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Emerging Contaminants in Ganga River Basin

with Special Emphasis on Pesticides

GRB EMP : Ganga River Basin Environment Management Plan

by

Indian Institutes of Technology

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Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin: Environment Management Plan (GRB EMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Environment Management Plan (GRBEMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin: Environment Management Plan (GRB EMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRB EMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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1. Introduction

India is a predominantly agrarian economy that is also rapidly industrializing. Chemicals production in India has been unprecedented in the last few decades. Today, the chemicals manufacturing industry accounts for 3% of the country's GDP (Department of chemicals and petrochemicals, 2011). While India's chemical production is still far below that of developed and most developing nations, the consequences are becoming visible already. A news report in the prestigious scientific journal, *Nature,* highlighted the gravity of the situation where concentrations of some common medicines (drugs) like ciprofloxacin and cetirizine were found at concentrations of 31 and 1.4 mg/L (Nature, 2009). Pharmaceutical companies in the area that were discharging large amounts of wastewater were responsible for the situation. Given the lack of regulations for dealing with the discharge of such chemicals, no action can be taken in these cases. There are many more examples of such unchecked releases of unregulated but harmful chemicals, also called emerging contaminants (EC).

The list of ECs includes pharmaceuticals, personal care products, antibiotics, prescription and non-prescription drugs, steroids and hormones, pesticides, plasticizers, surfactants, and fire retardants (Bhandari *et al.*, 2009). Major sources of these chemicals include residential, agricultural and industrial activities. This report provides a summary of EC regulations in different countries, a brief introduction to the major EC categories, and the current state-of-knowledge in India regarding emerging contaminants in Ganga river basin.

1.1 Regulations for Emerging Contaminants and Research in other Countries

Many developed nations already have maximum contaminant levels (MCLs) and health advisory levels (HALs) for a variety of these ECs. Guidelines and health advisory levels for pesticides are summarized in **Table 1** while those for heavy metals are summarized in **Table 2.** At present in India, there are no regulations or guidelines for individual pesticides in drinking water. IS10500 recommends a level of 1 micro-g/L for total pesticides while standards are recommended for various heavy metals and are included in **Table 2.**

An extensive survey was conducted in the US for a large number of chemicals that are routinely found in streams and are potentially toxic to animals or humans (Kolpin *et al.*, 2002). Water samples from 139 streams across the US were analyzed for 95 contaminants. 82 of the analyzed contaminants were detected and natural contaminants like steroids were detected most frequently. Non-prescription drugs and pesticides were the other frequently detected categories of contaminants. Concentrations of surfactants were the highest amongst all contaminant categories followed by steroids and plasticizers.

Table 1: Guidelines or advisory levels for pesticides in different countries

Pesticide	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	US 2011 ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**
1,2-dichloropropane				0.05		
1,3-dichloropropene				0.02		
2,4-D	0.0001	0.03		0.04		
Acephate		0.01		0.02		
Aldicarb	0.001	0.001	0.0007	0.01		
Aldrin (and dieldrin)	0.00001	0.0003		0.00004		
Ametryn	0.005	0.05				
Amitrole	0.001	0.01				
Asulam		0.05				
Atrazine	0.0001	0.04	0.005	0.002		
Azinphos-methyl	0.002	0.003	0.02	0.004		
Benomyl		0.1				
Bentazone		0.03		0.4		
Bioresmethrin		0.1				
Bromacil	0.01	0.3		0.4		
Bromophos-ethyl		0.01				
Bromoxynil		0.03	0.005			
Carbaryl	0.005	0.03	0.09			700
Carbendazim		0.1				
Carbofuran	0.005	0.01	0.09	0.008		
Carbophenothion		0.0005				
Carboxin	0.002	0.3				
Chlordane	0.00001	0.001		0.0002		2
Chlorfenvinphos		0.005				
Chlorothalonil	0.0001	0.03				
Chlorotoluron				0.04		
Chloroxuron		0.01				
Chlorpyrifos		0.01	0.09	0.04		20
Chlorsulfuron		0.1				
Clopyralid	1	1				
DDT	0.00006	0.02		0.001		
Diazinon	0.001	0.003	0.02	0.01		0.6
Dicamba		0.1	0.12			
Dichlobenil		0.01				
Dichlorprop				0.1		
Dichlorvos	0.001	0.001				
Diclofop-methyl		0.005				
Dicofol		0.003				
Dieldrin (see aldrin)	0.00001	0.0003				0.2

Pesticide	**ADWG 2004** *Australia*		**CDWQG 2008** *Canada*	**NZWQG 2005** *New Zealand*	**JWQG 2004** *Japan*	**US 2011** ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**
Difenzoquat		0.1				
Dimethoate		0.05		0.008		
Diphenamid	0.002	0.3				
Diquat	0.0005	0.005	0.07	0.01		
Disulfoton	0.001	0.003				
Endrin				0.001		
Hexachlorobenzene				0.0001		
Isoproturon				0.01		
Malathion				1		
Oryzalin		0.3		0.4		
Oxadiazon				0.2		
Oxamyl	0.005	0.1				
Paraquat	0.001	0.03	0.01			
Parathion		0.01				
Parathion methyl	0.0003	0.1				2
Pebulate	0.0005	0.03				
Pendimethalin		0.3		0.02		
Pentachlorophenol	0.00001	0.01		0.009		
Permethrin	0.001	0.1		0.02		
Phenylphenol				1.4		
Picloram		0.3	0.19	0.2		
Piperonyl butoxide		0.1				
Pirimicarb		0.005				
Pirimiphos-ethyl		0.0005				
Pirimiphos-methyl		0.05		0.1		
Primisulfuron methyl				0.9		
Procymidone				0.7		
Profenofos		0.0003				
Promecarb		0.03				
Propachlor	0.001	0.05				
Propanil	0.0001	0.5		0.02		
Propargite		0.05				
Propazine	0.0005	0.05		0.07		
Propiconazole	0.0001	0.1				
Pyridate				0.1		
Pyriproxifen				0.4		
Terbuthylazine				0.008		
1,2-dibromo-3-chloropropane				0.001		
2,4,5-T	0.00005	0.1		0.01		
2,4-DB				0.1		

Pesticide	**ADWG 2004** *Australia*		**CDWQG 2008** *Canada*	**NZWQG 2005** *New Zealand*	**JWQG 2004** *Japan*	**US 2011** ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**
Cyanazine				0.0007		
Diuron		0.03	0.15	0.02		
DPA(2,2-DPA)		0.5				
EDB	0.001	0.001				
Endosulfan	0.00005	0.03				
Endothal	0.01	0.1				
EPTC	0.001	0.03				
Ethion		0.003				
Ethoprophos	0.001	0.001				
Etridiazole	0.0001	0.1				
Fenamiphos		0.0003				
Fenarimol	0.001	0.03				
Fenchlorphos		0.03				
Fenitrothion		0.01				
Fenoprop		0.01		0.01		
Fensulfothion	0.01	0.01				
Fenvalerate		0.05				
Flamprop-methyl		0.003				
Fluometuron		0.05				
Formothion		0.05				
Fosamine		0.03				
Glyphosate	0.01	1				
Heptachlor including its epoxide	0.00005	0.0003		0.00004		
Hexaflurate		0.03				
Hexazinone	0.002	0.3		0.4		
Lindane	0.00005	0.02		0.002		0.2
Maldison		0.05				
MCPA				0.002		
MCPB				0.03		
Mecoprop				0.01		
Metalaxyl				0.1		
Methidathion		0.03				
Methiocarb	0.005	0.005				
Methomyl	0.005	0.03				
Methoxychlor	0.0002	0.3	0.9	0.02		
Methyl parathion				0.01		
Metolachlor	0.002	0.3		0.01		
Metribuzin	0.001	0.05		0.07		
Metsulfuron-methyl		0.03				
Mevinphos	0.005	0.005				

Pesticide	**ADWG 2004** *Australia*		**CDWQG 2008** *Canada*	**NZWQG 2005** *New Zealand*	**JWQG 2004** *Japan*	**US 2011** ***United States***
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**MCL**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**
Molinate	0.0005	0.005		0.007		
Monocrotophos		0.001				
Napthalene				20		
Napropamide	0.001	1				
Nitralin		0.5				
Norflurazon	0.002	0.05				
Propyzamide	0.002	0.3				
Pyrazophos		0.03				
Quintozene		0.03				
Silvex(see						
Simazine	0.0005	0.02	0.01	0.002		
Sulprofos		0.01				
Temephos	0.3	0.3				
Terbacil	0.01	0.03				
Terbufos	0.0005	0.0005	0.001			
Terbutryn	0.001	0.3				
Tetrachlorvinphos	0.002	0.1				
Thiabendazole				0.4		
Thiobencarb		0.03				
Thiometon		0.003				
Thiophanate		0.005				
Thiram		0.003				
Triadimefon	0.1	0.002				
Trichlorfon		0.005				
Triclopyr		0.01		0.1		
Trifluralin	0.0001	0.05	0.045	0.03		
Vernolate	0.0005	0.03				

Table 2: Guidelines or advisory levels for heavy metals in different countries

Heavy metals	**ADWG 2004** *Australia*		**CDWQG 2008** *Canada*	**NZWQG 2005** *New Zealand*	**JWQG 2004** *Japan*	**CWQG 2006** *China*	**SAWQG** *South Africa*	**IS10500**
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**Limiting value**	**TWQR**	**Permissible (desirable)**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Aluminum			0.1/0.2		0.2	0.2	0 - 0.15	0.2 (0.03)
Arsenic	0.007		0.01	0.01	0.01	0.01	0-10	0.05
Cadmium	0.002		0.005	0.004	0.01	0.005	0 - 0.005	0.01
Chromium (VI)	0.05		0.05	0.05	0.05	0.05	0 - 0.050	0.05
Copper	2	1		2	1	1	0 - 1	1.5 (0.05)

Heavy metals	ADWG 2004 *Australia*		CDWQG 2008 *Canada*	NZWQG 2005 *New Zealand*	JWQG 2004 *Japan*	CWQG 2006 *China*	SAWQG *South Africa*	IS10500
	Guideline value	**Health value**	**MAC**	**MAV**	**Target value**	**Limiting value**	**TWQR**	**Permissible (desirable)**
	mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Iron		0.3			0.3	0.3	0 - 0.1	1.0 (0.3)
Lead	0.01		0.01	0.01	0.01	0.01	0 - 10	0.05
Manganese	0.5	0.1		0.4	0.05	0.1	0 - 0.05	0.3 (0.1)
Mercury	0.001		0.001	0.002	0.005	0.001	0 - 1	0.001
Molybdenum	0.05			0.07	0.07			
Nickel	0.02			0.02				
Silver	0.1			0.1				
Zinc		3			1	1	0 - 3	15 (5)

1.2 Overview of Emerging Contaminants

Pharmaceuticals (Adams, 2009): Pharmaceuticals include prescription and non-prescription drugs and are discharged into the environment by human use, industrial wastewaters, and animal husbandry activities. Many of these chemicals are endocrine disruptors. Endocrine disruption effects of hormonal pharmaceuticals, due to their high potency at extremely low concentrations, are of particular concern for humans and animals. Antibiotics are also especially important because of their potential to form and promote antibiotic resistance for human pathogens, and their potential to significantly impact natural microbial consortia (Kümmerer, 2001). Other classes of pharmaceuticals, such as analgesics and psycho-pharmacologicals, may also be important due to their strength and common use.

Personal Care Products (Champagne, 2009): Personal care products (PCPs) include those compounds which are marketed for direct use primarily on the human body (mainly dermal contact). Prescription drugs, over-the-counter pharmaceutical products with documented physiological effects (Daughton and Ternes, 1999), nutraceuticals and food supplements are excluded from this category. PCPs are generally not intended for injection or ingestion. There are thousands of chemicals that are constituents of PCPs. These are diverse and are used as active ingredients or preservatives in cosmetics, skin care, dental care, hair care products, soaps, cleansers, insect repellents, sunscreen agents, fragrances, and flame retardants. Many of these PCPs are used in large quantities, and often at dosages and frequencies higher than recommended.

The active ingredients in a number of PCPs are considered bioactive chemicals. This implies that they have the potential to affect the flora and fauna of soil and aquatic receiving environments. In some cases, bioactive ingredients are first subject to metabolism by the consumer and the excreted metabolites and parent components are then subject to further transformation in the receiving environment. Personal care products differ from pharmaceuticals in that large quantities can be directly introduced into receiving environments (air, surface and ground water, sewage, sludge and bio-solids, landfills, soils) through regular use, such as showering, bathing, spraying, excretion or disposal of expired or used products. Because of this uncontrolled release, they can bypass possible treatment systems. As a result, PCPs are referred to as pseudo-persistent contaminants (Barceló and Petrovic, 2007).

The environmental fate and effects of many of the broad class of chemical constituents found in PCPs are poorly understood. PCPs can be considerably persistent and can bio-accumulate in non-target aquatic organisms (Ternes *et al.*, 2004). Some PCPs have been found to exhibit negative hormonal and toxic effects on a number of aquatic organisms at concentrations as low as µg/kg (Daughton and Ternes, 1999). To date, few studies have considered the interactive effects of combined low concentrations of various classes of PCPs, and whether their chemical constituents, metabolites and transformation products have any significance with respect to ecological function. Of particular concern is the fact that subtle immediate effects could occur and go undetected in the flora and fauna of receiving environments, but long-term cumulative effects could result in irreversible changes by the time they are recognized (Daughton and Ternes, 1999). Data are also limited regarding the effects of unexpected exposure on human health.

Steroids and Hormones (Limpiyakorn *et al.*, 2009): Hormones are the body's chemical messengers that affect and control most of the organisms' major activities including growth, development, metabolism, sexual and reproductive functions, psychological and physiological well-being. Based on their chemical structure, hormones can be divided into 3 broad classes: peptide hormones, amine hormones and steroid hormones. Peptide hormones consist of polypeptide hormones and oligo-peptide hormones. Peptide hormones are from the anterior pituitary gland, placenta, stomach, duodenum, pancreas and liver. Oligo-peptide hormones are from the posterior pituitary gland and the hypothalamus. Peptide hormones consist of chains of amino acids and examples would include insulin and growth hormones. Amine hormones are derived from the amino acids, tyrosine and tryptophan. Examples of major amine hormones are dopamine, nor-epinephrine, and epinephrine. Steroid hormones are synthesized by chemical modification of cholesterol and derived from the adrenal cortex, gonads and placenta. Steroid hormones can be subcategorized into corticosteroids and sex steroids.

Of concern in the environment are peptide hormones and steroid hormones. In the mid-1990s, several researchers reported the presence of steroidal estrogen hormones in surface waters, municipal wastewaters and wastes from concentrated animal feeding operations (Ternes *et al.*, 1999a; 1999b; Matsui *et al.*, 2000; Koplin *et al.*, 2002; Hanselman *et al.*, 2003). Estrogens have endocrine disrupting properties and are known to disrupt the endocrine system of humans, aquatic and animal species at ng/L (Tyler *et al.*, 2005; Purdom *et al.*, 1994). Human and animal steroidal hormones have extremely high estrogenic potency in comparison to synthetic chemicals such as organo-chlorine aromatic compounds. For example, the estrogenic potency of endogenous steroidal estrogens was reported to be

10,000-100,000 times higher than exogenous endocrine disrupting compounds (Hanselman *et al.*, 2003). Studies by several researchers have found that aquatic species such as turtles, trout, and minnows were sexually inhibited or reserved by the presence of natural estrogens at concentrations as low as few tens of ng/L (Jobling *et al.*, 1998; Irwin *et al.*, 2001; Lange *et al.*, 2001). At a concentration of 5 ng/L of estradiol, production of female specific proteins was found to be induced in male Japanese medaka (Tabata *et al.*, 2001).

In recent years, use of estrogenic compounds in hormone therapy of humans and in livestock farming has increased. Since estrogenic compounds are naturally produced, it is expected that the presence of these compounds in wastewaters and in the environment will continue to increase. The fate and behaviour of these compounds in the environment are not well understood. Consequently, the risks of these chemicals to humans, aquatic organisms and animals are also not well understood. Many estrogenic compounds are not routinely analyzed or the analysis methods are too tedious or are not available in media such as bio-solids and sediments. Currently available analytical methods allow for the quantification of steroids like cholesterol, coprostanol, stigmastanol, and hormones like methyltestosterone, testosterone, estradiol (17β-E2 and 17α-E2), estriol (E3), and estrone (E1)). These compounds are frequently detected in municipal wastewaters and livestock farming and streams (Koplin *et al.*, 2002).

Phthalate Plasticizers and Degradation Products (Barnabé *et al.*, 2009): Plastic products have always been of major concern in terms of toxicity and persistence in the environment. They contain a myriad of additives including plasticizers, which can make up to 40% of plastic formulations. Plasticizers are low molecular weight organic compounds that are essential for effective processing and tailoring of plastic formulations. The production of flexible plastics with multiple applications ranging from automotive industry to medical and commodity products is due to plasticizers. They are manufactured in hundred millions of tons annually and represent an overwhelmingly large fraction of the plastic industry.

It has been established that plasticizers are toxic to a certain extent and some can exhibit endocrine-disrupting properties. In fact, these compounds may also leach out from the plastics as they are not chemically bound to the plastic polymers. Hence, leaching is a major process for contamination of the environment by the ubiquitous plasticizers. Meanwhile, it has been estimated that the average ingestion rate of plasticizers could be about 8 mg per person per day. The abundance, potential endocrine-disrupting effects and the growing interest in their fate, transport and treatment makes them emerging contaminants of major concern. It is also corroborated by the fact that their biodegradation in the environment can release breakdown products which can be potentially more toxic than the parent compounds. Hence, there is a need to understand the fate and behavior of plasticizers and their degradation products in natural and engineered environments, including industrial and municipal effluents, sewage sludge, and landfill leachates.

Surfactants (Yan *et al.*, 2009): Surfactants (surface active agents or wetting agents) are organic chemicals that reduce surface tension in water and other liquids. Surfactants represent major, multipurpose groups of organic compounds. Nearly 3×10^{10} kg of surfactants are produced per year all over the world (Berna *et al.*, 1998). The most familiar use of surfactants is in soaps, dishwashing liquids, laundry detergents and shampoos. Other important uses are in industrial applications such as lubricants, emulsion polymerization, textile processing, mining flocculates, petroleum recovery, and a variety of other products and processes. Surfactants are also used as dispersants after oil spills (Scott and Jones, 2000; Petrovic *et al.*, 2002).

There are hundreds of compounds that can be used as surfactants. These are usually classified by their ionic behavior in solutions: anionic, cationic, non-ionic or amphoteric (zwitter-ionic). The two major groups of surfactants are the anionics and non-ionics with a global production of around 2.5 and 0.5 million tons per year, respectively (Lara-Martin *et al.*, 2006). Their main components are linear alkylbenzene sulfonates (LAS) for the anionics and alkylphenol polyethoxylates (APEOs) for the non-ionics.

Brominated Fire Retardants (Banerji *et al.*, 2009): Fire retardants are substances that can delay or prevent combustion. The most common fire retardant is water. However, many chemicals can be used as fire retardants and these eventually enter the environment and are potentially toxic. BFRs are endocrine-disrupting chemicals that are potentially toxic and bio-accumulative. There are more than 175 different types of compounds that are used as fire retardants. These compounds can be placed in four categories – halogenated organics, phosphorus-based, nitrogen based and other inorganic compounds. The halogenated compounds (chlorinated and brominated) are the most common fire retardants as they are less expensive and are quite effective. In this group, brominated compounds are more common than the chlorinated types. The phosphorus and nitrogen-based fire retardants are monoammonium phosphate, diammonium phosphate, ammonium polyphosphate and ammonium sulfate. These compounds individually or in combination are mixed with other chemicals such as corrosion inhibitors, alcohol, gum thickeners and surfactants in a fire retardant formulation. In the other inorganic compounds category, compounds like aluminium hydroxide, antimony oxides and chlorides may be included.

Brominated fire retardants (BFRs) are the most common fire retardants and have serious environmental effects. There are more than 75 different brominated fire retardants (Birnbaum and Staskal, 2004). BFRs contribute to about 38% of the global bromine demand. The electronic industry is the major consumer of BFRs. The four main applications of BFRs in computers are: printed circuit boards, connectors, plastic covers and cables. BFRs are also used in many other products such as TV plastic covers, carpets, paints, upholstery and domestic kitchen appliances. Their effectiveness for fire prevention and hindrance to the spread of fire makes them very useful fire retardants. Since they are not bound to the polymers, they can enter the environment by leaching.

Pesticides (Zhang *et al.*, 2009): The word "pesticide" is a generic term, which covers any substance or mixture of substances used for preventing, destroying, repelling or mitigating pests, or intended for use as plant regulators, defoliants or desiccants (USEPA, 2007a). Pests are considered to be any unwanted living organism that can cause damage to crops, humans or other animals. Examples of pests include insects, mice, unwanted plants (weeds), fungi, bacteria and viruses. Pesticides are not just natural or synthetic chemicals, but can include microorganisms or their components such as endotoxins from *Bacillus thuringiensis*, or macroorganisms such as predatory wasps specifically bred to control caterpillars and aphids (Tyagi *et al.*, 2002; Hamilton and Crossly, 2004). Currently, the most common types of pesticides being used are herbicides, insecticides, fungicides and bactericides. Other pesticides being applied include nematicides for controlling parasitic microscopic worms living in soil, avicide for birds, molluscicide for snails and slugs, piscicide for fish, algicides, rodenticides, and miticides (AGCare, 2007).

1.3 Emerging Contaminants in Ganga River Basin

Of the categories noted above, monitoring and assessment of water quality in India has been limited to heavy metals, pesticides, and antibiotics in the last few decades. Separate chapters have been written on each of these contaminant categories and the extent to which these contaminants are present in various environmental media due to contamination of the waters of Ganga river basin.

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2. Pesticides in Ganga River Basin

Pesticides have contributed greatly to the increase in crop yields in agriculture by controlling pests and diseases and also by controlling insect-borne diseases like malaria, dengue, encephalitis, filariasis, etc. (Abhilash and Singh, 2009). Pesticides are indispensable in modern agriculture, but their use or misuse may lead to contamination of both, ground water and surface water. These pesticides enter into rivers like those of the Ganga watershed through various pathways. Some of these pathways are described as follows .

(a) When fertilizers, insecticides, and fungicides are applied to cropland, some residue remains in the soil after plant uptake and is transported to streams and rivers by surface runoff,
(b) Pollutants also may enter water bodies by wind or by their own passive movement,
(c) Spray drifts during application of pesticides may carry pesticides to surface waters,
(d) Volatilization and precipitation,
(e) Leaching into ground waters, and
(f) Drain flow and through flow (Carter, 2000)

Pesticides can be very dangerous and harmful to human beings and animals due to their potential cytotoxicity and/or genotoxicity. Pesticides are often persistent, broad-spectrum toxins that can accumulate in the food web posing a threat to both, the ecosystem and human health. Many of these compounds are 'endocrine disruptors' which are defined as chemicals that can interfere with the hormonal systems of organisms including humans. Some developing countries including India continue to use these compounds because of their low cost and versatility in industry and agriculture and their long-term efficiency against pests. Consequently, environmental problems associated with these toxic contaminants are of great concern. It is reported that approximately three million people are poisoned and 200,000 die each year around the world from pesticide poisoning, and a majority of them belong to developing countries. It is also believed that in developing countries, the incidence of pesticide poisoning may be greater than reported due to under-reporting, lack of data and misdiagnosis (Sarkar et al., 2008a).

2.1 Pesticide Manufacturing and Use in India

Use of pesticides in India began in 1948 while manufacturing of DDT and benzene hexachloride (BHC or Lindane) began in the year 1952 (Gupta, 2004). In 1958, India was producing over 5000 metric tonnes of pesticides. Currently, there are approximately 145 pesticides registered for use, and production has increased to approximately 85,000 metric tonnes. The first report of poisoning due to pesticides in India came from Kerala in 1958 where over 100 people died after consuming wheat flour contaminated with parathion. Despite the fact that the consumption of pesticides in India is still very low, about 0.5 kg/ha of pesticides against 6.60 and 12.0 kg/ha in Korea and Japan, respectively, there has been widespread contamination of food commodities with pesticide residues. In India, 51% of food commodities are contaminated with pesticide residues and out of these, 20% have pesticides residues above the maximum residue levels on a worldwide basis.

Lists of pesticides registered in India along with those banned are available on the website of the Central Insecticides Board (2011). No information could be found on the production and utilization of individual pesticides in the Indian market. This information is essential for tracking the use of certain pesticides and determining the risks associated with their use.

2.2 Classification of Pesticides

Basically pesticides are divided into three to four main classes (Mohapatra et al., 1995):

(a) Organochlorine pesticides (OCPs): These pesticides tend to be persistent in the environment and have a tendency to bioaccumulate. Organochlorines are responsible for many acute and chronic illnesses. Examples of organochlorine pesticides include DDT and its degradation products, DDD and DDE, which are known to be equally or more toxic than the parent compound. Endosulfan and Lindane (γ-hexachlorocyclohexane – also called HCH) are other commonly used OCPs in India (Abhilash and Singh, 2009).

(b) Organophosphorous pesticides (OPPs): Organophosphates work by interfering with the nervous system of insects, mammals, birds, and fish. Examples of organophosphate pesticides that are commonly used in India include Malathion (Flit), Parathion (Baygon), Quinalphos and Chlorpyrifos (Abhilash and Singh, 2009).

(c) *Carbamates:* Carbamates are esters of carbamic acid. These insecticides can cause enzyme inhibition. Examples of carbamates include Aldicarb (Chopra et al. 2011), Carbofuran and Carbaryl (Abhilash and Singh, 2009).

(d) *Synthetic Pyrethroids*: These are esters of chrysanthemic acid and its derivatives. To mimic the insecticidal activity of the natural compound 'pyrethrum' another class of pesticides, pyrethroid pesticides, has been developed. These are non-persistent compounds, which are sodium channel modulators, and are much less acutely toxic than organophosphates and carbamates. Compounds in this group are often applied against household and garden pests. Examples include cypermethrin and imiprothrin (Hit), prallethrin (All-Out), deltamethrin and allethrin (Mortein). The consumption of technical grade pesticides in India is presented in Table 3.

Table 3: Consumption of Technical Grade Pesticides in India (Mohapatra et al., 1995).

Pesticide	Consumption thousand tons
Organochlorine pesticides	29.8
Organophosphorous pesticides	13.6
Carbamates	1
Synthetic Pyrethroids	1

2.3 Pesticide Contamination in Ganga River Basin

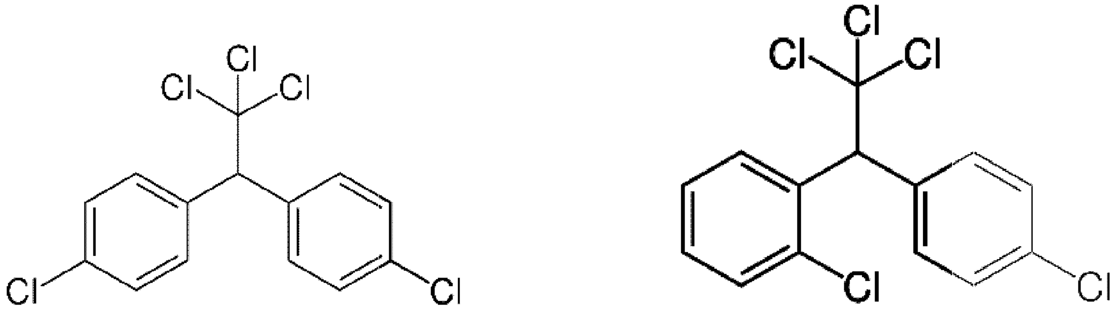
Research groups from different organizations in India have been actively monitoring pesticide levels in various environmental media including water, sediment, biota, agricultural products and humans for the last three decades. A summary of pesticide concentrations in different environmental media within the Ganga River basin is provided here.

2.3.1 Pesticides Detected and their Fate and Transport in the Environment

DichloroDiphenylTrichloroethane (DDT - $C_{14}H_9Cl_5$)

Dichloro**D**iphenyl**T**richloroethane (DDT - $C_{14}H_9Cl_5$) is one of the most well-known synthetic pesticides. It is a chemical with a long, unique, and controversial history. First synthesized in 1874, DDT's insecticidal properties were not discovered until 1939, and it was used with great success in the second half of World War II to control malaria and typhus among civilians and troops. After the war, DDT was made available for use as an agricultural insecticide (Wikipedia, 2011). DDT is currently banned world-wide under the Stockholm Convention and India is the only country that continues to manufacture and consume this pesticide (Wikipedia, 2011).

DDT is an organochlorine compound, similar in structure to the insecticide methoxychlor and the acaricide dicofol. It is a highly hydrophobic, colorless, crystalline solid with a weak, chemical odor. It is nearly insoluble in water but has good solubility in most organic solvents, fats, and oils. DDT does not occur naturally, but is produced by the reaction of chloral (CCl_3CHO) with chlorobenzene (C_6H_5Cl) in the presence of sulfuric acid, which acts as a catalyst.



p,p'-dichlorodiphenyltrichloroethane.

o,p'-dichlorodiphenyltrichloroethane

Structure of DDT

Commercial DDT is a mixture of several closely related compounds. The major component (77%) is the *p,p*-isomer while the *o,p*-isomer is also present in significant amounts (15%). Dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD) make up the balance. DDE and DDD are also the major metabolites and breakdown products in the environment. The term "**total DDT**" refers to the sum of all DDT-related compounds (*p,p'*-DDT, *o,p'*-DDT, DDE, and DDD) in a sample (http://en.wikipedia.org/wiki/DDT).

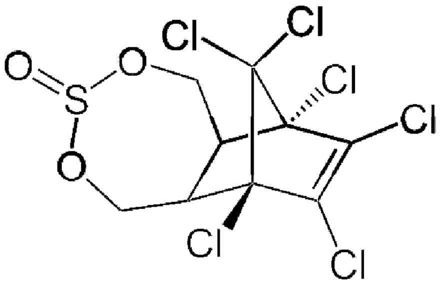
Fate and transport: When DDT enters the aquatic environment, it is quickly absorbed by organisms and by soil or it evaporates, leaving little DDT dissolved in the water itself. Its breakdown products and metabolites, DDE and DDD, are also highly persistent and have similar chemical and physical properties. DDT and its breakdown products are transported from warmer regions of the world to the Arctic by the phenomenon of global distillation, where they then accumulate in the region's food web. Because of its lipophilic properties, DDT has a high bioaccumulation potential, especially in predatory birds where these compounds are stored mainly in body fat. DDT and DDE are very resistant to metabolism; in humans, their half-lives are 6 to 10 years, respectively. DDT is toxic to a wide range of animals in addition to insects, including marine animals such as crayfish, daphnids, sea shrimp and many species of fish. Most famously, it is a reproductive toxin for certain bird species, and it is a major reason for the decline of the bald eagle, brown pelican, peregrine falcon, and osprey. Birds of prey, waterfowl, and song birds are more susceptible to eggshell thinning than chicken and related species, and DDE appears to be more potent than DDT (Wikipedia, 2011 http://en.wikipedia.org/wiki/DDT)

Endosulfan ($C_9H_6Cl_6O_3S$)

Endosulfan ($C_9H_6Cl_6O_3S$) is an organochlorine insecticide and became a highly controversial agrichemical due to its acute toxicity, potential for bioaccumulation, and role as an endocrine disruptor. Because of its threats to human health and the environment, a global ban on the manufacture and use of endosulfan was negotiated under the Stockholm Convention in April 2011. More than 80 countries had already banned it or announced phase-outs by the time the Stockholm Convention ban was agreed upon. However, it is still used extensively in India, China, and a few other countries.

Endosulfan has been used in agriculture around the world to control insect pests including whiteflys, aphids, leafhoppers, Colorado potato beetles and cabbage worms. Because of its unique mode of action, it is useful in resistance management; however, because it is non-specific, it can negatively impact populations of beneficial insects (http://en.wikipedia.org/wiki/Endosulfan).

Endosulfan is one of the most toxic pesticides in the market today, responsible for many fatal pesticide poisoning incidents around the world. Endosulfan can act as an endocrine disruptor, causing reproductive and developmental damage in both animals and humans.

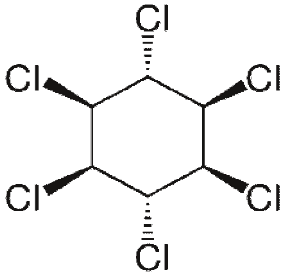


Structure of Endosulfan

Endosulfan breaks down into endosulfan sulfate and endosulfan diol, both of which have structures similar to the parent compound and are also of toxicological concern. The estimated half-lives for the combined toxic residues ranges from roughly 9 months to 6 years. Endosulfan is a very persistent chemical which may stay in the environment for lengthy periods of time, particularly in acid media. Endosulfan has relatively high potential to bioaccumulate in fish. It is also toxic to amphibians (Wikipedia, 2011; http://en.wikipedia.org/wiki/ Endosulfan).

Lindane or Hexachlorocyclohexane (HCH)

HCH – hexachlorocyclohexane, also called benzene hexachloride (BHC), is a six chlorine substituted cyclohexane, a polyhalogenated compound. It comes in many forms, some of which are pesticides. α-HCH, β-HCH, γ-HCH (lindane or gammaxene), δ-HCH, t-HCH. γ-HCH is considered as a pesticide and popularly known as lindane (Wikipedia, 2011; http://en.wikipedia.org/wiki/Hexachlorocyclohexane).



Structure of Lindane or Hexachlorocyclohexane (HCH)

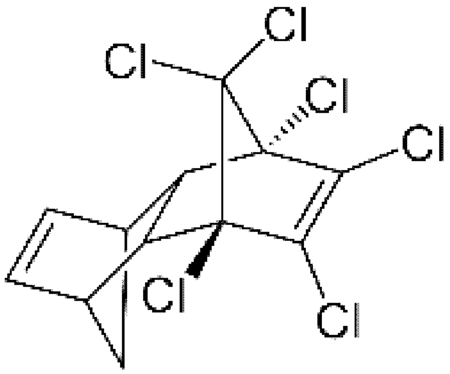
Lindane (γ-HCH) is an organochlorine chemical variant of hexachlorocyclohexane that has been used both as an agricultural insecticide and as pharmaceutical treatment for lice and scabies. The World Health Organization classifies Lindane as "Moderately Hazardous," and its international trade is restricted. In 2009, the production and agricultural use of Lindane was banned under the Stockholm Convention on persistent organic pollutants. A specific exemption to that ban allows it to be used as a second-line pharmaceutical treatment for lice and scabies (Wikipedia, 2011; http://en.wikipedia.org/wiki/Lindane).

It has an oral LD_{50} of 88 mg/kg in rats and a dermal LD_{50} of 1000 mg/kg. Most of the adverse human health effects reported for lindane have been related to agricultural uses and chronic, occupational exposure of seed treatment workers. Exposure to large amounts of lindane can harm the nervous system, producing a range of symptoms from headache and dizziness to seizures, convulsions and more rarely death. Prenatal exposure to β-HCH has been associated with altered thyroid hormone levels and could affect brain development (Wikipedia, 2011; http://en.wikipedia.org/wiki/Lindane).

When Lindane is used in agriculture, an estimated 12-30% of it volatilizes into the atmosphere, where it is subject to long-range transport and can be deposited by rainfall. Lindane in soil can leach to surface and even ground water and can bioaccumulate in the food chain. However, biotransformation and elimination are relatively rapid when exposure is discontinued. Most exposure of the general population to Lindane has resulted from agricultural uses and the intake of foods, such as produce, meats and milk, produced from treated agricultural commodities (Wikipedia, 2011; http://en.wikipedia.org/wiki/Lindane).

Aldrin ($C_{12}H_8Cl_6$)

Aldrin ($C_{12}H_8Cl_6$) is an organochlorine insecticide that was widely used until the 1970s, when it was banned in most countries. It is a colourless solid. Before the ban, it was heavily used as a pesticide to treat seed and soil. Aldrin and related "cyclodiene" pesticides became notorious as persistent organic pollutants.



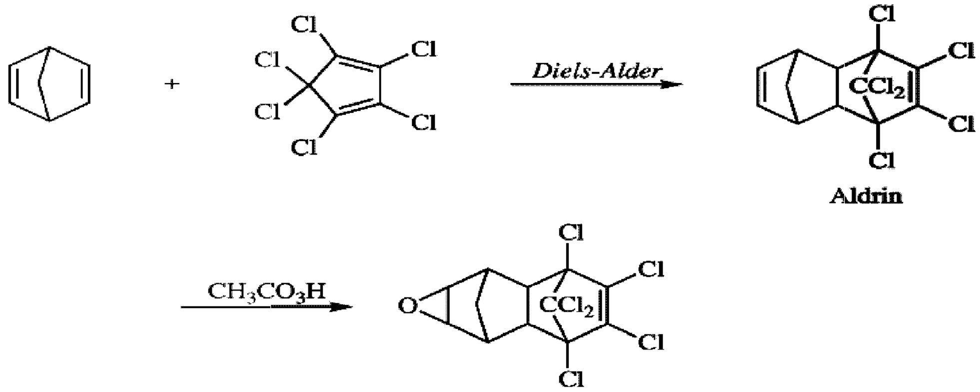
Structure of Aldrin

Aldrin has a rat LD_{50} of 39 to 60 mg/kg. Like related polychlorinated pesticides, aldrin is highly lipophilic and its solubility in water is only 0.027 mg/L, which exacerbates its persistence in the environment. It was banned by the Stockholm Convention on Persistent Organic Pollutants in 2009 (Wikipedia, 2011; http://en.wikipedia.org/wiki/Aldrin).

Dieldrin ($C_{12}H_8Cl_6O$)

Dieldrin ($C_{12}H_8Cl_6O$) is a chlorinated hydrocarbon and is closely related to aldrin, which reacts further to form dieldrin. Aldrin is not toxic to insects; it is oxidized in the insect to form dieldrin which is the active compound. However, it is an extremely persistent organic pollutant; it does not easily break down. Furthermore it tends to biomagnify as it is passed along the food chain. Long-term exposure has proven toxic to a very wide range of animals including humans, far greater than to the original insect targets. For this reason it is now banned in most of the world (Wikipedia, 2011; http://en.wikipedia.org/wiki/Dieldrin).

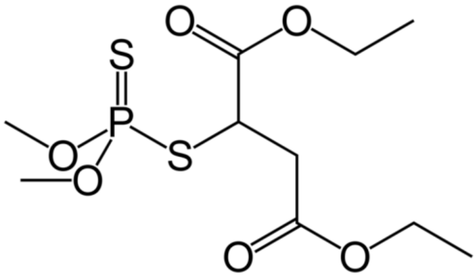
It can be formed from the synthesis of hexachloro-1,3-cyclopentadiene with norbornadiene in a Diels-Alder reaction, followed by epoxidation of the norbornene ring.



Structure of Dieldrin

Malathion

Malathion is an organophosphate compound which binds irreversibly to cholinesterase. Malathion is an insecticide of relatively low human toxicity. However, recent studies have shown that children with higher levels of malathion in their urine seem to be at an increased risk of attention deficit hyperactivity disorder. (http://en.wikipedia.org/wiki/Malathion).



Structure of Malathion

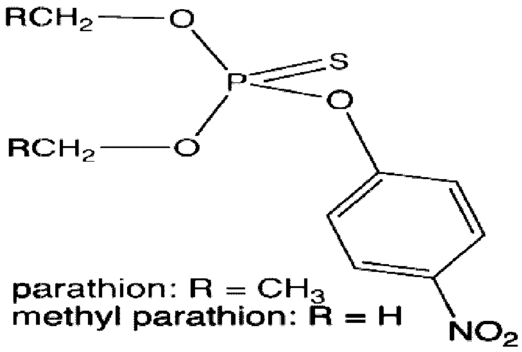
Malathion is a pesticide that is widely used in agriculture, residential landscaping, public recreation areas, and in public health pest control programs such as mosquito eradication. Malathion in low doses (0.5% preparations) is used as treatment for *Head lice, Body lice, Scabies.* Absorption or ingestion of malathion into the human body readily results in its metabolism to malaoxon, which is substantially more toxic. (http://en.wikipedia.org/wiki/Malathion)

Malathion should be used in well-ventilated rooms; lack of proper ventilation can seriously poison the occupants living or working in this environment. A possible concern is that malathion being used in an outdoor environment could enter a house or other building.

Parathion

Parathion, also called parathion-ethyl or diethyl parathion, is an organophosphate compound. It is a potent insecticide and acaricide. It is highly toxic to non-target organisms, including humans. Its use is banned or restricted in many countries, and there are proposals to ban it from all use. Parathion is generally applied by spraying. The usual concentrations of ready-to-use solutions are 0.05 to 0.1% (http://en.wikipedia.org/wiki/Parathion).

Parathion acts on the enzyme acetylcholinesterase, but indirectly. After being ingested by insects (and unintentionally, by humans), parathion is oxidized by oxidases to give paraoxon, replacing the double bonded sulfur with oxygen. (http://en.wikipedia.org/wiki/Parathion).



Structure of Parathion

Parathion is a cholinesterase inhibitor. It generally disrupts the nervous system by inhibiting the acetylcholinesterase. It is absorbed via skin, mucous membranes, and orally. Absorbed parathion is rapidly metabolized to paraoxon. Parathion has been used as a chemical weapon, and is very toxic to bees, fish, birds, and other forms of wildlife. Parathion can be replaced by many safer and less toxic alternatives (http://en.wikipedia.org/wiki/Parathion).

2.3.2 Pesticide Concentrations in Different Environmental Media

In Water: The most commonly monitored pesticides in the rivers of the Ganga river basin were hexachlorocyclohexane (HCH or Lindane), DDT and its products (DDD and DDE), and endosulfan. The earliest publication was in 1986 when DDT concentrations were measured in water samples from R. Yamuna. Total DDT concentrations were 0.24 micro-g/L (Pillai, 1986). Subsequent studies found average concentrations of total HCH and total DDT to be 245 and 247 parts per trillion (pptr or ng/L), respectively and endosulfan concentration was 38.3 ng/L (Agnihotri et al., 1994). A summary of pesticide concentrations reported in various publications is provided in Table 4 to Table 6.

Insecticide residues were found in Ganga river water near Farrukabad, India and the average concentration of *Aldrin* was more than that of *Dieldrin*. *Aldrin* residues often exceeded the World Health Organization (WHO) guideline value for drinking water, and the concentration of heptachlor occasionally exceeded the specified limits as well (Agnihotri et al., 1994).

Water samples were collected from 34 locations in Varanasi along R. Ganga and analyzed for DDT, HCH and endosulfan residues. Of the studies reported here, pesticide concentrations in this study were the highest with 12.9, 13.1 and 10.65 micro-g/L of total DDT, HCH and endosulfan, respectively. All these pesticides are capable of accumulating in the food chain of the river (Nayak et al., 1995). The authors suggest that pesticide levels were higher on the city-side of the river as compared to the cultivated side (opposite bank).

Residues of organochlorine pesticides (OCPs) namely, isomers of HCH and endosulfan, DDT and its metabolites, aldrin, and dieldrin were analysed in river Yamuna water along its stretch passing through Haryana and Delhi and the canals originating from it. The concentration of HCH and DDT at different sites along the river ranged between 12.76 – 593.49 ng/L (with a mean of 310.25 ng/L) and 66.17–722.94 ng/L (with a mean of 387.9 ng/L), respectively. In canals, the values were found between 12.38 – 571.98 ng/L and 109.12 – 1572.22 ng/L for HCH and DDT, respectively (Kaushik et al., 2008).

In a similar study, pesticides were analysed in water samples from the river Ghaggar in Haryana. Analysis showed that aldrin and dieldrin were below detection limits. Both, hexachlorocyclohexane (HCH) and dichloro-diphenyltrichloroethane (DDT) were traceable in all the water samples. High concentration of β-HCH among Total HCH indicates old pollution source whereas predominance of p,p-DDT among total DDT reflects its recent use in the catchment area of the river (Kaushik et al., 2010).

Pesticide residues were detected in River Ganga water between Kachla and Kannauj, U.P, India. Some pesticides like DDT, α-BHC, DDD, Aldrin, Dieldrin, were present in the concentration ranges of 3.33 - 5.33 ppb (or micro-g/L), 1.73 - 3.01 ppb, 0.88 - 2.41 ppb, 0.49 - 4.11 ppb. Organophosphorous pesticides like dimethoate and methyl parathion were also detected at concentration levels of 0.41-0.56 ppb and 0.16-0.50 ppb (Rehana et al., 1995).

Organochlorine pesticides were reported in the waters of Gomti river. Total OCPs residues ranged between 2.16 and 567.49 ng/L. It is suggested that the source of DDT contamination is from aged and weathered agricultural soils with signature of recently used DDT in the river catchments. (Malik et al., 2009).

Sewage water in Kolkata was evaluated for pesticides and heavy metals along with other water quality parameters in a detailed three-season study (Purkait et al., 2009). Total DDT, total HCH and total organophosphates were detected in all three seasons and the five locations that were sampled. Average (spatial) total pesticide concentrations ranged between 37 to 38.4 ng/L over the three seasons.

In Sediments of River and Marine Environments: The levels of 16 priority polycyclic aromatic hydrocarbons (PAHs) were identified during pre-monsoon, monsoon and post-monsoon seasons in sediments collected from the banks of River Yamuna, Delhi. The sum of 16 PAH compounds ranged from 4.50 to 23.53 µg/g with a mean concentration of 10.15 ± 4.32 µg/g (dry weight) (Agarwal et al., 2006).

Soil and surface water of the northern Indo-Gangetic alluvial plains region were found to be severely contaminated with several persistent organic pesticides. In samples collected in the Unnao district in the area between the rivers Ganga and Sai, β and δ- isomers of HCH were detected most frequently, whereas, methoxychlor was the least detected pesticide. The total OCPs level ranged from 0.36–104.50 ng/g and 2.63–3.72 µg/L in soil and surface water samples, respectively (Singh et al., 2007).

Organochlorine pesticide residues (OCs) such as hexachlorocyclohexane isomers (HCHs), dichlorodiphenyltrichloroethane and its six metabolites (DDTs), and hexachlorobenzene (HCB) have been found in sediment cores of Sunderban Wetlands in the Northeastern Part of Bay of Bengal, India. The pooled mean values of the mass fraction of ΣHCHs, ΣHCB, and ΣDDTs in the sediments were 0.05 – 12, 0.05 – 1.4, and 0.05 – 11.5 ng/g dry weight, respectively (Sarkar et al., 2008b).

Samples were collected and analyzed to determine the distribution of persistent organochlorine pesticide residues in bed sediments of Gomti river. Organochlorine pesticides were reported in sediments of Gomti river and ranged between 0.92 and 813.59 ng/g. The bed sediments of Gomti river were contaminated with Lindane, Endrin, Heptachlor epoxides and DDT (Malik et al., 2009).

In Biotic Environment: Organochlorine pesticides were reported in fish samples collected from Gomti river with concentrations ranging between 2.58 – 22.56 ng/g. Neither spatial nor temporal trends could be observed in the distribution of the OCPs. Aldrin was the predominant OCP, whereas, HCB and methoxychlor could not be detected. α-HCH and β-HCH among the isomers of HCH and p,p-DDE among the metabolites of DDT were the most frequently detected OCPs (Malik et al., 2007).

In Humans: Humans are exposed to various environmental chemicals such as Organo-Chlorine pesticide residues, etc. It is reported that organochlorine residues are present in blood of North Indian People. Analysis of maternal and cord blood samples of a normal person revealed the presence of organochlorine pesticide residue, mostly HCH followed by Endosulfan, DDE and DDT (Pathak et al., 2008).

In summary, it is evident that significant and detectable concentrations of commonly used pesticides like DDT and HCH which are considered persistent contaminants were found in most studies. While their concentrations in river water samples were below the permissible Indian standards for drinking water, they pose a risk to human health due to their potential for bioaccumulation. The high concentrations noted in fish tissue in various studies highlight food rather than water as a major route of exposure to these contaminants. A comprehensive health risk assessment can be done for pesticides that would account for all routes of exposure and the risks associated with exposure.

Table 4: Pesticide concentrations in water samples collected from Ganga River basin

S No.	River	∑ DDT	∑ HCH	∑ Endosulfan	Aldrin	Diedrin	2, 4-D	Heptachlor	∑OCPs	Malathion	Dimethoate	Methyl Parathion	∑OC+OP	Season	References
1	Yamuna	240	-	-	-	-	-	-		-	-	-			Pillai. M.K.K, 1986
2	Ganga	-	-	ND	-	-	-	-	<100	-	-	-			Sengupta et al, 1989
3	Ganga	247.2	244.6	38.3	25.6	12.7	-	36.7		-	-	-			Agnihotri et al, 1994
4	Ganga	12940	13144	10650	-	-	-	-		-	-	-			Nayak et al, 1995
5	Ganga	3074	1930	250	-	1753	ND	-		-	486.6	383.3			Rehana et al, 1995
6	Ganga	1460	-	ND	-	410	30	-		-	200	410			Rehana et al, 1996
7	Ganga	ND	(γ) 259	ND	ND	-	-	-		2658	-	ND			Shankararamak rishnan et al, 2005
8	Between Ganga and Sai	8	60	7	-	ND	-	4	90	-	-	-			Singh et al, 2007
9	Yamuna	506.74	191.34	-	-	-	-	-		-	-	-			Kaushik et al, 2008
10	Gomti								113.02 ±	-	-	-			Malik et al, 2009
11	Ganga	16.536	7.518	-	-	-	-	-		-	-	-	38.038	Summer	Purkait et al, 2009
12	Ganga	15.982	7.736	-	-	-	-	-		-	-	-	37.12	Winter	Purkait et al, 2009
13	Ganga	16.584	6.868	-	-	-	-	-		-	-	-	38.412	Monsoon	Purkait et al, 2009
14	Kuano	0.45-2	0.145-1	-	-	-	-	-		-	-	-			Singh et al, 2009
15	Ghaggar		119.74 ± 76.54	587.3 ± 201.18	-	-	-	-		-	-	-			Kaushik et al, 2010

Cells with dashes indicate pesticide was not monitored.

ND = Not detected

Table 5: Pesticide Concentrations in Sediments of Ganga River Basin

River	∑DDT	∑HCH	Endosulfan	Heptachlor	∑PAHs	HCB	References
	ng/l	ng/l	ng/l	ng/l	ng/l	ng/l	
Yamuna	240	-	-	-	-	-	Pillai. M.K.K: 1986
Ganga	0.875	6.96	-	-	-	-	Hans et al, 1999
Yamuna	-	-	-	-	10150	-	Agarwal et al, 2006
Between Ganga & Sai rivers	13.81	1.65	0.23	0.25	-	0.060	Singh et al, 2007
River Hooghly	0.05-11.5	0.05-12	-	-	-	0.015-1.4	Sarkar et al, 2009
Sunderbans	1.71	2.87	-	-	575.8	0.247	Binelli et al, 2008

Table 6: Pesticide concentrations in fish tissue samples from Ganga river basin

River	Tissue	∑DDT	∑HCH	Endosulfan	Dimethoate	Malathion	∑OCPs	Season	References
		ng/l	ng/l	ng/l	ng/l	ng/l	ng/l		
Gomti	Fish Tissue						9.66 ±5.6		Malik et al, 2007
Ganga	Cat Fish	7582.68	3061.12	-	-	-	-		Singh et al, 2008
	Carp Fish	3338.9	1360.243	-	-	-	-		
Gomti	Cat Fish	5891.633	3536.726	-	-	-	-		Singh et al, 2008
	Carp Fish	2018.19	2428.28	-	-	-	-		
Ganga	Fish Tissue	78.4	985.2	286.4	390	10.4		Season 1	Akthar et al, 2009
		276.4	1174.4	353.6	349.6	1000		Season 2	
		905.8	1166.4	746.4	823.2	784.8		Season 3	

2.4 Conclusions

- Pesticide contamination poses significant risks to the environment and non-target organisms range from beneficial soil microorganisms to insects, plants, fish, birds and humans.
- A limited number of studies have been conducted in the last three decades in Ganga river basin where pesticide concentrations have been monitored in various environmental media. In general, total DDT and total HCH concentrations have been reported in detectable and significant concentrations by most researchers.
- Pesticide levels in water samples from the Ganga River basin ranged from non-detectable to a maximum total pesticide concentration of 13.1 micro-g/L in the city of Varanasi. Only four of the fifteen studies reviewed here showed total pesticide concentrations higher than the permissible levels of 1 micro-g/L.
- Pesticide levels in sediments ranged from 0.05 ng/g to 240 ng/g.
- Significant and high pesticide levels have been reported in fish tissue with maximum total DDT concentration of 7.5 micro-g/g in cat fish and maximum total HCH concentration of 3.5 micro-g/g in cat fish. These results indicate that pesticides like DDT and HCH bioaccumulate to significant levels in fish tissue. Health risks associated with these levels of pesticides in food need to be examined in greater detail.
- In order to control water pollution by these substances, domestic and industrial wastes (both solid and liquid) should not be allowed to be discharged/dumped into water bodies without proper pretreatment.
- Further, constant monitoring and analysis for the most commonly used pesticides in all environmental media by appropriate agencies is essential for a comprehensive risk assessment.

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