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PESTICIDE POLLUTION: TRENDS AND PERSPECTIVE

If the credits of pesticides include enhanced economic potential in terms of increased production of food and fibre, and amelioration of vector-borne diseases, then their debits have resulted in serious health implications to man and his environment. There is now overwhelming evidence that some of these chemicals do pose potential risk to humans and other life forms and unwanted side-effects to the environment¹⁻³. No segment of the population is completely protected against exposure to pesticides and the potentially serious health effects, though a disproportionate burden is shouldered by the people of developing countries and by high risk groups in each country⁴. The world-wide deaths and chronic illnesses due to pesticide poisoning number about 1 million per year⁵.

The term pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematocides, plant growth regulators and others. Among these, organochlorine (OC) insecticides, used successfully in controlling a number of diseases, such as malaria and typhus, were banned or restricted after the 1960s in most of the technologically advanced countries. The introduction of other synthetic insecticides – organophosphate (OP) insecticides in the 1960s, carbamates in 1970s and pyrethroids in 1980s and the introduction of herbicides and fungicides in 1970s - 1980s contributed greatly in pest control and agricultural output.

Ideally a pesticide must be lethal to the targetted pests, but not to non-target species, including man. Unfortunately, this is not so the controversy of use and abuse of pesticides has surfaced. The rampant use of these chemicals, under the adage, “if little is good, a lot more will be better” has played havoc with human and other life forms. In India, the first report of poisoning due to pesticides was from Kerala in 1958, where over 100 people died after consuming wheat flour contaminated with parathion⁶. This prompted the Special Committee on Harmful Effects of Pesticides constituted by the ICAR to focus further attention on the problem⁷. Further, Carlson in 1962 warned that OC compounds could pollute the tissues of virtually every life form on the earth, the air, the lakes and the oceans, the fishes that live in them and the birds that feed on the fishes⁸. Later, the US National Academy of Sciences stated that the DDT metabolite, DDE causes eggshell thinning and that the bald eagle population in the United States declined primarily because of exposure to DDT and its metabolites⁹. Certain environmental chemicals including pesticides termed as endocrine disruptors are known to elicit their adverse effects by mimicking or antagonising natural hormones in the body and it has been postulated that their long-term, low-dose exposure are increasingly linked to human health effects such as immunosuppression, hormone disruption, diminished intelligence, reproductive abnormalities and cancer¹⁰⁻¹².

Regulation on Pesticides

The Government of India has taken steps to ensure the safe use of pesticides. The Insecticide Act, promulgated in 1968 and enforced on 1st August, 1971 envisages to regulate the import, manufacture, sale, transport, distribution, and use of insecticides, with a view to prevent risks to human beings or animals, and for matters connected therewith¹³. Prior to this, four insecticides mainly used in the public health programmes were being controlled under the Drugs and Cosmetics Act, 1940. It was desirable as a prerequisite to the enforcement of Insecticide Act, to evaluate the magnitude of pesticide pollution in the country and related health hazards to ensure their safe use for the benefit of the society. ICMR's National Institute of Occupational Health (NIOH), Ahmedabad, and several other national laboratories, farm universities and other R & D organisations have been engaged in toxicological evaluation of pesticides, synthesis of safer molecules and evaluation of environmental contamination due to pesticides. Currently, there are 165 pesticides registered for use in India¹⁴. There is a sequential rise in the production and consumption of pesticides in the India during the last three decades¹⁵. However, the consumption pattern of these chemicals in India differs with rest of the world¹⁵. The domestic demand in India accounts for about 76% of the total pesticides used in the country as against 44 % globally.

Necessity and Value of Pesticides

Pesticides constitute an important component in agriculture development and protection of public health in India since the tropical climate is very conducive to pest breeding. There are about 20 major diseases which have been brought under control by the use of pesticides. The major amongst them are malaria, filariasis, dengue, Japanese encephalitis, cholera and louse-borne typhus. In India, DDT spray was instrumental in reducing the annual incidence of malaria from 75 million in 1952 to present 2-4 million¹⁶.

Types of Exposure and Hazards

Different groups and segments of a population are exposed to pesticides in different ways and in different degrees. These are intentional (suicides and homicides) and unintentional exposures (occupational and non occupational exposure from water, air and food). The occupational hazards in industrial settings and the

ecological repercussions in the environment could be grouped as under:

- (i) Operational hazards could be during manufacture and formulation of pesticides in industrial settings and their distribution and use in field conditions.
- (ii) Direct toxic effects on non-target animal life such as pollinators, predators, wild life, *etc.* during application of pesticides.
- (iii) Post application hazards or indirect toxic effects which involve risk to non-target animals due to toxic residues of pesticides in food or due to pollution of the ecosystem, habitat as a whole such as water bodies or soil.

Acute Pesticide Poisoning

Pesticides are toxic chemicals, by design and as such they represent risks to the users. In developing countries, where users are often illiterate, ill-trained and do not possess appropriate protective devices, the risks are magnified¹⁷. The Poison Information Centre in NIOH, Ahmedabad reported that OP compounds were responsible for the maximum number of poisoning (73 %) among all agricultural pesticides¹⁸. In a study on patients of acute OP poisoning (N=190), muscarinic manifestations such as vomiting (96 %), nausea (82 %), miosis (64 %), excessive salivation (61 %), and blurred vision (54 %) and CNS manifestations such as giddiness (93 %), headache (84 %), disturbances in consciousness (44 %) were the major presenting symptoms¹⁹. Cardiac manifestations such as sinus tachycardia (25 %), sinus bradycardia (6 %) and depression of ST segments with T wave inversion (6 %) were also observed. The incidence of intermediate syndrome in cases of OP poisoning has also been reported^{20,21}. There are a number of reports from northern India on the abuse of aluminium phosphide, a grain preservative taken for self poisoning²²⁻²⁴.

Assessment of Human Exposure

In human beings, the pesticide residue level is an index of exposure, which may be acute, occupational or incidental. In acute exposure, the residue level has a diagnostic potential, and in the occupationally exposed, the residue level merits an insight reflective of industrial exposure. However, in the general population, the residue level is a measure of the incidental exposure and/ or average levels of the persistent pesticides which is mainly through the food chain.

Residues of OC insecticides, especially DDT and HCH have been detected in man and his environment the world over^{25,26}. However, by comparison very high level of these have been reported in human blood, fat, and milk samples in India²⁷⁻⁴³.

Residues in human blood

Since blood is the most accessible body fluid for ascertaining residue levels, scientists at the NIOH, Ahmedabad have attempted to provide a database on the residues of DDT and HCH including other cyclodiene derivatives *eg.* heptachlor, heptachlor epoxide, aldrin, oxychlordan, HCB and dieldrin in blood samples from general population of Ahmedabad (rural) area²⁸. Heptachlor epoxide and HCB were not detected in these blood samples. The total organochlorine insecticide content in all serum samples showed an average of 200.3 ppb with a range of 58.3-321.4 ppb. Among these chemicals, HCH and DDT were the chief contaminants and their order of persistency was HCH>DDT>dieldrin>oxychlordan>heptachlor>aldrin. Residues in the blood samples of the general population of other cities are given in Table I.

Table I. Levels of DDT and HCH content in human blood samples in general population in India.

City	Year	Number of samples	Total DDT (ppm)	Total HCH (ppm)
Lucknow ²⁹	1980	25	0.02	0.022
Delhi ³⁰	1982	340	0.71	0.49
Lucknow ³¹	1983	48	0.028	0.075
Delhi ³²	1985	50	0.301	–
Ahmedabad (rural) ²⁸	1992	31	0.048	0.148
Ahmedabad (urban) ³³	1997	14	0.032	0.039

Superscript nos. refer to the serial no. in the reference list.

Residues in human fat

Data on DDT and HCH residues in human fat samples in the general population from different cities are given in Table II. Studies conducted by the NIOH to monitor pesticide residues in autopsy fat samples from subjects from different parts of the country indicated a wide variation³⁴. The maximum DDT residues were detected

in age group of 20-39 years and the higher levels of HCH residues were found in the age group of ³ 40 years. No sex wise difference was observed for DDT and HCH residues.

The wide variation seen may be due to the geographical variations in consumption and use of these chemicals. However, the factors that may influence the storage and bioaccumulation of these chemicals are the compound intensity, efficiency of absorption, species, age, nutritional status and integrity of the organs⁴⁴. In the absence of a suitable animal, tissue culture or human biomarker model of biologic evidence to provide objective evaluation, the pharmacological interpretation of such small amounts of pesticide in the human body is not possible.

Table II. Levels of DDT and HCH residues in human fat samples in general population in India.

City	Year	Number of samples	Total DDT (ppm)	Total HCH (ppm)
Delhi ³⁵	1964	35-67	26.0	1.43
Delhi ³⁶	1973	94	21.8	–
Delhi ³⁷	1976	14	4.7	–
Chandigarh ³⁴	1980	10	20.03	2.44
Agra ³⁴	1980	14	12.02	2.0
Bombay ³⁴	1980	34	6.15	1.61
Calcutta ³⁴	1980	45	6.5	1.61
Bhopal ³⁴	1980	14	9.14	1.06
Ahmedabad ³⁴	1980	80	21.81	3.87
Bangalore ³⁴	1980	116	7.82	5.05
Meerut ³⁸	1981	32	4.7	–
Delhi ³⁰	1984	340	22.25	16.85

Superscript nos. refer to the serial no. in the reference list.

Residues in human milk

Monitoring of human milk is important from two standpoints. Firstly, pesticides tend to accumulate in the fat and are relatively easy to isolate and measure and secondly to evaluate their potential risk to infants, who rely solely on mother's milk for a substantial period. Residues of these compounds in human milk have been reported from different parts of the world as reviewed by Jenson²⁶ and from India^{29,39-43}. The levels of these

contaminants in the human milk samples collected from different cities are given in Table III.

Table III. Levels of DDT and HCH residues in human milk samples in general population in India.

City	Number of samples	Whole milk basis (ppm)	
		Total DDT	Total HCH
Lucknow ²⁹	25	0.127	0.107
Ludhiana ³⁹	75	0.51	0.195
Bangalore ⁴⁰	6	0.053	0.014
Calcutta ⁴⁰	6	0.114	0.031
Bombay ⁴⁰	6	0.224	0.053
Delhi ⁴¹	60	0.344	–
Delhi ⁴²	60	–	0.38
Ahmedabad ⁴³	50	0.305	0.224

Superscript nos. refer to the serial no. in the reference list.

In a multi-country study⁴⁵ (Belgium, China, FRG, India, Israel, Japan, Mexico, Sweden, USA and Yugoslavia) on the assessment of human exposure to selected organochlorine compounds, the residue levels for pp'-DDE and b-HCH were found to be higher in the human milk samples collected from developing countries like China, India and Mexico than in the participating developed countries.

Higher level of these chemicals in mother's milk is a reflection of their increased burden and their translactational passage. The toxicological implication of these findings could not be assessed precisely, however, preventive measures are warranted to reduce their body burden to avoid any potential health effect.

Residues in food commodities and average daily intakes

Pesticide residues in food are of concern. Their concentration in food samples varies greatly not only from region to region and year to year but also from one specific food item to another within the same food group. They can even vary substantially from one food sample to the next within the same region of the country. Perusal of the residue data on pesticides in samples of fruits, vegetables, cereals, pulses, grains, wheat flour, oils, eggs, meat, fish, poultry, bovine milk, butter and cheese in India indicates their presence in sizeable amounts⁴⁶⁻⁵².

Hexachlorobenzene (HCB, a fungicide) was identified in water, human milk and human fat samples collected from Faridabad and Delhi⁵⁰. In another study, HCB residues were present in various raw food commodities collected from markets from India⁵¹. DDT and HCH residues were detected in groundnut and sesamum oil samples collected from Tamilnadu⁵².

In a multi-centric study to assess the pesticide residues in selected food commodities collected from different states of the country⁴⁹, DDT residues were found in about 82 % of the 2205 samples of bovine milk collected from 12 states. About 37 % of the samples contained DDT residues above the tolerance limit of 0.05 mg/kg (whole milk basis). The highest level of DDT residues found was 2.2 mg/kg. The proportion of the samples with residues above the tolerance limit was maximum in Maharashtra (74 %) followed by Gujarat (70 %), Andhra Pradesh (57 %), Himachal Pradesh (56 %) and Punjab (51 %). In the remaining states, this proportion was less than 10 %. Data on 186 samples of 20 commercial brands of infants formulae showed the presence of residues of DDT and HCH isomers in about 70 and 94 % of the samples with their maximum level of 4.3 and 5.7 mg/kg (fat basis) respectively.

Measurement of chemicals in the total diet provides the best estimates of human exposure and of the potential risk. The risk of consumers may then be evaluated by comparison with toxicologically acceptable intake levels. The average total DDT and BHC consumed by an adult were 19.24 mg/day and 77.15 mg/day respectively⁵³. Fatty food was the main source of these contaminants. In another study, the average daily intake of HCH and DDT by Indians were reported to be 115 and 48 mg per person respectively which were higher than those observed in most of the developed countries⁵¹.

Residues in environmental samples

The residues of pesticides in air-borne samples collected from Ahmedabad were identified in studies by the NIOH. The levels of BHC and DDT ranged between 2.06-18.96 ng/m³ and 7.21-51.19 ng/m³ respectively⁵⁴. Maximum mean levels of BHC (8.12 ng/m³) and DDT (37.07 ng/m³) were recorded in March and June respectively. The maximum levels were seen in summer and the minimum in winter.

There are a few isolated reports⁵⁵⁻⁵⁷ on the residue levels in water. In Ahmedabad, the mean levels of DDT and HCH in drinking water samples were 47.4 and

256.9 ng/l⁵⁶ respectively. The residues have also been detected in both the surface and ground water samples of north eastern districts and Khasi hills of India^{58,59}.

Potential Risk in Occupationally Exposed Subjects

The high risk groups exposed to pesticides include the production workers, formulators, sprayers, mixers, loaders and agricultural farm workers. During manufacture and formulation, the possibility of hazards may be more because the processes involved are not risk free. In industrial settings, the workers are at increased risk since they handle various toxic chemicals including pesticides, raw materials, toxic solvents and inert carriers.

Workers exposed to HCH

A study on workers (N=356) in four units manufacturing HCH revealed neurological symptoms (21%) which were related to the intensity of exposure⁶⁰. Significant increase in liver related enzymes (alkaline phosphatase, ornithine carbamoyltransferase, α -glutamyl transpeptidase) was also noticed. A remarkably high concentration of HCH residues, especially of β -HCH was found in the serum samples of all exposed subjects. Circulating immune complexes of IgG and IgM were detected in representative samples. The type of work and workplace had a pronounced influence on serum HCH levels in the exposed subjects.

Formulators exposed to combination of pesticides

Observations confined to health surveillance in male formulators engaged in production of dust and liquid formulations of various pesticides (malathion, methyl parathion, DDT and lindane) in industrial settings of the unorganised sector revealed a high occurrence of generalized symptoms (headache, nausea, vomiting, fatigue, irritation of skin and eyes) besides psychological, neurological, cardiorespiratory and gastrointestinal symptoms coupled with low plasma cholinesterase (ChE) activity⁶¹. Cardiac abnormalities in terms of ECG changes were also noticed in formulators exposed to OP insecticides⁶². A study on workers associated with the formulation of various OC and OP pesticides in small scale industrial units showed depression in serum ChE activity, increased level of serum cholesterol, phospholipid and SGOT activities and generalized toxic symptoms in 73% subjects⁶³. In another study⁶⁴, the thyroid function of formulators exposed to a combination of pesticides in the organized sector was examined. Total T₃ was

suppressed significantly in formulators while a marginal decrease (about 7%) was noticed in T₄ level. TSH levels were also elevated by 28 % but the rise was statistically insignificant. These formulators had significantly low serum ChE activity and high serum BHC content, indicating appreciable exposure to their working environment⁶⁵. Elevated level of serum IgM and identification of a few circulating complexes indicated imbalances in the immune system under pesticidal stress. The results also showed a significant positive correlation in IgM and BHC residue levels. Skin diseases in workers handling pesticides were reported in a study⁶⁶ involving 117 workers (75 pesticide factory workers and 42 farm workers). Fifty five workers had pigmentation on the exposed parts; nine pityriasis versicolor; five chronic urticaria; four dermatitis and five psoriasis. Pigmentation and urticaria may be related to skin sensitivity in response to these chemicals.

Health effects of methomyl on sprayers

The magnitude of the toxicity risk involved in the spraying of methomyl, a carbamate insecticide, in field conditions was assessed by the NIOH⁶⁷. Significant changes were noticed in the ECG and the levels of serum LDH and ChE activities in the spraymen indicating the cardiotoxic effects of methomyl.

Reproductive performance in sprayers

Data on reproductive toxicity were collected from 1,106 couples when the males were associated with the spraying of pesticides (OC, OP and carbamates) in cotton fields⁶⁸. Data were also collected from 1,020 unexposed couples matched for age and socio-economic status. Analysis of the reproductive performance gave the following incidence rates for the former and latter groups respectively; abortion 26 % vs 15 %, still births 8.7 % vs 2.6 %, neonatal deaths 9.2 % vs 2.2 %, and congenital defects 3 % vs 0.1 %. A cytogenic study revealed a significant increase in chromatid breaks and gaps in chromosomes in the peripheral blood in grape garden workers exposed to pesticides⁶⁹.

Studies in malaria spraymen

Study was initiated to evaluate the effects of a short-term 16 week exposure in workers (N=216) spraying HCH in field conditions⁷⁰. Rise in serum HCH was highest (five-fold) in spraymen exposed for the first time, compared to spraymen who had worked previously for a number of

seasons. Another study on workers spraying DDT, malathion and cyfluthrin showed increased levels of serum IgG (malathion exposure) and serum IgA (cyfluthrin exposure)⁷¹. Observations confined to malaria spraymen exposed to HCH showed changes in serum A/G ratio, glucose level and HCH residues⁷².

Integrated Pest Management – A Viable Alternative

Integrated pest management (IPM), a new concept in the field of crop protection emphasizes the need for simpler and ecologically safer measures for pest control to reduce environmental pollution and other problems caused by excessive and indiscriminate use of the pesticides. The main components of IPM are pest surveillance, use of crop varieties resistant to pest, sound cultural practices, biological control and use of ecofriendly pesticides having less mammalian toxicity. Agenda 21 of the United Nations Conference on Environment and Development (UNCED) at Rio de Janeiro in June 1992 identified IPM as one of the requirements for promoting sustainable agriculture and rural development. Considering the harmful impact of pesticides on the environment, the Government of India recognised the benefits of IPM and adopted it as the main plank of the plant protection strategy in the overall crop production programme.

Questions to be Addressed

Risks vs benefits

Because of the extensive benefits which man accrues from pesticides, these chemicals provide best opportunity to those who juggle with the risk-benefit equation. The economic impact of pesticides in non-target species (including humans) has been estimated at approximately \$8 billion annually in developing countries⁷³.

What is required is to weigh all the risks against the benefits to ensure maximum margin of safety. The total cost benefit picture from pesticide use differs appreciably between developed and developing countries. For developing countries, it is imperative to use pesticides, as no one would prefer famine, hunger and communicable diseases like malaria at the cost of reasonable risks and therefore, it may be expedient to accept a reasonable degree of risk. Our approach on use of pesticides should be pragmatic. In other words, all activities on pesticides should be based on scientific judgement and not on commercial considerations.

There are some inherent difficulties in fully evaluating the risks to human health due to pesticides. For example, there are a large number of human variables such as age, sex, race, socio-economic status, diet, state of health, *etc.* – all of which affect human exposure to pesticides. But, practically a little is known about the effects of these variables. The long term effects of low level exposure to one pesticide are greatly influenced by concomitant exposure to other pesticides as well as to pollutants present in air, water, food and drugs.

Perspective and Recommendations

The data on environmental-cum-health risk assessment studies may be regarded as an aid towards a better understanding of the problem. Data on the occurrence of pesticide related illnesses among defined populations in the developing countries are scanty. Therefore, generation of base-line descriptive epidemiological data based on area profiles, development of intervention strategies designed to lower the incidence of acute poisoning and periodic surveillance studies on high risk groups are needed. Informed consent of the volunteers must be obtained prior to their participation in the study. Our efforts should include the investigations of outbreaks and accidental exposure with pesticides, correlation studies, cohort analyses, prospective studies and randomised trials of intervention procedures⁷⁴. Valuable information can be collected by monitoring the end product of human exposure in the form of residue levels in the body fluids and tissues of the general population. Importance of education and training of the workers as a major vehicle to ensure the safe use of pesticides is being increasingly recognised. A rational approach with the following viewpoints and recommendations is needed to ensure the safety.

- (i) Studies on heavily exposed population which may include: (a) workers with high and medium occupational exposure; (b) persons who have experienced one or more acute toxicity episodes; and (c) population in areas with highest pesticide consumption
- (ii) Pre-employment and regular post-employment periodical medical examination of the workers for assessment of health impairment due to exposure in the work environment.
- (iii) Referral data on case reports on episodes of accidents or pesticide poisoning. Also notification of pesticide poisoning to be made obligatory by all hospitals, medical practitioners to National Informatics Centre for proper storage and retrieval of information.

- (iv) Study of poisoning cases, morbidity data and vital records involving individuals exposed to pesticides in the factory or field.
- (v) Need for a nation-wide monitoring and periodic surveillance of pesticide residues in raw food commodities, and animal feed.
- (vi) Assessment of residue levels in biota with special attention to levels in fatty tissues of all life forms.
- (vii) Development of simple field tests for the identification of residues and their toxicity.
- (viii) Strengthening and establishment of a network of laboratories in different parts of the country in which initially the harmonization of methodologies with quality assurance should be started to obtain reliable residue data.
- (ix) Need for a regular review of acceptable daily intake (ADI) and minimum residue levels (MRL) for all pesticides cleared for use in the country.
- (x) Proper documentation of pesticide use in the country based on region-wise, crop-wise and in the public health programmes.
- (xi) Effective environmental health monitoring, preventive strategies, implementation of practices that reduce pesticide usage, and health promotion measures are identified as the areas that need urgent attention from the regulatory authorities and policy makers.
- (xii) There is a need to convey a message that prevention of adverse health effects and promotion of health are profitable investments for employers and employees both as a support to a sustainable development of economics.

To sum up, based on our limited knowledge with indirect and/or inferential information, the domain of pesticides illustrates certain ambiguity of a situation in which people are undergoing life-long exposure. Therefore, there is every reason to develop health education packages based on knowledge, aptitude and practices and to disseminate it within the community for minimising human exposure to pesticides.

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