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Downward mobility of lindane and endosulfan in soils of indo-gangatic plains of Uttar Pradesh, India

Sanjay Kumar Singh, Priyankar Raha, Sanjay Tiwari and Pankaj Singh

Abstract

The downward movement and distribution pattern of lindane and endosulfan in different agricultural soils of Uttar Pradesh, India consisting diverse nature of physico-chemical properties were estimated. The pH of soil ranged from 6.6 to 9.8 indicated that neutral to alkaline in reaction belonging to major textural group viz. sandy loam as well as sandy clay loam and loamy sand. The study showed the maximum retention of lindane and α & β isomers of endosulfan were noticed maximum in different textural group of soils up to 10cm soil column. The recovered amount of lindane fortified soils of Uttar Pradesh were 88.63, 79.02, 84.42, 81.77, 80.16 and 84.79 percent whereas, 89.73, 90.18, 94.39, 87.11, 89.33 and 90.68 of α - isomer and 90.80, 91.33, 92.17, 89.70, 90.27 and 92.12 of β - isomers of endosulfan in Varanasi, Basti, Chandauli, Azamgarh, Mirzapur & Banda soils respectively. The percentage of lindane and α and β isomers of endosulfan effluents received varied from 19.4 to 11.33 and 11.5 to 9.3 and 10.4 to 7.78 percentage. It was also noted that the soil parameters mainly organic matter and high clay content of the tested soil significantly restrict the lower movement of pesticides in soils. The adsorption and limited leaching of pesticides particularly in soil with high organic matter content is indicative of potential of the chemical to undergo limited leaching through soil profile hence reducing the risk of ground water contamination.

Keywords: Gas chromatograph, organic matter, movement, soil properties

Introduction

The indiscriminate and excessive use of pesticides has aroused concern on the fate of pesticide in soil and possible side effect on microbial communities and ground water quality. Persistence Organic Pollutants (POPs) are a series of chemicals that are toxic, persistence in the environment for the long period of times and bio-magnification as they entered through the food chain. The fate of pesticides is mainly determined by chemical characteristics and soil properties, (Pignatello, 1989) ^[37] affecting the mobility, persistence, bioactivity, toxicity and efficacy of pesticides in the soil environment (Becker *et al.*, 2011) ^[8]. It refers to association of molecules at the solid-fluid interface. India is one of the largest consumers of pesticides in South Asia (Agnihotri, 1999) ^[1] and extensively utilizes pesticides viz. endosulfan (1,2,3,4,7,7-hexachlorobicyclo(2.2.1)-2-heptene-5,6-bisoxymethylenesulfite) used all over the world, since 1954 when it was first brought for the commercial use (Maier-Bode, 1958) ^[28]. Organochlorines (OPs) represent an important group of POPs which have caused worldwide concern as toxic environmental contaminants (Devid *et al.*, 2011) ^[11]. Commercial endosulfan is synthesized as a mixture of two isomers approximately 70% α -endosulfan and 30% β -endosulfan which was used to control various pests in fruits, vegetables and other agricultural commodities. Due to its hydrophobic nature, endosulfan tends to get adsorbed to soil particles as because it has long persistence in the environment (Leung *et al.*, 1998) ^[25]. Endosulfan gets low degradation and often altered into endosulfan sulphate which an oxidative metabolite known to be as toxic and get persistent as the parent compound. The persistence of the residues of endosulfan that cause pollution in soil is dependent on various factors like soil type, soil particle size, rainfall etc. Under anaerobic conditions, the half-life of endosulfan in water is reported to be 1-6 months (ASTDR, 2000) and in soils the longevity of α , β and total endosulfan under aerobic conditions has been reported ranging between 12-39, 108-264 and 288-2241 days respectively (GFEA-U, 2007) ^[14].

Lindane is the γ -HCH isomers (>99% pure) and its technical grade, HCH are banned from use in a number of countries and restricted in several others (Bintein and Devillers, 1996) ^[9].

Lindane is a persistence organochlorine compounds that is widely distributed in the environment with a long half-life in various environmental compartments (simonich and Hites, 1995) [47]. It will stay on the upper layer of the soil and generally there very little movement of lindane and other HCH isomers to lower soil layers (Martijn *et al.*, 1993) [30].

The adsorption rate and adsorption capacity of endosulfan exhibited highest in organic matter rich soil that retarded the downward movement whereas, it was the least for sandy soil (Rama Krishna and Philip, 2008; Ahmad, 2019) [42, 1].

Endosulfan (α and β isomers) distribution in soil column is greatly important pertaining to its influence on crops and ground water contamination. Information on possible movement and distribution of endosulfan (Peterson and Batley, 1993) [36] in soils is useful in order to know the probable effectiveness of the chemical and its influence on quality of ground water.

In this study, we focused on studying movement mechanisms of endosulfan and lindane on six types of soils to quantify the transport of pesticides which may threat to drinking water quality. The organic matter, particle size as well as pH are important soil attributes for sorption of endosulfan in soils has been emphasized by many workers (Kumar, M. and Philip, L

2006; Laura *et al.*, 2011; Ayse *et al.*, 2009) [21, 23, 5]. The detection of organochlorine insecticides in surface and ground water and different other environmental components in Uttar Pradesh (Nayak *et al.*, 1995; Raha *et al.*, 1999; Raha *et al.*, 2003) [34, 40, 41] has brought attention to the studies the mechanism of vertical movement of endosulfan and lindane and their distribution in six different kind of soils of Uttar Pradesh with a view to ascertain the probability of its potential polluting the ground and surface water.

Materials and Methods

Chemicals: Endosulfan is a contact insecticide used worldwide in a variety of vegetables crops, fruits, cereals and tobacco (Antonius and Bayers, 1997) [3]. Technical grade of endosulfan consisting two isomers viz. α -endosulfan and β -endosulfan contains 7/3 ratio (Kennedy *et al.*, 2001) [20]. The analytical grade (98.9%) endosulfan used in this study was obtained from Indo Gulf Fertilizers and Chemicals Corporation Limited, Sultanpur, U.P. Analytical grade (98.9%) of lindane was received from Kanoria Chemicals Ltd., Renukot (U.P). All chemicals and solvent were used of analytical reagent grade and the reagents redistilled prior to use.

Table 1: The physical and chemical properties of soil.

	Endosulfan	α -endosulfan	β -endosulfan	Lindane
Empirical formula	C ₉ H ₆ Cl ₆ O ₃ S	C ₉ H ₆ Cl ₆ O ₃ S	C ₉ H ₆ Cl ₆ O ₃ S	C ₆ H ₆ Cl ₆
Molecular weight	406.95	406.93	406.93	290.85
Solubility in water (25 ⁰ C) μ g/L	60 to 100	530	280	7.3
Partition coefficient K _{ow}	3.55	3.83	3.52	-
Vapour pressure (25 ⁰ C) mmHg	1x10 ⁻⁵	1x10 ⁻⁵	1x10 ⁻⁵	95

Source: ATSDR (2000)

Soils

Five soil samples were collected from agriculture fields of various locations of Uttar Pradesh (Fig-1) which is already well defined soil group (Pathak and Sharma, 1985) [35]. The surface soil samples were collected randomly from 0-15 cm depth, air dried, ground and passed through a 2 mm sieve. The physico-chemical properties of soil were determined by prescribed standard Procedure (Black, 1965; Piper, 1951) [7]

[38]. The soil texture was determined and textural classes were classified based on sieve analysis method as per American Society for Testing and Materials (ASTM) standard. The surface area of soil was determined by modified ethylene glycol retention techniques and free iron and aluminium oxide was estimated calorimetrically. The properties of different type of soils were employed in the present study are given in (Table 2).

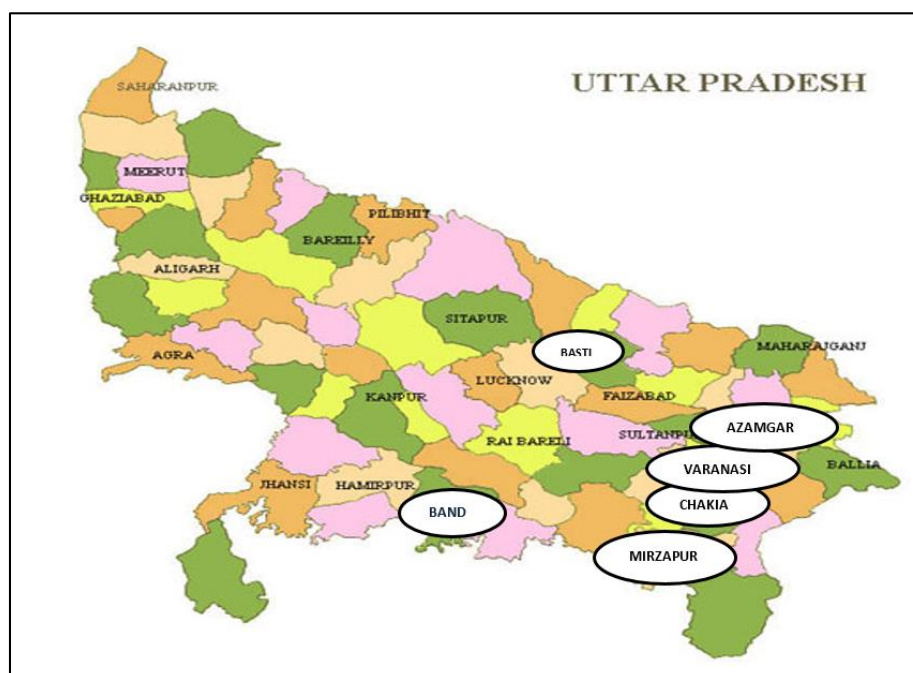


Fig 1: Map of Uttar Pradesh and soil sampling locations.

Mobility Studies in Column

The endosulfan and lindane leaching study was carried out in different soils using soil column in the laboratory. The soil column were constructed by using plastic tube (P.V.C) having internal diameter 1.8cm and the lower end of the each tube was fitted with glass to collect the effluent. The glass wool was plugged at the bottom of column and then, PVC column were filled in triplicate with 50g of processed soils having different bulk densities by constant tapping in order to pack the column to a constant volume. Prior to applying lindane and endosulfan, the soil columns were saturated with distilled water. Pesticide downward mobility in all the soils was measured by dispensing 5ml of each pesticide solutions ($500\mu\text{g ml}^{-1}$ lindane and $200\mu\text{g ml}^{-1}$ of endosulfan) to each column from burette on the surface of the soil column. The vertical movement of pesticides in the six different soils was determined in column as per standard method described by (Saeed *et al.*, 1997) [45].

Extraction of Pesticide from Soils

Pesticide from soil samples used for movement studied were extracted using standard solvent with liquid-liquid partition methods. The concentration of lindane and endosulfan was determined in the decanted after centrifugation and the effluents collected earlier during movement study. Samples were transferred into separatory funnel to which added n-hexane and shaken for one minute and allowed it to separate sufficient distilled water was added to facilitate partitioning of residues into hexane portion. In the partitioned liquid, the

hexane portion filtered and passed through anhydrous sodium sulfate to eliminate the moisture content present in aliquot. The process was repeated thrice in same manner and pooled n-hexane was concentrated to reduced volume (5ml) using rotary evaporator and the water leachate samples was also separated in same manner. The clean organic samples were taken for analysis in Gas Liquid Chromatography equipped with electron capture detector.

Pesticides Analysis

Samples of endosulfan and lindane were analyzed using Hewlett Packard 5890 A gas chromatograph with electron capture detector equipped with a HP 3392 A integrator. An on-column, split/split less capillary injection system and capillary column for analysis was as follow: 1.8 m \times 2 mm I.D. glass packed with DC-200, W.H.P. (80-100 mesh) column; oven 200 °C, injector 210 °C, detector 300 °C and carrier gas, N₂ flow rate 70 mL min⁻¹. During the analysis, it was held initially at a temperature of 130 °C for 1 minute, then the temperature was at a rate of 10°C/min. to 200 °C and held at 200 °C for 11 min. The injections were made in the split mode with a split ratio 1:20. Peaks were identified on the integrator by retention times.

Results and Discussions

Soil Analysis: Soil samples were collected from six different locations of Uttar Pradesh in respect to their physico-chemical properties mentioned in (Table 2).

Table 2: Physico-chemical properties of soil used for mobility study

Soil Properties	Soil Locations					
	Varanasi	Chandauli	Basti	Azamgarh	Mirzapur	Banda
Soil Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy clay loam	Loamy sand
Sand (%)	60.2	62.7	69.1	72.5	48.8	76.5
Silt (%)	22.8	23.7	12.4	20.0	28.6	13.5
Clay (%)	17.0	13.0	18.5	7.5	21.6	10.0
Organic matter (g kg ⁻¹)	3.5	7.0	4.3	1.8	2.8	8.3
CEC [Cmol(P ⁺) kg ⁻¹]	9.3	17.1	16.6	7.5	9.5	13.8
CaCO ₃ (%)	0.98	2.0	2.3	40.0	1.0	15.5
Surface area (m ² g ⁻¹)	178.75	163.37	187.61	102.71	157.15	163.54
EC (d S m ⁻¹)	0.11	0.34	0.41	1.08	0.20	0.21
pH	7.7	6.6	8.2	9.8	7.6	8.4

The soil pH analyzed in all soil samples ranged from 6.6 to 9.8 and the highest soil pH (9.8) was recorded in sample collected from Azamgarh followed by Basti (pH 8.2) indicating slightly alkaline in nature, which also reflected lowest organic matter and clay content however, CaCO₃ content (40%) was noticed highest with Azamgarh soil in comparison to rest of the soils given in (Table 2). The organic matter content ranged from 1.8 to 8.3 gkg⁻¹, where low organic matter content indicating, the higher in soil pH and CaCO₃ (Battacharya *et al.*, 2004) [6]. Textural classes of Varanasi, Chandauli, Basti and Azamgarh soils were classified on the basis of mechanical analysis as sandy loam which contained maximum 18.5 and minimum 7.5 percent clay whereas, Mirzapur and Banda soils were classified as sandy clay loam and loamy sand the clay content which occupied 21.6 and 10.0 percentage clay among the soil separates. The pH of Varanasi, Chandauli and Mirzapur soil noticed slightly acidic to neutral in reaction. The Banda and Chandauli soils were found richer in organic matter and moisture content and pH reflected neutral to slightly alkaline in nature. The properties of soils (Table 2) showed high

surface area (187.61 m²g⁻¹) in Basti soil followed by 178.75 m²g⁻¹ in Varanasi soil compared to other kind of soils. The soil attributes viz. organic matter and clay content is important concern to permit the movement of lindane, α and β isomers of endosulfan in the lower depth of soil column. The CEC of soils were ranged from 7.5 to 17.1 (Cmol (P⁺) kg⁻¹) which influenced by quantity of clay and organic matter. The maximum CEC of soil was associated with of Chandauli and Basti reflected high CEC (17.1 and 16.6 [C mol (P⁺) kg⁻¹]) followed by other examined soils.

Pesticide Movement Studies in Soil

The pesticide movement and adsorption in soil is affected by diversified properties in which soil organic matter is the principal adsorbent for many non-ionic organic compounds (Chiou *et al.*, 1979; Mader *et al.*, 1977; Xing and Pignatello, 1996) [10, 27, 55]. Lindane and endosulfan is nonionic, non-polar hydrophobic compound and thus, weak attractive interaction such as Vander Waals forces is the dominant forces of attraction in case of the adsorption of lindane, α and β isomers of endosulfan on soil surface and there is reason to

believe that the exchange complex of inorganic clays in soils played little in its adsorption. Downward movement of pesticide through soil column is important to determine their efficacy as well as their potential for crop damage and environmental pollution (Mersie and Foy, 1986) [31]. Endosulfan is less soluble; its absorption in soil is relatively high which possibly check to downward mobility in soil. The lindane, α and β isomers of endosulfan movement study was carried out with different soils containing diversified physico-chemical properties in the packed soil column, the distribution of pesticides were obtained throughout the column and even found their presence in the lower most soil core. Few quantities of pesticides viz. lindane α and β isomers of endosulfan residues were also detected in leachate fractions in types of soil (Fig. 2-7) where, maximum quantity of chemical was obtained within the 10 cm depth of soil. The range of adsorption of α & β isomers of endosulfan in Uttar Pradesh soils was noticed 63 to 86% by Singh *et al.*, (2012) [48]. The complete downward mobility of the chemicals through the soil column was not observed in all examined soils. The highest amount of insecticide leachates were obtained lindane,

α and β isomers of endosulfan in both, Azamgarh and Mirzapur soils followed by other soils might be due to reduced content of organic matter (Table 2). The adsorption and limited leaching of pesticides particularly in soil with high organic matter content is indicative of potential of the chemical to undergo limited leaching through soil profile hence reducing the risk of ground water contamination reported by Sinnakkannu *et al.*, (2005) [50]. The higher quantity of lindane leachates was noticed in Varanasi soil whereas, Banda soil obtained minimum quantity of α and β isomers of endosulfan in leachates showed in (Fig 2-7). The leachates of α and β - endosulfan was detected in leachate in descending order Azamgarh > Mirzapur > Varanasi > Basti > Chandauli > Banda soil respectively. Similarly, the lindane obtained in leachates in order to Azamgarh, Mirzapur, Banda, Bastia ns Varanasi respectively. The maximum retention of lindane concentration noticed in different textural group of soils upto 10cm soil column depth. The similar finding was also observed by.

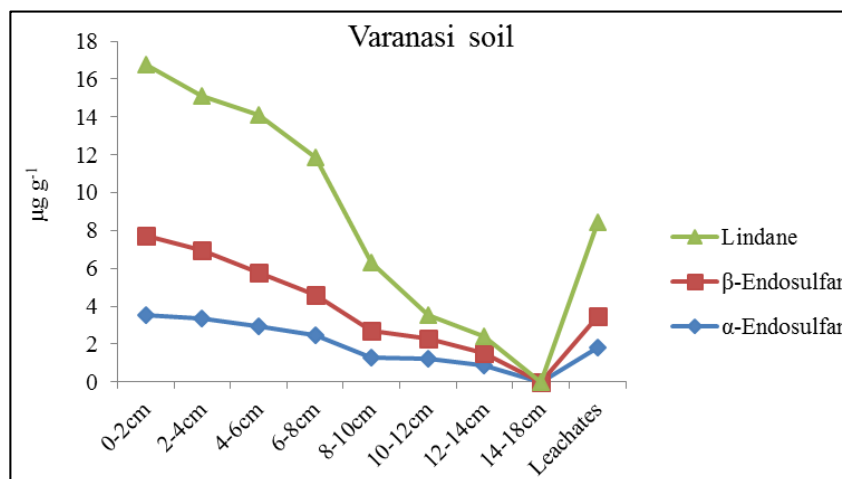


Fig 2: Mobility of Lindane and Endosulfan (α and β) in Varanasi soil at different depth

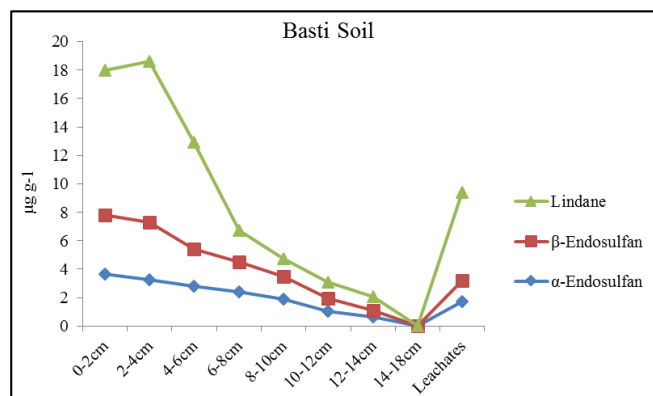


Fig 3: Mobility of Lindane and Endosulfan (α and β) in Basti soil at different depth

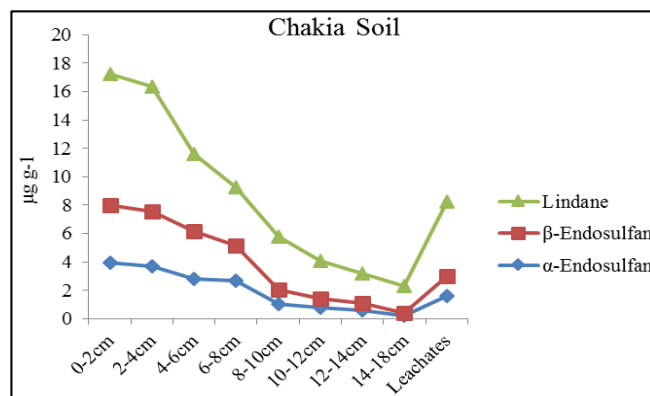


Fig 4: Mobility of Lindane and Endosulfan (α and β) in Chakia Soil at different depth

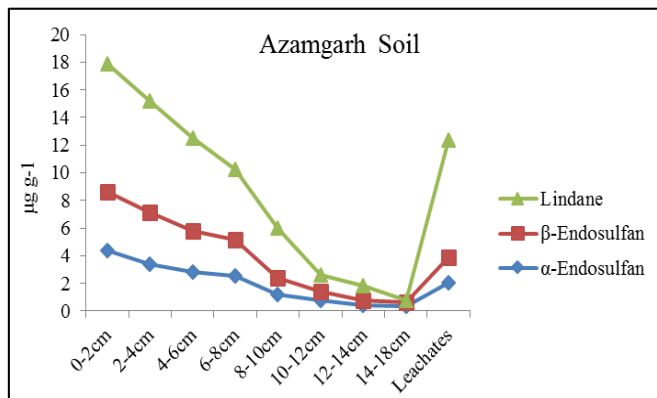


Fig 5: Mobility of Lindane and Endosulfan (α and β) in Azamgarh soil at different depth

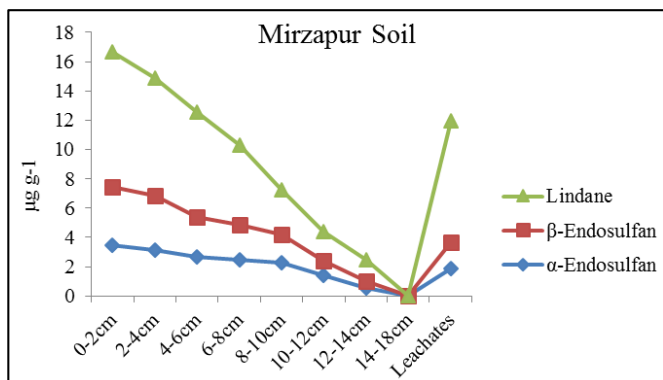


Fig 6: Mobility of Lindane and Endosulfan (α and β) in Mirzapur soil at different depth

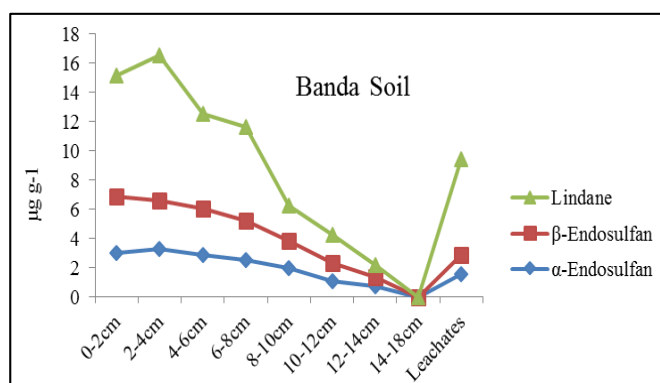


Fig 7: Mobility of Lindane and Endosulfan (α and β) in Banda soil at different depth

Shivaramaiah (2014) [46]. The higher concentration of lindane retention was observed in Varanasi soil (36.3 mg kg^{-1}) followed by Banda, Mirzapur, Azamgarh, Basti and Chandauli soils respectively. The order of adsorption of lindane in soil is directly proportional to the organic matter content (Singh *et al.*, 2013) [49].

The recovered amount of lindane fortified soils of Uttar Pradesh were 88.63, 79.02, 84.42, 81.77, 80.16 and 84.79 percent whereas, 89.73, 90.18, 94.39, 87.11, 89.33 and 90.68 of α - isomer and 90.80, 91.33, 92.17, 89.70, 90.27 and 92.12 of β - isomers of endosulfan in Varanasi, Basti, Chandauli, Azamgarh, Mirzapur & Banda soils respectively. Results revealed that the downward movement of endosulfan in all soils and its observed scanty move beyond the 10 cm soil depth except in the Azamgarh soil could be explained in terms of higher sorption coefficients of pesticides (Lin *et al.*, 2009) [26]. Leaching behavior of pure grade lindane and endosulfan isomers were studied in various textural group of soil in pact columns which was drenched with 100 ml of water when lindane and endosulfan incorporated into the surface of soil, the mobility of pesticide behaved differently in each soil due to significant interaction between soil and elution contents. The distribution of endosulfan was recovered throughout the soil column is directly associated with physico-chemical behavior of soil and chemical nature of pesticides showed in Fig 2-7. The relative mobility of endosulfan in soil profile is influenced by their longevity are key indicators of the potential for contamination of drainage effluent and ground water by that chemical (Weber and Keller, 1994) [54]. In study, found that comparatively greater movement in both α and β isomers of endosulfan was in Azamgarh whereas slower mobility was noticed in Chakia soil conforming the greater affinity of chemicals on the soil particles which showed more adsorption. The percentage of lindane and α and β isomers of endosulfan effluents received varied from 19.4 to 11.33 and 11.5 to 9.3 and 10.4 to 7.78 percentage depicted in figure-8 & 9. The variation of effluents between lindane and the two isomers may be due to variations in water solubility. On the other hand, the quantity of lindane and endosulfan retention was observed in the upper domain (0-10cm) and subsequently it was noticed less amount below the 10cm of soil column. In case of lindane less leaches was received as because it got more distribution throughout the soil column. The movement of pesticides in lower soil depth increases with frequency of irrigation, increasing temperature accelerates the degradation of pesticides slowing their migration and large quantity of clay and organic matter in the soil reduce pesticide mobility (Martinez Vidal *et al.*, 1994) [29]. The movement of α - endosulfan in soil column was comparatively higher than β isomers of endosulfan due to less adsorption. The highest concentration of α and β isomers of endosulfan was found in Basti soil with 2cm (4.397 & $4.47 \text{ } \mu\text{g}^{-1}$) followed by Varanasi (3.516 & $4.224 \text{ } \mu\text{g}^{-1}$) and the lowest amount was found in each soil depth in Banda soil. Studies showed that the content of pesticides was associated maximum in surface soil and decreasing gradually with depth. Similar trends with regard to fraction of α and β isomers of endosulfan were identified in all types of soils which retained in experimental soils due to less solubility to non-ionic nature of chemicals having strong affinity with organics and clay content.

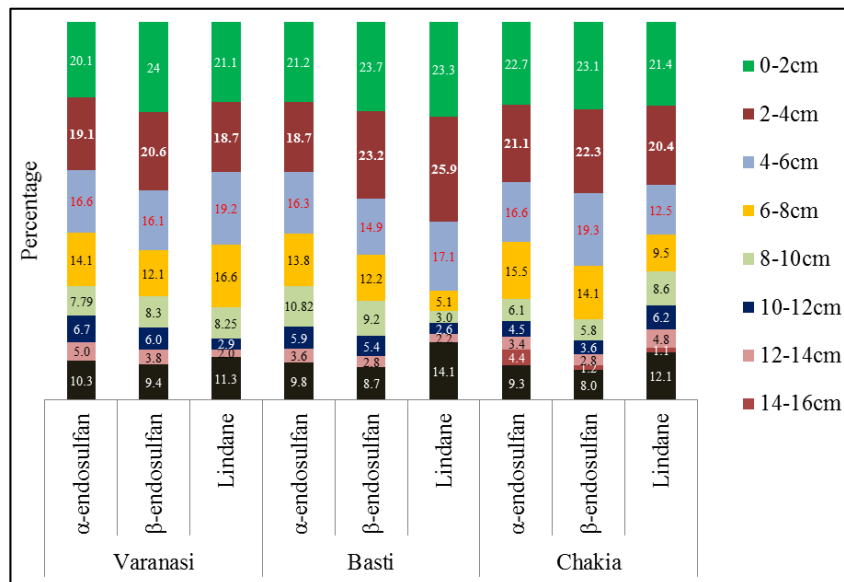


Fig 8: Distribution of Lindane and Endosulfan in soils of Uttar Pradesh

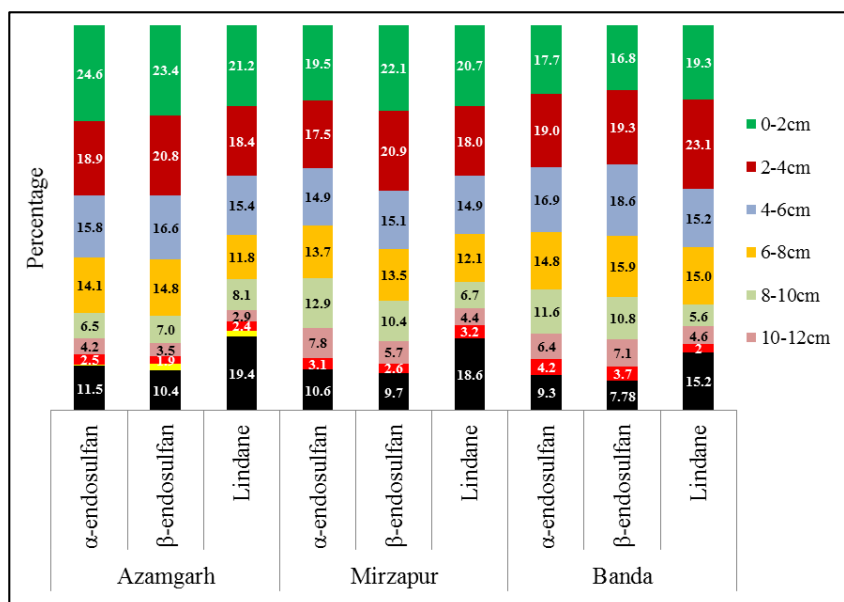


Fig 9: Distribution of Lindane and Endosulfan in soils of Uttar Pradesh

Several study of pesticide movement in soil columns have been carried out (Dousset and Mouvet, 1997; Mouvet *et al.*, 1997; Vereecken *et al.*, 1995) [12, 33, 52]. However, there have been little studies on the vertical migration of endosulfan, because it decomposes rapidly in soil and converted into other derivatives. The distribution of endosulfan along soil profile and amount of leachates obtained depending upon the rate of insecticide application and organic matter content (Mostafa and Shazad, 2010) [32]. This observation might be caused by the strong adsorption between pesticides and the test soils (Gua, *et al.*, 2003; Gibson, 2001) [16, 15].

Conclusion

The mobility of pesticide through the soil system and its persistency is the key indicator that made the potential contamination of surface and ground water. The study observed that the greater movement of lindane and α and β isomers of endosulfan was associated in the soil which contains less amount of organic matter and clay content. The poor mobility these pesticides was noticed in soil that conforming the higher adsorption in respective soils which obtained comparatively higher organic matter and clay

content. The degree of organic matter and clay content influenced the duration of pesticide accommodation in soil system. The presence of pesticide residues in studies soils is attributed to high persistence and accommodation for long period in soils. The continuous exposure of pesticides in the environment may contaminate of soil and ground water with these pesticide residues poses a significant health risk to the public from consuming potable water.

References

1. Agnihotri NP. Pesticide: Safety evaluation and Monitoring. All India Co-ordinated project (AICRP) on pesticide residues. Indian Agricultural Research Institute, New Delhi, India. 1999, 132-142.
2. Ahmad KS. Adsorption and removal of endosulfan through *Saccharum officinarum* derived activated carbon form selected soils. *Journal of Central south University*. 2019; 41:146-157.
3. Antonious GF, Bayer ME. Fate and Movement of Endosulfan under field conditions. *Environmental Toxicology and Chemistry*. 1997; 16:644- 649.

4. ASTDR. Toxicological Profile for Endosulfan. Agency of Toxic Substances and Disease Registry, Atlanta, USA. <http://www.atsdr.cdc.gov/toxprofiles/tp41.html>, 2000.
5. Ayşe DA, Ruhi M, Halil K, Faruk İ, Hüdaverdi A, Emel DA. Sorption of alpha and beta hydrophobic endosulfan in a Vertisol from southeast region of Turkey. *Chemosphere*. 2009; 74:1450-1456.
6. Bhattacharyya T, Pal DK, Chandran P, Mandal M, Ray SK, Gupta RK *et al.* Managing soil carbon stocks in the Indo-Gangetic Plains, India. Rice-Wheat Consortium for the Indo Gangetic Plains New Delhi, India; 2004; 44.
7. Black CA. Methods of soil analysis, part I., physical and Mineralogical properties, Including Statistics of measurement of sampling, No. 9 in the series Agronomy, American society of agronomy, 1965.
8. Becker L, Scheringer M, Schenker U, Hungerbühler K. Assessment of environmental persistence and long range transport of Endosulfan. *Environmental Pollution*. 2011; 159:1737-1743.
9. Bintein S, Devillers J. Evaluating the environmental fate of lindane in France. *Chemosphere*. 1996; 32:2427-40.
10. Chiou CT, Peters LJ, Freed VH. A physical concept of soil-water equilibria for nonionic organic compounds. *Science*. 1979; 206:831-832.
11. Devid AD, Anyakora C, Upko G, Adedayo A. Evaluation of the levels of organochlorine pesticide residues in water samples of Lagos Lagoon using solid phase extraction method. *Journal of Environmental Chemistry and Ecotoxicology*. 2011; 3:160-166.
12. Dousset S, Mouvet C. Leaching of Terbutylazine and Atrazine through laboratory soil columns. *C.R Academic Science Ser. Ila*. 1997, 325.
13. Fernandez MF. Human exposure to endocrine-disrupting chemicals and prenatal risk factors for cryptorchidism and hypospadias: a nested case-control study. *Environ Health Prospect*. 2007; 1:8-14.
14. GFEA-U. Endosulfan. Draft Dossier prepared in support of a proposal of endosulfan to be considered as a candidate for inclusion in the CLRTAP protocol on persistent organic pollutants. German Federal Environment Agency – Umweltbundesamt, Berlin. Gibson, http://www.agron.iastate.edu/courses/agron317/pigment_inhibitors.htm. 2007.
15. Gibson LR. *Agronomy 317. Principles of weed science: Herbicide mode of action*, http://www.agron.iastate.edu/courses/agron317/pigment_inhibitors.htm. 2001.
16. Guo J, Zua G, Shi J, Sun J. Adsorption, desorption and mobility of fomesafen in CHINESE Soils. *Water, Air and soil pollution*. 2003; 148:77-85.
17. Hartley GS, Graham-Bryce J. *Physical principals of pesticide behavior*. Academic press, London. 1980.
18. Helling CE. Pesticides mobility in soils. II Application of soil thin layer chromatography. *Soil Society of American Proceeding*. 1971; 35:737-743.
19. Jackson ML. *Soil chemical analysis*. Prentice hall of India Pvt. Ltd., New Delhi., 1973.
20. Kennedy IR, Sanchez-Bayo F, Kimber SW, Hugo L, Ahamad N. Off side movement of Endosulfan from irrigated cotton in new south wells. *Journal of Environmental Quality*. 2001; 30:683-696.
21. Kumar M, Philip L. Adsorption and desorption characteristics of hydrophobic pesticide endosulfan in four Indian soils. *Chemosphere*. 2006; 62:1064-1077
22. Lately J, Oddson JK. Mass transfer In: C.A.I. Goring and J.W. Hamaker (eds). *Organic chemicals in the soil environment*. Marcel Dekker, Inc. New York. 1972.
23. Laura JB, Bart VB, Andrea IS. Sorption of pesticide endosulfan by electro dialysis membranes. *Chemical Engineering Journal*. 2011; 166:233-239.
24. Leistra M. Transport in solution. In: R.J. Hance (ed.). *Interactions between herbicides and the soil*. Academic Press. Inc. London, 1980.
25. Leung AM, McDonough DM, West CD. Determination of endosulfans in soil/sediment samples from Point Mugu, Oxnard, CA, using capillary gas chromatography/mass selective detection (GC/MSD). *Environmental Monitoring and Assessment*. 1998; 50:85-94.
26. Lin K, Haver D, Oki L, Gang J. Persistence and sorption of fipronil and degradates in urban streams and sediments. *Environmental Toxicology and Chemistry*. 2009; 28:1462-1468.
27. Mader BT, Goss KU, Eisenreich SJ. Sorption of nonionic, hydrophobic organic chemicals to mineral surfaces. *Environmental Science and Technology*. 1977; 31:1079-1086.
28. Maier B. Properties, effects, residues and analytics of the Insecticide endosulfan. *Residue Review*. 1998; 22:1-44.
29. Martinez Vidal JL, Cervantes ocana D, Fernandez Alba AR, Aguilera A, Aguera A. Determination of Methan and Thiram in soils and vegetables Grown in Greenhouse. *Indian Journal of Environment Annals Chemistry*. 1994; 56:1-10.
30. Martijn A, Bakker H, Schreuder RH. Soil persistence of DDT, Dieldrin, and lindane over a long period. *Bulletin of Environmental Contamination and Toxicology*. 1993; 51:178-184.
31. Mersie W, Foy CL. Adsorption, Desorption and Mobility of Chlorsulfuron in soil. *J of Agriculture Food Chemistry*. 1986; 34:89-92.
32. Mostafa C, Sharifi S. Increase sorption Endosulfan by soil amendments and its effects on retention and leaching from soil. *World Congress of Soil Science, Brisbane, Australia, 2010*.
33. Mouvet C, Jeannot R, Riolland H, Maciag C. Stability of isoproturon, Bentazone Terbutylazine and Alachlor in natural groundwater, surface water and soil water samples stored under laboratory conditions. *Chemosphere*. 1997; 35:1083-1097.
34. Nayak, AK, Raha P, Das AK. Organochlorine Pesticide residues in middle stream of the Ganga River, India. *Bulletin of Environmental Contamination and Toxicology*. 1995; 54:68-75.
35. Pathak AN, Sharma AK. Soils of Uttar Pradesh and their management. In: *Soils of India and their Management* (Ed. T.M. Alexander). The Fertilizer Association of India. New Delhi. 1985, 405-426.
36. Peterson SM, Batley GE. The fate of endosulfan in aquatic ecosystems. *Environmental Pollution*. 1993; 82:143-152.
37. Pignatello JJ. Sorption dynamics of organic compounds in soils and sediments. In: *Reactions and Movement of Organic Chemicals in Soils*, Soil Science Society of America, Madison, WI (Special publication). 1989, 45-80.
38. Piper CS. *Soil & Plant Analysis*. Hans Pub., Bombay. 1991.

39. Priya G, George T. Adsorption & desorption of Alachlor in different soils. *Pesticide Research Journal*. 2010; 22:14-18.
40. Raha P, Agarwal NR, Samante S. Organochlorine pesticide residues in mother's milk. In: *Green Pesticides. Crop Protection and Safety Evaluation* (Eds. N.P. Agnihorti, S.C. Walia and V.T. Gajbhiye). Society of Pesticide Science of India. New Delhi. 1999, 231-234.
41. Raha P, Singh SK, Banerjee H. Organochlorine pesticide residues in ground water in world existing civilized city, Varanasi. *Indian Journal of Agricultural Environment & Biotechnology*. 2003; 2:94-107
42. Rama Krishna K, Philip L. Adsorption and desorption characteristics of Lindene, Carbofuran & Methyl parathion on various Indian soils. *Journal of hazardous, 2008*; doi:10.1016/s. Jhamat, 2008.03.107.
43. Reddy KN, Singh M. Effect of acrylic polymer adjuvants on leaching of bromocil, diuron, norflurazo and simazine in soil columns. *Bulletin of Environmental Contamination Toxicology*. 1993; 50:449-457.
44. Ryan PA, Cohen Y. Diffusion of sorbed solutes in gas and liquid phases of low-moisture soils. *Soil Science Society of America Journal*. 1990; 54:341-346.
45. Saeed JAM, Rouse DI, Herken JM, Smith KP. Effects of soils water content and soil temperature on Efficacy of Metham-Sodium against verticillium dahliae. *Plant Disease*. 1997; 81:773-776.
46. Shivaramaiah HM. Adsorption, desorption and movement of endosulfan in agricultural soil. *International Journal of Food Agriculture and Veterinary Sciences*. 2014; 4:53-61.
47. Simonich SL, Hites RA. Global distribution of persistent organochlorine compounds *Science*. 1995; 269:1851-54.
48. Singh SK, Raha P, Banerjee H. Endosulfan Adsorption on soils of Uttar Pradesh and Uttaranchal. *Journal of Soils and Crops*. 2012; 22:234-243.
49. Singh SK, Raha P, Banerjee H. Adsorption of Lindane on soils of Uttar Pradesh and Uttaranchal. *Journal of Indian Society of Soil Science*. 2013; 61:233-236.
50. Sinnakkannu S, Abdullah AR, Abas MR. Adsorption, Desorption and Mobile herbicide in Malaysian Agriculture soils. *Malasian Journal of Soil Science*. 2005; 91:29-38.
51. US Department of Health and Human Services. Toxicological profile of Endosulfan. Agency for toxic substance and disease registry, Atlanta, 1990.
52. Vereeken H, Doring U, Kim DJ, Mouvet C, Moreau N, Burauet P *et al*. The fate and mobility of pesticides as Laboratory, Lysimeter and field scale. *BPSC Monograph*. 1995; 62:147-154.
53. Weber JB. Properties and behaviour of pesticides in soil. In: *Mechanism of Pesticide Movement into Ground Water* (Eds. R.C. Honeyutt and D.J. Schabacker). Lewis Publishers, London, 1994, 15- 41.
54. Weber JB, Keller KE. Mobility of pesticides in field lysimeters, in mechanisms of pesticide into ground water, Honeycutt, R.C. and Schabacker, D.J. (eds). C.R.C. Press, Boca, Raton, FL. 1994, 43-62.
55. Xing B, Pignatello JJ. Competitive sorption between atrazine and other organic compounds in soils and model sorbents. *Environmental Science Technology*. 1996; 30:2432-2440.