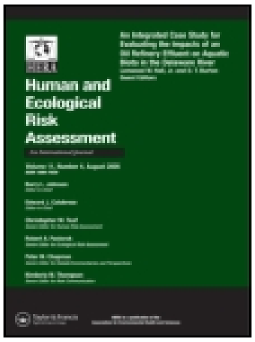

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HAZARD ASSESSMENT ARTICLES

Effects of Environmental Pesticides on the Health of Rural Communities in the Malwa Region of Punjab, India: A Review

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ABSTRACT

The Malwa region of Punjab, India, is facing an unprecedented crisis of environmental health linked to indiscriminate, excessive, and unsafe use of pesticides, fertilizers, and poor groundwater quality. The region has been described as India's "cancer capital" due to abnormally high number of cancer cases, which have increased 3-fold in the last 10 years. Studies of this region have also highlighted a sharp increase in many other pesticide-related diseases, such as mental retardation and reproductive disorders. The most affected individuals are the agricultural workers who are directly exposed to pesticides. The Malwa region of Punjab, India, is less than 15% of the total area of Punjab (only 0.5% of the total geographical area of India), but it consumes nearly 75% of the total pesticides used in Punjab. The high use of pesticides, along with environmental and social factors, is responsible for the high concentration of pesticide residues in the food chain of this region. Moreover, many banned and restricted pesticides are still in use in this region, warranting strict periodical health checkups and other interventions. The present review describes occupational, environmental, and social factors associated with pesticide use in the Malwa region of Punjab, India, and proposes some risk reduction interventions.

Key Words: Malwa region of Punjab, pesticides, cotton, reproductive disorders, cancer, neurological disorders.

INTRODUCTION

India witnessed a major increase in agricultural productivity in 1965 with the advent of the Green Revolution. This turned the country's agricultural regions into bread baskets with a major increase in productivity of food and cash crops

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like wheat, rice, pulses, jute, sugarcane, tea, cotton, and so on. The productivity of wheat and rice crops increased by 2- to 3-fold during this period (Khush 1999). Apart from food crops, the yield of cash crops also increased to a significant extent. The Green Revolution was based on introduction of new irrigation techniques, chemical fertilizers, synthetic pesticides, herbicides, and high-yielding varieties. The consumption of fertilizers increased from around 78,000 tons in 1965–1966 to 26.5 million tons during 2009–2010 (Sharma and Thaker 2011) while as per the report of Mathur *et al.* (2005), the pesticide consumption in India increased from 154 metric tons in 1954 to 88,000 metric tons in 2000–2001.

Among the various states of India, Punjab was the hub of the Green Revolution, which made the Punjab's farmers self-sufficient, no longer dependent on other states and countries for their basic needs of food (Sidhu and Byerlee 1992). As per the *Statistical Abstract of Punjab* (2005) report, the grain production in Punjab increased from 3.16 million tons in 1960–1961 to 25.66 million tons in 2004–2005. Similarly, the production of cotton increased from 0.12 million tons in 1960–1961to 0.37 million tons in 2007–08 (increase more than 3 times) with a mere 1.35-fold increase in the area under cotton cultivation (Barik 2010). This increased production had some major drawbacks, one of which was high use of pesticides (Shiva 1991; Yadav 2006).

Given the significant increase in the use of chemical pesticides and fertilizers in this vital agricultural region of India, this article catalogs the major pesticides used in the region, reviews the human health implications of human exposure to the pesticides, and derives a set of risk reduction proposals for consideration by the health and environmental authorities.

BACKGROUND

In order to protect their crops from losses due to pests and diseases, the farmers in Punjab use huge quantities of pesticides. Among various crops, the pesticide usage is highest in the cotton fields to protect the crop from attacks of the *Helicoverpa armigera* (American bollworm) pest (Mehrotra and Phokela 1992). Puri *et al.* (1999) reported about 54% of the total pesticide consumption of India on cotton alone, though it is grown in only 5% of the total cultivable area in India. As a result of which some regions of Punjab have started witnessing various diseases previously unknown to the local population.

The Malwa region of Punjab, locally called "Makheon Meetha (Sweeter than Honey) Malwa" for its rich agricultural produce and cotton farming, is one such part that is facing an unprecedented crisis of adverse human health events related to indiscriminate use of synthetic pesticides. Although some other factors like use of addictive drugs, tobacco smoking, presence of heavy metals (Pb, As, U) in the groundwater have also been reported to contribute to the present health crisis, higher usage of pesticides remains as one of the major factors. Some parts of the Malwa region in recent times have been reported for a very high number of cancer cases as well as reproductive disorders.

MALWA REGION OF PUNJAB, INDIA

The Malwa region is the largest part of the three main divisions (the other two being Majha and Doaba) of the present Punjab state of India. The Malwa region geographically lies between 29°–30' and 31°–10' North latitudes and 73°–50' and 76°–50' East longitudes and has been best described as the southern part of Punjab partitioned by the Sutlej River. It includes the districts of Fazilka, Bathinda, Mansa, Moga, Faridkot, Patiala, Sangrur, Barnala, Ferozepur, Muktsar, and Ludhiana (11 districts) that comprise an area of 32,808 km^2 (65.1% of Punjab's area). The total population of the Malwa region is 14.3 million (52% of Punjab's population), with nearly 62% being the rural population (The Indian Census 2011). As per the *Statistical Abstract of Punjab* (2011), out of a total area of 30200 km^2 in the Malwa region, approximately 86.5% is under cultivation (net sown area in year 2010–2011). Climatically, this region has two seasons; the Rabi season, which is characterized by winter to mild summer, and the Khariff season, having summer to mild winter. Rice, wheat, and cotton are the major crops with a net sown area of 16,950, 22,810, and 4730 km^2, respectively (area as per year 2010–2011) (*Statistical Abstract of Punjab* 2011).

Factors Responsible for Pesticide Contamination in the Malwa Region of Punjab, India

Occupational factors

Agriculture is the major occupation of the region's people. As per the report of Thakur *et al.* (2008), 70% of Punjab's population is directly or indirectly associated with agriculture and nearly the same trend is followed in the Malwa region. Cotton is a major crop in the Malwa region, which requires more use of pesticides to control the infestation of pests, as the pests have developed resistance to the pesticides (Shetty 2004). The farmers and primarily agricultural workers are inadvertently exposed to pesticides through occupational use at all stages starting from pesticide purchase, transport, storage, dilution of pesticide concentrate, leaking of spray equipment, and inhalation during pesticide spraying (Maroni *et al.* 2000). Rural communities that are not directly linked with agriculture are often affected by the spray drift, working near fields after spraying, washing work clothes, and through home pesticide storage and polluted drinking water or proximity to obsolete pesticide dumps, and so on. Continuous use of pesticides has made the pests resistant to most of the pesticides. So the farmers prefer increased concentrations and an increased number of sprays to make the pesticides more effective.

Environmental factors

Both soil characteristics and climatic conditions in the region contribute to the increased effects of pesticides to people in the Malwa region. Pesticides are mainly used on cotton crops during the months of July and August. During these two months, the temperature of the region is quite high (varying from 30°C to 45°C) with high speed winds and rainfall. Due to high temperature the sprayed pesticides remain suspended in the air for a long time and due to high wind speed, they drift long distances, making the general public vulnerable to pesticide exposure. Moreover, high rainfall during the period leads to mixing of pesticides. In general, the Malwa region has a silty soil texture, which results in less water holding capacity and leads to easy leaching of pesticides into the groundwater. Moreover, the soil of the cotton belt has low organic matter (Tiwana *et al.* 2007) due to which the soil sorption capacity gets reduced, which also enhances the leaching capacity of pesticides into groundwater.

Social factors

The social factors that increase the risk of pesticide contamination are farmers' illiteracy, lack of personal protective equipment, and insufficient knowledge of pesticide hazards. Farmers use pesticides in much higher concentrations than recommended, which is another reason for fast deposition of pesticides in this region. Many banned and restricted pesticides have been detected in the Malwa region as mentioned in Table 1. Also, the pesticides that are restricted for use in agriculture are still being used by farmers. Lack of awareness among farmers for the disposal of used pesticide containers leads to the malpractice of using empty pesticide containers for storage of food items. Also, it was reported that the farmers were using 30–35 pesticides spray for a single cotton crop as against 8–10 recommended by agriculture experts in some parts of the Malwa region (Thakur *et al.* 2008).

FACT FILE OF PESTICIDES USED IN THE MALWA REGION

The change in agricultural practices because of the use of pesticides in the Malwa region of Punjab has been periodically highlighted. The black soil in the region is suitable for cotton cultivation, which is susceptible to attacks from *Helicoverpa armigera* (American bollworm). As per the Kheti Virasat (2007), Malwa's cotton belt is less than 0.5% of the total geographical area of India and 15% of Punjab's area, however, it consumes 75% of the total pesticides used in Punjab (Misra 2007). The five major districts under cotton cultivation are Firozpur, Faridkot, Muktsar, Bathinda, and Mansa comprising 90% of the area of the Malwa region and responsible for maximum usage of pesticides. So many pesticides have been used in this part that they have become an integral part of villagers' life in this region. Different scientists working in the Malwa region have reported the presence of pesticides in environmental samples as well as in the living systems.

In various environmental samples, pesticides have been detected in groundwater, surface water, ambient air, and soil samples. In living systems, the pesticides have been reported in human blood, milk, animal blood, animal milk, tissues of animals, and also in crops, vegetables, and plants. The literature review of pesticides reported by different researchers working in the Malwa region of Punjab is listed in Table 1, which highlights the area and source of samples, pesticides detected, and their concentrations. Nearly 17 different types of pesticide residues have been detected in the region. Most of these have now been categorized into banned or restricted pesticides by the Government of India (CIBRC 2012).

Additionally, a survey of nearly 40 pesticide bulk sellers in the Malwa region was done to learn the major pesticides currently in use. The pesticides along with their trade name, ingredients, and crops with their pests and plant diseases in the region are listed in Table 2. It was observed that pesticides with the same active ingredients are sold by different manufacturers under different trade names as listed in Table 2. It is also revealed that pesticides with 21 different active ingredients are currently used in the Malwa region (Table 2).

Table 1. List of pesticide residues reported by different researchers in the Malwa region of Punjab, India.

Area	Source	Pesticide detected	Concentration	Ref.
Ludhiana	Human Milk	DDT (R) (Dichlorodiphenyltrichloroethane)	0.510 mg/l	Kalra and Chawala (1981)
		BHC (beta-Hexachlorocyclohexane)	0.195 mg/l	
Ludhiana and Sangrur	Buffalo milk	DDT	Above 0.05 mg/kg	Battu *et al.* (1989)
Selected Cotton growing area only	Human Milk sample	DDT	0.52 mg/kg	Kalra *et al.* (1994)
		HCH (Hexachlorocyclohexane)	0.19 mg/kg	
Ludhiana	Human Milk sample	DDT	Exceed 0.05 mg/kg	Battu *et al.* (2004)
		HCH (R) (including α, β, γ, δ)	0.10–0.98 mg/kg (22 samples in 1999)	
Abohar, Bathinda, Malout, Mansa, Muktsar	Cotton seed sample	Endosulfan	Abohar—0.013 mg/kg	Singh (2004)
			Malout—0.006–0.007 mg/kg	
			Muktsar—0.004 mg/kg	
			Mansa—0.012 mg/kg	
		Chlorpyriphos	Abohar—0.014 mg/kg	
			Bathinda—0.019 mg/kg	
			Malout—0.002–0.010 mg/kg	
			Mansa—0.003–0.024 mg/kg	
		Ethion	Abohar—0.018–0.047 mg/kg	
			Malout—0.037 mg/kg	
			Mansa—0.066 mg/kg	
			Muktsar—0.041–0.049 mg/kg	
		Cypermethrin (R)	Bathinda—0.014 mg/kg	
			Malout—0.033 mg/kg	
			Mansa—0.023 mg/kg	
			Muktsar—0.049 mg/kg	

Amritsar, Bathinda, Gurdaspur, Hoshiarpur, Jalandhar, Ludhiana, Mohali, Patiala, Sangrur	Milk Plants	DDT	0.01 mg/kg	Cheema *et al.* (2004)
Mahi Nangal, Jajjal and Balloh in Bathinda Dher in Ropar district	Human Blood	t-HCH	0.0570 mg/l	Mathur *et al.* (2005)
		Heptachlor (B)	0.0006 mg/l	
		Aldrin (B)	0.0062 mg/l	
		Chlordane (B)	0.0090 mg/l	
		t-DDT	0.0652 mg/l	
		t-endosulfan	0.00046 mg/l	
		Chlorpyriphos	0.0662 mg/l	
		Malathion	0.0301 mg/l	
		Monocrotophos (R)	0.0948 mg/l	
		Phosphamidon (B)	0.0366 mg/l	
Bathinda and Ludhiana	River Water	DDT, Aldrin, Endosulfan, BHC	Data not available	Tiwana *et al.* (2007)
Ludhiana (Poultry Farm)	Poultry feed	HCH	0.65 mg/kg	Aulakh *et al.* (2006)
		DDT	0.91 mg/kg	
		Endosulfan sulphate	0.42 mg/kg	
		Heptachlor epoxide	0.02 mg/kg	
	Chicken Muscle	HCH	0.11 mg/kg	
		DDT	0.24 mg/kg	
		Endosulfan sulphate	0.10 mg/kg	
		Heptachlor epoxide	0.07 mg/kg	
	Eggs	HCH	0.26 mg/kg	
		DDT	0.51 mg/kg	
		Endosulfan sulphate	0.17 mg/kg	
		Heptachlor epoxide	0.11 mg/kg	

(Continued on next page)

Table 1. List of pesticide residues reported by different researchers in the Malwa region of Punjab, India. *(Continued)*

Area	Source	Pesticide detected	Concentration	Ref.
Ludhiana	Biopsy Human Fat Sample	DDT (100% Samples)	6.86 mg/kg	Aulakh *et al.* (2007)
		HCH (83.6% Samples)	5.72 mg/kg	
Talwandi Sabo in Bathinda	Tap Water	Heptachlor, Endoepoxide, Melathion, Dimethionate, γ-HCH, δ-HCH, Exoepoxide	Above Minimal permissible limit a. Heptachlor = 0.00003 mg/l b. Malathion = 0.0005 mg/l	Thakur *et al.* (2008)
	Groundwater	Heptachlor, Endoepoxide, Melathion, γ-HCH, δ-HCH		
	Vegetables (Potato, Bottle gourd, Carrot, Round gourd, Cauliflower, Grapes, Bitter gourd)	Heptachlor, γ- HCH, α -HCH, Chlorpyrifos, Aldrin, Ethion,Melathion, Heptachlor, Sulphate, Heptachlorendoepoxide, α-Endosulfan, β- endosulphan, Phorate, Exo- endoepoxide, Endosulphan, 4, 4, DDT,	Above minimal residual limit (mg/l) are: i. Heptachlor (0.055) ii. Chlorpyrifos (0.01) iii. Ethion (1.00) iv. Phorate (0.050)	
Ludhiana	Butter Samples	α-HCH	0.098 mg/kg	Gill *et al.* (2009)
		β-HCH	0.048 mg/kg	
		γ-HCH	0.196 mg/kg	
		d-HCH	0.01 mg/kg	
		p,p′-DDD	0.142 mg/kg	
		p,p′-DDE	0.114 mg/kg	
		p,p′-DDT	0.022 mg/kg	
		Endosulphan	0.023 mg/kg	
		Dieldrin	0.003 mg/kg	
Patiala	Cauliflower	Chlorpyriphos	1.17 mg/kg	Department of Agriculture and Cooperation (2009)
Ludhiana	Cabbage	Chlorpyriphos	0.080 mg/kg	

B: Banned pesticides, R: restricted pesticides (Central Insecticides Board and Registration Committee, India [CIBRC] 2012).

Table 2. List of major pesticides used in the Malwa region of Punjab, India.

S. no.	Active ingredient	Trade name	Crop
1	2, 4-Dimethyl Sodium Salt and Ethyl Ester	Kissan-80	Maize, Sugarcane, Wheat, Aquatic weeds
2	Acetamiprid	Pride, Manak, Nagarjuna Ennova, Avtar Pride	Cabbage, Okra, Chilli, Rice, Cotton
3	Carbendazim	Bengard	Paddy, Wheat, Cotton, Barley, Brinjal, Grapes, Ber
4	Cartap	Padam	Rice
5	Cartap Hydrochloride	Sanvex	Rice
6	Chlorpyrifos	Dursban, Chloro (Sacban)	Rice, Paddy, Beans, Gram, Cotton
7	Clodinafop Propargyl	Point, Bijili	Wheat
8	Cyphermenthrin	Ripgaurd	Rice, Wheat
9	Diafenthiuron	Polo	Cotton, Cabbage, Chilli, Brinjal
10	Emamectin benzoate	Proclaim	Cotton, Okra, Cabbage, Chilli, Brinjal, Red gram
11	Fipronil	Jump	Cabbage, Chillies, Sugarcane, Cotton, Rice, Grapes
12	Glyphosate	Lagaam	Cotton, Rice
13	Imidacloprid	Confidor, Midas, Nagarjuna Mida, Imiden, Midaconfidor, Sacdor	Cotton, Rice, Okra, Sunflower, Chillies, Sorghum
14	Lambda-Cyhalothrin	Corolamdba, Hero	Cotton, Rice, Brinjal, Tomato
15	Mancozeb 63% + Carbendazim 12%	Companion, Cross man	Groundnut, Paddy, Potato
16	Metsulfuron Methyl	Fuse, Dot, TejAlgrip, Sacrip	Wheat, Rice, Sugarcane
17	Monocrotophos	Bolwan, Monocil	Paddy, Maize, Black gram, Green gram, Sugarcane, Cotton, Mustard, Caster, Citrus fruits
18	Paraquat Dichloride	Parasac	Potato, Cotton, Rice, Wheat, Maize
19	Propaquizafop	Agil	Soybean, Black gram
20	Spiromesifen	Boram	Brinjal, Chilli
21	Thiamethoxam	Clux, Actara, Sactara	Rice, Cotton, Sorghum, Wheat, Okra, Mustard, Tomato, Brinjal

Further, an attempt has been made to study the carcinogenic potential and the hazardous nature of the pesticides listed in Tables 1 and 2 in view of the available literature. We can observe from Table 3 that of the total 17 pesticides reported, seven belong to the category of probable human carcinogen, one is a possible human carcinogen, and six are in the category of suggestive evidence of carcinogenicity but not sufficient to assess human carcinogenic potential, as categorized by the

Table 3. Class of pesticides detected in the Malwa region (Punjab) as per USEPA classification (2006, 2008, 2010), WHO Classification (2009), and reported target site along with its LD50.

S. No.	Pesticide	Pesticide class	USEPA carcinogenic class#	WHO class##	LD50	Target site
1.	Aldrin	OC	Group B2	O	—	Nervous system (Spiotta and Don 1952), Liver (Gold *et al.* 1991)
2.	Chlordane	OC	Group B2	II	460	Human erythrocytes (Suwalsky *et al.* 2005), Liver (Gold *et al.* 1991), Reproductive system (Manar *et al.* 2010)
3.	Chlorpyrifos	OP	Group E	II	135	Neurodevelopmental disorders (Saunders *et al.* 2012), Immune system (Thrasher *et al.* 1993)
4.	Cypermethrin	P	Not grouped	—	—	Reproductive system (Farag *et al. 20*10) Endocrine system (Waldbillig 1998)
5.	DDT	OC	Group B2	II	113	Hematopoietic, liver and lung (Gold *et al.* 1991), Immune system (Dalvie *et al.* 2004), Reproductive system (Ayotte *et al.* 2001)
6.	Dieldrin	OC	Group B2	O		Liver (Gold *et al.* 1991), Nerve system (Van der Bercken 1972)
7.	Dimethoate	OP	Not grouped	II	c150	Anticholinesterase activity (Sanderson and Edson 1964)
8.	Endosulfan	OC	Not grouped	II	80	Reproductive and developmental system (Saiyed *et al* 2003)
9.	Ethion	OP	Group E	II	208	Liver (Gold *et al.* 1991)
10.	Heptachlor	OC	Group B2	O	—	Liver, central nervous system, immune and renal systems (Fendick *et al.* 1990), Reproductive (Oduma *et al.* 2006)

11.	Heptachlor epoxide	OC	Group B2	—	—	Inhibition of gamma-aminobutyric acid (GABA) (Ghiasuddin and Matsumura 1982)
12.	Hexachlorocyclohexane	OC	Group B2	—	—	Immune system (Cornacoff *et al*. 1988), Liver (Gold *et al*. 1991), Reproductive system (Khanjani and Sim 2006)
13.	Lindane	OC	Not grouped	II	88	Blocks GABA-activated chloride channels (Ogata *et al.* 1988; Narahashi 1996), Reproductive system (Tiemann 2008)
14.	Malathion	OP	Not grouped	III	c2100	Acetylcholinesterase activity (Datta *et al.* 1994), Reproductive system (Thomas *et al.* 1992)
15.	Monocrotophos	OP	Not grouped	Ib	14	Acetylcholinesterase activity (Venkateswara *et al*. 2005), Reproductive system (Radhika and Kaliwal 2002)
16.	Phorate	OP	Group E	Ia	2	Acetylcholinesterase (Storm *et al*. 2000), Pulmonary activities (Henderson *et al.* 2004), immumne system (Saquib *et al.* 2011)
17.	Phosphamidon	OP	Group C	Ia	7	Acetylcholinesterase activity (Moser 2011)

as per USEPA classification (2006, 2008, 2010); ## as per WHO Classification (2009).

Ia = Extremely hazardous; Ib = Highly hazardous; II = Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use; O = Obsolete as pesticide, not classified;—not stated in the report; OP = Organophoshorus; OC = Organochlorine. Group B2 = Probable human carcinogen; Group C = Possible human carcinogen; Group E = Evidence for non-carcinogenicity for humans; Not grouped = Suggestive evidence of carcinogenicity but not sufficient to assess human carcinogenic potential.

U.S. Environmental Protection Agency (USEPA 2006, 2008, 2010) for the carcinogenic potential of pesticides. Only chlorpyrifos, ethion, and phorate are the three pesticides that have evidence for non-carcinogenicity for humans as per USEPA classification (2006, 2008, 2010). Similarly, as per the World Health Organization's (WHO's) classification (2009) regarding the hazard of pesticides, of the 17 reported in Table 3, two pesticides belong to the extremely hazardous category, one to the highly hazardous category, seven to the moderately hazardous category, one to the slightly hazardous category, and three to the non-hazardous category. Some of the pesticides are not listed in any category due to limited information. Further, the reported targets of the pesticides detected in the Malwa region are listed in Table 3. The list shows that most of these pesticides target the immune system, liver, reproductive system, nervous system, and blood system.

HEALTH EFFECTS OF PESTICIDES IN THE MALWA REGION OF PUNJAB, INDIA

Human beings are exposed to pesticides by oral ingestion, dermal absorption, and/or by inhalation. These routes of exposure vary for different pesticides depending on their properties such as volatility, water solubility, binding to fruit skin, and so on. The detection of pesticides like t-HCH, heptachlor, aldrin, chlordane, t-DDT, t-endosulfan, chlorpyriphos, malathion, monocrotophos, and phosphamidon in the blood samples (concentrations are given in Table 1) of the residents of this region indicates that they are actually being exposed to pesticides directly or indirectly. The consequences of unbridled use of these chemicals are faced mostly by the directly linked farmers' communities in the Malwa region. The following health effects have been reported by various researchers working in the Malwa region of Punjab, India.

Deaths Due to Pesticide Poisoning

There is evidence related to pesticide poisoning and deaths in the Malwa region. During the year 2001–2002, the maximum number of deaths due to pesticide poisoning occurred in the month of June (21%), which may be due to spraying of pesticides on the crops in this month whereas the minimum number of deaths were recorded in September (2%) in this region (Singh *et al.* 2003). Of the 31.6% insecticide poisoning cases, 32.9% were males and 26.3% were females admitted to the emergency medical ward of the Adesh Institute of Medical Sciences and Research (AIMSR), Bathinda, from 2007 to 2009 (Garg and Verma 2010). A total of 61 persons died after inhaling pesticides between the years 2004–2008 in the Bathinda district while spraying on their farms (Dhonti 2010).

Deaths due to pesticide poisoning have been reported worldwide and are a well-known fact. The WHO has estimated that every year 3 million cases of acute pesticide poisonings occur globally and out of this 10% die (Gunnell and Eddleston 2003).

Cancer Prevalence

A recent report from India's Department of Health and Family Welfare (DHFW 2013) indicates that the cancer prevalence (per million) in the Malwa region is

Table 4. Number of cancer patients reported by different agencies in the year 2001, 2002, 2005, 2009, and 2013 and cancer deaths in the last 5 years in selected districts in the Malwa region of Punjab.

		No. of Cancer Patients Per Million Population					Cancer deaths in last 5 years
S. No.	District	2001*	2002**	2005**	2009**	2013**	(2013**)
1.	Bathinda	358.9	352.6	592	750.0	1258	2058
2.	Muktsar	245.9	242.1	547	751.0	1363	1791
3.	Faridkot	260.6	256.7	280	446.2	1346	1112
4.	Mansa	Data Not Available	Data Not Available	574	498.1	1348.0	1212
5.	Patiala	348.5	335.6	Data Not Available	235.4	868	1498

*NCRP (2002); **DHFW (2011, 2013).

1089, which is much higher as compared to two other regions of Punjab, that is, Majha (647/million) and Doaba (881/million) as well as compared to India's national average cancer prevalence (800/million). Cancer is so prevalent in the Malwa region that the region has been called India's Cancer Capital. Four of the 11 districts in the Malwa region (Muktsar, Mansa, Bathinda, and Faridkot) are the worst afflicted by various cancers. The degree of the problem can be assessed from Table 4, where the number of cancer cases reported in this region for the years 2001, 2002, 2005, 2009, and 2013 in four cotton cultivating districts (Muktsar, Mansa, Faridkot, Bathinda) and one less known district for cotton cultivation (Patiala) have been listed. The data show a continuous increase in the number of cancer cases in the last 12 years. The highest number of cancer cases among the four districts are in Muktsar, followed in order by the Mansa, Faridkot, and Bathinda districts.

Among the various districts of the Malwa region, villages Giana and Jajjal in the Bathinda district have been declared as "cancer stricken villages." The Abohar-Jodhpur passenger train carries nearly 60 cancer patients per day to the Acharya Tulsi Regional Cancer Treatment and Research Institute situated in Bikaner, Rajsthan, India. The studies by Thakur *et al.* (2008) revealed that 125 cancer cases and 52 deaths per year per 100,000 population occurred in the Talwandi Sabo block of the Bathinda district. An epidemiological study was conducted in villages of the Talwandi Sabo block, Bathinda district, by the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, and reported that cancers of the female reproductive system were more common in Talwandi Sabo and a total of 7441 deaths were recorded in the period 1993–2003 (Kumar 2005). The recent survey by DHFW (2013) reported 34,430 cancer deaths in the Punjab and of this the Malwa region alone comprised 46% of the cases. Kaur *et al.* (2011) in their work revealed highly significant differences in DNA damage between farmers freshly exposed to pesticides and control subjects and freshly exposed and follow-up cases. The study ruled out factors like age, alcohol intake, and tobacco smoking as probable cause of alteration in DNA and held only pesticides responsible.

Most of the pesticides have been reported to be carcinogenic (Brody and Rudel 2003; Weichenthal *et al.* 2012). There is evidence of association of pesticides with brain cancer, leukemia, and lung cancer (Lee *et al.* 2004), colon cancer (Lee *et al.* 2007), chlordane with leukemia and colon cancer, heptachlor with leukemia, and dieldrin with lung cancer (Purdue *et al.* 2007). Pesticides are a common cause of pancreatic cancer (Andreotti and Silverman 2012), prostate cancer, breast cancer (Landau-Ossondo *et al.* 2009), brain tumors (Pogoda and Preston-Martin 1997), cutaneous melanoma (Fortes *et al.* 2007), leukemia, and non-Hodgkin's lymphoma (Meinert *et al.* 2000; Takashima-Uebelhoer *et al.* 2012).

Reproductive Abnormalities and Miscarriages

As per various reports from Kheti Virasat Mission, Faridkot (Punjab), the number of childless couples and young males with infertility was alarmingly high in more than 100 villages of the Malwa region (Dutt 2007). In the Jajjal village of Bathinda, 12.7% of boys (age 13–23 years) failed to show puberty (*i.e.,* voice change and moustaches); 3.4% of boys failed for enlargement of external genitalia, and 5.8% of girls (age 13–20 years) had not started menstruation before age 15 years and there were 0.012% cases of infertility (Halder 2007). Similar effects of pesticides on the reproductive system have also been reported by Whorton *et al.* (1977), Figà-Talamanca *et al.* (2001), and Bretveld *et al.* (2006).

Various reproductive problems have been recorded in male formulators engaged in production of dust and liquid formulations of various pesticides such as malathion, methyl parathion, DDT, and lindane (Gupta *et al.* 1984). Luccio-Camelo and Prins (2011) reported that DDT, DDE, methoxychlor, lindane, and dieldrin/aldrin interfere with the biosynthesis, metabolism, or action of endogenous androgens, resulting in a deflection from normal male developmental programming and reproductive tract growth and function. Khan *et al.* (2010) reported that the increased HCH levels cause a significant decrease in semen quality as well as sperm count. The cause of infertility among males is Y chromosome micro-deletion and alteration in sperm quality after organochlorine exposure, which affects the seminal and prostatic functions (Pant *et al.* 2004). Pesticides have the potential to interfere with androgen action and affect the development and maturation of the reproductive tract in males and cause declination in semen quality (Jurewicz *et al.* 2009). Miscarriages in the spouses of farmers have shown direct connection to pesticide exposure. The miscarriage rate varies with the pesticide used (Garry 2004; Kumar and Kumar 2007). Pathak *et al.* (2010) investigated the possible association of organochlorine pesticides in the pathogenesis of recurrent miscarriages. The increase in insecticide levels in the blood of vertebrates has been reported to cause reproductive dysfunction (Singh *et al.* 2008). It clearly suggests that exposure to pesticides can be a significant contribution towards various reproductive disorders.

Neurological and Behavioral Disorders

Thakur *et al.* (2008) reported the chronic effects of pesticides as inability to perform developmental tasks among rural children in cotton-growing areas of Bathinda. Pesticides have been reported to have adverse effects on mental and psychomotor development (Bouchard *et al.* 2011) and act as potent neurotoxins (Sherman 1995;

McConnell *et al.* 1999; Abou-Donia 2003). People exposed to pesticides may feel dizzy, confused, and may have reduced coordination, intelligence quotient (IQ) and learning disability, permanent brain damage (Bjørling-Poulsen *et al.* 2008), risk of Parkinson's disease (Rugbjerg *et al.* 2011), risk of dementia (Baldi *et al.* 2011), decrease in AChE (acetylcholinesterase) activity, and may also suffer from nephro toxicity (Singh *et al.* 2010).

Organophosphorus (OP) insecticides are potent inhibitors of serine esterases such as AChE (Buckley *et al.* 2005) and serum cholinesterase, which results in accumulation of acetylcholine and over-stimulation of acetylcholine receptors in synapses of the autonomic nervous system, central nervous system (CNS), and neuromuscular junctions (Lotti 2001). The exposure to cholinesterase inhibitors was associated with symptoms of depressive psychosis like depressed mood, lethargy, insomnia, and lack of concentration (Rowntree *et al.* 1950). It has been observed that certain pesticides competitively bind with the thyroid hormone binding protein, transthyretin (Meerts *et al.* 2000), and some bind more avidly than thyroxine T4, displacing T4 and potentially interfering with its transport to the developing brain (Schettler 2001).

Premature Hair Greying

Premature greying of hair has been reported in both males and females in this region. Premature greying of hair has been observed in 4.7% of children of age nearly 10 years from the Jajjal village of the Bathinda district (Halder 2007). Pesticides are known to produce reactive oxygen species (ROS) in the human body. Evidence from studies on epidermal melanocyte aging suggests that ROS damages both nuclear and mitochondrial DNA, which may lead to mutations in bulbar melanocytes (Van Neste and Tobin 2004). Nishimura *et al.* (2005) reported that defective self-maintenance of melanocyte stem cells due to exposure to environmental toxicants as one of the possible cause of change in hair color.

GOVERNMENT OF INDIA AND PUNJAB STATE GOVERNMENT INITIATIVES TO HANDLE THE PROBLEM

Cancer Control Policies and Programs

A cancer registry program was established in the Bathinda, Mansa, and Muktsar districts by the Indian Council of Medical Research (ICMR) in 2010 for 5 years at a cost of about rupees (Rs) 0.8 million per year. The cancer registries in medical colleges will create cancer registries of the neighbouring districts as per Government of India guidelines. The Punjab State Health Department has initiated a house-to-house survey in the various districts to learn the number of cancer cases. A house-to-house survey has already been conducted in Bathinda, Faridkot, Mansa, and Muktsar districts in 2005, 2009, and 2013. Onco-net service has been established by the Government of India in which the Regional Cancer Centre, Postgraduate Institute of Medical Education & Research, Chandigarh (PGIMER) will be connected to four district hospitals (Hoshiarpur, Sangrur, Bathinda, and Muktsar) for this service. Chemotherapy facilities have been established in the Government Medical College at Faridkot, Patiala and Amritsar (DHFW 2010).

Introduction of Improved Crop Varieties

India is now the world's second biggest producer of Bt cotton, with an estimated area of 3.8 million hectares under cultivation (James 2007). Bt cotton has notably reduced the incidence of acute pesticide poisoning among cotton growers (Kouser and Qaim 2011). Bt technology may not be the only option to reduce chemical pesticides' use in cotton production because in some regions, pesticides are overused, entailing a disruption of beneficial insects, and increasing pest levels (Pemsl *et al.* 2008).

Further Measures to be Taken

In order to prevent further environmental degradation and to promote the recovery of an already degraded environment and to safeguard the health of the people in the Malwa region of Punjab due to overuse of pesticides, the foremost requirement is to practice eco-friendly agriculture along with providing safe drinking water, food, and better medical care for the people. The following steps need to be taken.

Integrated pest management techniques

Integrated pest management (IPM) techniques like use of pheromones, trap crops, light traps, and bonfires to attract moths along with biopesticides need to be encouraged. Work in the cotton belt of Andhra Pradesh, India, has highlighted the use of these alternate pest management technologies and reported the success in terms of not only economic status of farmers but also environmental and health benefits to the region (Marten and Williams 2006). The works of Travisi and Nijkamp (2008) have also reported similar benefits with use of IPM. Further to achieve effective IPM, there is need to promote the use of biopesticides, provision of special subsidies, and loans for the farmers using eco-friendly techniques.

Training and awareness for good agricultural practices

Government and other related agencies should educate farmers and agriculture managers on good agricultural practices (GAP). Proper training should be given to the farmers and associated workers for use of particular pesticides. Farmers should be made aware for the necessity of using self-protection clothes and mask, avoidance of eating in workplaces, proper use of pesticide spray pumps, and disposal of pesticide containers and related equipment.

Providing safe drinking water and food

Pesticides enter the human body through consumption of pesticide-contaminated water and food. Pesticide testing laboratories need to be established in the Malwa region. Community water purifiers like reverse osmosis (RO) need to be installed so that people can have access to safe drinking water. The agricultural produce and other food items should be approved for consumption only after testing for the pesticides or their residual contents.

Health risk assessment and management

Healthy risk assessment due to dietary exposure, occupational exposure, residential exposure, and cumulative risk assessment should be continually conducted in these areas. Health risk management should be done at the community level by resource mobilization, information sharing, priority setting, shared decision-making, and implementation of selected initiatives.

CONCLUSIONS

The long-time over-use of pesticides appears to be a major cause for prevalence of various diseases in cotton cultivated districts of the Malwa region of Punjab. To safeguard human life from the toxic effects of pesticides, adequate steps need to be taken. Providing safe drinking water and uncontaminated foods are the foremost requirements. Screening of farmers for health risk should be done periodically. Further, steps should be taken to improve the medical management and mental health care of people with pesticide poisoning in health care facilities at different levels. There is an urgent need to reduce morbidity and mortality related to pesticide poisoning through review and improved pesticide policies. Implementation of sustainable epidemiological surveillance and monitoring of pesticides poisoning in clinical settings and communities is necessary. Strengthening of community programs about the safe use of pesticides can minimize the risks of intentional and unintentional pesticide poisoning.

ABBREVIATIONS

AChE	Aacetylcholinesterase
AIMSR	Adesh Institute of Medical Sciences and Research
BHC	beta-Hexachlorocyclohexane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DHFW	Department of Health & Family Welfare
GAP	Good Agricultural Practices
HCH	Hexachlorocyclohexane
IPM	Integrated pest management
ICMR	Indian Council of Medical Research
IQ	Intelligence quotient
MRL	Maximum Residual Limit
NCRP	National Cancer Registry Programme
O	Obsolete as pesticide, not classified; *not stated in the report
OC	Organochlorine
OP	Organophoshorus
PGIMER	Postgraduate Institute of Medical Education & Research, Chandigarh
U	Unlikely to present acute hazard in normal use
USEPA	United State Environment Protection Agency
WHO	World Health Organization

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