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An Examination of Pesticide Residues in Fruits and Vegetables: Awareness and Prosperity

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ABSTRACT

To support the growing global population, it is essential to improve agricultural productivity. Health awareness and economic prosperity have markedly increased the consumption of fruits and vegetables, particularly in emerging countries, over the last 50 years. The utilization of pesticides is a way employed to achieve these aims. Pesticides are employed to safeguard public health from vector-borne diseases. Approximately 1,000 chemicals, encompassing both organic and inorganic compounds, function as active ingredients in pesticides. Organochlorine and organophosphate insecticides are highly toxic and can persist in the environment for decades. Organochlorine pesticides, banned four decades ago, continue to be present in fruits and vegetables. Pesticides from soil and water accumulate in fruits and vegetables, particularly in those commonly consumed raw. The consumption of pesticide-contaminated fruits and vegetables by individuals leads to adverse health consequences. The immediate adverse effects on people include asthma, sore throat, eye and skin irritation, and diarrhea, while the long-term consequences encompass cancer, neurological diseases, reproductive problems, and diabetes, among others. This review aims to record the concentrations of common pesticides in fruits and vegetables and their impact on human health. This project will provide data for policymakers to formulate guidelines to reduce health risks to humans from consuming pesticide-contaminated fruits and vegetables.

Keywords: Ecology, Produce, Agrochemicals, Vegetables.

INTRODUCTION

Vegetables and fruits, essential to the human diet, serve as a principal source of carbohydrates, lipids, vitamins (A, B complex, C, E), minerals, antioxidants, dietary fibers, and other crucial components. Medical authorities recommend a diet rich in fruits and vegetables to reduce the risk of major non-communicable diseases, such as cancer, cardiovascular diseases, and obesity, and to prevent deficiencies in micronutrients and vitamins (Ali, 2024). In 2023, the worldwide output of fruits and vegetables was anticipated at 2.1 billion tonnes. India, the second-largest vegetable grower, contributes 12% to global vegetable production. In 2023, the global fruit market was appraised at 714 billion US dollars. To accommodate the rapidly growing global population, anticipated to reach 8.6 billion by 2030 (up from 7.6 billion in 2024), agricultural experts must improve agricultural output, especially in tropical areas. To augment agricultural productivity, the primary strategy is to manage pests and invasive species, including weeds and fungi, which affect around 23% of crop production; thus, fertilizers and pesticides have been utilized extensively and indiscriminately. Pesticides are widely utilized in public health to protect individuals against vector-borne diseases, including malaria and dengue fever (Zoolaf, 2024). In 2024, worldwide pesticide production totaled 4.3598 million metric tons, with a valuation of 26.22 billion US dollars. The agrochemical industry is anticipated to reach 311.48 billion US dollars by 2025. Notwithstanding its global prohibition owing to cost-effectiveness and extensive efficacy, DDT and BHC remain in use in developing countries, such as India. The application of pesticides to crops and soil increases agricultural production and food security; yet, indiscriminate use, inadequate spraying equipment, and incorrect application techniques result in the buildup of persistent chemical residues in crops and soil. The output of veggies exceeds that of cereal crops. Health specialists endorse the intake of fresh fruits and vegetables; nonetheless, pesticide residues provide food safety and health issues, particularly for those vegetables commonly consumed raw or minimally cooked (Syed et al., 2014).

A significant pathway for human exposure to pesticides is the consumption of agricultural goods. Various health concerns, such as cancer, endocrine disruption, neurological effects, genotoxicity, congenital anomalies, and diminished fertility, are linked to pesticides or

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their metabolites in the human body, as these substances affect xenobiotic metabolism by interfering with the enzymes that govern growth and reactive oxygen species and cause cellular and DNA damage. Dizziness, cephalalgia, dermal eruptions, and nausea may also manifest. enforced by pesticides. The harmful impacts of pesticides are especially apparent in children. This review aims to develop policies to reduce the health risks connected with the consumption of fresh fruits and vegetables.

RESEARCH ELABORATIONS

The unregulated and indiscriminate application of pesticides throughout the sowing and growing phases of vegetables and fruits results in the accumulation of these persistent hazardous pollutants in the produce (Donkor et al., 2016). The literature review reveals that more than 50% of global vegetables and fruits are contaminated by one or more pesticides. About 30% of the vegetables and fruits displayed pesticide levels over the allowable threshold. Foster's research revealed that in the United States, 20% of fruits and vegetables contain elevated pesticide levels (one or more). The 'Dirty Dozen' list includes fruits and vegetables with the greatest pesticide residues: strawberries, apples, cherries, spinach, nectarines, blueberries, green beans, potatoes, peppers, and kale. In a study of 30,000 fruit and vegetable samples, found that strawberries, blueberries, green beans, potatoes, and peppers displayed elevated pesticide levels, with 8% of the samples surpassing allowable limits. A report from The Hindu Daily, dated 23 July 2024, said that 16% of 195 samples from 19 vegetables and 12 fruits displayed pesticide levels substantially surpassing legal thresholds. found that over 90% of fruit and vegetable samples from ten countries are tainted with the insecticides chlorpyrifos, profenofos, dimethoate, and fenitrothion (Ssemugabo et al., 2023). The samples from the United Arab Emirates (UAE) exhibited the highest concentration. The greatest concentration of pesticides was detected in root vegetables. The levels of the pesticide chlorpyrifos in fruits and vegetables grown in China, India, Ghana, Thailand, and the UAE exceed the maximum allowable limits, with samples from Ghana showing concentrations 30 times higher than UK standards (Lim et al., 2020). assessed pesticide concentrations in 232 samples of tomatoes, cabbage, and Swiss chard, indicating that almost 50% of the samples included at least one

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pesticide, 20% had two or more, and 155 samples exhibited pesticide levels surpassing acceptable limits. Chlorpyrifos pesticide concentrations in fruit and vegetable samples from the UAE, China, India, Ghana, and Thailand are beyond legal thresholds.

Approximately 47.5% of samples of vegetable tomatoes, onions, watermelons, cucumbers, sweet peppers, and Chinese cabbage grown in Tanzania display pesticide levels over acceptable thresholds. one pesticide residue was identified in 49.1% of samples, two pesticide residues were observed in 31.1% of samples, and three pesticide residues were detected in 11.7% of samples. Organophosphate pesticides were identified in 95.2% of all samples, followed by organochlorine at 24%, pyrethroids at 17.3%, and carbamate pesticides at 9.2%. The concentrations of DDT, HCH, and heptachlor in cabbage and tomatoes, along with aldrin in lettuce grown in Ghana, are beyond the established permissible limits. found that pesticide concentrations in 40.7% of vegetables and 38.9% of fruits exceeded maximum residue limits (MRLs). The USA Environmental Working Group disclosed that more than 90% of samples of strawberries, apples, cherries, spinach, nectarines, and kale in the USA are contaminated with two or more pesticides. It was demonstrated that more than two types of pesticides are found in 50% of the examined samples. A total of 18 chemicals were assessed in various kale samples. identified twenty-one pesticide types, including organophosphates, carbamates, dithiocarbamates, pyrethroids, and neonicotinoids, in fresh fruits and vegetables grown in Uganda. All samples included at least one pesticide; 64% contained between 2 and 9 pesticides, while 25.6% were contaminated by more than 10 pesticides. found that the residual concentrations of diazinon, tebuconazole, trifloxystrobin, bioallethrin, and cypermethrin in leafy vegetables, namely lettuce, tomato, and cucumber grown in Iran, exceeded the permissible limits during their examination of pesticide residues, including DDT and malathion.

Documented organophosphate and carbamate pesticide concentrations within permissible limits in food produced in Nigeria. In the Middle East, almost 90% of fruits and vegetables are contaminated with insecticides, and the concentration of insecticides in 61% of produce exceeds the allowed limit. found in their study of 16 varieties of fruits and vegetables grown in Turkey that 12% of the samples analyzed showed pesticide levels surpassing permissible limits. Ahmed et al. reported that the concentrations of the insecticides chlorpyrifos and fenitrothion surpassed the EU legal threshold in 15% of tomato samples and 27.5% of

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eggplant samples grown in Bangladesh. The concentrations of the pesticide imidacloprid in spinach, beetroot, mustard plant, bitter gourd, and guava exceeded the allowed limit by 2 to 12 times, while the pesticide difenoconazole in oranges, guavas, mustard plants, and lemons exceeded permissible limits by 6 to 1533 times. Out of 211 vegetable samples collected from Saudi Arabia, detected pesticide residues in 145 samples, with 44 samples above the maximum residue limit. The detected pesticides included methomyl, metalaxyl, imidacloprid, and cyproconazole. In the vegetables pepper, garden egg, and okra farmed in Ghana, residues of the banned insecticides DDT, lindane, and hexachlorocyclohexane exceed permitted limits. They also ascertain that DDT and lambda-cyhalothrin inhibit seed germination and seedling vitality.

RESULTS AND DISCUSSION

Individuals globally are indisputably subjected to pesticides, with exposure and adverse health impacts being more pronounced in developing nations. Infants and children, owing to their developing bodies, are more susceptible to the harmful effects of pesticides. The ingestion of pesticides via fruits and vegetables leads to neurological disorders, DNA damage, excessive salivation, dermal and ocular irritations, hematological abnormalities, infertility, miscarriages, fetal malformations, auditory impairment, psychiatric effects, diabetes, cancer, and additional health issues. Organochlorines (OCs) and organophosphates (OPs) affect the neurological system and may result in organ damage and carcinogenesis. Exposure to carbamate and dithiocarbamate pesticides precipitates respiratory and developmental complications. Pyrethrins and pyrethroids elicit systemic effects. The WHO estimates that around 385 million people globally suffer from unintentional acute pesticide poisoning annually, leading to 220,000 deaths.

Multiple studies have established a link between pesticide exposure and neurological problems, including Parkinson's and Alzheimer's diseases, along with neurotoxic and cognitive effects. Extended exposure to organochlorine pesticides leads to cerebral impairment, hence facilitating the onset of Alzheimer's disease and dementia. The cognitive functions of

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schoolchildren exposed to organophosphate insecticides during the prenatal phase are compromised. Parkinson's disease arises when pesticides or their metabolites disrupt mitochondrial processes and alter xenobiotic metabolism. Exposure to organophosphate pesticides correlates with Parkinson's disease, as these substances elevate the production of reactive oxygen species, resulting in oxidative damage. Various carbamate and specific organophosphate pesticides inhibit acetylcholinesterase enzyme function, resulting in hyperstimulation of cholinergic receptors in the nervous system. Lindane and endosulfan affect the central nervous system, increase lipid peroxidation, and cause DNA damage in brain tissue, leading to seizures and neuronal hyperexcitability. Pyrethroid and organophosphate insecticides cause brain injury and disrupt cellular function by inducing oxidative stress. Exposure to organochlorine and organophosphate pesticides increases the likelihood of cognitive impairment. Children exposed to organophosphate insecticides prenatally demonstrate reduced IQ and compromised memory.

Human exposure to pesticides contributes to the onset of diabetes. The literature review on epidemiological studies reveals that organochlorine and organophosphate pesticides elevate the risk of glycemic control impairment, leading to diabetes. Organochlorine and organophosphate insecticides impair the normal operation of the endocrine system, resulting in diabetes. The metabolites of organochlorine pesticides increase the prevalence of type 2 diabetes and associated complications. have shown that heightened concentrations of DDT and/or heptachlor epoxide in the bloodstream augment the risk of diabetic neuropathy.

Many respiratory disorders in people are due to pesticide exposure. The initiation of asthma is significantly associated with pesticide exposure. Pyrethroids and organophosphate insecticides increase the prevalence of asthma, especially in children. The bronchial mucosa is impaired, making the airways very susceptible to pollutants. The accumulation of pesticides in the human body disrupts hormonal signaling, reduces semen quality, and negatively impacts fertility in both sexes. Hood et al. have shown that the buildup of organophosphate insecticides is directly linked to erectile dysfunction. The buildup of organochlorine pesticides leads to neural tube defects (NTDs). Exposure to pesticides causes limb deformities, urogenital malformations, ocular abnormalities, and orofacial clefts. The accumulation of pesticides results in spontaneous abortion, fetal demise, and neonatal mortality. Multiple studies have demonstrated a positive correlation between pesticide exposure and multiple myeloma, as well

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as breast, bladder, colon, brain, and liver malignancies. Pesticides, particularly organophosphates, compromise breast tissue DNA by interfering with estrogen receptors, resulting in DNA alterations and heightened malignancy.

Chlorpyrifos buildup in breast tissue affects the redox process and negatively impacts the antioxidant defense system. Organochlorine insecticides (DDT, chlordane, and heptachlor) affect mammary cells by stimulating estrogen synthesis, hence elevating the risk of breast cancer. The accumulation of the herbicides imidazolinone, imazaquin, and imazethapyr is linked to bladder and colon cancer. Specific organophosphate insecticides impair brain DNA and promote the development of cancer cells by disturbing hormonal balance. Multiple investigations have established a definitive association between the accumulation of organochlorine pesticides and the occurrence of liver and pancreatic cancer.

CONCLUSION

The utilization of pesticides in agriculture and public health is crucial for sustaining a growing population and protecting individuals from vector-borne diseases. However, unregulated and indiscriminate use in agriculture and public health over the last 60 years, combined with their persistence, has resulted in considerable negative health impacts on humans. Fruits and vegetables include organophosphates, carbamates, dithiocarbamates, pyrethroids, and banned organochlorine pesticides, including DDT, BHC, heptachlor, and aldrin. More than 60% of global vegetables and fruits are contaminated by one or more pesticides. Contamination in around 25% of samples is above permissible levels. Contamination levels are elevated (65-70%) in developing nations. Pesticides bioaccumulate in adipose tissues of humans and animals, demonstrating extended persistence. The consumption of pesticides via contaminated fruits and vegetables results in allergies, neurotoxicity, damage to the central and peripheral nervous systems, immune system impairment, DNA damage, reproductive disorders, endocrine disruption, diabetes, obesity, cardiovascular diseases, and psychiatric effects.

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