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Pesticide Residues in Animal Feed: Status, Safety and Scope

Atul Kumar[1], Ankaj Thakur[2], Vaishali Sharma[3], Shubham Koundal[4]

[1]Assistant Professor, [3,4]Post Graduate Scholar, Department of Veterinary Public Health and Epidemiology, [2]Assistant Professor, Department of Instructional livestock Farm Complex, Dr. G.C. Negi College of Veterinary and Animal Sciences, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh 176062, India.

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Abstract

Rapid increase in population has undoubtedly put enormous pressure on the food production system across the globe. However, to meet this ever increasing food demand and for controlling the pests and vectors, there has been extensive usage of chemicals especially pesticides. Although, pesticides finds an important place in intensive agriculture for enhancing the crop yield and storage; and in animal husbandry for preventing pest infestations but their unregulated and indiscriminate use is a serious health concern. Unfortunately, the rampant use of pesticides poses a potential health risks to humans, animals, and environment as well as to non-target species accruing to biodiversity loss, emergence of resistant pests and other ecological imbalances. Therefore, various steps has been taken to curb their haphazard use and many governments are now imposing restrictions on their usage. But, numerous formulations are still in use, both in agricultural and domestic settings; thereby leading to contamination of natural resources and risks for future generations. The present review focuses on various aspects of pesticides usage in agricultural and animal husbandry practices, their impact on health and the possible alternatives to their use.

Keywords: Pesticides; Animal feed; Health impacts; Environmental health; Consumption pattern.

Introduction

Maintaining balance between increasing population and supply of sufficient food is a major challenge for most of the developing nations, including India. Although, the green revolution enhanced the global food production by many folds during 1966–2000 but the usage of chemical pesticides to achieve these goals also posed some serious threats.[1,2] Since, most of the pesticides used are toxic and have raised a number of environmental worries, including human and

Corresponding Author: Atul Kumar, Assistant Professor, Department of Veterinary Public Health and Epidemiology, Dr. G.C. Negi College of Veterinary and Animal Sciences, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh 176062, India.

E-mail: dratul9@gmail.com

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animal health hazards, therefore, these potentially toxic chemicals have proved to be major threat to 'One Health'. One health is a collective approach dealing with human, animal and environmental health. As per World Health Organization (2018), pesticides are chemical compounds that are used to kill pests, including insects, rodents, fungi and unwanted plants (weeds). It covers a broad variety of compounds like insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. Pesticides used in agriculture not only protect the crops from being damaged but also increases their yield. Use of pesticides dates back to the times of ancient Romans where people used to burn sulphur for killing pests and used salts and ashes for controlling weeds.[3] The Rig Veda also mentioned earliest record of using poisonous plants for controlling pests. During 15th–17th century, substances like arsenic, mercury, lead and tobacco leaves extract were being used in crops to kill pests. The 19th and 20th century period witnessed the discovery of various effective and inexpensive pesticides such as Aldrin, DDT, Dieldrin, BHC, 2, 4-D, Chlordane and Endrin.[3,4] Although, in 1960s, following the publication of 'Silent Springs' by Rachel Carson, use of DDT was recognized as a threat to biodiversity and has now been restricted for use in many countries including India. But, worldwide production of pesticides has increased exponentially at a rate of about 11% annually, from 0.2 million tons in 1950s to more than 5 million tons by 2000.[5] Approximately, 2 million tonnes of more than 800 different kinds of pesticides are used every year worldwide out of which India accounts for only 3.75%.[6]

The main purpose behind the introduction of pesticides was to prevent and control insect pests and spread of diseases in the field crops and of course controlling the vector borne disease transmission. Owing to the use of persistent pesticides in crops, there is always a risk of low levels of their residues occurring in animal feed. Therefore, animal feed, whether in the form of commercially available materials or from natural grazing on grass or straw, provides the main exposure route for animals to environmental contaminants and pesticides. The consumption of contaminated animal feed and fodder by the food producing animals further leads to occurrence of their residues in animal products like milk, meat and eggs. Unless the residues are managed at the pre/post-harvest stages or during the storage of animal feeds, it is very difficult to prevent contamination of animal products. Finally, these residues can be transferred to humans via the food chain leading to long-term human health implications. Therefore, food is the major source of human exposure to various contaminants and thus the concerns regarding food safety especially for foods of animal origin are increasing worldwide.[7] Most of the pesticide residue-monitoring programmes have focused on food crops, fruits, and vegetables, products of animal origin such as milk, meat and eggs. However, concerning the presence of residues in animal feed and fodder, there are few reports which highlight the status of pesticide residues in feed and foddersamples from India (Table 1).

Table 1: Pesticide residues reported in various animal feeds and fodder from India

Region	Sample type (*n*)	Method of detection	Detected pesticides (Concentrations in ppm)	References
India (Uttrakhand)	Fodder grasses	Gas-liquid chromatography	∑ –HCH (0.156 – 0.574) ∑ –DDT (0.164 – 0.631)	[8]
India (Andhra Pradesh)	Paddy straw	–	∑ -HCH: ND – 1.92 DDE: ND – 6.26	[9]
India (Punjab)	Wheat straw	GC-ECD	BHC = 0.060 ∑ –DDT = 0.048	[10]
India (Punjab)	Wheat straw	–	∑ –HCH= 0.02 – 0.18 ∑ –DDT = 0.05–10.94	[11]
India (Uttar Pradesh)	Cattle feed (32)	GC-ECD	∑ –DDT (0.236) Endosulfan I (0.029) Endrin (0.020) Aldrin (0.156)	[12]
India (Delhi)	Animal feed (12)	GLC	∑ DDT (ND – 0.251) ∑ HCH (0.007 – 1.86)	[13]
India (Punjab)	Animal Feed (31)	–	DDT, Endosulfan, HCH, Malathion,	[14]
India (Uttrakhand)	Rice Straw	–	∑ –HCH (0.002 – 0.117) ∑–DDT (ND – 0.05)	[15]

Region	Sample type (*n*)	Method of detection	Detected pesticides (Concentrations in ppm)	References
India (Assam)	Concentrate feed and fodder (15)	–	Lindane (0.025 – 0.041) β-endosulfan (0.028) Endosulfansulphate (0.045 – 0.049)	[16]
India (Punjab)	Poultry feed	GC-ECD	Mean HCH (0.65), ∑ –DDT (0.91), Endosulphan (0.42) Heptachlor epoxide (0.02)	[17]
India (Haryana)	Animal Feeds	–	pp-DDT (0.007 ± 0.005)	[18]
India (Uttar Pradesh)	Animal Feed stuffs (533)	GC-ECD	∑ –HCH (0.01 – 0.306), ∑ -DDT (0.016 – 0.118), Endosulfan (0.009 – 0.237)	[19]
India (Haryana)	Dry and Green Fodder	GC-ECD	∑–OCP (1.1 – 1.2)	[20]
India (Andhra Pradesh)	Poultry Feed		HCH, DDT, Aldrin, Carbendazine and Thiram	[21]
India (Punjab)	Fodder (106)	GC-ECD/FTD	HCH, DDT, endosulfan, cypermethrin, deltamethrin, chlorpyrifos and monocrotophos	[22]
India (Uttrakhand)	Feed and fodder samples (40)	HPLC	α endosulphan (0.402) β endosulphan: (0.147) Endosulphansulphate (0.373)	[23]
India (Haryana)	Poultry Feed (50)	GC-ECD	∑ HCH (618.28) ∑ Endosulfan (135.63)	[24]
India (Telangana)	Fodder samples (48)	GC-ECD/PFD	Phorate (0.01 – 0.561)	[25]

Pesticides Consumption Patterns in India and worldwide

Over the last 60 years, farmers have achieved major progress in foodstuff production via the application of pesticides.[26] Pesticides are used in agriculture to control pests, weeds and have contributed to considerable increase in global food production through increasing yield. Reduction of pest activities and agricultural losses at a reasonable amount improved crop yield and thus ensure reliable supplies of agricultural produce at affordable prices to consumers. Also, pesticides improves the cosmetic appeal and quality of the final produce which is important for buyers. When used properly pesticides improve nutritional value of food and safety.[27] Pesticides can be considered as a productive, labor-saving, and effective tool for pest management. According to the US Environmental Protection Agency (US EPA), pesticides proved to be effective in controlling disease organisms too. They can protect the health of humans and animals by controlling insect and rodent populations which are responsible for transmission of many infectious diseases. Use of insecticides to control the insects being considered the effective and only practical way to reduce or stop spread of deadly diseases such as malaria, resulting in an estimated 5000 deaths every day.[28] Approximately, 20 major diseases in India have been brought under control by the application of pesticides; major amongst them are malaria, filariasis, dengue, Japanese encephalitis and louse-borne typhus.[29] Other kinds of benefits include the maintenance of aesthetic quality, suppression of nuisance causing pests, and the protection of other organisms including endangered species from pests. Pesticides are also used in houses and buildings to protect from structural damage causes by organisms like termites and wood boring insects. The transport sector makes extensive use of pesticides, predominantly herbicides. Also, the herbicides and insecticides are used in maintaining of turf on sports pitches, grounds, golf courses etc.

Due to excessive usage of pesticides, its worldwide consumption is estimated to be approximately 2 million tonnes per year. Out of which 45% is consumed by Europe alone, 25% by USA, and remaining 25% is used by the rest of the world.[29] The world's largest pesticide consumer is Japan and the largest pesticide market is in Asia.[30] In India, the usage of pesticide started in 1948 with the application of DDT. Now, India is the fourth largest global producer of pesticides after the USA, Japan, and China[31,32] In India, the consumption pattern of pesticides is tilted more towards the use of insecticides that too organophosphates in comparison to other pesticides.[7,31] This consumption pattern is sharply different to the rest of the world where herbicide and fungicide are used in higher

proportions.[29] However, the consumption of pesticides in India is only 0.6 kg/ha which is lowest in the world, while in UK and China, it is 5–7 kg/ha and 13 kg/ha, respectively.[32] In India, only 84 out of 230 registered pesticides, are actually used in the agriculture sector, and only 25–30% of the total cultivated area of the nation, i.e. 143 million hectare is under pesticide cover. Consumption pattern of pesticides are highly inconsistent and vary from one region to another. Countries like China, United States, France, Brazil and Japan are the largest pesticide producers, consumers or traders in the world.[30] According to one of the estimates certain countries such as Mauritius, New Zealand, Malaysia, Ireland, Kuwait, Netherlands, Israel, and Chile consumed more than 800 kg fertilizers per hectare of harvested land in 2010.[33] In addition to pesticides some countries such as Mexico, United States and Canada are also using biopesticides. Consumption of biopesticides in these countries accounts for 44% of the world.[30] The use of biopesticides helps in reducing pollution and harmful effects caused due to excessive use of pesticides. In India, with the start of low cost natural and organic farming practices, government is focusing on meagre use of pesticides. States like Sikkim and Himachal Pradesh are front runners in phasing out usage of pesticides for farming practices.

Routes of human exposure to pesticides and their impact on One Health

The environment is considered as a major source of exposure to pesticides. It is estimated that about 47% of the chemical products which are being used are deposited at or adjacent to soil and water resources.[34] Pesticides are found at detectable levels in many compartments of the environment. Once pesticides gets released into environment, they persist there in the form of residues and poses a great risk to live stock and human health. They gets entry into the body and tend to build up in the fatty tissues of living organisms, causing serious harm to the health and a potential loss of biodiversity. Exposure to pesticides can occur directly from occupational, agricultural, and household use, while they can also be transferred indirectly through diet. Farmers and their families are at greater risk to exposure of pesticides than the general population. About 56.7% of the population in India is engaged in agricultural activities and is exposed to the pesticides.[32] The main sources of exposure to pesticides in the population are plant foods (fruits, vegetables, grains) or animal (beef, pork, fish, dairy products, eggs, etc.), and to a lesser extent water, air, soil etc. Pesticide exposure during pregnancy is associated with an increased risk of spontaneous abortion, fetal death and early childhood cancers such as acute lymphocytic leukemia.[35] Pesticides can enter human and animal food chain through various pathways and the portal of entry can be oral, cutaneous, respiratory or ocular.

Effects of pesticides on One Health

Effect on environment: Most of the pesticides are not easily degraded in the environment, i.e. they usually persist for a very long time, such pesticides are considered as persistent organic pollutants (POPs) e.g. aldrin, chlordane, DDT, dieldrin, endrin, heptachlor and hexachlorobenzene.[29,36] This ability to resist degradation and remain in the environment for many years dependon their physical and chemical properties. These POPs have the ability to bioaccumulate and biomagnify, they can be bio-concentrated by up to 70,000 folds relative to their initial concentration.[36] Pesticides pollute soil, leach to underground and surface water and affect other vegetations. In addition to destroying insects or weeds, pesticides can be toxic to other non-target organisms including birds, beneficial insects and other wild flora and fauna. Water contamination by pesticides is widespread. During a survey in India, 58% of drinking water samples drawn from various hand pumps and wells were found to be contaminated.[37] The study conducted on water samples collected from different sites upstream and downstream sections of river Yamuna in Delhi showed that the concentration of aldrin and dieldrin residues ranged from 0.0005–0.05 microgram/ml (upstream) and 0.0001 to 0.1 microgram/ml (downstream), respectively.[38] Surface water samples taken from five lakes of Nainital (North West India) contained 6.054–31.336 µg/l of DDT and 3.121–8.656 µg/l of HCH, in places where insecticide has never been used for vector control.[39] Organochlorine pesticides were detected even in the snow on Nanjiabawa Peak in Tibet, with an elevation of 4,250 m.[30] Once water bodies are polluted with toxic chemicals, it may take years for the contamination to disintegrate or be cleaned up. Also, the increasing incidences of pesticide residues in the dairy products, meat, eggs etc are of a great concern for ensuring food safety and human health. Persistence of chemical fertilizers in the environment resulted in series of undesirable effects through contamination of air, food and water resources. Discharge of industrial effluents, untreated domestic waste and ever increasing use of agrochemicals in modern farming system resulted in contamination of soil

and ground water sources. Most of the pesticide applied cause harm to other non-target organisms; including birds, useful insects, fishes etc. It may take many years to remove the toxic chemicals from water bodies' once contaminated. The heavy and repeated long term treatment of soil with pesticides and chemical fertilizers cause reduction in the populations of beneficial soil microorganisms. Mycorrhizal fungi grow with the roots of many plants and aid in nutrient uptake adversely affected by application of herbicides in the soil.[28] Excessive pesticide use resulted in environmental damage by contaminating soil, water, plants etc. and also increased resistance in the target pest organisms.

Effect on human and animal health: The main sources of pesticides in the human food chain are the foods of animal origin and environmental exposure. It has been concluded that humans are exposed to these toxic compounds via diet in a much higher degree compared to other exposure routes such as inhalation and dermal exposure. The main pathway for the contamination of animal origin food is the ingestion of the contaminated feed and/or water by the animals[40] (Ledoux, 2011). Exposure to pesticides causes a wide range of health problems. Its poses significant risks to the environment ranging from beneficial soil microorganisms, to insects, plants, animals, humans, birds etc. On an average 10,000 deaths occur annually due to use of chemical pesticide worldwide, with 3/4thof these occurring in developing countries.[41] In India, the first report of pesticide poisoning was documented from Kerala in 1958, where more than 100 people died after consuming wheat flour contaminated with parathion.[37] An accidental emission of methyl isocyanate from a pesticide factory located in Bhopal resulted in more than 5,000 deaths. Pesticide impacts on human health are highly variable. In Saran district, Bihar a tragedy happened in 2013 in which more than 30 children died because of consuming of monocrotophos, a deadly organophosphorus pesticide.[31] In a study it is found that pesticide residues in food can prevent the availability of folic acid leading to the birth of children with NTD (Neural Tube Defect).[41] Some pesticides are known to act as endocrine disruptors which elicit theiradverse effects by antagonizing natural hormones in the body. The long-term, low-dose exposure of such chemicals is increasingly linked to human health effects such as immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities, cancer etc.[28] Some of the known endocrine disrupting chemicals which are present in large quantities in our environment include DDT, lindane, atrazine, carbaryl, parathion etc.[42] Pesticides may also induce oxidative stress in body and the stress markers present in plasma linked with POPs exposure leading to generation of free radicals and resulting in many debilitating chronic diseases.[43] Exposure to DDT and its metabolites cause's eggshell thinning as a result of this bald eagle population in the United States declined. OPs were expected to degrade rapidly in the aquatic ecosystem, but researches have shown that they persist days/ weeks and are accumulated by crustacean and fish causing adverse effects. OCs also greatly affects the top predators in terrestrial food chains and accumulates in adipose tissues of animals and humans, transferred to young ones through milk and act as endocrine disruptor.[5] Some herbicides may produce acute toxicity and sublethal effects on fish that reduces their chances for survival.[28] Glyphosate or glyphosate-containing products can cause sublethal effects in fish such as erratic swimming and labored breathing.[44] 2, 4-D herbicides caused physiological stress responses in sockeye salmon and reduced the abilities of food-gathering in rainbow trout.[28] On the basis of effects produced, the impact of pesticides on human health can also be categorized into acute and chronic effects. Acute health effects are sometimes misdiagnosed or not properly recognized as being associated with pesticide toxicity. They often include headache, stinging of the eyes and skin, irritation of the nose and throat, skin itching, appearance of the rash and blisters on the skin, dizziness, diarrhoea, abdominal pain, nausea and vomiting, blurred vision, blindness and very rarely death. Chronic or long-term effects of pesticides may take few hours or as long as months or years to manifest and are usually fatal. They may lead to adverse effects such as a fourfold increased risk of early-onset of Parkinson's disease, shortened attention span, memory disorders, reduced coordination, depression, cancer, reproductive problems including miscarriages, reduced infant development, birth defects etc.[37] Also, long-term pesticide exposure damages the immune system and can cause hypersensitivity, asthma and allergies.

Regulation of Pesticides

Continuous and increased use of pesticides poses a significant risk to environment, animal and human health. Therefore, pesticides must be regulated in order to ensure their safety, marketing, proper use and disposal. They should be properly monitored to avoid unacceptable risks to humans, animals, or the environment. Recognizing proper regulatory standards and management practices of using

the pesticides are the alternative ways to prevent the adverse effect of pesticide residue on the environment. Globally, pesticide regulation was given little attention until the 1940s. In 1962, the publication of Silent Spring highlighted the issues regarding the environmental damage caused by synthetic pesticides. By 1980s, the use of DDT was banned in developed nations, and the need for new and improved pesticide legislation was recognized. In the late 1960s, a new arena was opened in which "integrated pest management" (IPM) was introduced.[3] IPM is a method in which biological predators or parasites are used for controlling the pests. In 1970–1980s, pyrethroids, sulfonylureas, synthetic fungicides triadimefron and metaxyl were introduced. 179 nations including India signed an international treaty in 2001 (Stockholm Convention) that was intended to completely ban twelve Persistent Organic Pollutants (POP's) including DDT.[3] The Stockholm Convention has classified most of the organochlorines as environmental hazards because of persistence and bioaccumulation effect and banned their use [45]. The convention is designed to protect human health and the environment from POPs which have become a leading global issue. In addition to this, signatories are also required to take necessary measures to prevent/control the release of POPs and ensure the safe disposal of such substances when they become waste.

Various countries across the globe usesmaximum residue limits (MRLs) to regulate pesticides. MRLs are defined as the upper legal levels of a concentration for pesticide residues (expressed in mg/kg) in or on food or feed based on good agricultural practices and to ensure the lowest possible consumer exposure. As an example, the European Union has established maximum contents for these compounds in animal feed which can be as low as 5 µg Kg^{-1} for some OCPs in fish feed and β-HCH in cattle feed. In the rest of feed materials these values can be as low as 10 µg Kg^{-1} relative to feedstuff with moisture content of 12%. In India, Ministry of Health and Family Welfare regulates tolerance limits of pesticide and agrochemical in food products through the Food Safety and Standards Act (FSSA), 2006. The Ministry of Agriculture regulates the manufacture, sale, import, export and use of pesticides through the Insecticides Act, 1968 and the Insecticides Rules, 1971. All insecticides (including fungicides and herbicides per Section 3e) are listed in the "Schedule," and must undergo a registration process with the Central Insecticides Board & Registration Committee (CIB & RC). As of May 15, 2019, there are 288 registered insecticides under Section 9(3) of the Insecticides Act, 1968. Although FSSAI vide Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011 has established tolerance limits for various food commodities such as milk, meat, egg, fish, water, food grains, pulses, vegetables, fruits etc., but still such limits for animal feed materials have not yet been set in India.However, the MRLs of a pesticide in feed can be derived on the basis of its legal permissible limit in milk and its rate of transference from feed to milk. In spite of ban, DDT and BHC are still in production in India and are being detected in many matrices. Out of their total production in world India accounts for manufacturing of 77% DDT and 95% BHC.[46]

Conclusion

Pesticides are considered as an effective, quick and inexpensive way of controlling weeds and insect pests. They have proved to be a useful for the farmers as well as for people all around the world through their contributions to increase agricultural yield and by providing benefits to society. Ideally, pesticides should be selective in nature and must not harm other non-target organisms. However, it is difficult to achieve such absolute selectivity and the issue of hazards posed by pesticides to human health and the environment has raised concerns about the safety of pesticides. Therefore the use of pesticides should be properly monitored and regulated in order to ensure the safety of humans, animals and environment. Animal feed plays an important part in the food chain and has implication for the composition and quality of the livestock products that people consume. Under this scenario, it is important to understand the crucial issues like; what are the environmental and health costs of pesticide use. Therefore new methods should be found out in order to minimize the use of harmful pesticides and to maximize the production and ways out of crop protection from insect pests.

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