Review Article

Navigating Pesticide Residue Accumulation in Arable Soils: Insights for Sustainable Agriculture

ABSTRACT

Adoption and application of wide range chemicals as pesticides for shielding crop against undesirable weeds, insects and pests has increased the overall agricultural productivity in recent decades. According to reports, pesticides which are exposed to a variety of environmental circumstances over an extended period of time caused many of their derivatives to survive in the environment. Accumulation of these chemical in ecosystems lead theirabsorption in non-target creatures, planted crops and arable soils, and therefore,causing serious detrimental environmental hazards and many concerns have been brought to light on a worldwide scale. In fact, there may still be health hazards for people associated with the food chain transportation of these pesticide residual compounds. Pesticide residues absorption, on the other hand, is more difficult to understand. Characteristics of the planted crops, the physicochemical qualities of the pesticides and the ambient factors can all have a significant impact on the pesticide residue uptake process and bioavailable concentrations. In the meanwhile, presentarticle will emphasize on overview of these pesticide residue forms and their fate in agricultural soils, mechanisms and factors hindering plant uptake for essential nutrients.To make reasonable risk forecasts for human health, future research must conduct field-based investigations in natural settings.

Keywords: Agrochemicals, human risks, mechanisms, durability, pesticides

Introduction

Around the world, a vast variety of chemical compounds are widely employed as pesticides in agriculture to get rid of unwanted pests from the crops (Sharma *et al.*, 2020). Any organism that has detrimental, undesired impacts on crops or animals, such as insects, plant pathogens, weeds, molluscs, birds, mammals, or nematodes, is referred to as a pest (Yadav and Devi, 2017). A wide range of pesticide groups, each with unique chemical and physical characteristics, are regularly employed in agriculture.Pesticides are classified into a number of types, such as herbicides, fungicides, rodenticides, bactericides, algaecides, nematicides, molluscides and ovicides, etc., depending on their intended use and the organism they are intended to kill (Hassaan and El Nemr, 2020). Around the world, a vast variety of chemical compounds are widely employed as pesticides in agriculture to get rid of unwanted pests from the crops. Furthermore, the chemical components used in the production of pesticides might be either organic or inorganic. Inorganic pesticides, like copper sulphate, ferrous sulphate and sulphur, are defined as simple compounds without carbon in their chemical structure (Hassan, 2019). In contrast, the active ingredients of organic pesticides such as glyphosate, pyrethrin and captain are based on compounds containing carbon. There are numerous viable pathways (or modes of entry) that are specific to each kind of pesticide that can penetrate their target pests, including contact, stomach, fumigant, and systemic poisons. Certain insecticides are consumed by the pest through its mouth and spread throughout its body, eventually killing it. Indeed, insecticides such as malathion have the ability to target the developing stomach and kill it (Karim *et al.*, 2020). Furthermore, some pesticides only work on the intended pests when the chemicals physically come into contact with the organism's epidermis and penetrate through the lesion. Additionally, fumigants release a toxic vapor that enters pests' respiratory systems and kills them through poisoning. Even while employing pesticides has advantages, improper use of those chemicals over several decades may cause pesticide residues to contaminate land and water. Pesticide degradation is caused by a few processes, including photochemical oxidation, photolysis, hydrolysis, and metabolism, which also produce residual products (Shubham *et al.*, 2021). These residues are common in agricultural soils and pose a serious risk to the environment because of their long environmental half-lives. Aquatic environments are contaminated in part by pesticide residues.Nonetheless, a variety of characteristics have been identified as controlling elements for pesticide residue behaviour in soil. Basically, a pesticide's physicochemical characteristics affect how residues in soil are bound and end up. The varieties of pesticide residues, their destiny, and plant uptake mechanisms in agricultural soils are highlighted in this chapter. The detrimental effects of pesticide residues, especially on humans, are also covered, along with the determining factors that affect how plants absorb these residues.

Possible sources of pesticide residues in farming soils

1. **Types of Residues**

The majority of pesticides sprayed get spread and further interacts with the surroundings. Pesticide residues are the leftovers of pesticides and their breakdown products that are found on and in food. There are numerous varieties of pesticide residues in the environment.The efficiency and chemical and physical characteristics of pesticides are reflected in the classification of pesticides according to their chemical makeup (Raina, 2011). Typically, synthetic and plant-originated organic compounds are frequently utilized as pesticides, however, numerous inorganic substances are also employed as pesticides in the world. Pesticides can be classified into four main classes based on their chemical composition: carbamates, organo-chlorines, synthetic pyrethroids and organo-phosphorus (Chormey*et al.*, 2020). One of the first classes of synthetic pesticides used in agriculture are organochlorine insecticides. Dichlorodiphenyltrichloroethane (DDT), endosulfan, heptachlor, and chlordane are a few examples of frequently used organochlorines. These insecticides may have a long-lasting residual influence on the environment. Organochlorine pesticides have been around for a while, but because of their extended residual effects, several nations have switched to using other pesticides, like organophosphorus and carbamate, which have shorter residual effects (Pearce *et al.*, 2019).

Organo-phosphorus pesticides are part of a wide range of pesticides used in pest control because of their many uses. In addition, these pesticides have decreased environmental damage, slow pesticide resistance, and are biodegradable. Pesticides that target the transmissions of nerves in insects, such as carbamates, are physically and functionally similar to those that target organophosphorus pests. Carbamates could break down quickly and cause less pollution in the environment (Cueff*et al.*, 2020). Carbofuran, aminocarb, carbaryl, aldicarb, and pirimicarb are a few examples of carbamates.Synthetic pyrethroid pesticides are among the safest organic pesticide categories for food crops, and they are more stable and have a longer residual effect than natural pyrethrins. Furthermore, the majority of synthetic pyrethroids have very little persistence and are easily broken by light, and their toxicity to birds and mammals is minimal. By highlighting the pesticide activity and identifying the target organism, the pesticides are categorized. Herbicides (glyphosate), insecticides (chlorpyrifos), fungicides (chlorothalonil), rodenticides (warfarin), bactericides (copper complexes), larvicides (like Methoprene), virucides (like scytovirin), nematicides (aldicarb), molluscicides (like metaldehyde), algaecides (like copper sulphate) and acaricides (bifonazole) are some examples of the pesticide classes. Ovicides (lbenzoxazine), termiticides (fipronil)and lampricides (trifluoromethyl nitrophenol) (Golge*et al.,* 2020).

In agricultural settings, herbicides are used to either completely eradicate all vegetation or selectively control weeds without endangering the crop. These pesticides may enter plants through the roots or the leaves, respectively, and the selectivity of the pesticide may vary depending on how differently plants absorb the chemicals, how they metabolize them, and how they translocate. Herbicides are categorized according to the chemicals they contain. Insecticides are sprayed on plants or soil to keep pests like insects out of crops. Insecticides can also be categorized based on their chemical makeup. Examples of this include the organic insecticides DDT and endosulfan, the organochlorine insecticides chlorpyrifos and fenitrothion, the carbaryl and methomyl insecticides, the pyrethroid insecticide permethrin, and the neonicotinoid insecticide acetamiprid. In agriculture, fungicides are used to prevent fungal diseases in cereals, fruits, and vegetables. The chemical makeup of fungicides determines their classification. Among the frequently used fungicides are cyproconazole (azole fungicide), thiabendazole (benzimidazole fungicide), fenpropimorph (morpholine fungicide) and chlorothalonil (organo-chlorine fungicide) (Wong *et al.*, 2017).

2. Fate of pesticides residues in soil

As was already established, the majority of pesticides which are used on plants or soil end up dispersing throughout the surrounding area. Even if the area where pesticides are applied is very small, over time, pesticides may spread by adsorption into the soil, volatilization into the air, or dissolution in water. Through processes including surface runoff and flooding, herbicides sprayed on the soil may cause unintentional dissemination and non-target contamination in the soil and surface water bodies. Percolation can also contaminate lower soil layers and groundwater (Yu *et al.,* 2006). Following pesticide application, a variety of processes, including volatilization, adsorption, photochemical decomposition, chemical decomposition, microbial decomposition, movement and organism uptake, may have an impact on the fate and behaviour of the deposited pesticides on soil and plant surfaces. The soil is heterogeneous physically, and the lateral and vertical variations in soil structure led to a complex water flow through the soil profile. The pace of pesticide transportation through the soil is determined by the qualities of the pesticide, the environment, and the soil (Wong *et al.,* 2017).Since, adsorption either directly or indirectly affects the magnitude of the other influencing processes; it has a significant impact on the interactions that occur between soil colloids and pesticides. The adsorption process may be affected by the adsorbate's physicochemical properties, such as its water solubility, acidity and basicity, size, shape and configuration, polarity, charge distribution and polarizability. The soil interaction in the clay-water system affects the characteristics of the adsorbent and adsorbate. Also, the pH of the soil solution would affect the adsorbate's degree of attachment and separation. The crucial soil system feature of surface acidity controls the adsorption and desorption of organic molecules. Since, adsorption is an exothermic process and desorption is an endothermic process, soil system temperature may have an impact on adsorption processes. Three different adsorption mechanisms can be distinguished: hydrogen bonding, chemical adsorption, and physical adsorption. As a result of short-range dipole–dipole interactions, van der Waals forces could be formed between adsorbent and adsorbate to form physical adsorption. Chemical adsorption can result from chemical interactions between the adsorbent and adsorbate caused by mechanisms such ion exchange.Yu *et al.,*(2006) demonstrated, for instance, that the adsorption and three pesticides *i.e.*chlorpyrifos, myclobutanil and butachlor had their desorption processes heavily regulated by soil organic matter (OM).

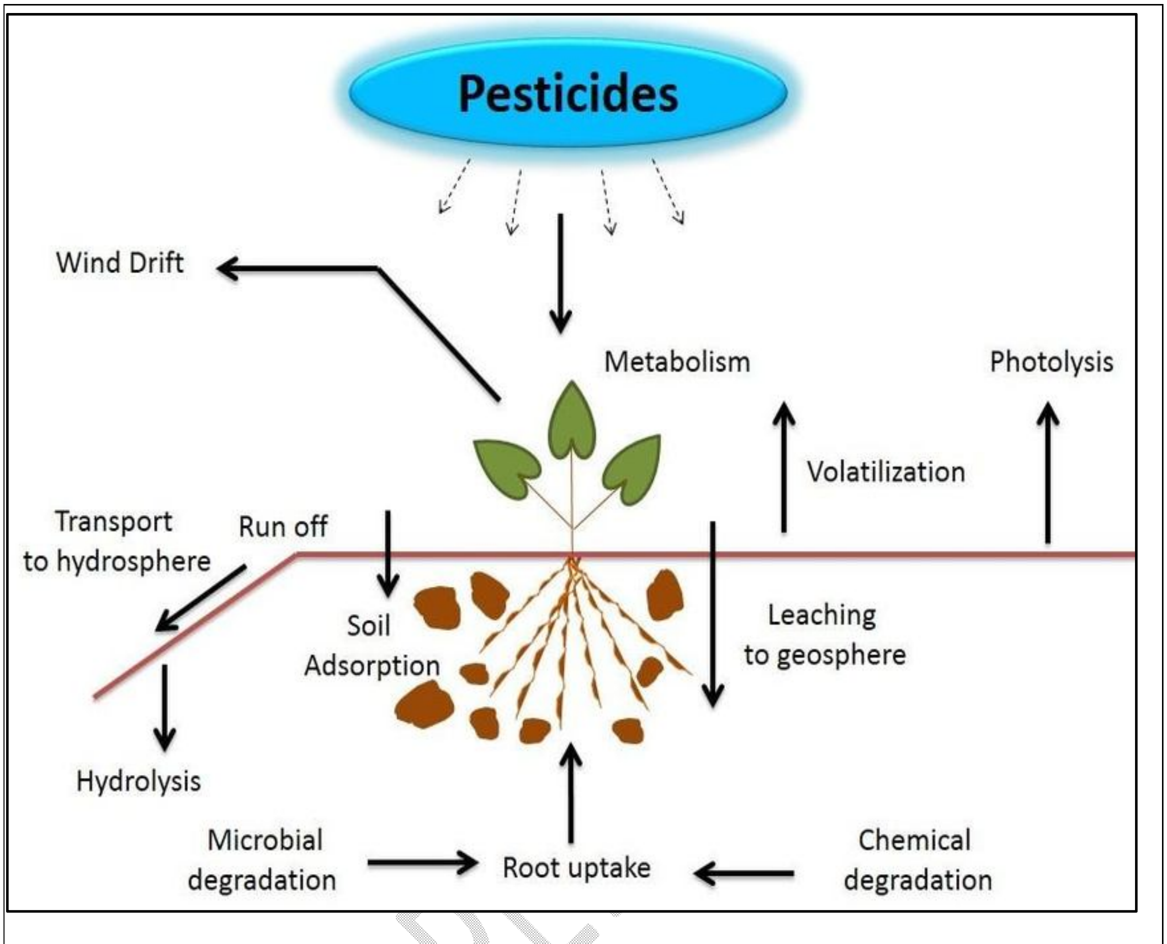

Fig.1 Environmental fate of pesticides

Numerous soil-related variables, including vegetation, preferred flow, soil moisture, amendments, soil tillage, and aided transport, might affect the mobility of pesticides. Van der Waals forces could be used by the organic matter (OM) produced by vegetation to adsorb hydrophobic pesticides, whereas carboxyl and phenolic groups in the OM could create hydrogen bonds with hydrophilic pesticides (Fig. 1)(Katagi, 2013). Pesticides can be transported by the movement of water in three different ways: downhill, upward, and through soil airspace and soil water diffusion. Percolating water can facilitate the flow of relatively non-volatile pesticides, whereas air diffusion plays a more significant role in the movement of highly volatile pesticides. Leaching is defined as the release of insecticides into the soil solution. It can be the consequence of the pesticide desorbing from soil surfaces or dissolving from its original form. The characteristics of the pesticides (sorption, degradation, and solubility) and the soil (type, texture, and structure) govern the leaching of pesticides. For instance, the quick sorption severely restricts the amount of nicosulfuron herbicide that can be leached from clay minerals. Furthermore, mesotron does not move in soil below 20 centimetres because of its limited mobility and low rate of degradation (Rouchaud, 2001). The type of soil has a significant impact on pesticide leaching, whilst the qualities of the pesticide have a role. Additionally, the evapotranspiration ratio and soil moisture content may have an impact on leaching. Because pesticide leaching is more common in light-textured soils than in heavy-textured soils and because changes in soil texture typically have an impact on changes in soil structure, both soil texture and structure may have an impact on pesticide movement and leaching. The timing and duration of the first rainfall following pesticide application, as well as other meteorological factors, have a significant influence on the fate of pesticides in the soil. Pesticides are generally degrading due to processes such photolysis, photochemical oxidation, hydrolysis, and metabolism.

Pesticide breakdown is aided by the rhizosphere's high biomass and microbial activity. Pesticides may break down in plant tissues as a result of endophytic bacterial activity or enzymatic processes within the plant (Isensee and Sadeghi, 1997). The breakdown of atrazine to hydroxy atrazine is an example of abiotic pesticide degradation, and according to Wang *et al.,* the soil colloidal surface Bronsted acidity acts as a catalyst for this conversion.

Pesticide residues may build up in the bodies of soil microorganisms such earthworms. Earthworms typically absorb more pesticide residues, such as butachlor and myclobutanil, as soil organic matter (OM) levels decline. Two possible routes for the accumulation of pesticide residues in earthworm bodies are ingestion of contaminated soil and passive diffusion through the dermis of the earthworm. Earthworms are unable to accumulate chlorpyrifos pesticide through their dermis because of the pesticide's high sorption onto soils (Linden *et al.,* 2009). Pesticides and pesticide residues have the potential to decompose, translocate, and accumulate in plant tissues in addition to soil macro- and microorganisms. Plant absorption is the term used to describe the process by which pesticides enter vegetation.

Mechanisms of pesticide residue uptake, translocation and bioaccumulation in plants

Environmental plants, including food crops, are susceptible to contamination from pesticide residues. Plants can absorb pesticides from the soil and air through their roots, or through their aerial parts (leaves, fruits, and shoots), respectively (Fig. 2). Herbicides enter plants through their leaves as well as their roots, but some other organic contaminants enter plants only through their roots in the soil. Since plant roots are typically the first tissue that soil pesticides come into contact with, organic pesticides are less volatile and are typically absorbed by plants through their roots. There are two ways that pesticides are absorbed by plants: passive absorption and active uptake (Chen *et al.,* 2012).

For instance, the primary mechanism of fungicide uptake, such as imazalil and tebuconazole, herbicide uptake, such as phenyl urea, and insecticide uptake, such as o-methyl carbamoyl oxime, is passive uptake. Certain organic pesticides, such as phenoxy acid herbicides, absorb pesticides during the active uptake phase by working against a chemical potential gradient with the help of carriers in root cell membranes (Su and Zhu, 2007). Essential elements of plant root uptake include energy metabolism and transport proteins on the cell membrane (Shubham *et al.,* 2021). Pesticide concentration in the soil, the physicochemical characteristics of pesticides, the interaction between soil microorganisms and pesticides, plant species, exposure duration, temperature, and other system variables all affect how efficiently and to what extent pesticides are absorbed from the soil. The primary mechanism responsible for the transfer and translocation of organic pesticide residues from soil to plants is the plant's evapotranspiration process. Contact insecticides do not go through the plant's circulatory system or pierce plant tissue. Furthermore, because it is difficult for partially soluble organic pesticides to reach the shoots, they typically concentrate in the roots of plants. Pesticides such as systemic herbicides (e.g. glyphosate) can be absorbed into plants and translocated into untreated tissues. The flow of pesticides in plant tissues can be either unidirectional or multidirectional, meaning that while some pesticides can only go upward in the plant, others can move both downward and upward (Lv*et al.,* 2017).

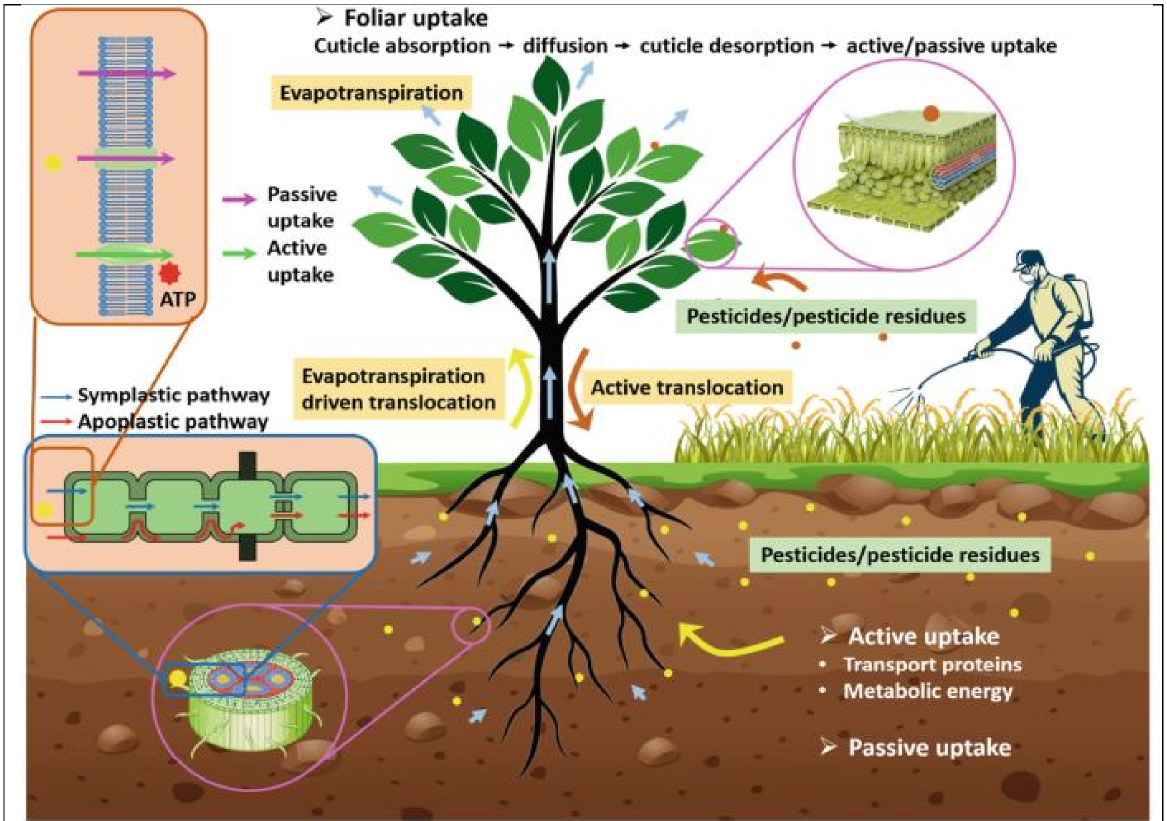

Fig. 2 Mechanisms of the uptake, translocation and bioaccumulation of pesticide residues in plants

The apoplastic and simplistic pathways are the two routes by which pesticides travel through plant tissues. The route that passes through the plant cortex's protoplasts is known as the symplastic pathway, while the route that passes through the intercellular space and cell walls is known as the Apo plastic pathway. Previous research has shown that the physicochemical properties of pesticides and plants might affect their absorption and translocation mechanisms. As a result, non-polar chemical pesticides like propiconazole and phenanthrene are typically translocated via the Apo plastic pathway, whereas polar organic pesticides like atrazine, imidacloprid, and carbendazim are most likely to be translocated via the symplastic pathway (Fig. 2) (Kirkwood, 1999). Additionally, the long-distance transportation route of these molecules inside the plant is determined by their physicochemical characteristics. For instance, big organic molecules with limited membrane permeability will be transported via phloem, but small organic molecules are transported either by xylem or by phloem.

Plant cuticle, which functions as a potential barrier for pollutant penetration, plays a significant role in the process of pesticide uptake through the foliar portions of a plant. A complex extracellular substance called a cuticle protects the outside of the aerial sections of plants. Pesticide drop behaviour on plant surfaces may be impacted by the physicochemical characteristics of the cuticle, which in turn influences penetration rate and efficiency. Diffusion controls this penetration, which happens in three stages: absorption into the cuticle, diffusion through it, and desorption out of it. Cuticle hydration can promote the penetration of hydrophilic compounds while decreasing the viscosity of wax can promote the transit of hydrophobic compounds through the cuticle (Florence *et al.,* 2015). Phloem tissues can facilitate the active translocation of pesticides absorbed through foliar absorption to stems and roots. Crosswise pesticide diffusion from phloem to xylem may occur when pesticide uptake is strong. Diffusion resulting from a change in concentration or transpiration might propel these processes. In the end, these activities result in the buildup of pesticide residue in a variety of plant tissues, including stems, roots, leaves, fruits, and tubers.Organic pesticide residues' ability to bioaccumulate in plant tissues can be influenced by their physicochemical characteristics, such as their poor water solubility and lipophilicity. The bioaccumulation of pesticides may be accelerated by an increase in these variables because non-polar contaminating molecules dissolve in plant lipids but are less soluble in water. Because the capacity of a contaminant to pass through biological membranes increases with decreasing molecule size, the size of the contaminating molecule plays a significant role in pesticide accumulation. Additionally, the herbicides' limited biodegradability causes bioaccumulation in plant tissues. By altering the chemistry of the pesticides, the biodegradation process brought on by plant metabolic activity counteracts the effects of bioaccumulation (Xu *et al.,* 2009).

Factorsinfluencing plant uptake of pesticide residues

The variables influencing how well plants absorb pesticide residues from the soil are crucial, particularly in light of the potential health risks to humans and/or herbivores. Numerous parameters have been identified as influencing the intake of pesticide residues through roots, their translocation to the aerial portions of plants, or their accumulation in plant roots cultivated under irrigated soils in actual agricultural systems, as seen in Fig. 3. Since it is difficult to predict how agricultural soil will contain pesticide residues when it comes to plant uptake, a combination of environmental conditions, plant physiology parameters, and the physicochemical features of the residues might influence plant uptake.

1. **Environmental Factors**

Crop plants' uptake and accumulation of pesticide residues are generally shaped and determined by the features of their agricultural surroundings, such as the soil and climate. Moreover, plant absorption is significantly influenced by the level of pesticide residue bioavailability and bio accessibility in the rhizosphere Furthermore, the persistence of pesticide residues in soil and plant uptake can both be significantly impacted by soil texture. For instance, the bioavailability of pesticide residues in the soil is limited by the texture of loamy soil, which results in lower plant uptake. On the other hand, sandy soils allow for quicker contaminant uptake and percolation, which reduces the bioavailability of pesticide residues in the rhizosphere, according Khan *et al.,* 2018.

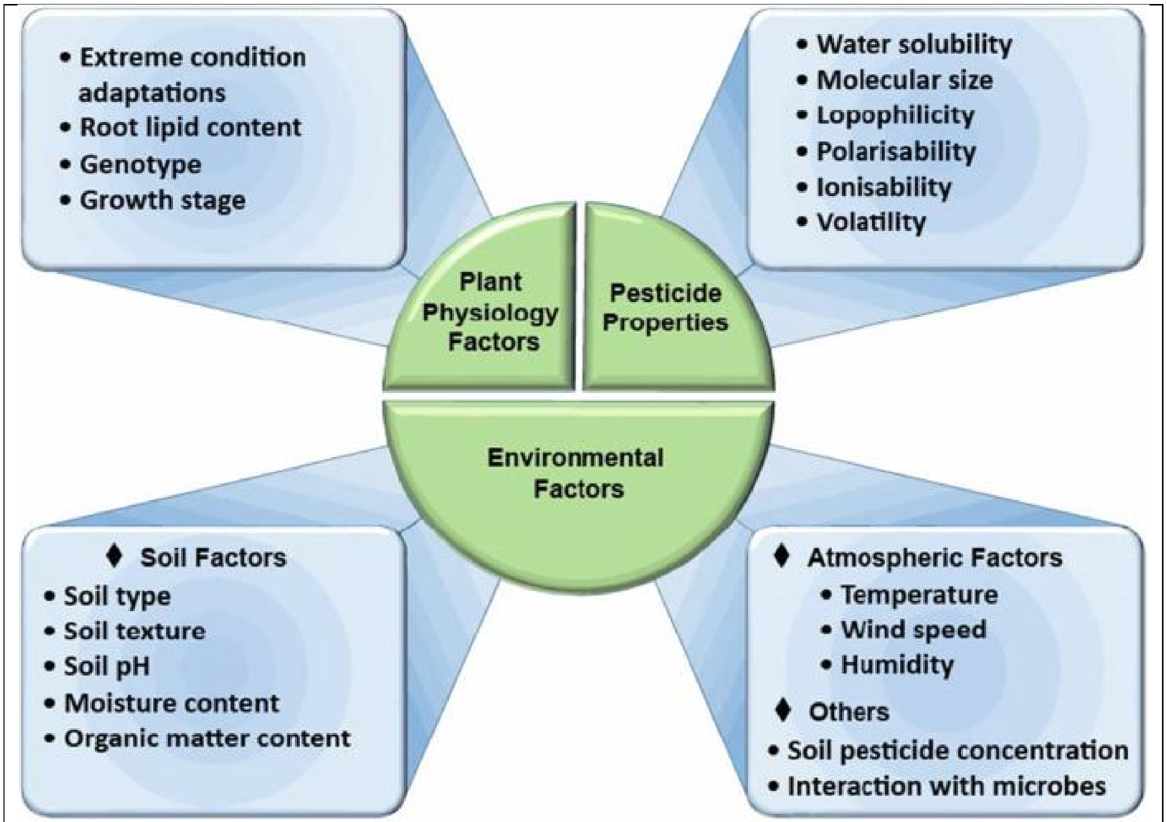

Fig. 3 Factors influencing the uptake of pesticide residues by plants

In actuality, the soil's acidic pH typically encourages pesticide residues to sorb onto the soil while also favouring plant uptake of residues. However, acidic soil makes it easier for residues to develop in a neutral form, which creates the ideal environment for plant uptake.

Apart from the previously listed variables, air humidity, wind direction, and ambient temperature can also have an impact on the absorption and build-up of pesticide residues in crop plants. Elevated temperatures, strong winds, and low humidity levels have a beneficial impact on plants' evapotranspiration rate, leading to increased uptake of pesticide residues. It is emphasized that agricultural locations with dry, hot climates are more likely to have pesticide residues absorbed from the soil than those with cold or humid climates (Fig. 3).

2. Plant Physiology Factors

Although the general intake from the soil and translocation through the plant are largely determined by the physiology of the plant, the transpiration mechanism itself is plant-specific. Furthermore, because the evapotranspiration process and the uptake of wastes from the soil are closely related, plants have evolved some adaptation mechanisms to reduce the rate of transpiration (Ahuja *et al.,* 2010). Most notably, compared to plants growing in ideal conditions, those grown in drought-stressed environments show reduced potential for residue uptake from soil because they have evolved numerous methods for minimizing resource consumption.

Therefore, it has been discovered that plants have a variety of defence mechanisms to deal with such harsh abiotic environmental conditions (Wu *et al.,* 2016). These mechanisms include stomatal closure, hormone modulation, antioxidant formation, induction of stress proteins, and osmotic adjustment. Furthermore, the plant's genotype influences its capacity to absorb pesticide residues. It was discovered that even among agricultural plant varieties that belong to the same species, the absorption capacity of pesticide residues exerts distinct patterns (Sun *et al.,* 2019). Furthermore, the lipid content of plant roots controls the accumulation of pesticide residues; as a result, partitioning into lipids is thought to be the main sorption mechanism of poorly soluble pesticide residues. Depending on the crop's growing season, there are significant differences in the possible uptake of pesticide residues from agricultural soil into the aerial portions of plants. Rainy-season crops are less likely to absorb pesticide residues from the soil, therefore the summer months have a beneficial effect on uptake. These residues are transferred to the plant's aerial parts, such as shoots, leaves, or fruits, once they are absorbed by the plant.

3. Physicochemical Properties of Pesticide Residues

Several physicochemical properties of pesticides influence their toxicity to non-targeted species as well as the persistence of pesticide residues in the environment. Furthermore, the water solubility of pesticide residues affects their active adsorption through the roots (Aktar *et al.,* 2019). Pesticides come in a range of chemicals, from highly soluble to insoluble. The mobility of wastes in the soil environment is influenced by their solubility properties. High soluble pesticide residues have the potential to leach downward and dissolve readily in rainwater, lowering their bioavailability in the rhizosphere (Farha *et al.,* 2016). It is possible for insoluble residues to remain in soil for an extended amount of time when they are firmly adsorbed on different inorganic and organic soil fractions.

The fundamental chemical makeup of the substance is important since it affects how long the pesticide remains in the ground. However, at low soil pH conditions, pesticide molecules in their ionic form may be more desirable to plants for uptake (Fu *et al.,* 2020). Furthermore, the majority of pesticides readily decompose into other products that may be more complicated or fleeting than their parent molecules. On the other hand, those recently developed items might become less hazardous substances. However, since they are two of the elements influencing how well plants absorb pesticide residues, volatilization and photochemical modification of pesticide residues are particularly interesting (Abhilash *et al.,* 2016). High volatility pesticides would evaporate entirely in a short amount of time, lowering the amount of residue left in the soil environment.

Impact of pesticide residues on human and environmental health

Pesticide overuse and usage have led to numerous environmental and health-related problems across the globe. According to Bhandari *et al.,* excessive pesticide use puts the health of over two million individuals in poor nations at risk. Additionally, earlier estimates suggested that between 5,000 and 20,000 people died each year from pesticide exposure (Farha *et al.,* 2016). Pollution of the environment has resulted from the use of several chemical pesticides and the residues they leak into the environment. Pesticides may have genotoxic, neurotoxic, and carcinogenic effects on human health. The toxicity of pesticide compounds, the extent of exposure, and the duration of exposure can all influence how detrimental pesticides and their residues are to human health. Exposure refers to the coming into touch of a pesticide ingredient with the human body. This can occur through the direct skin absorption of pesticides, inhaling pesticide-containing dust and air, or consuming contaminated food or drink. The human body may have negative consequences if the exposure level to pesticides exceeds the permissible dosage level.

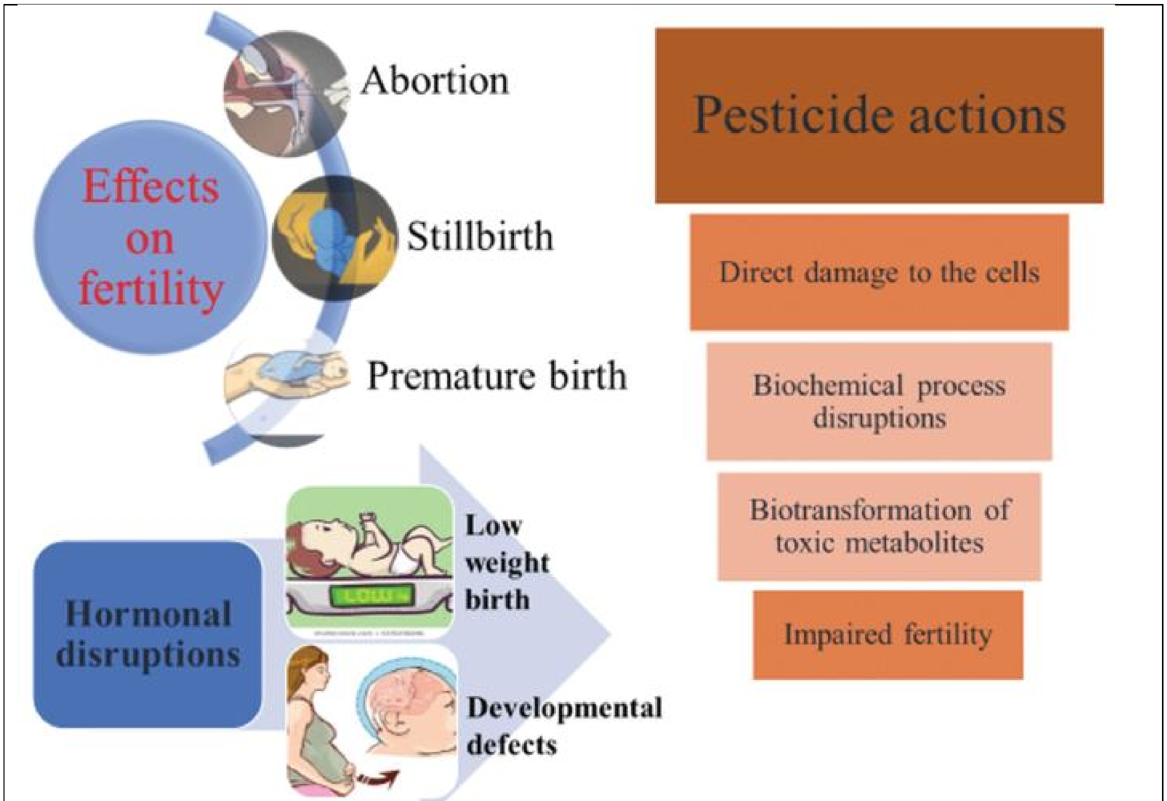

Fig. 4Major Impacts on Human Health of pesticide residue

The ability of a chemical agent to have negative health effects over extended exposure is known as chronic toxicity. The insecticides and their residues that are present in the harvest may be the cause of this persistent toxicity. A person may have a wide range of symptoms including headaches, nausea, dizziness, aches in the body, blurred vision, skin rashes and cramping as a result of pesticide poisoning (Abhilash *et al.*, 2016). Several types of cancer, neurodegeneration, blood diseases, impacts on reproduction, birth defects, genetic change, endocrine disruption, and issues with the kidneys, lungs, and digestive system are only a few of the numerous chronic effects of pesticide exposure (Fig. 4) ((Florence *et al.*, 2015)).Numerous studies have found that eating contaminated food is the major way that people might come into contact with pesticides. The concentrations of pesticides dichlorvos, chlorpyrifos, dimethoate, and diazinon found in dry brown beans and watermelons in Nigeria were greater than permitted residual limits. Pesticide residues of dimethoate, acetamiprid, imidazolyl, carbofuran, malathion, metalaxyl and DDT were found in numerous samples of cowpeas, millet, soybeans, white pepper, egusi seeds, and maize that were taken from Cameroon. The gherkin plant is vulnerable to a variety of pests and diseases, including bacterial, fungal, and metalaxyl. Analyses of samples taken in Turkey revealed the residues of these chemicals. Additionally, Chinese cucumber and cabbage samples are frequently examined for pesticides such acetamiprid, aldicarb, carbofuran, metalaxyl, pirimicarb, carbaryl and isoprocarb.

Pesticide residues can have negative consequences on the environment in addition to human health. Overuse of pesticides can accelerate the buildup of residues in the soil, which in turn can have an impact on the microorganisms and soil structure. Pesticide degradation products have the ability to change enzyme activity, microbial diversity, and biochemical reactions. Additionally, it can lessen biomass and fertility in the soil (2).

Pesticide breakdown products are more harmful than the original pesticide, according to Chandran et al. Long-term pesticide residue in the soil can threaten the ecosystem by propagating through food chains (Chen *et al.,* 2012). Excessive use of pesticides can impact non-target creatures in the ecosystem and cause pests to become more resistant to the chemicals. For instance, pesticides like carbamates and other organophosphorus insecticides can lower populations of earthworms, pollinators, and natural predators—all of which are crucial for pest control (8). It has been noted that by harming non-target plants, such as some uncommon species, volatile herbicides can have an impact on primary producers (9). Surface runoff, irrigation, leaching from treated soil, cleaning pesticide spray equipment, and unintentional spills are some of the ways that pesticides can build up and contaminate surface water bodies (Chen *et al.*, 2012). Tebuconazole fungicide has the potential to contaminate aquatic organisms, according to Lv*et al*.(21).

Conclusion

The world's food output must increase by about 70% to meet the demand brought on by the continually expanding population. The use of anthropogenic pesticides to reduce the impact of pests on crop yields has become commonplace, significantly boosting agricultural productivity. Agricultural soils are contaminated with pesticide residues due to overuse of pesticides, even with advancements in pest management. Enough evidence has been gathered from laboratory trials to conclude that pesticide-based soil pollutants are primarily absorbed by different plant species and sink into the soil. Since pesticide residues can affect human health when ingested through the food chain, it is quite concerning when they build up in edible plants. Given that the majority of food production is dependent on the quality of the soil, it is critical to evaluate the pathways and patterns of pesticide dispersal in the agricultural environment using both qualitative and quantitative methods. However, because laboratory testing can only be done in a restricted number of settings, it may be challenging to estimate the possible danger of plant absorption. In order to account for these constraints and generate plausible risk estimates for human health, it is evident that research should be carried out in real-world settings. Furthermore, different parts of the world may experience varying pesticide effects and plant uptake of residues. When comparing tropical statistics to their temperate counterparts, notable differences may occur.

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