current problems and preventing future issues



©2023 NTU JOURNAL OF AGRICULTURAL AND VETERINARY SCIENCES, NORTHERN TECHNICAL UNIVERSITY.  
THIS IS AN OPEN ACCESS ARTICLE UNDER THE CC BY LICENSE: <https://creativecommons.org/licenses/by/4.0/>

## Introduction

The distribution of various types of veterinary pharmaceuticals has led to serious environmental and public health concerns, particularly in the food products derived from animals. Over the past five years, there has been an increase in the usage of veterinary medicinal products and a corresponding rise in the quantities of these substances entering the environment [1][2]. Veterinary drugs are classified as therapeutic, prophylactic, growth promoter, and functional modulator drugs, including antimicrobial, antiparasitic, nonsteroidal anti-inflammatory drugs, sedatives, corticosteroids, and beta-agonists [3]. According to the European Federation of Animal Health, approximately one-third of the veterinary pharmaceuticals used in poultry and pig farms consist of antibiotics [4]. Pharmaceutical residues from veterinary drugs can be transmitted through animal-sourced food products, animal excretions, and farm utilities into agricultural soil, surface water, groundwater, aquaculture systems, and rivers. Despite associated health risks and their toxic effects on human consumers [5], these residues can persist in the environment for decades, veterinary medicines constitute the primary source of antibiotic resistance in humans according to the World Health Organization (WHO) [6][7]. Short term health associated effect of drug exposure lead to human allergenicity and toxicity while the long term including severe health issues like disruption of intestinal microflora, carcinogenicity and teratogenicity [7]. Antibiotic exposure eliminate nitrogen producing bacteria in the soil, inhibit weeds and crops growth and bioaccumulation, veterinary drug persistence, transformation and availability determined by its reactive characteristics with environmental elements and biodegradability. The process for treating and removing these chemicals is extremely complex [8]. Therefore, the current review aims to highlight the effects of veterinary medicines on human health as consumers of animal products and its impact on the biological and environmental resources as well as, to review the risks of these chemical compounds and the global programs to control its exposure.

## Environmental Impacts of Veterinary Pharmaceuticals

It has been widely recognized by researchers and health specialists that drug pollution is a serious issue that requires immediate and crucial solutions. It is essential to address this problem for enhancing living conditions in a healthy environment, preventing the deterioration of ecosystems, and to prevent the distribution of drug-resistant diseases [5]. The veterinary drugs are often excreted through the urine, feces, and body secretions of grazing animals, directly

into pastures, water sources, and farming areas. Additionally, they can enter the environment through the process of fertilizing with manure from intensively medicated animals [2][9][10]. The release of expired animal drugs to water sources, aquaculture, agricultural lands, or through the burial of contaminated carcasses of chronically diseased animals poses significant risks of contaminating groundwater, soil, and the surrounding ecosystems. Moreover, the biological disposal of poultry field wastes, as well as targeted food products from animals with a history of long-term medication, can result in the absorption of these chemicals by the soil or their flow into surface water such as lakes, rivers, lagoons, tanks, etc., and may also reach groundwater reservoirs, agricultural lands, and forests [9][11].

## Contamination of Water resources

### • Surface water

Diverse veterinary antibiotics were detected in waste water Treatment Plants globally associated with significant human health implications, [12], referred that groups of waste water Treatment stations in Canada were contaminated with veterinary purposed sulphamethazine, with concentrations reached up to 3.278 µg/L, water drained from animal raising farms with concentrating feeding programs, similar results observed by [13], in the lagoons at different areas close to the cattle and swine facilities in USA, the water samples examined revealed presence of sulfamerazine, erythromycin, sulfamethazine, tiamulin, monensin, sulfathiazole and Lincomycin, the authors conclude that groundwater underlying livestock waste water impound with drugs contamination. [14], also reported the impact of veterinary drug pollution in surface water and pristine area in mountain river (Poland), water samples showed that antibiotics was the higher among other types of drugs including erythromycin (0.89 ng/L), vancomycin (2.99 ng/L), oxytetracycline (0.27 ng/L), sulfamethoxazole (0.20 ng/L), clindamycin (0.36 ng/L), and trimethoprim (0.29 ng/L). Lim et al [8], during examination of water sample from 11 wastewater Treatment Plants, detected analgesics and antibiotics in high concentrations including acetylsalicylic acid, chlortetracycline, oxytetracycline and acid, sulfamethoxazole, erythromycin, and trimethoprim, correlated the amount of contamination with the annual manufacturing of each antibiotic during the year. [15] reported in their study that water treatment stations in Korea were contaminated with veterinary oriented antihelminth drugs like albendazole with doses reached from 3.85-241 µg/L with albendazole metabolites like amino albendazole, hydroxyfenbendazole and salfon fenbendazole, and suggest that source of these drugs come from livestock farms in the neighboring areas or come through the sewage water. [16] demonstrate the

level of oxytetracycline in the water at drainage basin in Japan that reached between 2ng/L to 63 ug/L ,the author suggested that intense usage of this antibiotic in the farms of cattle ,chickens, and swine is the main source of contamination particularly, at the winter season where drug used as prophylactic against the respiratory diseases and diarrhea.[17] mentioned that antibiotics concentration in Naerinceon river varied with seasons and noted that sulfonamides and tetracyclines were higher in dry season compared with rainy season and attributed this to the effect of rain in the dilution of drugs concentration and the lower temperature during this season in slowing of biodegradability. [13] found that irrigation area ,and drainage water from dairy cow facilities in many Australian sites were contaminated with penicillin ,oxytetracycline and sulfonamide with concentration reached to 321,109,432 ng/L respectively . and connect these highly pollution with dairy activities and treatment of foot rot (table1, table 2).

#### • Groundwater contamination

The underground water provide a great dependable source of drinking water to humans and animals on our plant, the pollution in this sources of water with chemical substances descended from veterinary pharmaceuticals can be a harmful for public health and restrict animal production process, according to [18] , group of groundwater bodies were investigated in Spain ,Catalonia had a high concentration of sulfonamides formulated drugs reached 3460 ng/L ,represented 20% of the whole chemical drugs contamination in the area .[18] referred that the source of contamination of the water result from fertilizing of organic manure fertilizer form pretreated animals.[19] suggested that water pumping plant from concentrated animal food facilities were the main cause of groundwater contamination with erythromycin and monensin in USA, Nebraska and concentration reached to 2380 ng/L and 2350 ng/L respectively ,[20] found that sulfadimethoxine and famethazine present in high concentration in the examined groundwater samples with concentrations reached to 0.22 ng/L and 0.068 ng/L respectively.[13] also reported that sufamethazole and sulfathiazole were high in groundwater samples and attribute that to the anerobic condition of water storage which in turn increases ammonia concentration, facilities soil infiltration of these contaminants to the groundwater reservoirs (table1,table 3).

#### • Agricultural Soils Contamination

Contamination of soil with veterinary pharmaceutical commonly occur as result of fertilizing with organic animal manure or through watering with contaminated irrigation water source ,[6] explained the recorded cases of soil contamination in China ,where higher concentration of oxytetracycline, chlortetracycline , sulfonamides and sulfamethazine detected in the soil fertilized with cattle manure, similar results reported by [21], when they detect hazardous quantities of

antimicrobial drugs in agricultural farms fertilized with poultry manure and tetracyclines were the most frequent type reached to 0.40 mg/kg ,

Testing of some soil samples found traces of the antibiotic drug enrofloxacin present in quite low amounts. at levels of 0.02 and 0.05 mg per kg of soil were detected. This shows how persistently stable such compounds can be, since the soils were fertilized with manure seven months prior and still contained residuals of the fluoroquinolone medication. [21]

A study of [22] looked at the presence of various antibiotic drug classes - tetracyclines, sulfonamides, trimethoprim and fluoroquinolones - in manure samples from pigs, chickens and turkeys. The tetracycline antibiotic specifically detected in 22 out of 30 pig manure samples, with levels ranging from 0.36 to 23 mg/kg. The researchers propose this finding likely the main cause of soil contamination, since these animals provided with tetracyclines as food additives (table 1,table 4).

#### Human health concerns

Veterinary pharmaceutical pass from the environment to the plant and water, lead to contamination of human food source. The overuse of antibiotics in various sectors has led to their widespread presence in the environment. from livestock, aquaculture and agriculture end up in wastewater and soils. Pharmaceutical factories and water treatment plants also contribute to environmental contamination [24].

This exposure plays a role in increasing antibiotic resistance. Bacteria are often subjected to very low antibiotic concentrations in the environment, allowing them to adapt and evolve over time. Mutations from sub-lethal drug amounts seem particularly important for resistance emergence.

Even exposure to non-killing antibiotic levels can cause mutations in bacteria. These changes can accumulate, resulting in strains that are hard to treat [25][26].

Studies found that sub-minimum inhibitory concentrations of certain drugs in *E. coli* induced mutagenesis. This was linked to increased reactive oxygen species, leading to acquired resistance. Mutations were observed in specific genes associated with antibiotic targets. Resistance also emerged faster following exposure to quinolone levels below standard measurements. Likewise, single mutations gave pathogens 100-times greater tolerance to that drug [27][28].

Veterinary medication residues in foods sources have been shown to cause allergic reactions in humans through consumption. Drugs like penicillin, cephalosporins, and tetracyclines are common culprits, inducing effects ranging from mild rashes to life-threatening anaphylaxis.  $\beta$ -lactams specifically provoke allergic responses. Beyond this, sulfamethazine, oxytetracycline and furazolidone residues carry immunopathological implications as well [29][30].

Teratogenic and carcinogenic impacts are also a concern. Any chemical disrupting fetal development can lead to structural or functional birth defects, as demonstrated for certain anthelmintics, benzimidazoles, and enrofloxacin in animal studies. Meanwhile, antibiotic remnants that bind to or alter intracellular components like DNA may induce cancer over the long run, exemplified by reported chloramphenicol tumors. Nitrofurans, nitroimidazole and quinoxaline residues also interact with cellular molecules in ways that could change DNA and promote oncogenesis [31][32][33].

Unintended dietary exposures to veterinary drug residues via foods present immunological, teratogenic and carcinogenic risks to humans through various reaction and toxicity mechanisms within the body. Careful management is important to safeguard public health from public health consequences (table 5).

### **Management and environmental control**

Limited public understanding about prudent veterinary pharmaceutical use has exacerbated the issue of antibiotic residues polluting the environment. Effective communication is vital to inform people about insignificant usages that negatively impact health [34].

Targeting multiple groups can enhance outreach efforts. Pharmaceutical industries and professional organizations upholding standards can lend great influence. Social influencers also play a pivotal role by legitimizing issues [33][34].

Designing of educational incentives assessed over time may prove impactful, especially training women, economically disadvantaged communities, and those employed in agriculture and fishing. Standard-setting agencies like the WHO and national health bodies initiate important global and local initiatives annually to spread best practices [35].

Events promoting understanding among multifaceted stakeholders concerning antibiotic selection pressures are advantageous. Promoting infection control and ongoing surveillance allows continuously addressing the threat of antimicrobial resistance. A holistic approach engaging an array of relevant players through different mediums remains most promising for building antibiotic stewardship [36][37].

### **Conclusion**

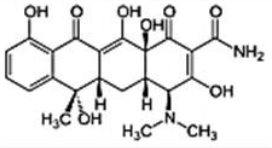
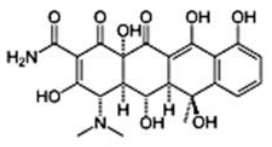
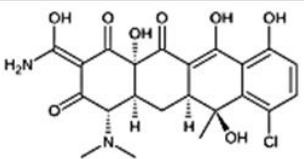
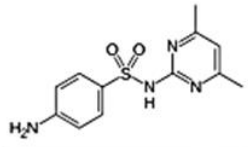
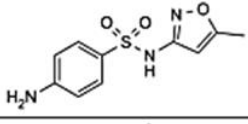
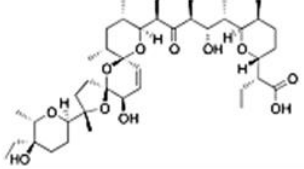
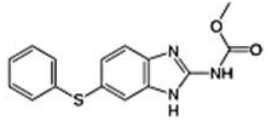
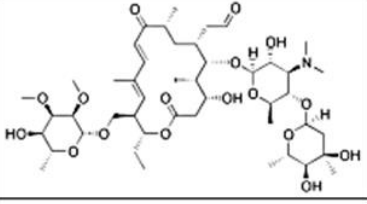
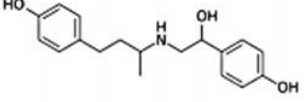
It is recognized by environmental experts that active drugs and their metabolites have contributed globally to aquatic and land contamination. While the knowledge is growing, large information gaps remain on their effects. The impacts of these chemicals in the

environment are still largely unknown. This review shows a clear need to track not just presence of veterinary compounds in different areas worldwide, but primary sources as well. Identifying sources is key to shaping regulatory monitoring, as it addresses current problems and preventing future issues.

### **Acknowledgment**

Authors thank Department of animal production – College of Agriculture and Forestry - University of Mosul for their encouragement and assistance

**Table 1:** the common types of pharmaceuticals used in veterinary fields

Class	Compound	CAS-Nr	Structure	Formula
Antibiotics	Tetracycline	60-54-8		$C_{22}H_{24}N_2O_8$
	Oxytetracycline	79-57-2		$C_{22}H_{24}N_2O_9$
	Chlortetracycline	57-62-5		$C_{22}H_{23}ClN_2O_8$
	Sulfamethazine	57-68-1		$C_{12}H_{14}N_4O_2S$
	Sulfamethoxazole	723-46-6		$C_{10}H_{11}N_3O_3S$
	Salinomycin	53003-10-4		$C_{62}H_{70}O_{11}$
Anthelmintic	Fenbendazole	43210-67-9		$C_{15}H_{13}N_3O_2S$
Feed additives	Tylosin	1401-69-0		$C_{40}H_{77}NO_{17}$
	Ractopamine	97825-25-7		$C_{18}H_{23}NO_3$

**Table 2:** the global reported veterinary pharmaceuticals in surface water sources and their concentrations

References	Location	Type of pharmaceutical	Concentration	Contamination source
Koné <i>et al</i> [12].	Canada	1- Trimethoprim 2- Sulphamethoxazole 3- Venlafaxine 4- Fluoxetine	1-3.528 µg/L 2- 278 µg/L 3- 0.808 µg/L 4- 0.799 µg/L	Surface water, sewage treatment plant
Bartelt-Hunt <i>et al</i> [13].	USA	sulfamerazine; sulfamethazine; erythromycin; monensin; tiamulin; and sulfathiazole. Lincomycin; ractopamine; sulfamethazine; sulfathiazole; erythromycin; tiamulin and sulfadimethoxine	30 to 3600ng/L	lagoons and adjacent groundwater
Kulik <i>et al</i> [14].	Poland	1- erythromycin 2- vancomycin 3- oxytetracycline 4- sulfamethoxazole 5- clindamycin 6- trimethoprim	1-0.89 ng/L 2-2.99 ng/L 3-0.27 ng/L 4-0.20 ng/L 5-0.36 ng/L 6-(0.29 ng/L]	surface water
Lim <i>et al</i> [8]	Korea	chlortetracycline, oxytetracycline, acetylsalicylic acid	1.85-143.83 µg/L	Sewage water, wastewater plants
Matsuin <i>et al</i> [16]	Japan	oxytetracycline	2 ng/L to 68 µg/L	stream waters, catchment water

**Table 3:** the global reported veterinary pharmaceuticals in ground water sources and their concentrations

References	Location	Type of pharmaceutical	Concentration	Contamination source
García-galán <i>et al</i> [17].	Spain	19 types of sulfonamides	0.01 ng/L to 3460.57 ng/L	ground water, wells
Bartelt-Hunt <i>et al</i> [13].	USA	Steroid hormones	up to 390ng/L.	groundwater
Batt <i>et al</i> [18]	USA	Sulfamethazine Sulfadimethoxine	1- 0.076- 0.215 µg/L 2- 0.046 - 0.068 µg/L	ground water wells
Fisher <i>et al</i> [20]	Australia	sulfadimethoxine and famethazine	0.22 ng/L and 0.068 ng/L	groundwater

**Table 4:** the global reported veterinary pharmaceuticals in soil and their concentrations

References	Location	Type of pharmaceutical	Concentration	Contamination source
Wang <i>et al</i> [6]	China	Amoxicillin, Albendazole, Ciprofloxacin, Ivermectin, Sulfadimidine, Sulfamethoxazole, Tylosin, Trichlorfon	49mg/kg	Soil, aquaculture
Karcı and Balcıoğlu [21]	Turkey	Tetracyclines, sulfonamides, and fluoroquinolones	0.05-0.5 mg/kg	spiked soil and manure samples
Martínez-Carballo <i>et al</i> [22]	Austria	1- Chlortetracycline, 2- oxytetracycline 3- Enrofloxacin	46 mg/kg 29 mg/kg 90 mg/kg	soils fertilized with manure
Slana <i>et al</i> [23]	Slovenia	Tiamulin Enrofloxacin Tylosin Sulfadiazine Oxytetracycline Gentamicin	0.096g/g -0.647g/g	Manure and agricultural soil

**Table 5:** common antibiotic adverse effect in the contaminant environment [32]

Class	Type	adverse effect
Tetracycline	Oxytetracycline	Blood changes, Damage calcium reach teeth & bone, wheezing and asthmatic attack
Macrolides	Erythromycin	Pyloric stenosis in infant, sever vomiting, teratogen, hart deformity in infant
Amphenicol	Chloramphenicol	Human carcinogenic, genotoxic, toxic to kidney, heart, liver, damage of bone marrow causes plastic anemia
B – lactamase	Ampicillin	Hepatitis, allergic action, dermatitis, anemia, thrombocytopenia, leukopenia, asthmatic attack

## References

- [1] Kołodziejska, M., Maszkowska, J., Białk-Bielińska, A., Steudte, S., Kumirska, J., Stepnowski, P., & Stolte, S. (2013). Aquatic toxicity of four veterinary drugs commonly applied in fish farming and animal husbandry. *Chemosphere*, 92(9), 1253-1259.
- [2] Bottoni, P., Caroli, S., & Caracciolo, A. B. (2010). Pharmaceuticals as priority water contaminants. *Toxicological & Environmental Chemistry*, 92(3), 549-565.
- [3] Aidara-Kane, A., Angulo, F. J., Conly, J. M., Minato, Y., Silbergeld, E. K., McEwen, S. A. (2018). World Health Organization (WHO) guidelines on use of medically important antimicrobials in food-producing animals. *Antimicrobial Resistance & Infection Control*, 7, 1-8.
- [4] Schmerold, I., van Geijlswijk, I., & Gehring, R. (2023). European regulations on the use of antibiotics in veterinary medicine. *European journal of pharmaceutical sciences*, 189, 106473.
- [5] Kaczala, F., & E Blum, S. (2016). The occurrence of veterinary pharmaceuticals in the environment: a review. *Current Analytical Chemistry*, 12(3), 169-182.
- [6] Wang, N., Guo, X., Shan, Z., Wang, Z., Jin, Y., & Gao, S. (2014). Prioritization of veterinary medicines in China's environment. *Human and Ecological Risk Assessment: An International Journal*, 20(5), 1313-1328.
- [7] WHO (2014) Evaluation of certain veterinary drug residue in food. Technical Report Series 988: 7-32
- [8] Lim, S. J., Seo, C. K., Kim, T. H., & Myung, S. W. (2013). Occurrence and ecological hazard assessment of selected veterinary medicines in livestock wastewater treatment plants. *Journal of Environmental Science and Health, Part B*, 48(8), 658-670.
- [9] Kim, S. C., & Carlson, K. (2005). LC-MS2 for quantifying trace amounts of pharmaceutical compounds in soil and sediment matrices. *TrAC Trends in Analytical Chemistry*, 24(7), 635-644.
- [10] Howard, P. H., & Muir, D. C. (2010). Identifying new persistent and bioaccumulative organics among chemicals in commerce.
- [11] Alalaf, A. S., & Alnuaimy, R. (2024). Evaluating The Influence of Vitamin E and Selenium on The Uterine Health of Adult Female Goats: A Histological Study. *Egyptian Journal of Veterinary Sciences*, 1-9.
- [12] Koné, M.; Cologgi, D.L.; Lu, W.; Smith, D.W.; Ulrich, A.C. Pharmaceuticals in Canadian Sewage treatment plant effluents and surface waters: occurrence and environmental risk assessment. *Environ. Technol. Rev.*, 2013, 2, 17-27.
- [13] Bartelt-Hunt, S., Snow, D. D., Damon-Powell, T., & Miesbach, D. (2011). Occurrence of steroid hormones and antibiotics in shallow groundwater impacted by livestock waste control facilities. *Journal of contaminant hydrology*, 123(3-4), 94-103.
- [14] Kulik, K., Lenart-Boroń, A., & Wyrzykowska, K. (2023). Impact of antibiotic pollution on the bacterial population within surface water with special focus on mountain rivers. *Water*, 15(5), 975.
- [15] Sim, W. J., Kim, H. Y., Choi, S. D., Kwon, J. H., & Oh, J. E. (2013). Evaluation of pharmaceuticals and personal care products with emphasis on anthelmintics in human sanitary waste, sewage, hospital wastewater, livestock wastewater and receiving water. *Journal of hazardous materials*, 248, 219-227.
- [16] Matsui, Y., Ozu, T., Inoue, T., & Matsushita, T. (2008). Occurrence of a veterinary antibiotic in streams in a small catchment area with livestock farms. *Desalination*, 226(1-3), 215-221.
- [17] García-Galán, M. J., Garrido, T., Fraile, J., Ginebreda, A., Díaz-Cruz, M. S., & Barceló, D. (2010). Simultaneous occurrence of nitrates and sulfonamide antibiotics in two ground water bodies of Catalonia (Spain). *Journal of Hydrology*, 383(1-2), 93-101.
- [18] Batt, A. L., Snow, D. D., & Aga, D. S. (2006). Occurrence of sulfonamide antimicrobials in private water wells in Washington County, Idaho, USA. *Chemosphere*, 64(11), 1963-1971.
- [19] Awad, Y. M., Kim, S. C., Abd El-Azeem, S. A., Kim, K. H., Kim, K. R., Kim, K., ... & Ok, Y. S. (2014). Veterinary antibiotics contamination in water, sediment, and soil near a swine manure composting facility. *Environmental earth sciences*, 71, 1433-1440.
- [20] Fisher, P. M., & Scott, R. (2008). Evaluating and controlling pharmaceutical emissions from dairy farms: a critical first step in developing a preventative management approach. *Journal of Cleaner Production*, 16(14), 1437-1446.
- [21] Karcı, A., & Balcıoğlu, I. A. (2009). Investigation of the tetracycline, sulfonamide, and fluoroquinolone antimicrobial compounds in animal manure and

- agricultural soils in Turkey. Science of the total environment, 407(16), 4652-4664.
- [22] Martínez-Carballo, E., González-Barreiro, C., Scharf, S., & Gans, O. (2007). Environmental monitoring study of selected veterinary antibiotics in animal manure and soils in Austria. *Environmental Pollution*, 148(2), 570-579.
- [23] Slana, M., & Dolenc, M. S. (2013). Environmental risk assessment of antimicrobials applied in veterinary medicine—a field study and laboratory approach. *Environmental toxicology and pharmacology*, 35(1), 131-141.
- [24] Barathe, P., Kaur, K., Reddy, S., Shriram, V., & Kumar, V. (2024). Antibiotic pollution and associated antimicrobial resistance in the environment. *Journal of Hazardous Materials Letters*, 100105.
- [25] Barathe, P., Kaur, K., Reddy, S., Shriram, V., & Kumar, V. (2024). Antibiotic pollution and associated antimicrobial resistance in the environment. *Journal of Hazardous Materials Letters*, 100105.
- [26] Altaey, O. Y., Hasan, A. A., & Alhaaik, A. G. (2025). Early-life development of spleen in white rabbit (*Oryctolagus cuniculus*): A morphometric and histochemical analysis: <https://doi.org/10.12982/VIS.2025.012>. *Veterinary Integrative Sciences*, 23(1), 1-13.
- [27] Andersson, D. I., & Hughes, D. (2014). Microbiological effects of sublethal levels of antibiotics. *Nature Reviews Microbiology*, 12(7), 465-478.
- [28] Hughes, D., & Andersson, D. I. (2012). Selection of resistance at lethal and non-lethal antibiotic concentrations. *Current opinion in microbiology*, 15(5), 555-560.
- [29] Bayou, K., & Haile, N. (2017). Review on antibiotic residues in food of animal origin: economic and public health impacts. *Applied Journal of Hygiene*, 6(1), 1-8.
- [30] Redwan Haque, A., Sarker, M., Das, R., Azad, M. A. K., & Hasan, M. M. (2023). A review on antibiotic residue in foodstuffs from animal source: global health risk and alternatives. *International Journal of Environmental Analytical Chemistry*, 103(16), 3704-3721.
- [31] Beyene T (2016) Veterinary drug residues in food-animal products: its risk factors and potential effects on public health. *J Vet Sci Technol* 7(1):1–7
- [32] Ngangom, B. L., Tamunjoh, S. S. A., & Boyom, F. F. (2019). Antibiotic residues in food animals: Public health concern. *Acta Ecologica Sinica*, 39(5), 411-415.
- [33] Shahid A, Ali M, Muzammil S et al (2021) Antibiotic residues in food chains; impact on the environment and human health: a review. *Appl Ecol Environ Res* 19(5):3959–3977
- [34] Mathew, P., Sivaraman, S., & Chandy, S. (2019). Communication strategies for improving public awareness on appropriate antibiotic use: Bridging a vital gap for action on antibiotic resistance. *Journal of family medicine and primary care*, 8(6), 1867-1871.
- [35] Ha, T. V., Nguyen, A. M. T., & Nguyen, H. S. T. (2019). Public awareness about antibiotic use and resistance among residents in highland areas of Vietnam. *BioMed research international*, 2019(1), 9398536.
- [36] Michaelidou, M., Karageorgos, S. A., & Tsioutis, C. (2020). Antibiotic use and antibiotic resistance: Public awareness survey in the Republic of Cyprus. *Antibiotics*, 9(11), 759.
- [37] Fleming-Dutra, K. E., Hersh, A. L., Shapiro, D. J., Bartoces, M., Enns, E. A., File, T. M., ... & Hicks, L. A. (2016). Prevalence of inappropriate antibiotic prescriptions among US ambulatory care visits, 2010-2011. *Jama*, 315(17), 1864-1873