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Pesticide Consumption and its Risks to the Human Health and Environment-A Review

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ABSTRACT: In order to boost the agricultural production by preventing or controlling pests, diseases, weeds, and other plant pathogens pesticides are widely in use. But the application of pesticides in current agricultural practices has led to serious impacts to human health and the environment. Serious concerns are raised for human exposure to residues from fruits and vegetables as they are considered very important components of the human diet. The intake of 5 or more servings per day is considered essential for a good health and it is encouraged for vitamin deficiency prevention and also different diseases such as cancer or obesity. Reports considering monitoring programs of pesticides residues in fruit and vegetable products in Europe, USA, and Canada, have shown that most samples have amounts of residues between 6.7 and 58%. Well-known effects of pesticides such as chronic neurotoxicity, endocrine disruption, immune impacts, genotoxicity, mutagenicity, and carcinogenesis have been increasing public concern for food safety. Consequently, pesticides contamination of fruits, vegetables and grains has become a health issue across the entire world. This paper is an attempt to highlight the concentration of pesticides in different vegetables in India and their possible risk to human health and environment.

I. INTRODUCTION

Pesticides came into extensive use in agriculture and public health as early as 1944. Pesticides have contributed to dramatic increases in crop yields and in the quantity and variety of the diet. Also, they have helped to limit the spread of certain diseases. Pesticides are chemical substances, which are commonly used in modern agriculture practices to protect the crops from different pests and diseases. The use of pesticides in agriculture is directly related to an increase in farm productivity.

Numbers of agriculture products, especially vegetables, are important component of the human diet as these are sources of vitamins and minerals. Generally, vegetables supply 16% of magnesium, 19% of iron and 9% of calories on the basis of total recommended intake values [1]. But, fresh vegetables could also be a potential source of harmful and toxic pesticides. Thus, food safety has become a major public concern worldwide [2]. Vegetables are commonly traded at national and international level, and the list of applied pesticides is generally not known [3]. Nowadays, application of pesticides is essential in modern agriculture to enhance the productivity and eliminating pests as well as diseases that spoil vegetables and fruits [4, 5, 6].

On one side, pesticides are very useful to increase harvest productivity, while on the other side, these may lead to some drawbacks in shape of pesticide residues, which remain on fruits and vegetables. This could be a possible health risk to consumers [7, 8, 9]. Therefore, pesticides should be controlled at optimum level due to their relative toxicity to the environment and human health [10, 11]. More than thousand compounds could be used to agricultural crops in order to control unwanted molds, insects, and weeds [12]. Investigation of pesticide residue levels in vegetables is a main concern of many researchers to evade possible risks of toxicity to human health [13]. Therefore, governments and private organizations of international level have established maximum residue levels (MRLs), which usually guide to control the amount of pesticides in foods. MRL for pesticide residues corresponds to maximum amount of that residue (expressed in mg/kg) that is formally permitted in particular food items [14].

A. Consumption of pesticides

At the global level, the use of pesticides has proved to assist solving of many problems facing human health and food production.

However, such usage has occasionally been accompanied with hazards to man and the environment. At national, regional, and international levels, the problem of pesticide harm should be handled scientifically within collaborative action plans; to take as much benefits as possible from using these toxicants without significant hazard to human beings. To promote initiation of the concerned plans, the situation of pesticides in each country should be thoroughly investigated and clarified. The average consumption of pesticides by some countries is presented in Table 1.

Table 1: Consumption of pesticides in some of the major countries.

S. No.	Country	Pesticide consumption(kg/ha)
1.	Taiwan	17.0
2.	Japan	12.0
3.	USA	7.0
4.	Korea	6.6
5.	Europe	2.5
6.	India	0.5

Mahindru [15]

B. Pesticide consumption India

India has 170 mha of arable land with average pesticide consumption of 0.5 kg/ha. In terms of total pesticide consumption, India is placed tenth in the world. India is the second largest producer of vegetables in world after China and accounts for 13.4% of world production. Surveys carried out by institutions spread throughout the country indicate that 50-70% of vegetables are contaminated with insecticide residues [16]. Vegetables are a major constituent of Indian diet with a per capita consumption of approximately 135g per day as against the recommendation of approximately 300g per day [17].

India is an agrarian country, and the majority of Indians are vegetarians. Their average diet consists of 150–250 g of vegetables in each meal in total per day [18]. Pesticides in India were introduced during the mid-sixties and are now being extensively used in agriculture e.g., fruits, vegetables and other crops. The benefits reflected in terms of enhanced farm productivity and control of vector-borne diseases were so overwhelming that the real awakening to the problem of toxic residues left by pesticides came into sharp focus only around 1960. The problem of contamination of our food commodities, especially fruits and vegetables by pesticide residues constitutes one of the most serious challenges to public health. The hazards of toxic residues can be considerably reduced if pesticides are used in accordance with 'Good Agricultural Practice' (GAP). Dietary ingestion is one of the pathways through which the general population is exposed to pesticides on a daily basis. Several studies indicate that certain foods contain higher levels of pesticide residues, such as fruits, juices, and vegetables [19]. The National Research Council's (NRC) report on pesticides in the diets of infants and children concluded that dietary intake represents the primary source of pesticide exposure in children.

India currently uses about 60,000 tons of pesticides, a decline of 1/3 since five years ago. Worldwide, there has been a 44% increase in the use of herbicides over the past decade, with a concomitant reduction in insecticides by 30%. Since insecticides still account for 70% of total pesticides used in India, it is likely that insecticide residues will continue to be an issue for at least another decade, even if the declining in use continues [16].

Table 2: Consumption of pesticides in India in Metric tons (Tech. Grade).

Year	Quantity	Year	Quantity
1953-1954	154	1996-1997	56114
1960-1961	8620	1997-1998	52239
1965-1966	14630	1998-1999	49157
1970-1971	24320	1999-2000	46195
1975-1976	45613	2000-2001	43584
1980-1981	54775	2001-2002	47020
1985-1986	61881	2002-2003	48350
1990-1991	75033	2003-2004	41020
1995-1996	61260	2004-2005	40672

Jayakumar.http://www.chemicalmanagement.org [20]

Table 3: Consumption of pesticides in Madhya Pradesh during 2002-2003 to 2010-2011 in Metric Tones.

Year	Quantity
2002-2003	1026
2003-2004	662
2004-2005	749
2005-2006	787
2006-2007	879
2007-2008	877
2008-2009	927
2009-2010	914
2010-2011	894

Mahindru, [16]

As per information derived from Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RMVSKVV), Gwalior the insecticide consumption of the district during 2011 was 0.01 lit/ha.

Table 4: Production of pesticides during 2002-2003 to 2010-2011 in Metric Tonnes.

Year	**Malathion** (Quantity)
2002-2003	4000
2003-3004	3945
2004-2005	4710
2005-2006	2740
2006-2007	4040
2007-2008	3660
2008-2009	3842
2009-2010	3288
2010-2011	3337

Mahindru, [13]

Generally, children are exposed to more pesticides than adults because they eat more food per unit body mass than adults, and because their diets differ in nature from those of adults. Due to this exposure, pesticide-related health risks are greater in children than adults [21, 19].

C. Monitoring of pesticide residues in vegetables collected from supervised trials, markets,and farmer's fields

Lee Fook and Seeneevassen in 1998 analyzed 52 samples of the vegetable and fruit extract for the presence of organophosphorus insecticide dichlorvos, diazinon, fenitrothion, methamidophos, profenofos, phosphamidon, Malathion,and parathion. The following insecticides: Cypermethrin, deltamethrin, methamidophos, profenofos, and Malathion have been detected in some of the samples of vegetables and fruits analyzed, but they have been mostly detected below the MRL. The results obtained showed that 61.5% of the vegetables and fruit samples analyzed contained Not Detectable Limit (NDL) of the monitored insecticides, 36.2%of the samples gave results with levels of insecticide residues below the MRL, while 2.3% of the samples showed results above the MRL. Only three samples contained levels of insecticide residues above the MRL.

Hussain *et al*., [22] undertook studies to access level of some commonly used pesticides *viz.* cypermethrin, methamidophos, monocrotophos, cyfluthrin, dieldrin, and methyl parathion respectively in three varieties of mango samples collected from the grower fields of Multan division. The samples were treated with organic solvent cyclohexane and ethyl acetate (1:1), cleaned on Gel Chromatograph (GPC) and analyzed on auto system GC-ECD. All the samples were found to be contaminated with a degree of variation of pesticides residue studied. However, all the samples were within permissible limits being set by FAO/WHO with reference to public health.

Kole *et al*., [23] monitored the pesticide residues in farm gate samples of brinjal (46), cauliflower (29), chili (5), okra (15), pointed gourd (23), potato (9) and tomato (5) in two districts of West Bengal. About 50% of the samples were found to be contaminated with various pesticides (0.01-2.23ppm) of which 16% were above MRL. Among the vegetables, frequency of contamination was maximum in chili and okra (80%). No sample contained residues of dicofol and endosulfan above MRL. Lo and Matthews [24] tested 243 batches of ingredients and detected low levels of agro-chemical residues in 21% samples of organic food ingredients.

The residue level can arise in organic food also through environmental contamination or even the fraudulent use of agro-chemicals. Duara *et al.*, [25] studied the residues of cypermethrin and fenvalerate on brinjal by single application of cypermethrin at 22.5, 45 and 75ga.i.ha^{-1} and fenvalerate at 30, 60, and 112.5g a.i.ha^{-1}. The residues were determined in terminal shoots at different time intervals and fruit at harvest. Results showed that the residue levels were found to be below MRL at 7th day of the pesticide under study.

Arora and Singh [26] collected the samples of okra, brinjal and soil from non- IPM and IPM fields of village Raispur, in Ghaziabad District (UP). These samples were analyzed for chlorpyriphos, cypermethrin, and monocrotophos. The residues of chlorpyriphos and cypermethrin in okra were found to be 0.01µg g^{-1} while they were not detected for IPM trials and 5.75 and 1.25µg g^{-1} for IPM and non-IPM fields, respectively. The residue levels of insecticides applied in okra and brinjal in IPM trials were found to be below MRL. Dissipation and decontamination of cypermethrin and fluvalinate residues in okra were studied by Saghir *et al.*, [27] by applying cypermethrin and fluvalinate in two doses. The initial deposits of both the doses were less than MRL. Washing of okra fruits with tap water removed cypermethrin residues to the extent of 41.2-48.3% in samples processed on the same day and 37.1-46.0% 5th day. In case of fluvalinate, the extent of removal was 38.0-44.2% when processed on the same day and 32.4-41.8% on 5th day.

Dissipation of ethion (0.1%) and chlorpyriphos (0.05%) on chili (*Capsicum annum* L.) was studied by Mahalingappa *et al.*, [28] by spraying the crop four times at fortnight interval starting from 45 days after transplanting. An initial deposit of 1.84 mg kg^{-1} of ethion and 0.67 mg kg^{-1} of chlorpyriphos, dissipated to 0.17 (90.8%) and 0.07 mg kg^{-1} (89.6%) by 30 days after fourth spray, respectively. Half-life (RL_{50}) values of 9.4 and 9.9 days and the waiting periods (T_{tol}) of 17.6 and 21.2 days were calculated for ethion and chlorpyriphos, respectively. The residues in shade dried red chilies on 30th day after last spray were 1.29 and 0.62 mg kg^{-1}, which dissipated to 0.35 and 0.02 mg kg^{-1} respectively, for ethion and chlorpyriphos on 90th day. Dissipation of monocrotophos and quinalphos on brinjal fruits was studied following application at the rate 500 and 1000g a.i.ha^{-1}.Initial deposits of monocrotophos were 1.93 and 2.59 mg kg^{-1} on brinjal fruits, which dissipated below detectable level and 0.24 mg kg^{-1} in four days, respectively. In the case of quinalphos, initial deposit 0.76 and 1.05 mg kg^{-1} at lower and higher doses, respectively, dissipated to extent of 81-86% on second day. A waiting period of 4 and 2 days for monocrotophos and quinalphos, respectively, has been suggested [29].

The residues of chlorpyriphos and monocrotophos were determined in mango fruit (Dushehri) from IPM and non-IPM trials at Rehmankhera, Lucknow, and U.P. during 2002-2003. The residues of chlorpyriphos in pulp were 0.22 and 0.61 µg g^{-1} while the residues in peel were 0.20 and 0.59 µg g^{-1}, respectively and in whole fruit, residues were 0.45 and 1.33µg g^{-1} respectively. Residues of monocrotophos were found to be BDL in all samples. Residues of chlorpyriphos were higher in non-IPM than IPM samples but below MRLs in both the cases [30]. Reduction of chlorpyriphos residues from cauliflower by culinary processes was studied [31]. Effect of washing, cooking, saltwater dipping, dipping in boiled salt water, dipping in detergent solution was studied on the reduction of chlorpyriphos residues from contaminated cauliflower curds. The results indicated that levels of chlorpyriphos residues can be reduced significantly by mild detergent washing or by washing and cooking. The analysis showed that various food processing techniques substantially lowers the residues of chlorpyriphos in cauliflower curds (27.0-73.3%) but none were able to satisfactorily bring down the residue below the tolerance level of 0.01µg g^{-1}.The estimation and dissipation of bifenthrin and chlorpyriphos residues from groundnut stalk and seed, obtained from the sprayed field trial during Kharif 1997-1998 was worked by Reddy and Divakar [32]. The results indicated, that the residues of two insecticides reached non- detectable level from seeds collected at harvest and it is concluded that the groundnut stalk could be fed to the cattle and seeds can be consumed by human beings without any threat of insecticide residue problem.

Kumari, [17] monitored residue levels of Organochlorines, synthetic pyrethroids, organophosphates and carbamates, determined in unprocessed and processed market samples of three vegetables viz. brinjal, cauliflower, and okra at different interval of time to know the residue levels and evaluate the effect of different household processes (washing and boiling/cooking) on reduction of residues. Estimation carried out by gas-liquidchromatograph with electron capture detector and nitrogen phosphorus detector equipped with capillary columns showed that washing reduced the residues by 20-77% and boiling by 32-100%. Maximum (77%) reduction of OP insecticides was observed in brinjal, followed by 74% in cauliflower and 50% in okra by washing. The same trend was observed in boiling process in which 100% reduction of OP insecticides was observed in brinjal followed by 92% in cauliflower and 75% in okra.

Boiling was found comparatively more effective than washing in dislodging the residues. Persistence and dissipation of mancozeb in tomato fruits was studied by Kumar *et al*., [33] following foliar application of mancozeb 75WP at the dose of 1.5 and 3kg a.i.ha^{-1}. The residues reached to half of the initial deposits after 3.3 and 4.3 days at normal and double dose treatment, respectively, with safe waiting periods of 2 and 10 days. Anand *et al*. [34] worked on persistence of mancozeb residues in tomato. Excessive and indiscriminate use of mancozeb may lead to higher residues in/on fruits, which may be harmful to human beings. Keeping this in consideration investigations were planned for subtropical conditions at Punjab, India following seven applications of ten days interval @ 0.2 and 0.4% respectively. Residues were found to be below detectable levels after 10 and 15 days of applications at 0.2 and 0.4% concentrations, respectively. A field experiment was conducted to determine the residue of imidacloprid of 70WS as seed treatment and imidacloprid 200 SI as foliar treatment in a farmer's field at palavedu village, Tamil Nadu. The residue of imidacloprid was found below the detectable limit [34]. The residues of mancozeb in unwashed and washed cauliflower curds and tomato fruits were reported by Kaur *et al*., [36]. The initial residues of mancozeb after 3 and 4 sprays when applied @ 0.25% in unwashed and washed cauliflower curd samples were 8.43, 8.62 and 5.96, 6.88 mg kg^{-1} respectively. The residues declined significantly after washing and reached below MRLs of 5.25mg kg^{-1} on first and third day of last application in the case of three and four sprays. In case of tomato when 4, 7 and 9 applications of mancozeb @ 0.4% were made, the initial deposit of 1.76, 2.97 and 4.03 mg kg^{-1} were observed for unwashed tomatoes collected one day after the last spray. The residues were below detectable levels on first day for washed tomatoes.

Persistence of mancozeb was studied under field conditions in west Bengal, India in tomato and potato crop following foliar spray application @750 and 1500 g a.i.ha^{-1} .Residues were determined after 3 sprays of mancozeb applied as per the GAP. Mancozeb residues were below the detectable limits on the 5th day for the recommended dose and 7th day for double the recommended dose. The suggested waiting period ranges between 4 to 5 days for potato tuber and 5 to 6 days for tomato fruits. The half- life values varied from 1.2- 1.3 days for the foliages of these vegetables as well as fruits and tubers [37].Gupta *et al.* [38] worked on the persistence of imidacloprid (@20 and 40 g a.i.ha^{-1}), acetamiprid and thiamethoxam (@ 25 and 50 g a.i.ha^{-1} for both) in gram following seed dressing (3 and 6 g a.i.kg^{-1} seed) by foliar application. The residues in green plant persisted beyond 30 days after sowing, and no residues were detected after 45 days. The residues of imidacloprid persisted beyond 3 days but no residues were detected on 5th day. Similarly, the residues of thiamethoxam and acetamiprid persisted beyond 5 days but no residues were detected on 10th day except for high dose of thiamethoxam. Similar trend was observed in combine treatment (seed dressing+foliar spray) of thiamethoxam and no residues were detected in harvested seed and fodder samples.The work on field bio efficacy of some newer insecticides (profenofos 50 EC, Rocket 44 EC and cypermethrin 25EC) against mixed population of aphids infecting tomato crop was carried out through field trials of two years [39]. Application of Rocket proved superior to other treatments whereas Profenofos was found least effective.

Residues of different insecticides in/on and their effect on *Trichogramma* spp. was studied by Samanta *et al*., [40]. Dissipation of residues of quinalphos @ 500 and 1000g a.i.ha^{-1}, methomyl @ 400 and 800g a.i.ha^{-1} and alphacypermethrin @ 30 and 60g a.i.ha^{-1} were studied in/on brinjal (Muktakeshi) under field conditions at Kalyani, West Bengal during kharif season of 2000-2001. In all, five sprays were given at 15 days interval. The initial residues on brinjal fruits after the last spray were to the magnitude of 4.78 and 6.98 µg g^{-1} for quinalphos, 3.98 and 5.65 µg g^{-1} for methomyl and 0.755 and 1.025 µg g^{-1} for alpha cypermethrin for lower and higher doses, respectively. The residues dissipated with the half- life of 1.1-1.5 days for quinalphos, 1.0-1.4 days for methomyl and 1.8-2.4 days for alpha cypermethrin. The residues reached BDL after 10 days for lower dose and 15 days for higher dose for all the insecticides. The safe waiting periods (T_{mrl}) determined for brinjal was within 4.8-7.4 days, 4.4-6.5 days and 1.3-3.0 days for quinalphos, methomyl and alphacypermethrin, respectively. Fruit samples of 1-5 days showed the presence of quinalphos Oxon in amounts ranging from 0.01-0.34 µg g^{-1}. Decontamination process like washing and cooking dislodged 28.2-76.1% residues depending on insecticides and dosage whereas 21.1-60.1% surface residues was removed by washing alone. The study on residual toxicity on *Trichogramma chilonis* Ishii and *Trichogramma japonicum* Ashmead showed that the insecticides differed considerably in their persistency period of efficacy and index of persistent toxicity (PT value) towards both the species. Based on PT value, alphacypermethrin was found to be safest towards both the parasitoids.

Considering the retention period of toxic residues, both the parasitoids could be released in the crop ecosystem after 3-5 days of alphacypermethrin spray, 4-6 days of methomyl spray and 6-7 days of quinalphos spray depending upon treatment doses and parasitoids species. Since the toxicity of the pesticides is well established, it becomes necessary to monitor seasonal vegetables regularly, covering a larger area, of the state, and to educate farmers regarding potential risks and safe use of pesticides.

D. Pesticides in soil

Thirteen soil samples spreading over many talukas of Mandya and Mysore districts of Karnataka state were collected for presence of DDT and DDE residues and were measured using the immunoassay and gas liquid chromatography [41]. Data from ELISA indicated that all the samples contained DDE residues, while 8 out of 13 had DDT. The average concentrations of DDE ranged from 0.06 to 0.25 ppm, while that of DDT varied from 0.4 to 4 ppm in soil samples. Arora and Singh, [26] collected the samples of okra, brinjal and soil from non-IPM fields of village Raispur, in Ghaziabad District (UP).These samples analyzed for chlorpyriphos, cypermethrin and monocrotophos. The residues of these insecticides in soil were 0.4µg g^{-1} before start of okra trial and increased to 4.22 and 1.4 µg g^{-} Prakash *et al*., [42] studied 45 soil samples of surface (0-15cm) and sub-surface (15-30cm) soils from agricultural sites of Delhi, Haryana, Haridwar, Uttar Pradesh and around the hexachlorocyclohexane (HCH) manufacturing plant of IPL, (Indian Pesticide Limited). They also studied nine samples of different commercial brands of drinking water from markets in Delhi and were analyzed for the presence of residues of HCH isomers. Thirty-nine of the 45 soil samples contained residues of β-HCH (2.5g/kg to 463mg/kg of soil) and the remaining showed the presence of γ-HCH (0.08g/kg to 43.00mg/kg).

Studies were made on the persistence of imidacloprid, diazinon and lindane in soil under groundnut (*Arachis hypogaea* L.) cultivation during kharif from 1997-1999 [43]. Following seed treatment, diazinon residue persisted till 60 days with average half-life of 29.32 days in soil. Similarly, diazinon residue in soil treated field persisted till 60 days with average half-life of 34.87 days. Nevertheless, seed treatment of imidacloprid and lindane resulted in their persistence in soil till 90 and 120 days with average half-life of 40.96 and 53.39 days, respectively. Within 90 days, the imidacloprid residues lost ranged from 73.17 to 82.49% while such losses for lindane residues ranged from 78.19 to 79.86% within 120 days.

Persistence of carbosulfan was reported under laboratory conditions in black, red and alluvial soils following application @ 5 and 10 mg kg^{-1} [44]. Carbosulfan residues progressively declined with time and reached below detectable level within 75 days in red and alluvial soils and 90 days in black soil. However, more than 95% of carbosulfan degraded within 60 days after incubation irrespective of the soil type and concentration.

The mobility of OP pesticides was studied in soil by Environment Agency, (2003) using Thin Layer Chromatography. The effect of soil organic matter and its fractions *i.e.,* humic and fulvic acids, clay content, soil pH and exchangeable cations were investigated. The pesticides mobility followed the order thiometon<dimethoate<phosphamidon<malathion<dichlorovos in both soils while malathion was more mobile than phosphamidon in Agra sandy loam soil. The OM, HA, FA clay content, pH and exchangeable cations were found to decrease the pesticide mobility in soils except for malathion and phosphamidon which showed an increase in mobility on addition of humic acid to soil. The results have been explained on the basis of their adsorption/complexation, the nature of soil colloids and the molecular structure of pesticides.

Field trials were conducted for three consecutive years (2001-2003) during winter season to evaluate the persistence and dissipation of mancozeb in cucumber and cropped soil following foliar applications of Indofil M45 (mancozeb 75WP) applied as per the GAP [45]. Residues of mancozeb were found BDL on the 5^{th} day for the recommended dose and 7^{th} day for double the recommended dose in the case of whole plant and residues were found BDL after 3^{rd} and 5^{th} day for recommended and double dosages respectably for soil. The safe waiting period ranged between 4.65 to 7.02 days for cucumber to give a MRL of 0.5mg/kg. The half-life values ranged between 1.19 to 1.43 days (for cucumber) and 1.16-1.26 days (for cropped soil).

Persistence of paclobutrazol residues in soils of some mango growing areas of India have been reported [46]. Under laboratory conditions, following fortification of the soils at 2.5µg g^{-1},paclobutrazol residues persisted beyond 210 days in four soil samples collected from mango orchards located at Lucknow (Uttar Pradesh), Malda (West Bengal), Nuzvid (Andhra Pradesh) and Konkan (Maharashtra). The dissipation of the residues followed first order kinetics. The half-life of paclobutrazol in different soils varied from 31.6-41.9 days. The change in soil pH (5.7 to 7.5) had no significant effect on the persistence of the residues.

Studies have been carried out to find the degradation pattern of the herbicide fluchloralin in 12 different soils with varying pH, EC, CEC, texture and organic carbon contents by an incubation study at field capacity moisture level.

The results showed that the degradation of fluchloralin was influenced by the clay content and the persistence was longer in soils with higher clay content. After 60 days of incubation the residues were below detectable level in soils with low clay content while traces were detected in soils having higher clay percentage. The half-life ($T_{1/2}$) ranged from 6.1-12.0 days in the soils [47].

A two season study (October 2005 to January 2006 and October 2006 to January 2007) on the persistence of propineb (two doses) was undertaken with potatoes at two different locations having two different types of soils [48]. The results showed that residue was detectable up to 20 days after the last application of the fungicide. The half-life values varied from 2.59 to 3.48 days. A safe waiting period of 10 days is recommended for potatoes

E. Risks to human health with pesticide residues

The assessment of pesticide impact on human health is not an tranquil because of differences in the periods and the levels of exposure, type of pesticides, concoctions used in the field, and the geographic and meteorological characteristics of the agricultural areas where pesticides are applied [49,50]. Considering that human health risk a function of pesticide toxicity and exposure, a greater risk is predictable to ascend from high exposure of moderately toxic pesticide than from little exposure to a highly toxic pesticide. But still it is the subject of great controversy that whether or not nutritional exposure of the general population to pesticide residues found on food and drinking water consists of a potential threat to human health [51]. Regardless of the difficulties in assessing risks of pesticide use on human health, the authorization for pesticide commercialization requires data of potential negative effects of the active substances on human health. These data are usually obtained from several tests focused on e.g., metabolism patterns, acute toxicity, sub-chronic or sub-acute toxicity, chronic toxicity, carcinogenicity, genotoxicity, teratogenicity, generation study, and also irritancy trials using rat as a model mammal or in some cases dogs and rabbits [52]. The respective toxicity tests for human health risk assessments required by EPA [53] are the acute toxicity test, the sub-chronic toxicity test, the chronic toxicity test, the developmental and reproductive tests, the mutagenicity test and the hormone disruption test, which measures the pesticide potential to disrupt the endocrine system (consists of a set of glands and the hormones they produce that regulate the development, growth, reproduction, and behaviour of animals including humans). The acute toxicity experiments are obligatory for the calculation of the median lethal dose (LD_{50}), which is the pesticide dose that is required to kill half of the tested animals when entering the body by a particular route. For example, if the substance is swallowed the figure is an oral LD_{50}, whereas if absorbed through the skin it is a dermal LD_{50}. In addition, the acute inhalation lethal concentration (LC_{50}), which is the pesticide concentration required to kill half of the exposed (for 4 hours) tested animals to a pesticide, is also calculated.

II. CONCLUSIONS

Pesticides played a very important role in providing unswerving supplies of agricultural products at very low and reasonable prices to common people by refining the quality and quantity of produce, and ensuring high profits to farmers. Even though pesticides are developed to function with reasonable certainty and minimal risk to human health and the environment, various studies have raised concerns about health risks from exposure of farmers and from non-occupational exposure of the population to residues found on food and drinking water. Several indicators have been used for the assessment of the impending risks of pesticides to human health and the environment which have shown very less certainty. Thus there is a need for improvement and development of new substitute indicators that should increase the accuracy and reliability of pesticide risk assessment and thus contribute to reduction of the possible adverse effects of pesticides on human health and the environment. The exploration of some biological agents and for management of pests with development of new modified pesticides with novel modes of action and the execution of alternative cropping systems could minimalize exposure to pesticides and the undesirable effects of exposure on human health.

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