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Pesticides in vegetable production in Bangladesh: A systemic review of contamination levels and associated health risks in the last decade

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ABSTRACT

This paper reviewed the published data on the levels of different pesticide residues in vegetables (tomato, eggplant, beans, gourds, cauliflower, cabbage, cucumber, potato, carrot, onion, red chilli, red amaranth, lady's finger, spinach, coriander, and lettuce) from Bangladesh in the last decade. Vegetable production in Bangladesh has increased tremendously (37.63%) compared to the last decades, along with its pesticide use. The most observed pesticide groups used in vegetable production were organophosphorus, pyrethroids, carbamate, organochlorine, nereistoxin analogue group, and neonicotinoids. More specifically, chlorpyrifos, dimethoate, diazinon, and malathion were the most used pesticides. More than 29% of the vegetable samples (1577) were contaminated with pesticide residue; among the contaminated samples (458), most cases (73%) exceeded the maximum residue limits (MRLs). The pesticide-contaminated vegetables were cucumber (51%), tomato (41%), cauliflower (31%), miscellaneous vegetables (36%), eggplant (29%), beans (23%), cabbage (18%), and gourds (16%). Among the pesticide-contaminated samples, vegetables with above MRL were gourds (100%), beans (92), tomato (78%), eggplant (73%), miscellaneous vegetables (69%), cucumber (62%), cabbage (50%), cauliflower (50%) ($p < 0.05$). It was also observed that a single vegetable was often contaminated with multiple pesticides, and farmers did not follow a proper withdrawal period while using pesticides. Hazard quotation (HQ>1) was observed in adolescents and adults in tomato, eggplant, beans, cauliflower, cabbage, cucumber, lady's finger, lettuce, and coriander. There was no health risk observed (HQ<1) in gourds, potato, carrot, onion, red chilli, red amaranth, spinach, and okra. The highest acute and chronic HQ (aHQ, cHQ) was observed for cypermethrin (bean) in adolescents (aHQ=255, cHQ= 510) and adults (aHQ=131, cHQ=263). It was also observed that these pesticides harmed air, soil, water, and non-target organisms. Nevertheless, the review will help the government develop policies that reduce pesticide use and raise people's awareness of its harmful effects.

1. Introduction

Bangladesh is an agrarian country where the agriculture sector plays a pivotal role in the national economy. About 80% of the people of this country live in rural areas, and agriculture is their primary livelihood source. The agriculture sector is the most important and comprises about 13.02% of the national GDP (Gross Domestic Product), which employs around 40.60% of the total labour force [22]. The performance of this sector significantly impacts national development, employment generation, poverty alleviation, income inequality, food security, nutritional attainment, and so on [53].

Bangladesh is endowed with fertile soils and favourable climatic conditions for producing various crops throughout the year [84]. Since independence in 1971, the food production of this country has increased tremendously. In the early years, people were primarily interested in producing rice-based crops [57]. But now, the scenario is different as people are more interested in growing various other high-value crops [43]. Thus, the government of Bangladesh has called for a departure from "rice-led" growth to a more diversified production that includes several non-rice crops like vegetables, maize, legumes, livestock, and so on [57].

Vegetables are cultivated worldwide by large commercial growers to small subsistence farmers [38]. Farmers usually cultivate vegetables with a high price in the market to gain economic solvency. In Bangladesh, vegetable cultivation increases day by day as people are more conscious about their healthy diet [2]. Although vegetable farming

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was only performed in the early years at the household level, now it has moved from the household to the commercial field level [55]. The production of vegetables has more than doubled over the years, making it one of the fastest-growing vegetable producers in the world [2]. Compared to other crops, vegetables are far more beneficial to farmers. It helped to generate cash for the growers and vibrant the rural economy [91].

Vegetables are an integral part of our healthy diet. Vegetables have low fat and calories, high vitamins (A, B1, B6, B9, C, E), minerals, dietary fibre, and phytochemicals [66,67]. There is little chance of malnutrition when people take enough vegetables into their diet [55]. But vegetables can be the reason for health hazards when contaminated with different chemicals such as pesticides. Farmers use pesticides to protect vegetables from insects, pests and disease attacks. If farmers do not maintain the withdrawal period, the pesticide residue will remain in the vegetables and cause harm to the consumers.

Over the last decades, many studies have been conducted to determine the pesticide residue in vegetable production in Bangladesh [10, 101,102,23,4,5,53,6,63,64,82,90]. But the data were either on one pesticide group, a single pesticide, or a combination of pesticides in a single vegetable or a group of vegetables. For a complete scenario of pesticides used in Bangladesh, the overview of all pesticides in vegetable production needs to be summarized. This document summarizes the results of those studies and shows the actual scenario of pesticide contamination in vegetables. Over the last decades, vegetable production in our country increased tremendously compared to the other decade. Besides vegetable production, pesticide use has also increased in the last decades. This study is to make the scientific community in Bangladesh realize the need for further research to generate a comprehensive and reliable database in the last decade. So the main aim of this review is to document, evaluate, and analyze the data (last decade) on the levels of different pesticide residues in vegetables (tomato, eggplant, beans, gourds, cauliflower, cabbage, cucumber, potato, carrot, onion, red chilli, red amaranth, lady's finger, spinach, coriander, and lettuce) in Bangladesh. It also revealed the vegetable production scenario, major pesticide use, hazard analysis, and the impact of pesticide usage in Bangladesh.

2. Materials and methods

This review has been conducted according to the guidelines of systematic reviews followed by Moher et al. [80]. Published literature on pesticide residue detection in vegetables was collected from peer-reviewed esteemed journals and online technical and government reports using a systematic approach. The following keywords were used to search the literature: (detection and quantification) or only "detection" or only "quantification", "use of pesticides", "vegetable production", "pesticide residue", "pesticide contamination", "the impact of pesticide usage", "health risk", "Bangladesh" and so on. We carefully examined, downloaded, and evaluated the papers or materials we had searched. In this review, we only considered original research data written in English. In order to fit the subject of interest, the research works underwent extensive revision. The analysis will now focus on 107 articles. A reference management tool called Mendeley was used to maintain the complete articles in PDF format. Hence, we came up with these criteria: (a) Use of pesticides in vegetable production, (b) Pesticide residues in vegetables, (c) Levels of contamination, (d) Associated health risks, (e) Impacts on human, animal, and environment.

2.1. Selection and analysis

At first, a total of 423 articles that primarily fit the area of interest were selected. However, after careful evaluation, it was observed that among the primarily selected articles, 199 were not research articles, not accessible, and didn't meet the criteria. Therefore, upon further assessment, they were excluded from the records. There were 224 publications in total that contained original research data, of which 09 were not written in English and were excluded from the list. Out of 215 papers, 105 were not taken into consideration for this study because they lacked sufficient information on our selection criteria. The remaining 110 were chosen as the relevant study resources for the review (Fig. 3).

3. Vegetable production scenario in Bangladesh

Vegetable production in Bangladesh is increasing rapidly. In the last decades, the country grew vegetables on 9.98 lakh acres of land to produce 29.93 lakh tonnes of vegetables [34]. In Bangladesh, vegetables are grown on only 2.63 per cent of cultivable land [21]. Although a small portion of cultivable land is being used for vegetable cultivation, its production has seen a 37.63% significant rise in the last decades. The Department of Agricultural Extension (DAE) estimates that during the 2018–19 fiscal year, Bangladesh produced over 26.7 million tons of vegetables on around 1.25 million hectares of land. DAE [33]. At present, more than 60 different types of vegetables of indigenous and exotic origin are grown in various regions throughout the year [32]. Based on the cultivating season, vegetables are categorized into summer/rainy season vegetables, winter season vegetables, and all-season vegetables. Summer/rainy season vegetables are grown from May through October during the monsoon season. However, winter vegetables are cultivated for a short period between November and April. In the winter season, about two-thirds of the total vegetables are produced [88]. In Bangladesh, 60–70% of vegetables are grown in the winter, and most areas have a marketable excess during that time [107]. While the daily recommended amount of vegetables for Bangladesh is 250 g, the average daily intake per person is only 56 g [45]. Thus, for this high consumer demand, farmers are getting more involved in vegetable production along with rice cultivation.

Nowadays, farmers are practising intensive agricultural farming to produce more vegetables.

In total cultivable land for vegetable production, brinjal grows in 12% of the land, tomato in 7% of the land, pumpkin in 7% of the land, radish in 6% of the land, arum in 5% of the land, beans in 5% of the land, cauliflower in 5% of the land, water gourd in 4% of the land, bitter gourd in 4% of the land, cabbage in 4% of the land, point gourd in 2% of the land, other vegetables (potato, spinach, carrot, cucumber, red amaranth, onion, okra and so on) in 39% of the land (Fig. 1).

The vegetables were cultivated in Sylhet, Moulvibazar, Habigan, Mymensingh, Sunamganj, Jessore and Savar districts. The main winter

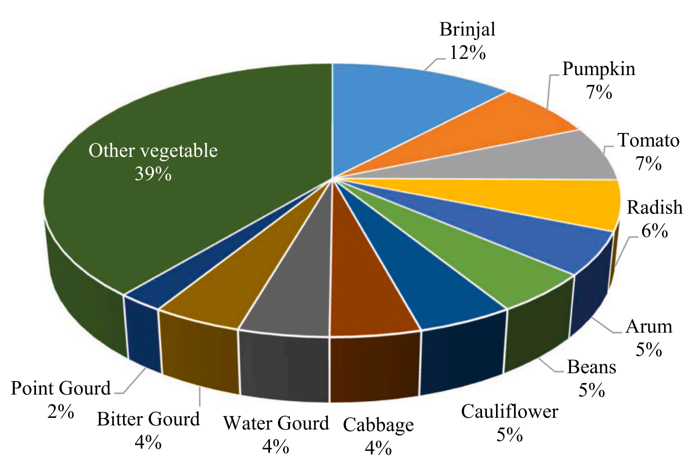

Fig. 1. Cultivable land (the area used in percentage) used for different vegetable production in Bangladesh (brinjal 12%, pumpkin 7%, tomato 7%, radish 6%, arum 5%, beans 5%, cauliflower 5%, cabbage 4%, water gourd 4%, bitter gourd 4%, point gourd 2%, and other vegetables (potato, spinach, carrot, cucumber, red amaranth, onion, okra and so on) 39% [22].

vegetables were tomato, cabbage, cauliflower, bean, gourd, radish, carrot, red amaranth, and eggplant. At the same time, the major summer vegetables were pumpkin, okra, cucumber, bitter gourd and so on [22]. In summer, the vegetable was produced on 524 acres of land, and the total production was 1871 tons, whereas in winter, vegetables were produced on 547 acres of land, and the total production was 2465 tons. The area-wise (acre) individual vegetable production (tons) in Bangladesh is shown in (Fig. 2).

4. Obstacles encountered in vegetable production in Bangladesh

Bangladesh is a tropical country, and the environment of this country is favourable for many insects, pests, bacteria, fungi, and unwanted plant development. Many tropical regions receive heavy rainfall annually, adding to many vegetable diseases [1]. Rain, heavy dews, high temperatures, and dry climates (primarily for insect infection, which is influenced by rain) have been identified as key factors encouraging pest establishment [70]. Insect pests directly damage vegetable production or act as vectors for several viral diseases. Insects distort leaves, stunting growth and killing young plants. The edible roots of plants are damaged by larvae (caterpillars). Adults and larvae eat plant sap, which makes white spots on the leaves; plants infected with it may wilt or die [47]. Thus, farmers are constantly faced with many difficulties while cultivating vegetables [1]. The consequences of climate change, such as global warming, temperature changes, and biotic and abiotic factors, may hinder vegetable cultivation [18]. Climate change hinders vegetable production by retarded growth, unable to seed germination, unable to adjust to high/low temperatures and making them vulnerable to insect pests and disease attacks. Now, the main problems of vegetable cultivation are- increasing insect and pest attacks [92], disease problems [52], climate changes [89], drought, salinity and so on [51]. Farmers use pesticides to protect vegetables from insects, pests, and disease attacks and improve production and aesthetic value.

5. Pesticide usage in Bangladesh

The usage of chemical inputs such as pesticides has risen to boost agricultural production and productivity in Bangladesh. Pesticides are routinely employed in vegetables and other crops or plants due to their vulnerability to insects and disease attacks [76,104].

In Bangladesh, estimates showed that 25% of vegetables in the country were lost annually because of pest infestation [79]. Although the usage of pesticides began in 1951, it was moderate until the 1960 s. It was observed that 84 active chemicals with various formulations and 242 trade names of pesticides were registered for crop and vegetable protection in our country [17], which indicated the tremendous surge in use.

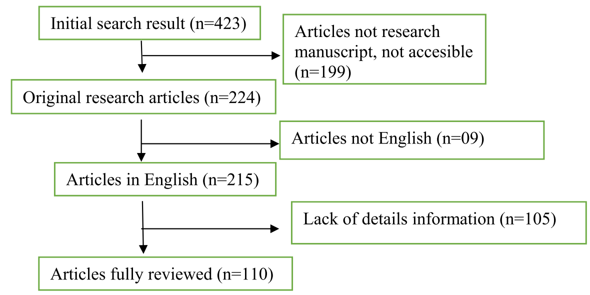

Fig. 3. Criteria for selecting and excluding scholarly articles on the use of pesticides in vegetable production.

Bangladeshi farmers used insecticides along with a small number of herbicides, fungicides, acaricides, and rodenticides in the form of granules, liquid, and powder for vegetable production [48]. Carbamates were used up to 64% of the crop-producing region, whereas organophosphates were used up to 35% of the crop-producing area [27]. Since 1990, organophosphorus pesticides have been the preferred group of pesticides for vegetable production in Bangladesh, as organochlorine insecticides were banned due to their persistence and severe toxic effects on the environment. About 77% of farmers used pesticides at least once (37% applied once, 31% applied twice, and the rest applied 3–5 times) in a crop. Farmers also sprayed these vegetables 17–150 times throughout each growing cycle [13]. According to the Department of Agriculture Extension, around 95% of farmers didn't wait for the pre-harvest interval (PHI) following pesticide application [32]. Furthermore, several pesticides used in Bangladesh were prohibited or restricted worldwide [83,99]. Most farmers apply pesticides without understanding their actual requirements or efficacy, resulting in high pesticide application frequencies in Bangladesh [20]. Because of their ignorance and unconsciousness about pesticide use, more than 90% of pesticides are used unnecessarily, indiscriminately, and excessively [32]. Farmers prefer pesticides over fertilizers as they keep insect pests

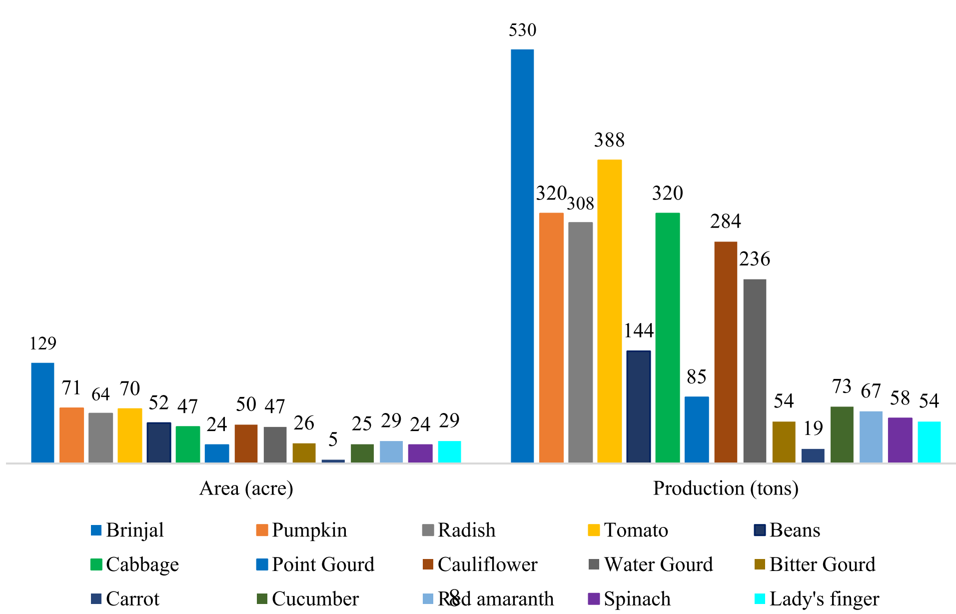

Fig. 2. Figure showing the area-wise (acre) individual vegetable production (tons) in Bangladesh [22].

in check while ensuring better production than fertilizers. The price of the pesticide is also a major factor in this case. At the same time, pesticide use is higher in underdeveloped regions than in developed ones, as people are more prone to grow organic vegetables in developed regions. Thus the indiscriminate use of pesticide lead to residues in the vegetables, and thus, fresh vegetables get contaminated with hazardous pesticides, and food security has become a significant public health concern [108].

6. Pesticides in vegetables of Bangladesh

This review documented the results of previously reported data. It evaluated the residual levels of different pesticides in vegetables (i.e., tomato, eggplant, beans, gourds, cauliflower, cabbage, cucumber and miscellaneous vegetables including potato, carrot, onion, red chilli, red amaranth, spinach, coriander, lettuce, and okra) collected from the different area of Bangladesh in the year 2010–2022 (Tables 1–8). More than 29% of the vegetable samples were contaminated with pesticide residue, and it was cucumber (51%), tomato (41%), cauliflower (31%), miscellaneous vegetables (36%), eggplant (29%), beans (23%), cabbage (18%), and gourds (16%). Among the contaminated samples, most cases (73%) exceeded the maximum residue limit (MRL) in vegetables, and among them, gourds (100%), beans (92), tomato (78%), eggplant (73%), miscellaneous vegetables (69%), cucumber (62%), cabbage (50%), cauliflower (50%) contained above MRL ($p < 0.05$).

Farmers in this country used different types of pesticides (Tables 1–8). The widely used pesticides were organophosphorus, pyrethroids, carbamate, organochlorine, nereistoxin analogue group, neonicotinoids and so on. More specifically, chlorpyrifos, dimethoate, diazinon, and malathion were the most used pesticides. In Bangladesh, Organophosphorus (OPs) is the most widely used pesticide for controlling insects and mites on vegetables. They are very functional and have a broad spectrum of activity [19]. They were invented in the early 19th century, but their effects on insects, similar to humans, were discovered in the 1932 s [87]. Since 1990, organophosphorus pesticides have been widely used in Bangladesh. In Bangladesh, 35% of the crop-producing area is treated with organophosphates [28]. Through ingestion and contact, humans are generally exposed to organophosphorus [19]. The most common OPs detected were chlorpyrifos, diazinon, malathion, dimethoate, parathion, fenitrothion, phenthoate, acephate, quinalphos, phenthoate, parathion, pimethoate, phosphamidon, pirimiphos-methyl, and dichlorvos (Tables 1–8).

Carbamate pesticides have low mammalian toxicity, rapid disappearance, and a broad spectrum of activity [54]. They interfere with the transmission of nerve signals by blocking the acetylcholinesterase enzyme resulting death of the pest by paralyzing it [110]. The most common carbamate pesticides used by farmers were carbaryl, carbosulfan, carbofuran, pirimicarb and so on.

Due to adverse health and environmental effects, many organochlorines were banned, such as DDT, chlordane, toxaphene, and so on [65]. So, the farmers of our country used endosulfan and dicofol for vegetable production. Pyrethroid pesticides were highly toxic to insects and fish [110]. They affect the central nervous system by causing changes in the dynamics of the Na+ channels in the nerve cell membrane. These changes caused neuronal hyperexcitation [86]. Cypermethrin, permethrin, allethrin, bifenthrin, and deltamethrin were common examples. Neonicotinoids disrupted a specific neurological pathway in insects and were frequently used by farmers for vegetable production [31]. Imidacloprid was the most common neonicotinoid in use. Nereistoxin was a naturally occurring insecticide that blocked the nicotinic acetylcholine receptor in the insect body. Cartap was the most commonly used nereistoxin.

Different analytical methods were used to know the level of pesticide residues in contaminated vegetables. The most commonly used techniques were gas chromatography coupled with mass spectrometry (GC-MS), flame thermionized detector (FTD), flame ionization detector (FID), thermal conductivity detector (TCD), electron capture detector (ECD), flame photometric detector (FPD) and high-performance liquid chromatography (HPLC). The extraction method used either solid-phase extraction or liquid-liquid extraction (Tables 1–8).

It was observed from a study that pesticides were commonly found in 8 types (eggplant, tomato, cauliflower, cabbage, potato, cucumber,

Table 1
Pesticides contamination status of tomatoes reported by different areas of Bangladesh (2010–2022).

Area of Collection	Total Sample	Contaminated Sample	Samples above >MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Field samples of Dhaka, Narayanganj, Comilla, Mymensingh, Kushtia, Rajshahi, Faridpur, Chittagong, Jessore and Sylhet	30	16	6	GC-MS	Chlorpyrifos Diazinon Malathion Carbosulfan Phenthoate Dimethoate Carbofuran Carbaryl	0.040–0.700 0.007 0.010–0.060 0.027 0.034–0.040 0.016 0.004–0.050 0.300	0.500 0.010 0.020 0.050 NE 0.020 0.020 0.500	Chowdhury et al.[29]
2. Bogura, Dhaka, Kishoregonj, Jessore, Khulna, Gopalgonj, Mymensingh, Rajshahi, Natore, Narail, and Satkhira	27	4	3	GC-MS	Quinalphos	ND-0.321	0.010	Rahman et al. [90]
3. Narayanganj district	70	42	42	HPLC-PDA	3. Carbofuran Diazinon Dimethoate linuron Parathion Phosphamidon	0.673 1.888–3.612 0.657–1.888 0.540 0.116 0.693	0.020 0.010 0.020 0.050 0.050 0.010	Alam et al. [14]
4. Bogura District	5	1	1	GC-MS	Diazinon Chlorpyrifos	0.57 0.025	0.010 0.500	Hossain et al. [58]
5. Different markets of Rajshahi District	6	2	2	GC-FTD	Dimethoate	0.047–0.139	0.020	Begum et al. [23]
6. Local markets of Savar Upazila	14	6	1	HPLC	Cypermethrin, Chlorpyrifos	0.02–0.55 0.34	0.200 0.500	Alamgir et al. [15]
7. The local market of Tangail, Rangpur, Jamalpur, Jessore, Comilla, Narsingdi, Gazipur and Dhaka	30	3	3	GC-FTD	Chlorpyriphos	0.138–0.443	0.500	Ahmed et al. [3]

Table 2
Pesticides contamination status of eggplant reported by different areas of Bangladesh (2010–2022).

Area of Collection	Total Sample	Contaminated Sample	Samples above >MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Markets samples of Mymensingh district	30	5	1	GC-FTD	Chlorpyrifos Dimethoate, Quinalphos	0.108–0.173 0.013–0.028 0.042	0.500 0.020 0.200	Alam et al. [10]
2. Field samples of Faridpur, Chittagong, Dhaka, Comilla, Mymensingh, Narayanganj, Kushtia, Jessore, Rajshahi and Sylhet	30	14	4	GC-MS	Malathion Carbofuran Chlorpyrifos, Diazinon, Carbaryl Fenitrothion	0.008–0.040 0.005–0.050 0.200–0.390 0.005–0.700 0.030 0.007	0.020 0.020 0.500 0.010 0.050 0.010	Chowdhury et al.[29]
3. Narsingdi district	16	11	14	GC-FTD, GC-ECG	Diazinon, Malathion, Quinalphos, Cypermethrin, Fenvalerate	0.035–0.708 0.014–0.630 0.016–0.344 0.077–0.531 0.09	0.010 0.020 0.200 0.200 0.200	Islam et al. [62]
4. Bogura, Dhaka, Gopalgonj, Jessore, Khulna, Kishoregonj, MymensinghNatore, Narail, Rajshahi, and Satkhira	27	4	3	GC-MS	Quinalphos	ND-0.128	0.200	Rahman et al.[90]
5. The different markets of Dhaka	16	8	3	HPLC	Carbaryl, Carbofuran, Pirimicarb, Phenthoate, Diazinon, Parathion, Dimethoate, Phosphamidon, Pirimiphos-methyl	0.003–0.006 1.86 0.007–0.008 0.077 0.022 0.006 0.183 0.022 0.008	0.050 0.020 0.020 0.010 0.010 0.050 0.020 0.010 0.030	Chowdhury et al.[30]
6. Narayanganj district	70	35	35	HPLC-PDA	Diazinon Fenitrothion Dimethoate linuron	0.453–4.514 0.657–1.073 1.806 0.657–1.073	0.010 0.010 0.020 0.050	Alam et al. [14]
7. The local market of Bogura, Cumilla, Rajshahi, Rangpur, Rajshahi, Khagrachari, Cox's bazaar, Barishal, Jamalpur and Dhaka	36	3	3	GC-FTD	Dimethoate Quinalphos	0.032–0.217 0.081	0.020 0.010	Ahmed et al. [5,6]
8. Market of Keraniganj Upazila	3	No	No	GC-MS	Malathion Cypermethrin Chlorpyrifos Cyhalothrin	-	0.020 0.200 0.500 0.200	Naher et al. [82]
9. The local market of Mymensingh District	50	11	5	GC-FTD	Diazinon, Dimethoate, Quinalfos, Chlorpyrifos	0.0146–0.023 0.054–0.109 0.018–0.363 0.083–1.617	0.010 0.020 0.200 0.500	Aktar et al. [8]
10. Bogura District	10	3	2	GC-MS	Carbaryl Diazinon Chlorpyrifos	4.43 0.32 0.4	0.050 0.010 0.500	Hossain et al. [58]
11. Markets of Rajshahi District	6	1	1	GC-FTD	Dimethoate	0.052	0.020	Begum et al. [23]
12. Chuadanga district	10	10	10	HPLC	Cartap	0.954–3.3	0.500	Alam et al. [11]
13. Field and market samples of Jessore	8	4	1	GC-FTD, GC-ECD	Malathion, Fenitrothion, Cypermethrin	0.207 0.316 0.036–0.728	0.020 0.010 0.200	Fatema et al. [46]
14. The local market of Jessore, Comilla, Narsingdi, Tangail, Rangpur, Jamalpur, Gazipur and Dhaka	30	4	4	GC-FTD	Quinalphos Chlorpyriphos Cypermethrin	0.069–0.326 0.420–0.445 0.026	0.200 0.500 0.200	Ahmed et al. [3]
15. Retail markets near Jahangir-Nagar University, Savar, Dhaka	78	9	2	GC-FTD	Dimethoate, Chlorpyrifos, Diazinon	0.049–0.058 0.043–0.049 0.045–0.059	0.020 0.500 0.010	Isla et al.[63]
16. Wet market of Dhaka, Narsingdi Jessore sadar	6	3	3	GC-MS	Quinalphos	20.65–32.54	0.200	Hasan, Rahman[53]

carrot, and onion) of vegetables (210 samples) collected from several vegetable-growing regions in Bangladesh. The most frequently detected pesticides were chlorpyrifos, carbofuran, diazinon, carbaryl, malathion, endosulfan, cypermethrin, and dimethoate. Pesticide residues were detected in 51.30% of the total samples. Some samples contained multiple residues (10.47%), and 38.89% of samples had levels above the MRLs. The study indicated the overuse of pesticides in vegetable production in this country. The study also suggested regular monitoring of the pesticide levels in vegetable production and proper education for farmers regarding the potential risks and safe use of pesticides [29].

A study conducted in the Bogura district revealed that the farmers indiscriminately used carbamate and organophosphorus pesticides in vegetable production (eggplant, tomato, & cucumber). The study also revealed that the farmers were not aware of the effects of pesticides on

Table 3
Pesticides contamination status of different types of beans reported by different areas of Bangladesh (2010–2022).

Area of Collection	Type of Bean	Total Sample	Contaminated Sample	Samples above >MRL	Detection technique	Detected pesticide	Detected Value (mg/ kg)	MRL (mg/ kg)	References
1. Local markets of Gazipur districts	a. Yard long bean	15	3	3	GC-FTD	Chlorpyrifos Dimethoate	0.171 0.074	0.050 0.050	Tasnim et al. [101,102]
	b. Hyacinth bean	15	2	2	GC-FTD	Chlorpyrifos	0.062–0.106	0.050	
2. Local markets of Narsingdi district	a. Yard long bean	15	4	4	GC-FTD	Chlorpyrifos Dimethoate	0.086–0.134 0.053–0.098	0.050 0.050	Tasnim et al. [101,102]
	b. Hyacinth bean	15	3	3	GC-FTD	Dimethoate Quinalphos	0.053 0.365–0.454	0.050 0.200	
3. Narsingdi district	Country bean	18	12	12	GC, FTD, ECG	Diazinon, Malathion, Quinalphos, Fenitrothion, Cypermethrin, Fenvalerate Propiconazole	0.054–0.798 0.014–0.082 0.012–0.287 0.027 0.114–0.264 0.102–0.804 0.028–0.552	0.500 2.000 0.200 0.100 0.050 1.000 0.100	Islam et al. [62]
4. Bogura, Dhaka, Gopalgonj, Jessore, Khulna, Kishoregonj, MymensinghNatore, Narail, Rajshahi, and Satkhira	Country bean	27	11	8	GC-MS	Dimethoate Chlorpyrifos	ND-0.424 ND-0.064	0.050 0.050	Rahman et al.[90]
5. The different markets of Bogura District	a. Country bean	35	4	2	GC-FTD	Quinalphos, Dimethoate, Chlorpyrifos	0.009 0.008–0.009 0.009–0.107	0.200 0.050 0.050	PARVEN [85]
	b. Yard long bean	35	5	3	GC-FTD	Quinalphos, Dimethoate, Chlorpyrifos	0.008–0.321 0.009 0.008	0.200 0.050 0.050	
6. The local market of Cumilla, Bogura, Rangpur, Rajshahi, Khagrachari, Cox's bazaar, Barishal, Jamalpur and Dhaka	Hyacinth bean	36	6	6	GC-FTD	Chlorpyriphos Dimethoate	0.082 0.303–0.961	0.050 0.050	Ahmed et al. [5,6]
7. Market of Keraniganj Upazila	Bean	3	2	2	GC-MS	Malathion Cypermethrin, Cyhalothrin	955.82 1968.99 4.24	2.000 0.050 0.020	Naher et al. [82]
8. Markets of Rajshahi District	Bean	6	No	No	GC-FTD	Acephate Dimethoate Diazinon Malathion Chlorpyrifos Quinalphos Fenitrothion	No	0.030 0.050 0.500 2.000 0.050 0.200 0.100	Begum et al. [23]
9. The local market of Jessore, Comilla, Narsingdi, Tangail, Rangpur, Jamalpur, Gazipur and Dhaka	a. Yard long bean	15	3	3	GC-FTD	Quinalphos Chlorpyriphos Cypermethrin	0.096–0.247 0.368 0.563	0.200 0.050 0.050	Ahmed et al. [3]
	b. Hyacinth bean	15	3	5	GC-FTD	Chlorpyriphos Quinalphos	0.260 0.196–0.407	0.050 0.200	
10. Wet market of Dhaka, Narsingdi, Jessore sadar	Country bean	6	2	2	GC-MS	Dimethoate	38.65–44.92	0.050	Hasan, Rahman[53]

humans, animals, and the environment [58].

A scientific study found that different types of vegetable samples (eggplant, yard long bean, bitter gourd, snake gourd, pointed gourd, okra, tomato, hyacinth bean and cabbage) from all over Bangladesh were heavily contaminated with pesticide residue. The analysis was performed by GC-FTD and GC-ECD. The results showed that 21.78% of samples were contaminated with chlorpyriphos, quinalphos, acephate and cypermethrin residue, either as single or multiple residues. Moreover, 18.26% of samples had residue above MRL [3]. Another study showed similar results in cauliflower samples. About 13.33% of the total samples had 6 insecticide residues (cypermethrin, quinalphos, diazinon, malathion, fenitrothion and acephate), exceeding the MRL irrespective of single or multiple residues. The presence of the highest residue levels of insecticides in cauliflowers may be due to their irrational and repeated use before harvest [4]. Another scientific study unfolded the fact that raw salad (lettuce and coriander) in Dhaka city was heavily contaminated with pesticide residue. The author also concluded with a suggestion that continuous monitoring of pesticide residue would be needed on a large scale, and pesticide dealers/retailers and vegetable growers should be given training on the safe use and handling of pesticides [5,6].

A survey was conducted in the Narsingdi district of Bangladesh regarding pesticides used in vegetable production like eggplant, cauliflower, and country bean. The study found that diazinon, malathion, quinalphos, fenitrothion, cypermethrin, fenvalerate and propiconazole were the most commonly used pesticide. Among the collected samples, 64% were contaminated with pesticide residue, and 52% exceeded the maximum residue limit (MRL) [62]. Another study concluded that malathion, cypermethrin, chlorpyrifos, and cyhalothrin residues were present in eggplant, cauliflower, lady's finger, and bean samples. The detected pesticide residue also exceeded the MRL in some samples [82]. A study in Savar, Dhaka, concluded that bitter gourd samples were contaminated with acephate, dimethoate, fenitrothion, chlorpyrifos, quinalphos, diazinon and malathion pesticides [63]. On the other hand, Islam et al., [61] reported that imidachloropid was present in spinach samples at the level of 35 ppm collected from Mymensingh Sadar.

Table 4
Pesticides contamination status of different types of gourds reported by different areas of Bangladesh (2010–2022).

Area of Collection	Type of gourd	Total Samples	Contaminated Sample	Samples above>MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Retail markets of Dhaka	Pointed gourd	70	8	8	GC-FTD	Dimethoate, Fenitrothion, Chlorpyrifos, Quinalphos, Diazinon Malathion	0.080–0.105 ND 0.051–0.809 0.076–0.180 0.120 ND	0.010 0.010 0.010 0.010 0.010 0.020	Islam et al. [64]
2. Retail markets near Jahangirna-gar University, Savar, Dhaka	Bitter gourd	65	8	8	GC-FTD	Acephate, Dimethoate, Fenitrothion, Chlorpyrifos, Quinalphos, Diazinon Malathion	ND 0.062–0.095 ND 0.023–0.159 ND 0.058 ND	0.010 0.010 0.010 0.010 0.010 0.010 0.020	Islam et al. [63]
3. The local market of Jessore, Comilla, Narsingdi, Tangail, Rangpur, Jamalpur, Gazipur and Dhaka	a. Bitter gourd	20	8	8	GC-FTD	Quinalphos Chlorpyriphos	0.065–0.226 0.094–0.441	0.010 0.050	Ahmed et al.[3]
	b. Snake gourd	23	4	4	GC-FTD	Chlorpyriphos Acephate Quinalphos	0.0035–0.120 0.066–0.236 0.094	0.050 0.010 0.010	
	c. Pointed gourd	10	2	2	GC-FTD	Chlorpyriphos	0.267–0.302	0.050	

Table 5
Pesticides contamination status of cauliflower reported by different areas of Bangladesh (2010–2022).

Area of Collection	Total Sample	Contaminated Sample	Samples above>MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Markets samples of Mymensingh district	30	5	3	GC-FTD	Chlorpyrifos Dimethoate, Quinalphos	0.036–0.045 0.092–0.721 0.009–0.025	0.050 0.200 0.200	Alam et al. [10]
2. Local markets of Gazipur district	15	2	2	GC-FTD	Chlorpyrifos	0.058–0.120	0.050	Tasnim et al. [101,102]
3. Local markets of Narsingdi district	15	2	2	GC-FTD	Chlorpyrifos Dimethoate	0.120 1.266	0.050 0.200	Tasnim et al. [101,102]
4. Field samples of Faridpur, Chittagong, Dhaka, Comilla, Mymensingh, Narayanganj, Kushtia, Jessore, Rajshahi and Sylhet	22	10	4	GC-FTD	Cypermethrin Chlorpyrifos Acephate Carbaryl	0.020–0.460 0.024–0.080 0.019 0.020–0.100	0.500 0.050 0.500 0.050	Chowdhury et al.[29]
5. Market of Keraniganj Upazila	3	2	2	GC-MS	Malathion Cyhalothrin	858.83 2.83	0.500 0.020	Naher et al. [82]
6. Markets of Rajshahi District	6	No	No	GC-FTD	Acephate Dimethoate Diazinon Malathione Chlorpyrifos Quinalfos Fenotrothion	ND	0.500 0.200 0.500 0.500 0.050 0.200 0.100	Begum et al. [23]
7. Field samples of Jessore, Gazipur and Rangpur	75	29	10	GC-FTD GC-ECD	Cypermethrin, Quinalphos, Diazinon, Malathion, Fenitrothion Acephate	0.044–0.177 0.174–0.197 ND ND ND 1.181	0.500 0.200 0.500 0.500 0.100 0.500	Ahmed et al. [4]
8. Narsingdi district	8	4	4	GC, FTD, ECG	Diazinon, Malathion, Quinalpho	0.093–0.156 0.043–0.655 0.026–0.033	0.500 0.500 0.200	Islam et al. [62]

According to Rahman et al., [90], an effective management plan was needed for stringent regulation and regular monitoring of pesticides in vegetables to educate farmers and consumers about pesticides' detrimental effects on human health.

In Bangladesh, pesticide uses is increasing day by day due to there being no updated food regulations, monitoring, law implementation etc. Monitoring of pesticide residues should be legitimized. From the review results, it can be concluded that farmers indiscriminately used pesticides in vegetable production and did not follow the proper withdrawal period.

6.1. *Health risk assessment*

Health risk estimations were done based on pesticide residues

Table 6
Pesticides contamination status of cabbage reported by different areas of Bangladesh (2010–2022).

Area of Collection	Total Sample	Contaminated Sample	Samples above >MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Field samples of Faridpur, Chittagong, Dhaka, Comilla, Mymensingh, Narayanganj, Kushtia, Jessore, Rajshahi and Sylhet	21	12	4	GC-FTD	Endosulfan Malathion Carbofuran Chlorpyrifos Cypermethrin	0.010–0.120 0.010 0.013–1.00 0.020–0.050 0.062	0.050 0.020 0.020 1.000 1.000	Chowdhury et al.[29]
2. Markets of Rajshahi District	6	No	No	GC-FTD	Dimethoate	ND	0.050	Begum et al. [23]
3. The local market of Jessore, Comilla, Narsingdi, Tangail, Rangpur, Jamalpur, Gazipur and Dhaka	64	4	4	GC-FTD	Quinalphos Chlorpyriphos	0.065–0.226 0.094–0.441	0.200 1.000	Ahmed et al. [3]

Table 7
Pesticides contamination status of cucumber reported by different areas of Bangladesh (2010–2022).

Area of Collection	Total Samples	Contaminated Sample	Samples above >MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Field samples of Dhaka, Narayanganj, Comilla, Mymensingh, Kushtia, Rajshahi, Faridpur, Chittagong, Jessore and Sylhet	28	16	10	GC-FTD	Chlorpyrifos Cypermethrin, Carbaryl Diazinon Dicofol	0.018–0.270 0.070 0.020–0.300 0.007–0.060 0.140	0.050 0.200 0.050 0.010 0.200	Chowdhury et al.[29]
2. Bogura District	10	4	2	GC-MS	Diazinon Chlorpyrifos	0.18 0.02–0.05	0.010 0.050	Hossain et al. [58]
3. The local market of Mymensingh District	3	1	1	GC	Imidachloropid	35	1.000	Islam et al. [61]

detected in different vegetable samples reviewed in (Tables 1–8). Health risk indices of pesticide residues via dietary intake of vegetables were assessed according to the guidelines recommended by the [40] followed by Bhandari et al., [24].

Acute/short-term HQ assessment (aHQ).

The aHQ was calculated based on the estimated short-term intake (ESTI) and the acute reference dose (ARfD) as:

$$ESTI = (\text{the highest level of residue x food consumption})/\text{body weight} \quad (1)$$

$$aHQ = (ESTI/ARfD) \text{ x } 100\%$$

Chronic/long-term HQ assessment (cHQ)

The cHQ was calculated based on the estimated daily intake (EDI) and the acceptable daily intake (ADI) as:

$$EDI = (\text{mean level of residue x food consumption})/\text{body weight} \quad (2)$$

$$cHQ = (EDI/ADI) \text{ x } 100\%$$

This review was chosen to estimate the dietary risks of pesticide exposure in adolescents and adults. According to the European Food Safety Authority, 32 kg body weight for adolescents and 62 kg for adults were chosen as individual body weights in population groups [41]. Based on the final report on the Household Income and Expenditure Survey-2016–2017, the food consumption rate of vegetables in Bangladesh was 166.1 g per capita− 1 day− 1 [56]. HQ > 1 denotes a potential risk to human health [35], while an HQ ≤ 1 indicates no risk [25,100].

After health risk assessment, HQ> 1 was observed for carbofuran, diazinon, dimethoate, and phosphamidon in tomato; carbofuran, diazinon, dimethoate, and carbaryl in eggplant; malathion, cypermethrin, cyhalothrin, and dimethoate in beans; dimethoate and malathion in cauliflower; carbofuran in cabbage; imidacloprid in cucumber; malathion and cypermethrin in lady's finger; dimethoate in lettuce and coriander in adolescents and adults (Tables 1a-8a; added to the supplementary material). No health risk was observed in gourds, potato, carrot, onion, red chilli, red amaranth, spinach, and okra for any pesticides as the HQs were below level 1. The highest acute and chronic HQ (aHQ, cHQ) was observed for cypermethrin (bean) in adolescents (aHQ=255, cHQ= 510) and adults (aHQ=131, cHQ=263 (Tables 1a-8a; added to the supplementary material). It indicated the highest risks of dietary exposure through the congestion of these contaminated vegetables.

7. Impact of pesticide usage

Pesticides have become an unavoidable part of agricultural and public health practices [96]. Despite the benefits, their usage has detrimental environmental and public health consequences. Due to high biological activity and toxicity, pesticides are unique among ecological pollutants. Most pesticides do not distinguish between pests and other life forms. As a result, they can be hazardous to humans, animals, other living organisms, and the environment if handled indiscriminately [110].

7.1. Impact on human health

Pesticides can enter the human body through inhalation of polluted air, dust, and vapour, oral exposure by consuming contaminated food and water, and dermal exposure by direct contact with pesticides [94]. Inhalation and dermal exposure occur during applying pesticides in agricultural fields, forestry, household level, and by occupation [93]. Most farmers in Bangladesh did not use masks, gloves, or other protective equipment when spraying pesticides [48]. Over 87% of farmers openly admitted spraying pesticides with little or no care, and 92% did not take any measures during usage, storage, or transportation [36]. Pesticides could enter the human body during and after application through various routes. Pesticide residues were absorbed at varying rates in different parts of the body, including the scalp (3.7%), forehead (4.2%), ear canal (5.4%), abdomen (2.1%), forearm (1.0%), palm (1.3%), genital region (11.8%), and ball of the foot (1.3%) [77].

Table 8
Pesticides contamination status of miscellaneous vegetables reported by different areas of Bangladesh (2010–2022).

Area of Collection	Types of Vegetable	Total Sample	Contaminated Sample	Samples above >MRL	Detection technique	Detected pesticide	Detected Value (mg/kg)	MRL (mg/kg)	References
1. Field samples of Faridpur, Chittagong, Dhaka, Comilla, Mymensingh, Narayanganj, Kushtia, Jessore, Rajshahi and Sylhet	Potato	35	17	10	GC-MS	Diazinon	0.008–0.240	0.010	Chowdhury et al.[29]
						Propiconazole	0.018–0.033	0.020	
						Chlorpyrifos	0.026	0.050	
						Endosulfan	0.022–0.200	0.050	
						Cartap	0.310	NE	
						Carbosulfan	0.020	0.050	
						Carbaryl	0.012–0.300	0.050	
						acephate	0.015	0.020	
						Dimethoate	0.013–0.140	0.020	
						Fipronil	0.013, 0.008	0.010	
	Carrot	27	13	2		Fenvalerate	0.011–0.060	0.020	
						Carbofuran	0.012–0.015	0.020	
						propiconazole	0.032	0.050	
						Chlorpyrifos	0.030–0.400	0.100	
	Onion	17	10	3		Malathion	0.013–0.040	0.020	
						Chlorpyrifos,	0.010–0.500	0.200	
						Diazinon	0.009	0.010	
						Dimethoate,	0.010–0.012	0.020	
						Propiconazole	0.045	0.050	
2. Bogura, Dhaka, Gopalgonj, Jessore, Khulna, Kishoregonj, Mymensingh Natore, Narail, Rajshahi, and Satkhira	Red chilli	27	9	7	GC-MS	Dimethoate	ND-0.201	0.050	Rahman et al. [90]
	Red amaranth	27	3	3		Chlorpyrifos	ND-1.535	0.050	
3. Market of Keraniganj Upazila	Lady's finger	3	2	2	GC-MS	Malathion	302.27	2.000	Naher et al. [82]
						Cypermethrin,	500.48	0.500	
						Cyhalothrin	2.03	2.000	
4. The local market of Mymensingh District	Spinach	3	no	no	GC	Dichlorovs,	No	0.150	Islam et al. [61]
						Diazinon,		0.005	
						Chlopyrifos		0.200	
						Fenitrithion		0.006	
						Imidachloropid		0.500	
5. The market of Dhaka	Coriander	30	13	13	GC-MSD	Dimethoate	12.94–158.3	0.010	Ahmed et al. [5,6]
	Lettuce	30	7	7		Dimethoate	9.6–74.8	0.010	
6. Local market of Jessore, Comilla, Narsingdi, Tangail, Rangpur, Jamalpur, Gazipur and Dhaka	Okra	20	4	4	GC-FTD	Quinalphos	0.160	0.010	Ahmed et al. [3]
						Chlorpyriphos	0.056–0.090	0.500	

* GC = Gas Chromatography
GC-MS = Gas Chromatography-Mass Spectrometry
GC-FTD = Gas Chromatography with Flame Thermionized Detector
GC-ECD = Gas Chromatography with Electron Capture Detector
HPLC = High-Performance Liquid Chromatography
GCMS-EI = Gas Chromatograph Mass Spectrometry with Electron Impact Ionization
ND = Not Detected
NE= No established MRLs have been previously reported
MRL=Maximum Residue Level as determined by EC regulation 396/2005, which came into effect on 1 September 2008.

Oral exposure occurs when pesticide levels in food (mainly vegetables and fruits) and water exceed the MRL limit. Pesticide toxicity was determined by the type of pesticides (very, highly, moderately, and mildly dangerous), the method of exposure (oral, dermal, and inhalation), and the dosage received. It was estimated that pesticides poisoned over 1 million individuals yearly, resulting in 0.2 million deaths. Agricultural workers accounted for half of them, while the remainder was caused by contaminated food and water [110].

7.1.1. *Acute effect*

The acute disease developed within a few days of contact or exposure to the chemical. Acute illness in people is caused by pesticide drift from agricultural fields, pesticide exposure during the application, and intentional or inadvertent poisoning [37,71]. Pesticide poisoning causes various symptoms, including headaches, body pains, skin rashes, poor focus, nausea, dizziness, impaired eyesight, cramping, panic attacks, and in severe cases, coma and death [110]. Several toxic aspects measures were proposed to minimize the occurrences of acute pesticide poisoning, including limiting pesticide availability, replacing a less toxic but equally effective pesticide, and encouraging personal protective equipment [68,81].

7.1.2. *Chronic effect*

Chronic illnesses in humans are caused by prolonged exposure to sub-lethal pesticide concentrations (years to decades) [49]. Symptoms do not appear right away and appear at a later time. Furthermore, when pesticides are sprayed on crops and vegetables, they are brought to the market for sale without maintaining a withdrawal period, and consumers get exposed to pesticide residue [77]. Agricultural workers are at a higher risk of infection, but the general public is also in danger [49]. As pesticides become an increasingly important element of our ecology, the incidence of chronic illnesses has begun to rise [50]. The effects of pesticide usage on human health are shown in (Table 9).

Table 9
Effects of pesticide usage on human health [109,110,16,26,42,72,98].

General symptoms	Acute toxicity (Immediate)	Chronic toxicity (Year to decade)
• Excessive salivation • Nausea • Vomiting • Diarrhoea • Irritation of the nose, throat, eyes or skin • Inability to breathe • Headache • Abdominal cramps • Blurring of vision • Loss of appetite • Nervousness & fatigue • Restlessness • Muscular incoordination • Mental confusion • Insomnia	• Headache • skin rashes • Nausea • Extra mucous in the airways • Increased rate of breathing • Loss of reflexes • Uncontrollable muscular twitching • Unconsciousness • Muscular incoordination • panic attacks • Paralysis • Death	• Cancer • Neurodegenerative diseases including (Parkinson's and Alzheimer's) • Genetic disorder • Diabetes • Congenital disabilities • Infertility • Asthma • Chronic obstructive pulmonary disease (COPD

7.2. Impact on the environment

The farmers, institutions, and the general public use and dispose of pesticides extensively, creating many pesticide sources in the environment. Pesticides' range of action is nearly impossible to regulate.

Pesticide spreads in the air, gets absorbed in the soil, dissolves in the water, and eventually reaches a much larger region, even when administered in a relatively small area. Pesticides have a variety of outcomes once discharged into the environment. They are sprayed on crops, may travel via the air, and end up in other parts of the ecosystem, such as soil and water [110]. Directly applied pesticides might be washed away and reach adjacent surface water bodies by surface runoff, or they might percolate through the soil to lower soil layers and groundwater. It can potentially change soil microbial diversity and biomass, block soil respiration, and result in infertility [39,97].

Pesticide contamination of surface and groundwater is reported all around the world. Surface water and groundwater contain a variety of compounds, including certain pesticides. The mobility of pesticides in water leads to pesticide pollution of water resources [95]. Pesticide contamination of groundwater and surface water poses a serious and urgent threat to freshwater and coastal ecosystems around the world. Pesticide contamination directly impacts drinking water quality in local areas and indirectly affects the soil and food chain. Pesticide residues in water endanger biological communities, including humans. Pesticides have an influence not just on fish but also on aquatic ecology [9]. Pesticide contamination in the air has a significant pollutant with dangerous consequences for flora, fauna, and human health [73].

7.3. Impact on nontarget organisms

Pesticides harm nontarget creatures such as earthworms, natural predators, and pollinators, in addition to the target organisms [105]. It causes a decrease in the population of earthworms, which reduces soil respiration and leads to infertility. Insecticides are particularly harmful to some predators, such as parasitoids (important in pest control). The eradication of these natural predators had the potential to increase pest problems. Wild pollinators such as bees, fruit flies, beetles, and birds are harmed by pesticides. As a result, it resulted in indirect agricultural and vegetable output losses [106].

8. Discussion

The use of pesticides in vegetable production is increasing day by day in Bangladesh. Due to increased demand for vegetables, the frequency and quantity of pesticide use have increased over the past years in tomato, eggplant, cucumber, bitter gourd, beans, cauliflower, cabbage and okra production. There has been a trend to pesticide use in vegetable production as it gives better output in a cost-effective way. This leads to higher contamination of vegetables with pesticide residues and causes many health problems for consumers. The problems are not limited to Bangladesh, and it is a pressing issue on a global scale. It has been reported in Pakistan, India, and China that pesticides are used indiscriminately in vegetable production and cause many health problems to consumers [103,12,74].

In Bangladesh, different types of pesticides have been used for vegetable production throughout the decades, including OPs, carbamates, organochlorine, neonicotinoids, pyrethroids, etc. The review highlighted that a single vegetable could be contaminated with single or multi-residue pesticides, and most of the pesticides had residue above the FAO permissible limits. These findings indicated that farmers used a different type of pesticide for single-commodity production without knowing the consequences. Moreover, pesticide use trends were excessive in vegetable production throughout the decade without maintaining a proper withdrawal period before being marketed. The condition led to pesticide residues in the vegetable at the time of marketing, posing a threat to human health, such as cancer, kidney failure, heart attack, etc. The studies from neighbouring countries like China, Pakistan, and India showed similar findings [59,69,7]. From these findings, it has to be said that developing countries like China, Pakistan, India, and Bangladesh use pesticides in vegetable production. As for the developed country, it has been reported that America used pesticides judiciously [75].

Farmers had very shallow knowledge regarding the safe use and handling of pesticides with withdrawal periods. There was no monitoring system for pesticide purchase, use, or handling in vegetable production. Also, there are no complementing health and long-term monitoring systems for farmers and farm workers, nor were there any legislation or policy measures for farming's chemical application methods in Bangladesh. Thus, pesticide residues in vegetables have become a major public health concern for both consumers and governments.

Nonetheless, the areas in this review were the priority areas for effectively monitoring different pesticides in commodities on a routine basis. However, this study only focused on the data from the last decade and couldn't include data from past decades. So, mass data accumulation should be needed for comparative analysis and to alert the scientific community to further research on this vulnerable issue. Therefore steps should be taken to educate the farmers on the safe use of pesticides to reduce contamination of the foodstuff and environment. These should be done with the help of the government, agrochemical industries and NGOs. Furthermore, an effective campaign should be organized to educate the farmers about the routes by which contaminants enter the body and food and the importance of existing food safety laws.

9. Conclusions and recommendations

Pesticides are indiscriminately used in vegetable production in Bangladesh. Different types of pesticides are applied in Bangladesh, like other developing countries and cause many health hazards to the consumers. Nevertheless, there are no long-term monitoring programs applicable regarding this vulnerable issue. As a result of this review, it is clear that the data on regular monitoring, exposure and poisoning are insufficient. Therefore, a long-term regular monitoring program for pesticides applied in vegetable production and marketing is urgently needed with policy intervention.

It is nearly impossible to produce vegetables without applying pesticides. As a result, pesticides have now become a part of our food chain. However, the application of this toxic substance is hazardous for us. So, the review suggested ways to alternate pesticide use in vegetable production.

1. The most basic technique to prevent pesticide application is the integrated pest management (IPM) technique. It involves determining the pest threshold in the field, identifying the pests, and determining whether or not they are damaging. Targeted spraying should be used instead of broad-spectrum spraying if there is a pressing need [44].

2. Pesticides are loosely adhered to the surface or enter the layers of the vegetables; by washing and peeling, we can mitigate the load of pesticide contamination [78].

3. Use alternative ways to reduce pest infestation in vegetables such as neem. Many studies suggest that neem has a very effective way of handling pests [60].

4. All forms of media should be used to discourage farmers regarding pesticide use in vegetable production, i.e., radio, television, newspapers, agriculture staff, and schools; the launch of a contest on best management practices (BMP) and integrated pest management (IPM) by agricultural extension staff from all districts.

5. It is now common knowledge that the most important thing we can do is to adopt an organic farming system.

6. The government must implement an effective monitoring system regarding pesticide use, pesticide selling, and pesticide marketing. The law should be implemented; otherwise, the pesticides used in vegetable production will be increased.

7. For effective monitoring, the vegetable samples should be collected regularly, and a routine quantitative test should be performed to determine whether the samples have pesticide residue.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.toxrep.2023.09.003.

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