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EVALUATION OF IMPACT OF PESTICIDES ON THE BASIS OF THEIR PHYSICO-CHEMICAL PROPERTIES

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ABSTRACT

The term pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. When a pesticide is used in the environment, it becomes distributed among four major compartments: water, air, soil and biota. The fraction of chemical that will move into each compartment is governed by the physico-chemical properties of that chemical. To understand how pesticides move in the environment, one must first understand certain physical and chemical characteristics of pesticides, as well as how these characteristics determine a pesticide's interaction with the environment. This article throws light on impact of pesticides in environment on the basis of physicochemical properties so as to understand the underlying basis of their distribution in non target life.

INTRODUCTION

The Food and Agriculture Organization of the United Nations defines pesticide as any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage or marketing of food, agricultural commodities, wood and wood products or animal stuffs or which may be administered to animals for the control of insects, arachnid or other pest in or on their bodies (Food and Agricultural Organization of the United Nations. 1986). Pesticides include herbicides for destroying weeds and other unwanted vegetation, insecticides for controlling a wide variety of insects, fungicides used to prevent the growth of moulds and mildew, disinfectants for preventing the spread of bacteria and compounds used to control mice and rats (Pesticides, 2011).

Naturally occurring compounds or natural extracts have been used as pesticides since ancient times. The earliest pesticides were most likely salt, sulphurous rock, and extracts of tobacco, red pepper,

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and the like. A pesticide class is a group of pesticidal compounds that share a common chemistry. For example, all pesticides in the class organophosphate (OP) are derivatives of phosphoric acid, and all pesticides in the class organochlorine are composed of carbon, hydrogen, and chlorine. Depending on their chemical properties they may leach to groundwater and surface water, persist in soil or enter the organism bioaccumulating in food chain and consequently influence human health too. Now the rapidly using pesticide use is a source of poisoning and health hazards among exposed population (Das *et al.* 2006).

This article aims to understand interrelation between physical and chemical properties of pesticides and their distribution in the environment which would be beneficial for manufacturing pesticides with low persistence.

Physico-chemical properties of pesticides

Pesticides are distributed in the environment by physical processes such as sedimentation, adsorption and volatilisation depending on the pesticidal compound itself or the pesticide product or formulation. In pesticides the compound itself is also known as the active ingredient the chemical responsible for killing the target pest. The formulation is the manner in which the active ingredient is delivered. Typical formulations include liquids, dusts, wettable powders and emulsifiable concentrates. The pesticide formulation includes the active ingredient as well as other ingredients. The process of degradation will largely be governed by the compartment in which the pesticide is distributed and this distribution is governed by the physical processes.

Solubility

Solubility is a measure of the ability of a pesticide to dissolve in a solvent, usually water. Pesticides highly soluble in water dissolve easily and tend to not be adsorbed on soil and living organisms. Such pesticides are more likely to move with water in surface runoff or to move through the soil in water than are less-soluble pesticides. Solubility of a pesticide depends on dipole moment, hydrogen bonding, molecular size, pH and temperature.

Octanol/water partition coefficient (Kow)

Kow is defined as the ratio of a chemicals concentration in Octanol divided by its concentration in water Higher values (greater than 1000) indicate a pesticide that is very strongly attached to soil and is less likely to move unless soil erosion occurs. Lower values (less than 300-500) indicate pesticides that tend to move with water and have the potential to leach or move with surface runoff. Large Kow means low water solubility. Adsorption occurs because of an attraction between the chemical and soil particles. Adsorption increases with decreasing soil pH for ionizable pesticides (e.g. 2,4-D,2,4,5-T, picloram, and atrazine) (Andreu and Pico, 2004.). Kow values are important in that they can be used to estimate many chemical properties such as solubility and bio concentration factor since they are proportional to Kow. Thus Kow gives an overall estimate as to where a chemical will be distributed in the environment.

Vapour pressure

Vapour pressure and volatility are interrelated in that how chemicals are transported from a surface into the atmosphere. Vapour pressure is defined as the pressure that a chemical in the gas phase exerts over a surface. Pesticide volatilization depends on temperatures, wind, solubility, chemical properties and soil. Volatility is also more likely under conditions of low relative humidity. The potential for a pesticide to volatilize is measured by its vapor pressure. This measurement may be described in units of Pa (Pascals) or mmHg (millimetres of mercury). Pesticides that have high vapour-pressure values are more volatile. Vapours from such pesticides can move off-site and cause injury to susceptible plants. Vapours derived from volatilization of residue from previous spraying events combined with rainfall can also contribute to non-target exposure (Marrs, *et al.* 1989; Marrs, *et al.* 1991; Marrs, 1993 and Obrigawitch, *et al.* 1998).

Soil adsorption coefficient (Koc)

Soil adsorption coefficient measures the tendency of pesticides to be attached to soil particles. Kd is called the sorption coefficient and it measures the amount of chemical adsorbed onto soil per amount of water but organic content of soil is not considered. Soils vary in the amount of organic carbon content, which is mainly what determines the amount of pesticide adsorbed. Therefore the preferred value for determining soil's ability to adsorb is Koc, since it considers the organic content of soil.

$$K_{oc} = K_d \times 100 \ / \ \% \text{ organic carbon}$$

Koc depends on polarity, salinity, pH and organic content.

Hydrolysis

Hydrolysis is the reaction of pesticides with water to give new product. This reactivity is largely determined by the substituents bound to the pesticide. Hydrolysis depends on temperature and pH. Hydrolysis half life values helps to estimate how long a chemical will persist in an aqueous environment. If the pesticide resists hydrolysis then it may degrade via some other pathway such as microbial metabolism.

Persistence

Persistence is the ability of a pesticide to remain present and active in its original form for an extended period before degrading. A chemical's persistence is described in terms of its half-life, a comparative measure of the time needed for the chemical to degrade. The longer a pesticide's half-life, the more persistent the pesticide. Persistent pesticide residues are sometimes desirable because they provide long-term pest control and reduce the need for repeated applications. However, some persistent pesticides applied to soil, plants, lumber, and other surfaces or spilled into water or on soil can later harm sensitive plants or animals, including humans. It is especially important to prevent persistent pesticides from moving off-site through improper handling, application, drift, leaching, or runoff. The rate of pesticide degradation relates to the persistence of the pesticide.

Degradation processes break down pesticide compounds into simpler and often less-toxic chemicals. Some pesticides break down rapidly in a matter of days or even hours. Other pesticides can be detected in the environment for a year or more.

Bioconcentration factor

It is an indicator of how much a chemical will accumulate in living organisms such as fish. Once absorbed into an organism chemical can move through food chain. It depends on polarity, solubility and lipid content in organism. BCF can be an indicator of a pesticide’s tendency to accumulate in the food chain.

Photolysis, microbial reduction

In atmosphere pesticides are degraded by photochemical reactions and microbial reduction. In photochemical reactions pesticides are broken down in the presence of sunlight. Microbial reduction is the process of degradation of pesticides by microorganisms present in soil. Pesticides not degraded by these processes are likely to accumulate in soil and contaminate ground water.

Following table provides summarised information of physico-chemical properties of some pesticides and gives an idea how they will be distributed in the environment.

It is clear from the above table that pesticide having high water solubility will remain in water and tend not to be adsorbed on soil and living organisms. As the size increases, the water solubility decreases. Vapour pressure indicates volatilization which provides information about method of transportation by which the pesticide will be dispersed in the environment (air, water and soil). K_{oc} means increase in persistence as pesticide is protected from degradation. Pesticide movement rating is derived from relation between half life and sorption in soil. Half life of a pesticide in soil measures persistence. Thus by considering the overall physico-chemical properties of a

Table 1.

Chemical	Pesticide Movement Rating	Mol. Weight	Soil Half Life (days)	Vapour Pressure Mmhg	Solubility (Mg/L)	Soil K_{OC}
Aldicarb	High	190.29	30	1x10-4(25°C)	6000	30
Atrazine	High	215.69	60	1.4x10-6(30°C)	33	100
Chlorpyrifos	Very low	350.6	30	1.87x10-5 (25°C)	0.4	6070
Endosulphan	Extremely low	406.96	6	1.7x10-7	0.32	12400
Malathion	Extremely low	330.4	1	1.78x10-4 (25°C)	145	93-1800
2,4-D	Moderate	221	10	1.4x10-7(25°C)	pH 5: 29934±2957 pH 7: 44558±674 pH 9: 43134±336	20-136
Methyl bromide	Very high	94.95	55	1420 (20°C)	13400	22
Carbaryl	Low	201.2	10	0.00004 (25°C)	120	300

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pesticide we can evaluate their impact whether it will leach, persist in soil or accumulate in organism.

RESULTS AND DISCUSSION

The worldwide use of pesticides in agriculture results in the residues commonly found in environment from cropping fields and orchards to rivers, estuaries and oceans and even urban environment (Sanchez-Bayo, *et al.* 2011). The extreme toxicity of most of these man-made chemicals affect not only the target pests but also many other species of animals, although in different degrees (Sanchez-Bayo, *et al.* 2011). Pesticides are often considered a quick, easy and inexpensive solution for controlling weeds and insect pests in urban landscapes. However, pesticide use comes at a significant cost. Pesticide drift can account for a loss of 2 to 25% of the chemical being applied, which can spread over a distance of a few yards to several hundred miles. As much as 80–90% of an applied pesticide can be volatilized within a few days of application Majewski, 1995). Some pesticide drift occurs during every application, even from ground equipment (Glotfelty and Schomburg, 1989). Pesticide contamination poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms, to insects, plants, fish and birds. The health effects of pesticide exposure vary from one pesticide to another. While considering the potential environmental and health effects of pesticides, it is important to consider the toxicity of the active ingredient as well as the other ingredients in the formulation. These physico-chemical properties can be used to understand the underlying basis of distribution in non target life. Understanding the chemical and physical characteristics of a pesticide allows the applicator to make better decisions about which pesticide active ingredient to use for a particular situation. We need to understand the physico-chemical properties so that precautionary measures may be taken to mitigate their negative effects in human health and environment.

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