Pesticide Residues in Vegetables: A Vicious Trend to Break

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Abstract

Pesticide residues in cereals and vegetables have been related to various human health problems, including damage to the central and peripheral nervous systems, cancer, allergies and hypersensitivities, reproductive abnormalities, and immune system disruption. Pesticide residues may be decreased by using less pesticide, properly washing and processing food, utilizing natural and bio-pesticides, and closely enforcing pesticide limitations. Pesticide residues were identified in large concentrations in 509 samples of vegetables, spices, rice, wheat, and other foods in a government study conducted in 2013-14. MRLs were found in almost all vegetables, particularly during the wet season. Pesticide residues were found in the least amount in onion, tomato, cucumber, green pea, and coriander leaves. Chlorpyrifos, ethion, acetamiprid, dichlorvos, and cypermethrin were among the pesticide residues discovered in grapes. The 2011 Pollutants, Toxins, and Residues in Food Regulations regulate different pollutants, toxins, and residues in foods. If they get into the food chain, they may harm people's health and cause environmental problems. To maintain food safety, pesticides must be examined regularly. 25 independent labs assessed samples obtained from wholesale and retail marketplaces throughout the nation. Cardamom had the largest quantity of residues, including quinalphos, cyhalothrin-L, profenofos, bifenthrin, triazophos, and cypermethrin, with 128 confirmed contaminated samples. India produces the second-largest amount of vegetables in the world and has the world's second-largest population. Future cancer outbreaks in Punjab's Bhatinda express (reportedly a cancer express) and Odisha's Atabira district should be avoided. Although India uses less pesticide than industrialized countries, the unregulated and incorrect use of pesticides is gaining attention. Pesticide residues in vegetables and recommendations for reducing pesticide doses in daily meals are discussed.

Keywords: Pesticide, vegetables, fruits, residual

Introduction

Pesticide residues were identified in significant concentrations in 509 samples of vegetables, spices, rice, wheat, and other commodities, according to a government study performed in 2013-14. Almost all vegetables have high Maximum Residue Limits, particularly during the wet season (MRLs). Pesticide residues were discovered at the highest amounts in capsicum, green chili, and Cauliflower, and at the lowest in cabbage, Brinjal, tomato, Okra, bitter gourd, cucumber, green pea, and coriander leaves. Pesticide residues were identified in the greatest amounts in grapes, with chlorpyrifos, ethion, acetamiprid, dichlorvos, and cypermethrin being the most frequent pesticides.

The 2011 Food Safety and Standards (Pollutants, Toxins, and Residues) Regulations regulate the presence of pollutants, toxins, and residues in foods. Maximum limits for various metal contaminants, agricultural pollutants, pesticide residues, antibiotics, and pharmacologically active compounds in different foods are established in Chapter 2 of these laws. The research was carried out as part of the national plan "National Monitoring of Pesticide Residues," which has been in force since 2005. In their study, they analyzed a total of 16,790 samples, with 509 of them determined to be over the FSSAI and CODEX MRLs.

If trace chemicals, especially pesticides, get into the food chain, they may harm people's health and destabilize ecosystems. Pesticides must be tested regularly to comply with food safety regulations. The samples were obtained from various wholesale and retail locations around the nation and evaluated by 25 separate labs. Among the spice samples, cardamom contained the most residues, including quinalphos, cyhalothrin-L, profenofos, bifenthrin, triazophos, and cypermethrin, among the spice samples 128 found to be contaminated.

Because India is the world's second-largest vegetable grower and has the world's second-largest population, the pesticide residue problems outlined above might significantly impact India's health in the future. Rising cancer concerns in Punjab's Bhatinda express (reported to be a cancer express) and a similar incident in Odisha's Atabira area are merely alarming bells to be cautious of in the future. Although India uses fewer pesticides than other industrialized countries, pesticides' widespread and unscientific use is attracting attention. The time has come to take some vital personal and political measures before it's too late. This review study discusses a variety of pesticide residual problems in vegetables and some recommendations for reducing pesticide levels in human food.

What are pesticides?

The Food and Agricultural Organization (FAO) defines pesticides as any substance or mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted plant or animal species, causing harm during or otherwise interfering with the production, processing, storage, transportation, or marketing of food, agricultural commodities, wood and wood products, or animal feedstuffs, or substances that may contaminate food, agricultural commodities, wood and wood products, or animal feedstuffs. This category includes substances used as a plant growth regulator, defoliant, desiccant, or agent for thinning fruit or preventing premature fruit fall, also used to protect crops from deterioration during storage and transportation as a pre-or post-harvest treatment.

Pesticides include herbicides, insecticides, insect growth regulators, nematicides, termiticides, molluscicides, piscicides, avicides, rodenticides, predacides, bactericides, insect repellents, animal repellents, antimicrobials, fungicides, disinfectants, and sanitizers**.**

Consequences of pesticide residues

- Pesticide Residues in Food, Milk and Honey
- Pesticide–Pollinator Conflict leading to pollinators, natural enemy/beneficial insects population decreasing.
- Wild Birds and Mammals and human poisoning
- Groundwater and Soil and Environment pollution (9 of the 12 most dangerous and persistent organic chemicals are organochlorine pesticides: Stockholm Convention)
- Pesticide Resistance
- Rejection of Indian export consignments due to the presence of chemical residues
- Pesticides reduce crop yield by acting on N-fixers
- Pesticide residues have an impact on our system.

A. Pesticide residues have toxic impacts on human health.

Long-term neuropsychiatric and neurological disorders: Organophosphate exposure damages cholinergicneurons in the basal forebrain and limbic system, causing memory, cognitive, mental, emotional, motor, and sensory problems by disrupting this postulated sensory-limbic gating mechanism.

Cholinergic neuronal excitotoxicity and dysfunction induce neuronal injury. Accumulation of acetylcholine at synapses following exposure to organophosphates generates cholinergic neuronal excitotoxicity and malfunction. Overstimulating muscarinic acetylcholine receptors can disrupt the balance of excitatory and inhibitory processes, leading to neuronal excitotoxicity and seizures.

Memory and cognitive impairments persist: One of the most prevalent and long-lasting behavioral consequences of organophosphate exposure is memory and cognitive deficits.

Induction of oxidative stress has been identified as the principal mechanism of organophosphate toxicity in subchronic or chronic organophosphate exposure. Both acute and chronic poisoning with organophosphate chemicals causes oxidative stress in humans and experimental animals. In organophosphate poisoning, hyperglycemia is one of the mechanisms of oxidative damage.

Cancer development: Cancer research examines the dangers of consuming certain goods that include pesticide residues. Polychlorinated biphenyls, in particular, pose a more significant threat to consumers. The levels of organochlorine pesticide residues were found to be considerably greater in cancer patients.

According to the findings, increased pesticides in the blood of vertebrates promote reproductive failure. Men attending a reproductive clinic had reduced total sperm count, ejaculate volume, and percentage of morphologically normal sperm when they ate fruits and vegetables with significant pesticide residues. Pesticide exposure can result in diminished fertility, early and late pregnancy loss, a longer time to pregnancy, spontaneous miscarriage, and preterm delivery in women, as well as genetic mutations in sperm, a lower sperm count, damage to the germinal epithelium, and changes in hormone function in men.

B. Pesticide pollinator conflict

According to recent estimates, insect pollinators provide over $200 billion in pollination services to over two-thirds of agricultural species and most wild blooming plants. Many human factors lead to a decline in pollinator abundance and diversity, putting this vital food security and ecological function at risk. These include habitat degradation due to agricultural intensification, resulting in pollinator nutrition shortages, a loss of nesting and overwintering locations, and geographic isolation. The demand for increased (amount or potency) pesticide usage is a second key consequence of agricultural intensification. The question of whether pesticides pose harm to pollinators is widely contested, and the response depends on the amount of field-relevant exposure to a chemical and the presence of additional risks such as illness, inadequate nutrition, or other pesticides. In the case of neonicotinoids, exposure is primarily from their usage as systemic insecticides on the pre-coated agricultural seed. The neonicotinoid is translocated throughout the plant after germination, including the nectar and pollen eaten by pollinators. In the absence of any actual or perceived threat, their usage is preventive.

Although the exact degree of exposure to neonicotinoids is debatable and may be altered by soil deposit, current estimates imply imidacloprid, clothianidin, and thiamethoxam in plant nectar and pollen are exposed at a rate of 1–5 ppb. A move to a more effective pesticide may lower the quantity of pesticide used, but it would not affect the environmental danger. Furthermore, the efficacy of the drug may vary depending on the species. The neonicotinoids, for example, have low efficacy in humans due to their poor affinity for human receptors. They are, however, influential in bumblebees, who seem to be more sensitive than honeybees. Their effectiveness in other pollinators is uncertain, although it is critical. The acute toxicity of pesticides and the amount at which they become deadly to a single insect are not the only factors to consider. Pollinator performance may be harmed by chronic, sublethal poisoning at the individual or colony level, and such dangers have lately been identified.

C. Pesticide resistance

Pesticide resistance refers to a pest population's reduced sensitivity to a pesticide that previously efficiently suppressed the pest. Pesticide resistance evolves by natural selection, with the more resistant individuals surviving and passing on their acquired heritable genetic characteristics to their offspring. Resistance has been recorded in many types of pests (crop diseases, weeds, rodents, and so on), with 'crises' in insect control happening shortly after pesticide usage began in the twentieth century.

Insecticide resistance is defined as "a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species," according to the Insecticide Resistance Action Committee (IRAC).

For pest management, humans frequently rely nearly entirely on insecticides. This puts more pressure on resistance to evolve. Even after pesticides are no longer used, pesticides that do not degrade fast contribute to the selection of resistant strains. Managers may increase pesticide quantities/frequency in reaction to resistance, exacerbating the situation. Furthermore, certain insecticides are hazardous to pest-feeding or pest-competing species. This may allow the insect population to grow, necessitating the use of additional pesticides. Because farmers spend more for less gain, this is frequently referred to as a pesticide trap or a pesticide treadmill. Because they are exposed to greater pesticide concentrations and have less chance to reproduce with unexposed populations, pests with restricted diets are more likely to acquire resistance.

As a result, indiscriminate pesticide usage has always been linked to the pesticide residue problem, which needs to be handled by the farming community by adhering to the right approved amount and, most importantly, the safe and proper manner of pesticide application.

D. Impact of pesticide residues on Indian export

Residues in agricultural export consignments have often resulted in their rejection by importing nations. The most frequently used parameters for spices worldwide are currently ASTA cleanliness standards and USFDA standards. The problem becomes much more difficult now that most counties have established their criteria. The lack of MRLs for acceptable pesticides on chilli spice has become a practical issue in boosting chilli exports.

Table 1. Reasons for rejection of Agricultural products

Month and Year	Importing country	Agricultural products	Reasons
May, 2014	EU	Mango, Brinjal, Snake gourd, Bitter gourd, Taro (Ban on export of these for 3 years)	Several pesticide residues and fruit fly infestations
January, 2004 & 2005	UK & EU	Chilli powder	Sudan Red
November, 2001	Greece	Chilli powder and Red chilli	Ethion, Triazophos, Cypermethrin, Chloropyriphos
July, 2001	spain	Chilli	Cypermethrin

(Source: APEDA)

E. Influence of pesticides on nitrogen-fixing bacteria

Some agricultural herbicides have the potential to damage nitrogen-fixing microorganisms. Gulhane *et al.* (2015) researched to see how the herbicides Hilcyperil and Nuvan affected the desirable nitrogen-fixing bacteria, Rhizobium spp. and Azotobacter spp., which are critical for plant development and higher yields. Compared to Hilcyperil, Nuvan insecticide significantly hindered the development of both nitrogen-fixing bacteria. According to this research, pesticides have a differential influence on the development of nitrogen-fixing bacteria, and their activity varies in various areas. Indications have been found that pesticides used in the field, probably owing to their highly toxic nature, decreased the number of these bacteria in the field.

Persistence and dissipation of pesticide residues

A field experiment was done by Patil *et al.* (2018) at Rahuri (MH) to determine the pattern of triazophos dissipation in/on Brinjal after two foliar sprays at the approved dosage (500 g a.i./ha) and twice the recommended dose (1000 g a.i./ha) during the fruit initiation stage. The brinjal crop was treated twice with a ten-day gap between applications. Triazophos initial residues in brinjal fruits were 0.90 and 1.85 mg kg^{-1}, with a half-life of 2.10 and 2.04 days at the standard and twice recommended doses. After 7 and 10 days, triazophos residues were below the quantification limit (BQL) in both dosages. In light of this, a seven-day Pre-Harvest Interval (PHI) for triazophos might be recommended for residue-free Brinjal.

Table 2. Half-life of some pesticides in vegetables

Vegetable	Pesticide	Half-life (days)	References
Tomato	Mancozeb	3.76 – 4.14	Rani *et al*., 2013
	Flubendiamide	1.64 - 1.98	Paramashivam and Banerjee, 2013
Brinjal	Thiacloprid	0.47 – 0.50	Sahoo *et al*., 2013
	Prophenophos	2.15 – 2.31	Mukherjee *et al*., 2013
Cabbage	Emamectin benzoate	< 5 Days	Singh *et al*., 2013
	Fipronil	3.21 – 3.43	Bharadwaj*et al*., 2012
Okra	Spiromesifen	1.68	Raj *et al*., 2012
	Imidacloprid	1.07 and 2.41	Banerjee *et al*., 2012

Detection and extraction process of pesticide residues

1. **Physicochemical methods**

A) Separating techniques (its followed by quantification)

i. Chromatography (GC, HPLC- preferred)

ii. Electrophorosis

B) Methods based on spectral characteristics

i. NMR

ii. Mass spectrometry

[GC-MS method is used as a gold standard in pesticide residue analysis]

2. **Biological methods**

i. Antibody methods (pesticide specific antigens)

ii. Enzyme methods (acetyl choline estarage enzyme mostly used)

3. **Biosensors** (specificity of bio-membranes involved)

4. **QuEChERS** (quick, easy cheap effective, rugged and safe) method – a solid phase extraction method

5. **Pesticide finger printing** (by CFTRI, Mysore)

i. Simple quick method (for DDT, BHC, endosulphan, OPs, synthetic pyrethroids and carbamates)

ii. Vegetable tissue pressed on filter paper along with o-toluidine solution to give rise to some colour (green – DDT,persian blue – BHC, yellow – Endosulphan)

Reasons for agricultural pesticide residues being high in India

- Use of chemical pesticides indiscriminately
- Failure to adhere to established waiting times
- Utilization of substandard insecticides
- Pesticide vendors give farmers incorrect information and supply them with chemicals
- Sustaining the use of DDT and other pesticides in public health programmes
- Pesticide production plant effluents
- Improper pesticide dumping and cleaning of plant protection equipment
- Pesticides under development before commercialization
- Fruits and vegetables are treated

Strategies to reduce pesticide residue

1. **Eco-friendly pest management techniques**

i. Selection of pest tolerant varieties

Table 3. tolerant varieties of vegetables against the concerned pest

Crop	Pest	Tolerant varieties
Tomato	Fruit borer (*Helicoverpa armigera*)	ArkaVikash, PusaGourv, Pusa Early Dwarf, Punjab Keshari, Punjab Chhuhara
Brinjal	Sucking pests	PPR, Punjab Neelam, Punjab Chamkila, Punjab Barsati
Cabbage	Aphid (*Brevicoryne brassicae*)	All Season, Red Drumhead, Express mail
Cauliflower	Stem borer (*Hellula undalis*)	Early Patna, Kathmandu Local, EMS 3
Okra	Jassids (*Amrasca biguttula biguttula*)	IC-7194, Punjab Padmini
	Shoot and fruit borer (*Earias vittella*)	PMS 8, Perkins Long Green, Karnaul Special
Onion	Thrips (*Thrips tabaci*)	ArkaNiketan, PusaRatnar
Pumpkin	Fruit fly (*Bactocera cucurbitae*)	ArkaSuryamukhi
Bitter gourd	Fruit fly (*Bactocera cucurbitae*)	Hissar II

(Source: Kodandaram *et al.*, 2014)

ii. Planting/sowing time

Certain insect pests may be minimized in vegetable production by carefully planning the sowing or planting date. For example, planting cucurbits early in November may help avoid assault by red pumpkin beetles, but blossoming after October (e.g., bitter gourd) may result in fewer fruit fly infestations. Sowing okra during the second week of June attracts fewer borers, resulting in maximum, healthy output, but July planted Brinjal is vulnerable to shoot and fruit borers. Thus, synchronising the most sensitive stage of the crop with the insect pest's dormant phase decreases infestation and the need for chemical pest control intervention.

iii. Intercropping & Trap crops

iv.

Table 4. List of vegetable crops used as intercrops for the target pest

Crop Combination	Target Pest	References
Cabbage + Carrot	Diamond black moth	Bach and Tabashnik (1990)
Cabbage + Tomato	Diamond black moth	Srinivasan and Veeresh (1986)
Okra + Corn	White fly (YVMV)	Adhikary *et al*. (2015)
Bitter gourd + Maize	Fruit fly	Shooker *et al*. (2006)
Cabbage + Indian mustard	Diamond black moth	Srinivasan and Moorthy (1992)
Cabbage + Chinese cabbage	Diamond black moth	Satapathy *et al*. (2009 and 2010)
Brinjal + Coriander	Shoot and fruit borer	Khorseduzzaman *et al*. (1997) & Satapathy and Mishra (2011)

v. Bio-pesticides

Table 5. Use of biopesticides against target pests

Biopesticides	Trade name	Target pest
Azadirachtin (Neem based)	Neemarin, Azadirachtin, Multineem, Neemguard, Neemzol, Margocide	Caterpillars, leafhoppers, whiteflies, aphids
Bacillus thuringiensis kurstaki (Bacteria)	Halt, Biolep, Delfin, Dipel, Biovit, Thuricide	Caterpillars
Verticillium lecanii (Fungus)	Dispel, Boverin, Biotrol	Caterpillars, white grubs

Beauveria bassiana (Fungus)	Vertalec, Mycotal, Verticel	Aphids, thrips, whiteflies, scale insects
Nuclear Polyhedrosis Virus	H-NPV	*Helicoverpa armigera*
Nuclear Polyhedrosis Virus	S-NPV	*Spodoptera litura*

vi. Natural enemies

Table 6. List of pests and their natural enemies in vegetable crops

Pests	Parasitoids/predators
Plutella xylostella (Crucifers)	*Cotesia plutellae, Diadegma semiclausum, Brachymeria excarinata, Trichogamma toidaebactrae*
Crocidolomia binotalis (Crucifers)	*Lanteles crocidolomia, Palexorista solannis, Bracon hebetor*
Hellula undalis (Crucifers)	*Bracon spp.*
Helicoverpa armigera (Tomato)	*Trichogamma chilonis, T. brasiliensis, T. prestiosum, Campoletis chlorideae*
Earia spp. (Okra)	*Trichogamma chilonis, T. brasiliensis, T. ahaeae, Chelonus blackburni*
Spodoptera litura (Okra)	*Telenomus remus, Peribaeaorbata*
Aphis spp. (Okra)	*Coccinella septempunctata, Chrysoperla zastrowiarabica*

vii. GMOs

Genetically modified crops can act against heavy insecticide spray against many insects, the brilliant examples being Bt brinjal in Bangladesh and Bt Corn and a pleothera of crops in USA. But then again, there is a risk of minor pests rising to the status of major ones as in Bt cotton, thus indirectly raising the pesticide application. So proper care of these crops and proper research should be done for adopting these technologies.

viii. Organic farming

Eating organic foods rather than non-organic foods is one of the strategies used to lessen the influence of pesticide residue in food. According to typical meta-analyses, the frequency of detectable pesticide residues in non-organic crops was four times greater than in organic produce. According to research, organic food intake has been shown to lower pesticide residues in food. Across locations and production seasons, organic crops exhibit greater antioxidant concentrations and lower pesticide residue incidence than non-organic crops. Antioxidant-rich foods should be consumed to minimize the impact of chronic illness by reducing oxidative activity. Antioxidant-rich foods enhance dietary intake, which protects against chronic diseases.

2. Judicious use of chemical pesticides

i. Consideration of economic threshold level for pesticide application

Table 7 List of crop pests and their ETL

Crop	Pest	Economic Threshold Level (ETL)
Cabbage	Diamondback Moth (*Plutella xylostella*)	10 larvae (3rd & 4th instar) per plant in seedling stage
Cauliflower	Aphid	30 aphids/plant
Chilli	Mites (*Poloyphagotarsonemus latus*)	Single mite per leaf
Chilli	Thrips (*Thrips tabaci*)	2 thrips per leaf
Brinjal	Whitefly *(B. tabaci*)	5-10 flies / leaf
Brinjal	Shoot and Fruit Borer (*L. orbonalis*)	0.5% shoot and fruit damage
Tomato	FruitBorer (*Helicoverpa armigera*)	8 eggs in 15 plants or single larva per plant or 2% fruit infestation.
Okra	Fruit Borer (*Earias vittella*)	5.3 % of fruit infestaion
Okra	Leafhopper (*Amrasca biguttula biguttula*)	4-5 nymphs per plant
Pea	Aphids (*Acyrthosiphon pisum*)	3-4 aphids / stem tip

ii. Use of newer green chemistry molecules

Table 8. List of new chemicals with its targeted pest

Common names of new green molecules	Trade name(s)	Form	Recc. conc.		Target pests
			(%)	(ml) or (g/l)	
Abamectin	Vertimec	1.8 EC	0.[illegible]	[illegible]	Mites/thrips
Acetamiprid	Pride (for seed treatment)	20 SP	0.004	0.2	Sucking pests
Beta Cyfluthrin	Bulldock	2.5 EC	0.0035	1.5	Bores
Bt Formulations	Halt (WP), Dipel (8L), Biobit (WP)			0.5-1.0	DBM
Fenpropathrin	Danitol	30 EC	0.045	1.5	Borers
Fipronil	Regent	5 SC	0.01	2.0	Borers
Imidacloprid	Confidor, Sensor	17.8 SL	0.0045	0.25	Sucking pests
Indoxacarb	Avaunt	14.5 SC	0.0145	1.0	Borers

Advantages of newer insecticides

• Greater specificity to target pests

• Excellent efficacy at low rates or dosage

• High level of selectivity

• Non-persistence in the environment

• Low mammalian toxicity

• Less harmful to natural enemies than other broad-spectrum insecticides

• Less likely to cause outbreaks of secondary pests that natural enemies well control

3. Methods of pesticide application (Safety precautions in the use of pesticides)

a) Purchase

• Never buy pesticides in bulk; just buy what you need.

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• Don't buy pesticides unless they have a correct label

• Buy pesticides before they expire.

b) Storage

• Avoid storing pesticides on the premises or near grain storage;

• Never store pesticides near food;

• Keep all pesticides out of the reach of children and livestock;

• Don't expose them to sunlight for an extended length of time;

• Keep all pesticides in original containers with unbroken seals.

c) While Preparing Solution

• Always use clean water and wear clothing to protect your nose, eyes, mouth, ears, and hands.

• While filling the spray tank, don't eat, drink, smoke, or chew.

• Never combine pesticide granules with water unless they are wettable granules

• Avoid leaking pesticide solution while filling the spray tank.

d)

d) Handling

- Never transport any pesticides along with food material

e) Equipment

- Select the right kind of equipment and nozzle
- Don't blow nozzle with mouth
- Don't use the unwashed sprayer for weedicide or insecticide

e) While Applying Pesticides

• Apply insecticides preferably in the evening

• Avoid rainy, hot, sunny, or windy days

• Don't apply pesticides against the wind direction

• Thoroughly wash sprayers and buckets with soap water after spraying

• Buckets used for spraying should not be used for domestic purposes

• Avoid bringing animals or workers into the field right after spraying

f) Disposal

• Do not drain leftover spray solution into ponds;

• Crush and bury empty pesticide containers deep in the soil;

• Do not re-use empty pesticide containers for any other purpose.

4. Adoption of Integrated Pest Management Technology

5. Decontamination Methods (Baking, Blanching, Boiling, Canning, Drying, Washing, Peeling)

Table 9. Effect of food processing techniques on pesticide residue dissipation

Processing	Food ingredients	Pesticide	Residue dissipation	Reasons	Reference
Washing (30 s)	Bitter gourds	Endosulfan	59%	Microparticles of pesticide on the surface of food ingredients are easily washed by stirring of the water.	Nath and Agnihotri, 1984 & Miyahara and Saito, 1994
Washing	Golden apple	Phosalone	30-50%	Reduction due to dissolution of pesticide in water or solution. The removal efficiency of washing depends on the location of residue, age of residue, water solubility, and temperature	Marei *et al.*, 1995
Washing (Vinegar)	Tomato	HCB Dimethoate	51% 91%		Abou Arab, 1999 a,b
Peeling	Bitter gourds Mango	Endosulfan Fenthion Dimethoate	84% 100% 100%	Peeling off fruit skin removed all residues which are accumulated on the pericarp.	Nath and Agnihotri, 1984
Cooking (10min open cooking, 10 min steam cooking)	Bitter gourds	Endosulfan	63-68%	Increase volatilization and hydrolysis or other chemical degradation at high temperature, thus reduce residue level	Nath and Agnihotri, 1984

Table 10. Effects of household processing on reduction of pesticide residues in vegetables

Insecticides detected	Mean of residues in Brinjal [% reduction]			Mean of residues in Cauliflower [% reduction]			Mean of residues in Okra [% reduction]		
	UW	W	B	UW	W	B	UW	W	B
HCH	0.027	0.015 [44]	0.013 [52]	0.042	0.027 [36]	0.017 [59]	0.111	0.069 [38]	0.059 [47]
DDT	0.097	0.061 [37]	0.044 [55]	0.021	0.014 [34]	0.008 [61]	0.051	0.041 [20]	0.033 [35]
Endosulphan	0.048	0.035 [27]	0.029 [39]	0.044	0.029 [34]	0.019 [57]	0.280	0.178 [36]	0.172 [38]
SP	0.027	0.020 [26]	0.017 [37]	0.688	0.490 [29]	0.412 [40]	0.019	0.013 [31]	0.011 [42]
OP	0.009	0.002 [77]	0.0009 [100]	0.027	0.007 [74]	0.002 [92]	0.004	0.002 [50]	0.001 [75]
Carbamates	0.014	0.011 [21]	0.007 [50]	-	-	-	-	-	-

UW: Unwashed; W: Washed; B: Boiled, Numbers in parenthesis [ ] is % reduction of residues

Source: Beena Kumari, 2008 (Hissar, Haryana)

The author has concluded that boiling generally removes more pesticide residues than regular washing. They also concluded that most of the organophosphate chemical residues were easily removed after boiling. Thus organophosphates being the ruling chemical for pest control, boiling of vegetables is recommended for getting lowering pesticide residue in our food (Ramalakshmi *et al*., 2020)

6. Regulatory Control

Rules/acts for pesticides regulations in India

- The Insecticides Act, 1968 and Rules, 1971
- The Environment (Protection) Act, 1986
- Hazardous Waste (Management & Handling) Rules, 1989
- Water (Prevention & Control of Pollution) Act, 1974
- Air (Prevention & Control of Pollution) Act, 1981
- Prevention of Food Adulteration Act, 1954
- The Factories Act, 1948
- Bureau of Indian Standards Act

A. **Table 11. Pesticides Banned for Manufacture, Import, and Use (28 Nos.)**

Aldrin	Benzene, Hexachloride	Calcium Cyanide	Chlordane	Copper Acetoarsenite	CIbromo chloropropane	Endrin
Ethyl Mercury Chloride	Ethyl Parathion	Heptachlor	Menazone	Nitrofen	Paraquat Dimethyl Sulphate	Pentachlor oNitrobenzene
Pentachloro -phenol	Phenyl Mercury Acetate	Sodium Methane Arsonate	Tetradifon	Aldicarb	Chloro benzilate	Toxafen
Dieldrine	Maleic Hydrazide	Ethylene Dibromide	TCA (Trichloroacetic acid)	Metoxuron	Chloro fenvinphos	Lindane

B. **Pesticides / Pesticide Formulations banned for Use but their manufacture is allowed for Export (2 Nos.)**

i. Nicotin Sulfate

ii. Captafol 80% Powder

C. **Pesticides Withdrawn (7 Nos)**

i. Dalapon

ii. Ferbam

iii. Formothion

iv. Nickel Chloride

v. Paradichlorobenzene

vi. Simazine

vii. Warfarin

Conclusion

Pesticide residues accumulate in food grains and vegetables due to excessive pesticide use, which has been linked to some human health problems, including damage to the central and peripheral nervous systems, cancer, allergies and hypersensitivities, reproductive issues, and immune system disruption. Pesticide residues can be reduced by taking preventative steps such as using pesticides sparingly, washing and correctly processing food, practicing organic farming, using natural pesticides and bio-pesticides, and strictly enforcing and amending pesticide-related legislation.

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