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Evaluation of Toxicity Indices for Frequently Used Pesticides

Atul Gupta[1], Jeevesh Nadda[2], Ripan Kumar[1]

1Assistant Professor, Department of Chemistry, Swami Vivekanand Govt. College Ghumarwin -174021, India

[2]Assistant Professor, Department of Botany, Swami Vivekanand Govt. College Ghumarwin -174021, India

Abstract

Pesticides are used all over the world to boost agricultural production to meet out expanding food demand with increasing populations. Even though we firmly believe that using pesticides is inevitable, there are still significant concerns about the possible risks and health hazards associated with their uses. Pesticide toxicity indicators can be used to reduce pesticide use risks and address agro-environmental pollution. In view of this, the current study evaluates the various pesticide toxicity indices viz. toxicity potential (TP), environmental exposure potential (EEP), hazard potential (HP) for five frequently used pesticides of different classes namely atrazine herbicide, malathion insecticide, thiram fungicide, carbaryl insecticide and zineb fungicide. The values of pesticide toxicity indices illustrate atrazine and carbaryl as very toxic pesticides.

Keywords: environmental pollution, ground water, hazards, pesticides, toxicity

1. Introduction

The agriculture sector dominates the economic scenario in India, as agriculture in India is the chief earner of the overseas exchange and the occupation of nearly 60% of our population is agriculture. We, all, depend on this sector for our basic and essential necessities i.e. food, shelter and cloth. However, with the increasing population of India, there is a rapidly growing demand for food. This pressure of increasing food production, due to population explosion as well as limited cultivation area, requires the need of more efficient operations in agriculture to increase the yields and to improve the quality of crops. In view of the fact that in India, every year about 30% of the food production is lost due to insects/pests [1] therefore, one of the ways to improve quality as well of quantity of food produced is the use of pesticides. These chemicals have increased agricultural production by preventing crop losses before and after harvesting.

The pesticides have an important contribution in the modern agricultural practices and have become essential for the crop protection and pest management. These chemicals would continue to be indispensable in near future to meet the rapidly growing demand for food. Though we are fully convinced about the inevitability of these chemicals but we are also aware that these chemicals are extremely hazardous and potential pollutants of environment. If pesticide credits include increased economic growth through increased agricultural production, their debits have caused havoc in our environment. Of the total applied pesticide, as little as 1% reaches the target pests and rest enters the environment due to various natural processes like volatilization, evaporation and leaching. The pesticides and their metabolites are not completely degraded in the environment and thus, contaminating soil, water, air and foodstuff. Through foodstuff and drinking water, these exogenous chemicals ultimately enter our body and results in various adverse health effects [2].

The pesticide toxicity may be acute and chronic depending upon the exposure to pesticide compounds. The acute toxicity is the harmful effect caused with a single exposure or shorter duration to the pesticide compound. The symptoms generally observed in the victim are: respiratory tract irritation, allergic sensitisation causing cough, sore throat, skin and eye irritation, vomiting, diarrhoea, nausea, loss of consciousness, headache, dizziness, extreme weakness, seizures and may be death. The exposure to pesticides for longer duration causes chronic effects which include birth defects (teratogenesis); production of tumors (oncogenesis), either benign (noncancerous) or malignant (cancerous/carcinogenesis); genetic changes (mutagenesis); blood disorders (hemotoxic effects); nerve disorders (neurotoxic effects); endocrine disruption and reproductive disorders [3].

Concern about the environmental and health hazards due to excessive use of pesticides has prompted research to evaluate the impact of pesticides either on human health or on the environment. In this direction, new tools or techniques with greater reliability are needed to predict the potential hazards of pesticides for their safer uses. In this article, various pesticide toxicity indices viz. Toxicity potential (TP), Environmental exposure potential (EEP), Hazard potential (HP) are discussed and these toxicity indices are evaluated on some frequently used pesticides namely atrazine herbicide, malathion insecticide, thiram fungicide, carbaryl insecticide and zineb fungicide to predict their toxicity and environmental hazards.

2. Methodology

The methodology used in this manuscript to evaluate toxicity indices of pesticides depends on relatively simple input data which is easily obtainable from internet databases/literature. The values of toxicity indices provide an initial level of fundamental and important information about pesticides which can be used by the pesticide users and advisors to raise awareness on the effect of pesticide and therefore to take preventive measures to reduce pesticide risks and hazards.

2.1 Toxicity potential (TP)

The method to evaluate toxic potential was discussed by Dabrowski et al. [4]. In brief, five toxic effects viz. endocrine disruption potential, carcinogenicity, mutagenicity, teratogenicity and neurotoxicity were used to score each pesticide. Each toxic effect was classified into one of four different endpoint categories, namely Yes" (there is definitive evidence that the chemical causes the toxic effect), Possible" (there is evidence that the chemical may possibly result in the toxic effect), "No Data" (no studies have been performed to confirm whether the pesticide does or does not cause the toxic effect) and "No" (there is definitive evidence that the chemical does not cause the toxic effect). The scores for each of the different categories for each toxic effect were weighted according to scoring system presented in Table 1 [4]. The toxicity potential (TP) was evaluated by adding the scores assigned to each of the five toxic effects of each pesticide. More is the value of TP, greater is the toxicity of pesticides.

2.2 Environmental exposure potential (EEP)

The EEP scored pesticides in terms of their potential to contaminate water resources. The ability of a pesticide to move into the water phase (via runoff or leaching) is heavily influenced by its physicochemical properties. The Groundwater Ubiquity Score, GUS index has been devised to provide a relative indication of a chemical's potential for movement through leaching and runoff. GUS index incorporate half-life ($t_{1/2}$) and soil organic carbon partition coefficient (K_{OC}) values of the compounds and provide a score giving an indication of mobility. Pesticides can be classified as leacher (GUS>2.8), transition (2.8>GUS<1.8) and non-leacher (GUS<1.8) (Papa et al. 2004). The GUS score of a pesticide can be determined from the following equation:

$$GUS = \log t_{1/2}\left[4 - \log(K_{oc})\right]$$

Where, $t_{1/2}$ = pesticide persistence (half life) and K_{oc} = soil organic carbon partition coefficient of pesticide.

The value of Koc can be determined from soil adsorption study of the pesticides and is given as:

$$K_{oc} = K_d \times \left(\frac{100}{\%O.C.}\right)$$

Where %OC = percentage organic carbon content of soil, K_d is soil-adsorption coefficient. The value of Kd can be calculated by using the equation:

$$K_d = \frac{X}{C_e}$$

Where X is the amount of pesticide adsorbed mg Kg^{-1} of the adsorbent (soil); Ce is the equilibrium solution concentration (mg L^{-1}).

The detailed procedure for soil adsorption of pesticides and evaluation of values of different adsorption parameters including Koc were reported in our earlier work [5-8]. In this study, the GUS index was used as a measure of environmental exposure potential and scoring system used to rank pesticides in terms of EEP is presented in Table 2.

2.3 Hazard potential (HP)

This toxicity index provides an indication of the potential for exposure to highly toxic pesticides and is calculated as:

$$HP = TP \times EEP$$

Where TP is the toxicity potential score of the pesticide and EEP is the environmental exposure potential score of the pesticide. More is the value of HP, more hazardous is pesticide.

3. Results and Discussion

The hazards of five frequently used pesticides (Malathion, Thiram, Atrazine, Carbaryl and Zineb) have been determined by calculating their Toxicity potential (TP), Environmental exposure potential (EEP) and Hazard potential (HP) values. The details reported in literature about five toxic effects viz. endocrine disruption potential, carcinogenicity, mutagenicity, teratogenicity and neurotoxicity for these pesticides were used from literature to calculate their Toxicity potential (TP) values. The ground ubiquity scores (GUS) values for these pesticides have been calculated by using their literature reported $t_{1/2}$ and K_{oc} values [5-9]. The GUS values of these pesticides are used to determine their Environmental exposure potential (EEP). From values of TP and EEP, the Hazard potential (HP) values for these pesticides are determined and the results are presented in Table 3.

The values of GUS for pesticides indicate that atrazine herbicide is showing high leaching potential and high environmental exposure potential whereas malathion, thiram and zineb are non-leacher and have low environmental exposure potential. The carbaryl insecticide is showing medium environmental exposure potential. Similarly, atrazine and carbaryl pesticides show very high value of hazardous potential and therefore are very toxic. From table, it is also evident that toxic pesticide is more hazardous when it has high value of EEP i.e. when it moves to environment and contaminates it. For example, TP for atrazine and carbaryl pesticides are less as compared to other pesticides but their HP is more only because of their migration to environment (higher value of EEP).

Conclusion

The methodology presented in this paper is simple and provides the basic, important information about the pesticides that can be used to develop monitoring programmes, to identify priority areas for management interventions and to investigate optimal mitigation strategies. Highly toxic pesticides, i.e. pesticides with higher values of HP and TP, should be used in relatively low quantities and we should look for the suitable replacement of these pesticides. Similarly, pesticides with higher values of EEP should not be used near water bodies. The soils where such pesticides are used should be amended with additives of high organic content viz. manure, compost, cow dung etc. in order to increase its retention and consequently to reduce the mobility. This addition will also improve the fertility and health of the soil by serving as source of soil nutrients.

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Table 1: The scoring system used to rank pesticides for human health effects.

Toxic effect	Classification	Value
EDC	Yes	8
	Possible	6
	No Data	3
	No	0
Carcinogenicity	Yes	8
	Possible	6
	No Data	3
	No	0
Mutagenicity	Yes	6
	Possible	4
	No Data	2
	No	0
Teratogenicity	Yes	4
	Possible	2
	No Data	1
	No	0
Neurotoxicity	Yes	4
	Possible	2
	No Data	1
	No	0

Table 2: Scoring system used to rank pesticides in terms of their potential exposure risk to water resources based on their groundwater ubiquity score (GUS).

Environmental exposure potential (EEP)	**GUS score**	**Value**
High	GUS>2.8	4
Medium	2.8>GUS>1.8	2
Low	GUS<1.8	1
No Data	No Koc or DT50 Value	1.5

Table 3: Toxicity potential (TP), Environmental exposure potential (EEP), Ground Ubiquity Score (GUS) and Hazard potential (HP) for some commonly used pesticides.

Pesticide	**Class of Pesticide**	**TP**	**EEP**	**GUS**	**HP**
Malathion	Insecticide	23	1	GUS<1.8	23
Thiram	Fungicide	20	1	GUS<1.8	20
Atrazine	Herbicide	17	4	GUS>2.8	68
Carbaryl	Insecticide	18	2	2.8>GUS<1.8	36
Zineb	Fungicide	22	1	GUS<1.8	22