Asian Journal of Chemistry Vol. 18, No. 4 (2006), 2929–2940

Water Quality Monitoring of Pesticides and Associated Health Impacts

N.P. THACKER*, J.K. BASSIN, V. NITNAWARE, M. BISWAS, S.K. DAS and P. VAIDYA

National Environmental Engineering Research Institute
Nehru Marg, Nagpur-440 020, India

In the present work, the monitoring of water quality in the perspective of pesticides and their impact on human health is reported.

Key Words: Monitoring, Water quality, Pesticides, Health impacts.

INTRODUCTION

In the last few years, the presence of pesticide residues in beverages, ground and packaged water have been extensively highlighted by research publications and magazines pointing out the nature and magnitude of the problem. Pesticides, herbicides and fungicides have been introduced during the mid-sixties on a large scale along with the other inputs for propagating green revolution package in Indian agriculture. The main intention of the introduction of pesticides was to prevent and control insect pests and diseases in field crops. Initially, the use of pesticides reduced pest attack and paved the way for increasing the crop yield as expected. Simultaneously, increased use of chemical pesticides has resulted in contaminating the environment and long-term implications on the society are found to be many. Knowingly and unknowingly, now the farmers are addicted to using agro-chemicals indiscriminately and excessively, thus making the situation from bad to worse.

In India pesticide usage began in 1948 when DDT was imported for malaria control, whereas production started for hexachlorocyclohexane (HCH) in 1952. In 1993–94 the consumption of pesticides increased by 500 times from 154 tonnes in 1953 to 75000 tones. Currently India consumes 75417.70 MT of pesticides annually. The present production of pesticides is 81,803 MT annually which is the largest in Asia and ranks 12th in the world.

In India pesticides are mainly being used to protect crops from insects and for public health purposes. The pesticides used for different purposes move between different environmental compartments and ultimately affect human beings.

The implications of pesticide use have resulted into the extinction of useful organisms present in soil, plants and animals like earthworms, bees, spiders, etc. The disposal of empty containers after pesticide applications is one of the serious problems and has been responsible for pesticide contamination leading to chronic and acute problems to the exposed personnel.

Impact of pesticide uses

Pesticide application: Insecticides contribute 75% of the total pesticide consumption in the country and of that organochlorine and organophosphorus share 40 and 30% respectively (Fig. 1). In India pests cause crop loss of more than Rs. 6000 crores annually, of which 33% is due to weeds, 26% due to diseases, 20% by insects,

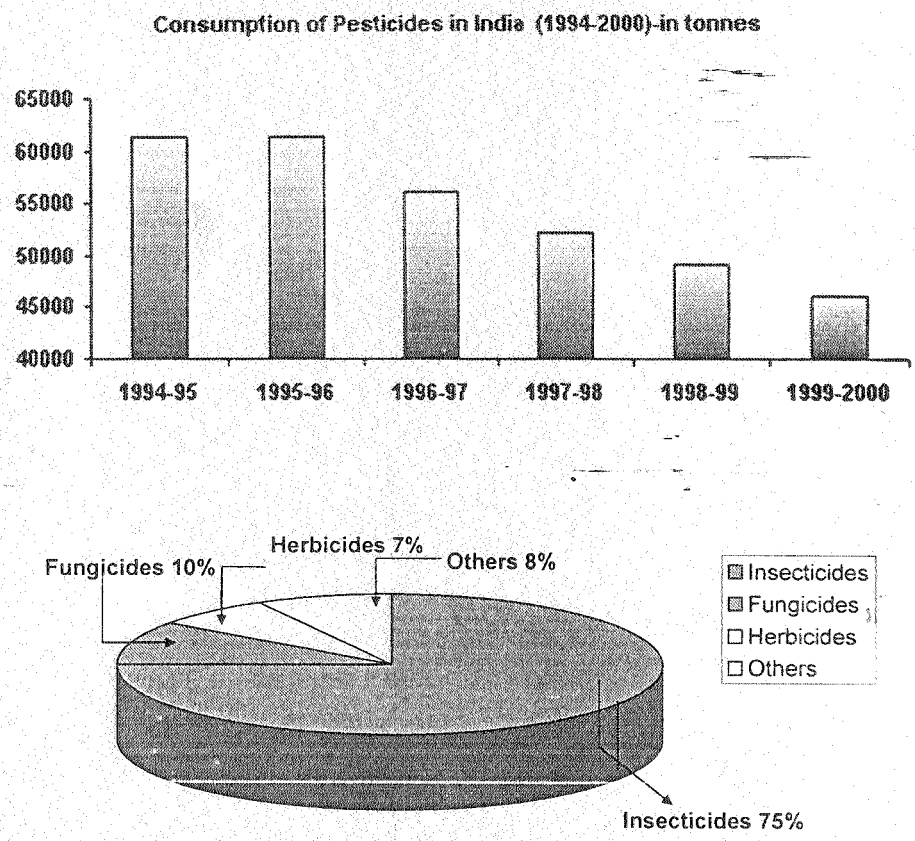

Fig. 1. Consumption of Pesticides in India

10% by birds and rodents and the remaining 11% is due to other factors. Application of synthetic pesticides has increased significantly from 1950–51 to the late nineties related to the fact that the farmers are increasingly aware of the adverse effects of such inputs. Since the last few years the focus on public policies towards pesticides has been changing more favourably for using biodegradable and environmentally sound pesticides like neemazol, repellin, wellgro, econeem and biopesticides.

Health effects: Green vegetables have been detected with pesticide residues and their health impacts were reported in the state of Rajasthan. Agricultural commodities like tea, egg powder and cashew kernels have been rejected on the contention of chemical contamination and presence of pesticide residue in European countries (Table-1)[1]. A report from the largely chilli producing state of Andhra Pradesh indicates that dry chilles too have pesticide particles and the importers refused to accept the consignment. Plantation Corporation of Kerala (PCK) reported that the continuous and indiscriminate application of pesticides on 2,200 ha cashew gardens in Padre village affected the flora and fauna and the local people became victims of severe health problems like cancer (Table-2).

Pesticide spraying

The Indian Institute of Health Management in Jaipur, Rajasthan reported newborn children with neural tube defect (NTD), a deformity that results from the incomplete closure of the neural tube during early pregnancy and correlated with

pesticides spraying[1]. Alarming NTD takes a heavy toll of the order of half a million babies every year in the world and in Rajasthan alone about 8,000 babies are reportedly affected. The study confirmed that the primary cause of NTD is the excessive use of pesticides on crop fields. Further, the study also notes that pesticides are mainly responsible for NTD as they are antagonistic to folic acid, a vitamin that is essential for the development of the brain. The pregnant women in the first few weeks of pregnancy have to eat leafy vegetables and grains because they contain folic acid that is essential for the development of the brain. Vegetables applied with heavy dose of chemical pesticides and obviously the pregnant women, who eat such contaminated and toxic vegetables and green leafs succumb to complications. The physician contends that pesticide residue in food can prevent the availability of folic acid leading to the birth of children with NTD.

TABLE-1

ENDOSULFAN RESIDUES IN KASARGOD DISTRICT IN KERALA ($\mu g\ L^{-1}$)

Sample items	Detected value of endosulfan	Maximum residue limit (MRL)	No. of times value exceeds MRL	Site/source of sample
Water	9.19	0.18	51	The Kodenkiri stream near Vaningar
Butter	14.00	NA	NA	Cow's milk of Saletadka
Cow's skin/fat tissue	49.99	0.10	500	From the abdominal region of cow from Padre
Vegetables	31.24	0.40–2.00	78–16	"Basale" leafy, spinach-like vegetables from Kajampady
Human milk	22.40	NA	NA	Lalitha, 35, resident of Kumbdaje village
Human blood	196.47	NA	NA	Muthakka Shetty, 50
Live frog	10.35	NA	NA	From a stream in Kumbdaje
Cashew	3.74	NA	NA	From plantation near Kajampady
Spices	212.28	NA	NA	Pepper bunch from Kajampady
Fish	22.24	NA	NA	From a tank in Kajampady
Soil	35.16	0.09	391	From Lalitha's house in Kumbdaje
Cashew leaves	6.52	NA	NA	From the heart of plantation at Periyal

Source: *Down to Earth* (2001).

TABLE-2

HEALTH DISORDERS IN PADRE VILLAGE OF KERALA

Disorders	No. of Cases
Cancer	49
Mental retardation	23
Congenital anomalies	9
Psychiatric cases	43
Epilepsy	23
Suicides	09
Total	156

Source: *Down to Earth* (2001).

Symptoms of poisoning

The vulnerable groups of pesticide toxicity are agricultural labourers, marginal and small farmers and women labourers that succumb to pesticide related health disorders in the long run. The brief symptoms of pesticide poisoning are given in Table-3.

TABLE-3
BRIEF SYMPTOMS OF PESTICIDES POISON IN INDIA

Category	System affected	Common symptoms
Respiratory	Nose, trachea, lungs	Irritation, tight chest, coughing, choking
Gastrointestinal	Stomach, intestine	Nausea, vomiting, diarrhoea
Renal	Kidney	Back pain, urinating more or less than usual
Neurological	Brain, spinal cord	Headache, dizziness, confusion, behaviour, depression, coma, convulsions
Hematological	Blood	Anemia (tiredness, weakness)
Dermatological	Skin, eyes	Rashes, itching, redness, swelling
Reproductive	Ovaries, testis, fetus	Infertility, miscarriage

Source: Kamrin, 1997.

Water quality monitoring

The organochlorine (OClP) and organophosphorous (OP) pesticide analysis in water samples were carried out following the 18th edition of Standard Methods for the Examination of Water and Wastewater, 1992, published by APHA, AWWA and WEF. The standardization techniques optimized for the examination of contaminated water under Indian conditions were deployed in the analyses of field samples. Quality assurance (QA) and quality control (QC) data were established for each of OCIPs, lindane [γ-hexachlorocyclohexane (γ-HCH)], endosulphan-I and endosulphan-II, *p*, *p*′-DDT, *p*, *p*′-DDE and *p*, *p*′-DDD, OPs, chloropyriphos, methyl parathion and malathion analyzed in the concentration range of (2–5 μg L^{-1}) commonly encountered in field samples (Tables 4 and 5).

TABLE-4
QA AND QC DATA ESTABLISHED FOR ORGANOCHLORINE PESTICIDES

Parameter	Lindane	Endo-I	Endo-II	*p,p*′-DDE	*p,*p′-DDD	*p,p*′-DDT
Recovery (%)	68.55	71.74	66.01	67.85	64.87	60.00
Std. deviation	0.13	0.09	0.21	0.15	0.15	0.20
Relative std. deviation (%)	9.20	6.08	11.67	11.67	11.33	17.72

TABLE-5
QA AND QC DATA ESTABLISHED FOR ORGANOPHOSPHORUS PESTICIDES

Parameter	Chlorpyriphos	Methylparathion	Malathion
Recovery (%)	75.50	73.04	76.25
Std. Deviation	0.06	0.08	0.05
Relative std. deviation (%)	5.19	6.09	5.02

Pesticide Levels in water

The levels of OCIPs, lindane, *p*, *p*′-DDT, *p*, *p*′-DDE, *p*, *p*′-DDD, endosulfan-I and endosulfan-II monitored in urban water resources, *viz.*, river, lake, tubewells and intake and final water of treatment plants of major cities in India. Baseline data was collected for OCIPs in 1982–84 in summer, winter and rainy seasons for major water sources of three of the major cities Delhi, Kanpur and Kolkata[2, 3]. Lindane, endosulfan and DDT levels monitored in raw, treated water and service reservoirs at Mumbai during 1995–96 in post-monsoon I and II, winter and summer seasons are reported[4] (Figs. 2–4). Lindane, endosulfan and total DDT levels monitored in lakes, rivers and tubewells in Nagpur in 1996 and 2004 during winter and summer

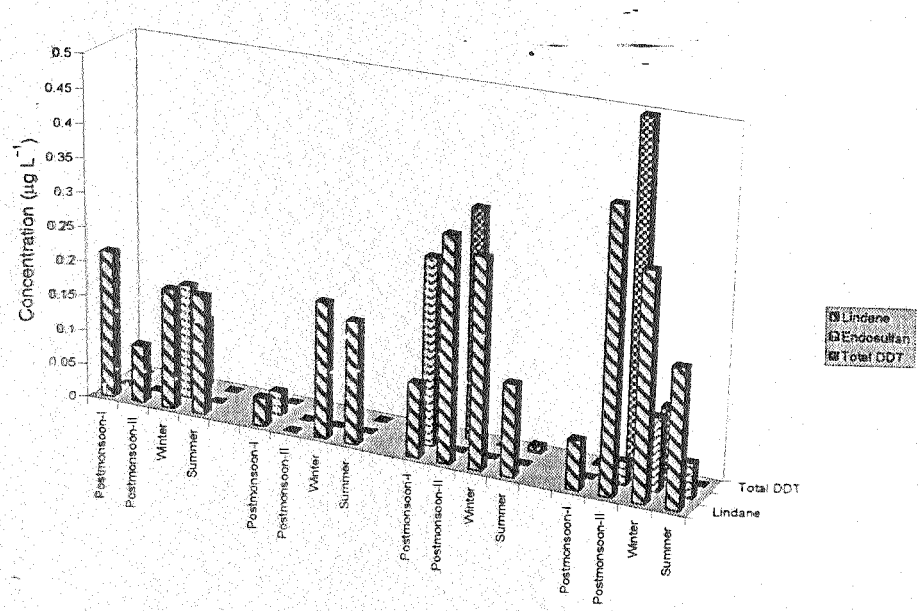

Fig. 2. Pesticide levels in treated water at Mumbai (1995–96) (WHO guideline values for lindane 2 µg L^{-1} and DDT 1 µg L^{-1})

seasons are reported[5, 6] (Figs. 5–7). The results of OCIPs monitoring during 2004 in final water of the Bhagirathi, Haiderpur, Nangloi, Okhla and Wazirabad treatment plants at Delhi are reported (Figs. 8–12). The results of the OCIPs and OPs analyzed in commercially available packaged drinking water are reported in Fig 13. The outcome of the pesticides monitoring studies has concluded the following:

- Data indicated the contamination of water resources with pesticides.
- Parts per billion levels (ppb) below the WHO guideline values of OCIPs and OPs were found in the samples analyzed excepting in some cases.
- In packaged drinking water the levels were found not detectable except in two samples 0.131 µg L^{-1} and 0.106 µg L^{-1} DDT reported within the regulated WHO guideline values.

Measures in legal framework

Pesticides are likely to cause health problems only in the long run in human body. Pesticides that have been banned or restricted from use in many countries are

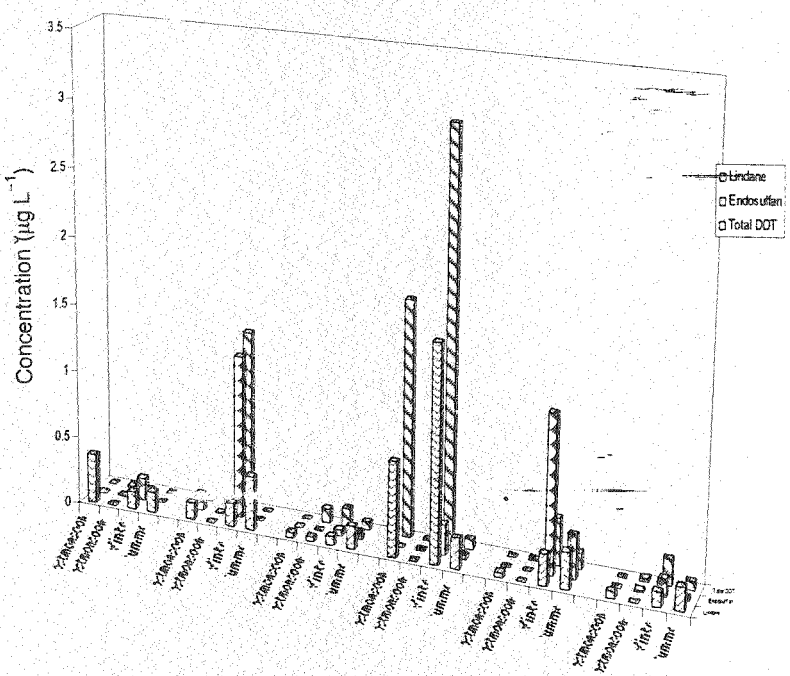

Fig. 3. Pesticide levels in service water reservoirs at Mumbai (1995–96) (WHO guideline values for lindane 2 µg L^{-1} and DDT 1 µg L^{-1})

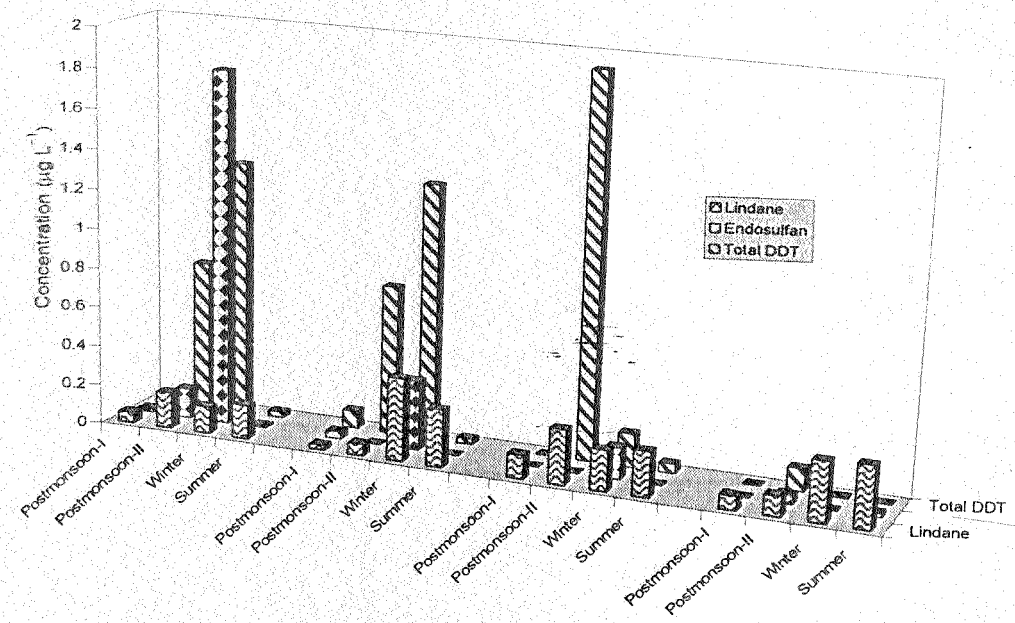

Fig. 4. Pesticide Levels in raw water at Mumbai (1995–96) (WHO guideline values for lindane 2 µg L^{-1} and DDT 1 µg L^{-1})

still used in India. Perhaps the user's cost is less and social cost is more as the farmers incur cost only in buying the pesticides whereas the government has to spend huge resources on pesticides related public health programs. All these point to the fact that developing countries like India have become dumping grounds for chemical pesticides. There is a necessity to make available enough literature on health problems associated with pesticide use to draw a drastic conclusion in Indian

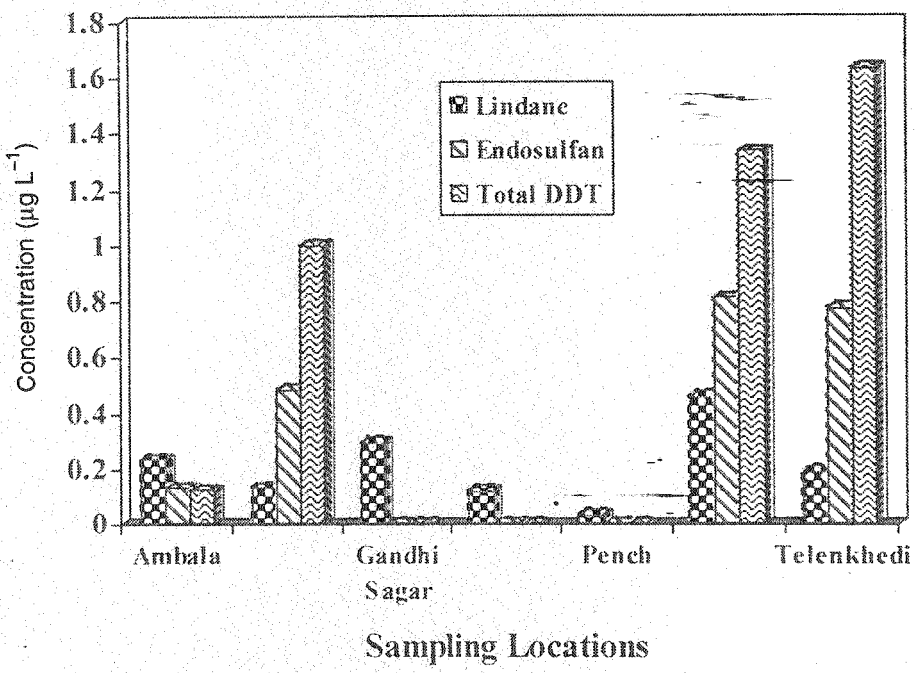

Fig. 5. Pesticides in lake water at Nagpur (East) (1996) (WHO guideline values for lindane 2 µg L^{-1} and DDT 1 µg L^{-1})

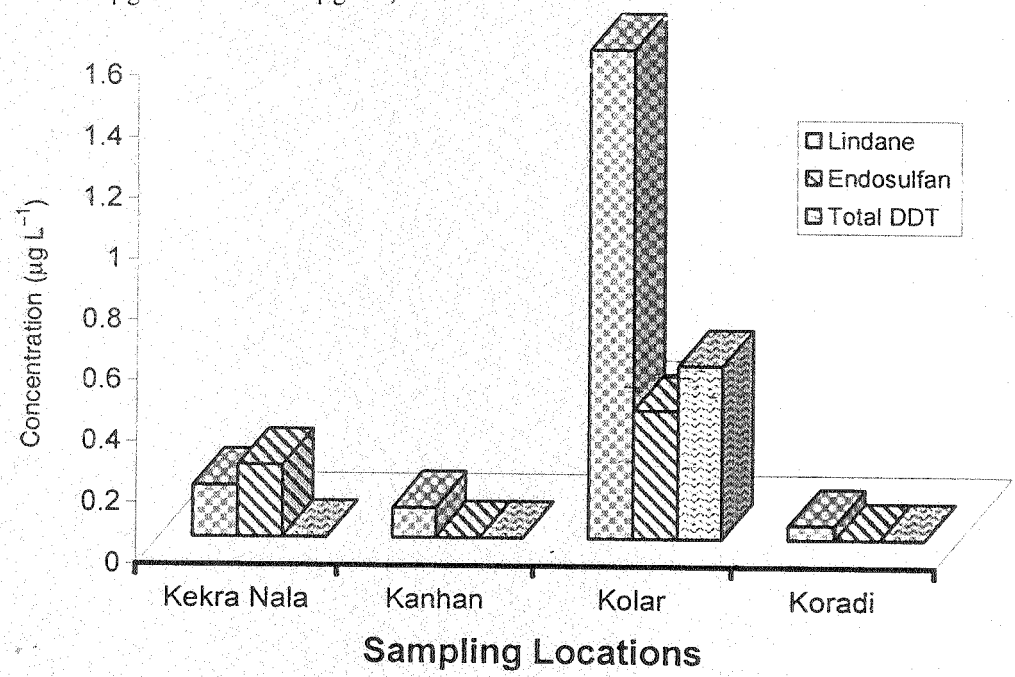

Fig. 6. Pesticides in lake water at Nagpur (West) (1996) (WHO guideline values for lindane 2 µg L^{-1} and DDT 1 µg L^{-1})

fields. There is dearth of scientific data on the beneficial and adverse effects of pesticide application in India under wider agricultural systems and for public health purposes.

Alternatives to synthetic pesticides

There has been a paradigm shift though slow from modern chemical farming towards sustainable farming, which depends on local farm resources across the

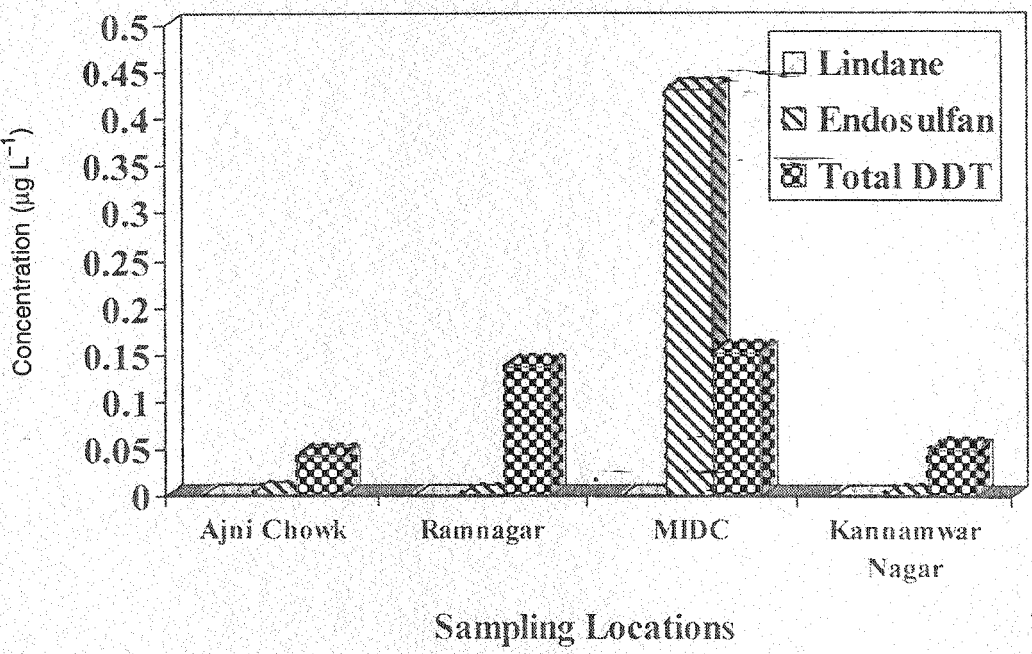

Fig. 7. Pesticides in tubewells at Nagpur (2004) (WHO guideline values for lindane 2 µg L^{-1} and DDT 1 µg L^{-1})

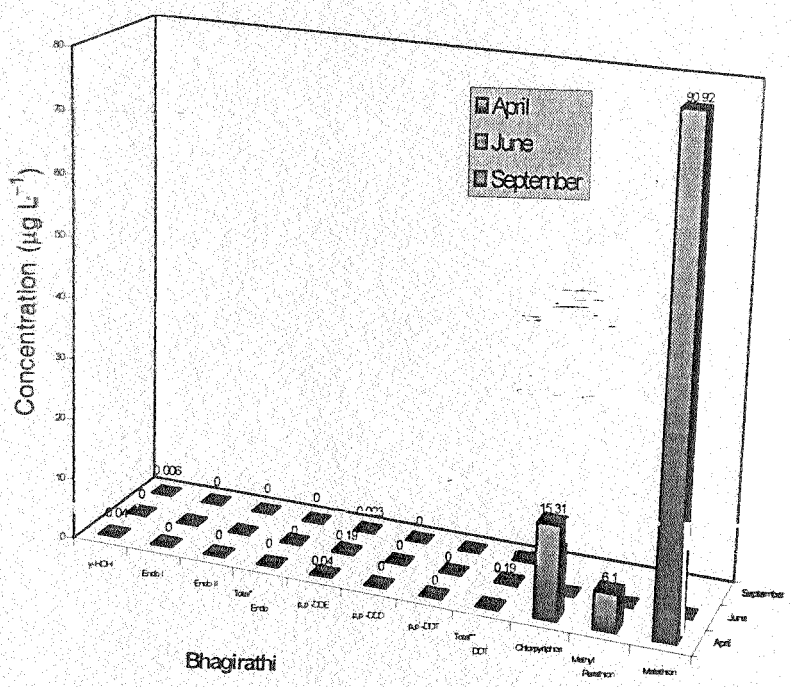

Fig. 8. Pesticide levels in treated water of Bhagirathi plant at Delhi (2004) (WHO guideline values for lindane 2 µg L^{-1}, DDT 1 µg L^{-1} and chloropyrifos 30 µg L^{-1})

globe. Based on the existing scenario and available inputs, considering the economic viability and environmental sustainability, the following are the suggested alternatives:

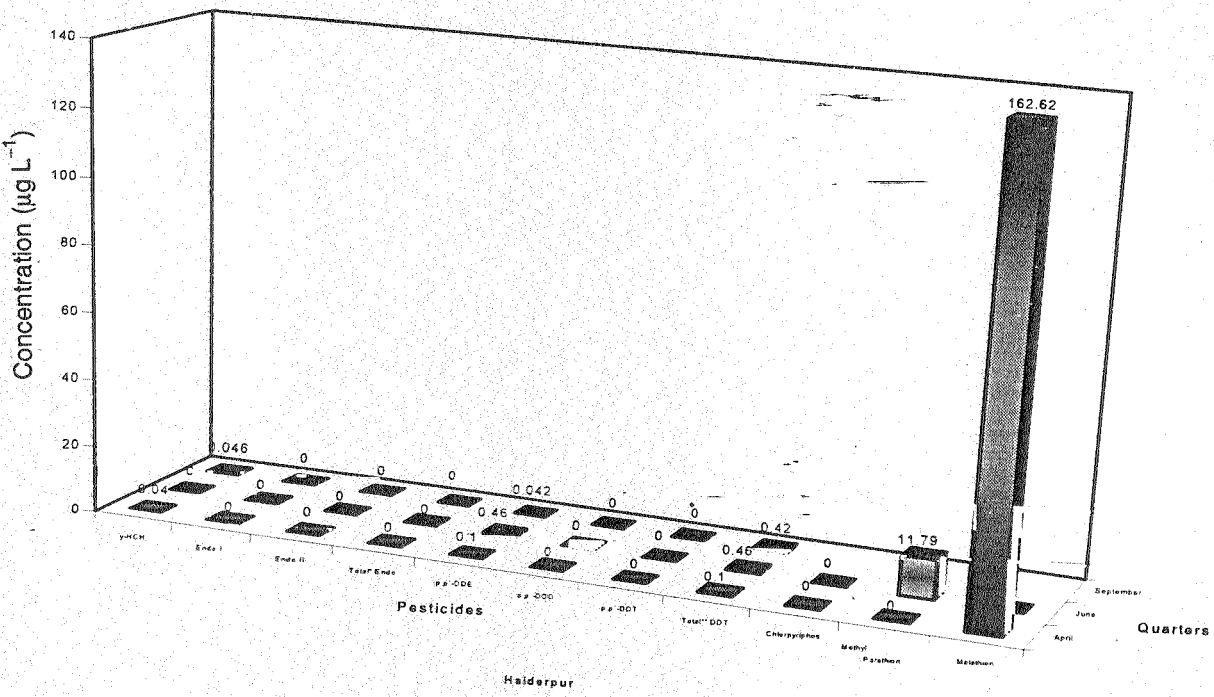

Fig. 9. Pesticide level in treated water of Haiderpur plant at Delhi (2004) (WHO guideline values for lindane 2 µg L^{-1}, DDT 1 µg L^{-1} and chlorpyrifos 30 µg L^{-1})

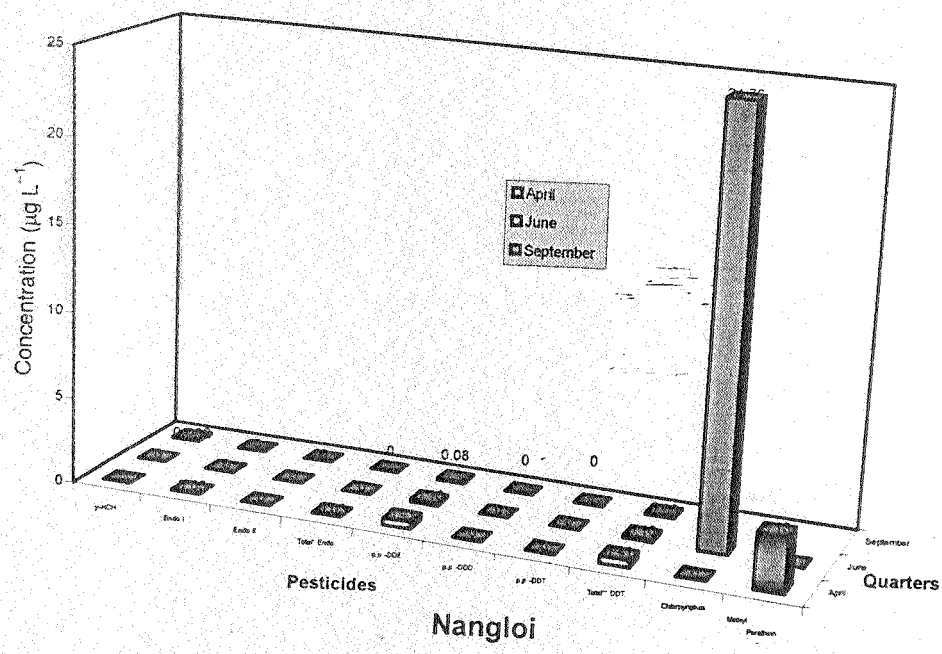

Fig. 10. Pesticide level in treated water of Nangloi plant at Delhi (2004) (WHO guideline values for lindane 2 µg L^{-1}, DDT 1 µg L^{-1} and chlorpyrifos 30 µg L^{-1})

- Application of environment friendly plant based solutions.
- To spend on labourers for developing alternatives, which will increase employment and protect the environment for sustainable agricultural development (SAD).

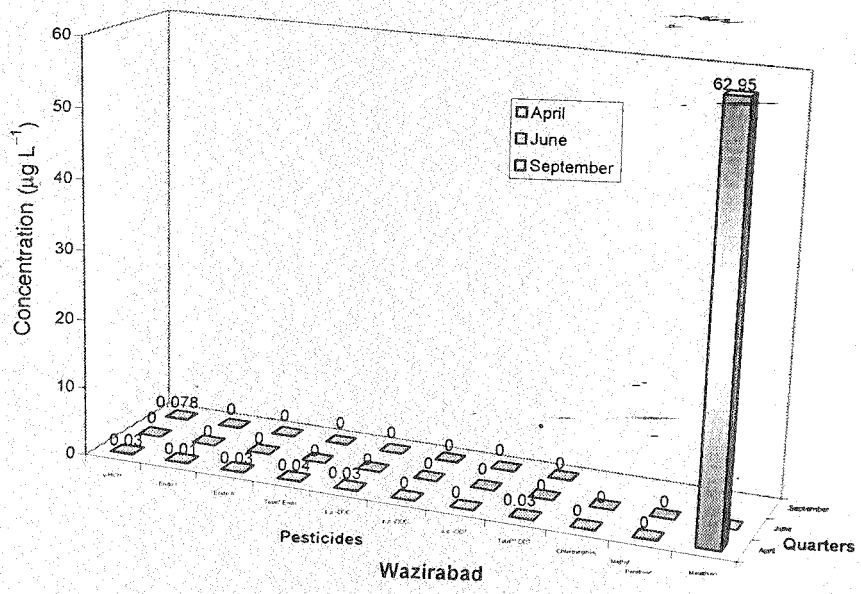

Fig. 11. Pesticide level in treated water of Wazirabad plant at Delhi (2004) (WHO guideline values for lindane 2 µg L^{-1}, DDT 1 µg L^{-1} and chlorpyrifos 30 µg L^{-1})

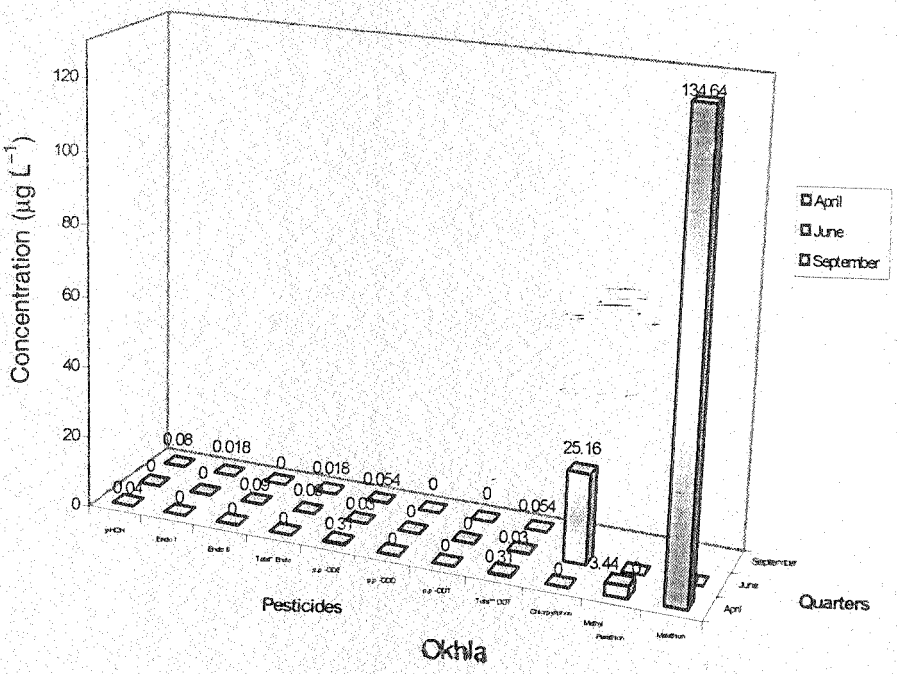

Fig. 12. Pesticide level in treated water of Okhla plant at Delhi (2004) (WHO guideline values for lindane 2 µg L^{-1}, DDT 1 µg L^{-1} and chlorpyrifos 30 µg L^{-1})

- Private agencies should start preparation and supply of inputs like earthworms and plant based decoctions in the larger interest for promoting SAD.
- The concept of integrated pest management (IPM) has to be advocated.

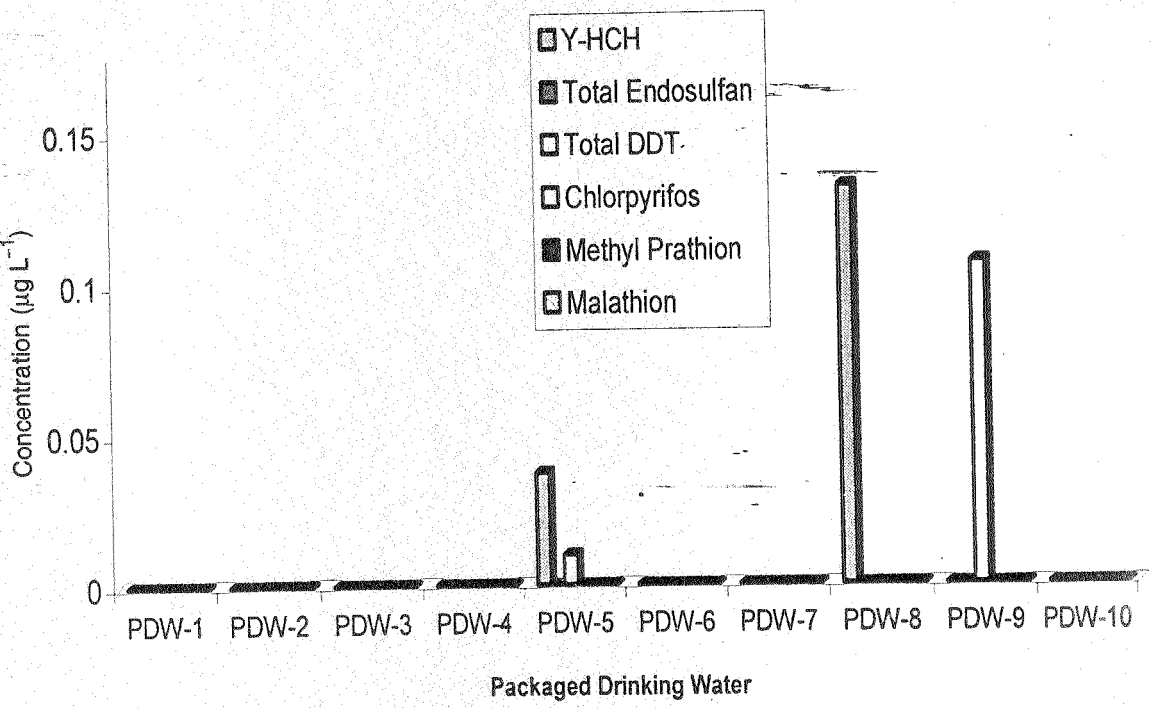

Fig. 13. Pesticide level in packaged drinking water (2004) (WHO guideline values for lindane 2 µg L^{-1}, DDT 1 µg L^{-1} and chlorpyrifos 30 µg L^{-1})

- Application of synthetic pesticide inputs must be a last option after every attempt.
- A strong political will, committed contingent of extension personnel, enough resources and above all the stakeholder's full participation and cooperation.

Conclusion and suggestions

The paper has discussed the health impacts of synthetic pesticides, quality assurance and quality control on analytical techniques deployed for OCIPs and OPs, levels and baseline data on OCIPs and OPs monitored in Indian cities in varied seasons in urban water resources, *viz.*, river, lake, tubewells, intake and final water of treatment plants, and in packaged water. The above discussion reveals that increased use of pesticides has caused economic, environmental, health and social problems. Lack of awareness among the farmers, deliberate suppression of facts, resource constraints, unlawful approaches, public policies and poor alternative mechanisms are found responsible for the present state of affairs. This calls for immediate policy attention and action. More environment friendly pest control mechanisms have to be researched, developed and employed for attaining SAD. Nevertheless, any policy decision towards promoting SAD *via* organic/ecological agriculture needs careful examination in the context of ecological balance, economic viability, food security and technical feasibility. The legal and administrative framework on pesticide trial, approval, monitoring and revision has to be hardened for promoting SAD. The following actions in respect of controlling/preventing pesticides impact on human health are suggested:

Action needs to be taken

- A nodal centre should be set up and entrusted with planning and implementing research on environmental protection from pesticides.
- Pesticide registration should be made very stringent.
- The pesticide industry, which is the main polluter, should be taxed or should pay for developing decontamination techniques.
- Monitoring of pesticides in food commodities and drinking water should be done regularly.
- Tolerance limit for pesticides should be re-evaluated and made lower in comparison with the present ones.
- Studies on the health effects of pesticides as well as epidemiological studies should be conducted to further minimize the intake of pesticide.
- Integrated pest control measures, organic farming and use of biopesticides, *e.g.*, neem, should be promoted and subsidies and markets should be created.
- A national programme to create mass awareness on synthetic and bio-pesticides, to monitor pesticide residues and to assess their environment impact, need to be launched and sustained.

ACKNOWLEDGEMENTS

Authors are grateful to the Director, National Environmental Engineering Research Institute, NEERI, Nagpur for his permission in carrying out this work. Authors are also thankful to the staff of Instrumentation Division at NEERI for their cooperation in carrying out gas chromatographic analysis.

REFERENCES

1. S. Rajendran, Environmental and health aspects of pesticide use in Indian agriculture, in: M.J. Bunch, V.M. Suresh and T.V. Kumaran (Eds.), Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15–17 Dec., 2003, pp. 353–373.
2. N.P. Thakkar and S.P. Pande, *Ind. Assoc. Water Pollution and Control Tech. Annual*, **11**, 16 (1984).
3. ————, *Indian Waterworks Association*, **18**, 313 (1986).
4. N.P. Thakkar, R.C. Dixit and V. Nitnaware, Water quality monitoring for priority pollutants in urban area, National Conference on Pollution, Prevention and Control in India, Indian Association for Environment Management, Nagpur, March 2–3, 2002
5. N.P. Thakkar, P. Kaur and A. Rudra, *Int. J. Environ. Edu. Inform.*, **16**, 367 (1997).
6. N.P. Thakkar, M.V. Vaidya and M. Sipani, Sustainability of Indian water systems for organohalides, 3rd Cong. Toxicol., Dev. Count., Cairo, Egypt, Nov. 19–23, 1995, Proc.-III, pp. 213–222.

(*Received*: 8 October 2005; *Accepted*: 2 May 2006) AJC-4824