Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 16, 2020

ENVIRONMENTAL IMPACT OF CHEMICAL PESTICIDE USE IN RICE USING EIQ MODEL

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Abstract

The agricultural sector has been witnessing a tremendous pressure and expectation to produce more form the limited available land resources mainly in the tropical climatic areas where human population is excreting a pressure too on the shrinking resources. Producers of the agricultural commodities have been using chemical inputs to safeguard their crops from insect pests and diseases to incur least losses due to such pests. They apply number of chemical sprays and basal doses of chemical inputs mainly as pesticidesand make the immediate environment contaminated which poses a great health hazard for the humankind and brings in many associated health problems to the society. Besides the new developments in agricultural technology, intensive use of pesticides poses a great environmental hazard. There are various agricultural crops where chemical pesticides have been observed in use in greater quantities namely in rice crop in India especially in Ludhiana region of Punjab State.This study was conducted in the rice growing area of Ludhiana District in northern India in four villages taking one hundred rice growing fields including four IPM fieldsfrom four blocks through a grid sampling plan. The application of Environmental Impact Quotient (EIQ) model was used to understand the environmental impact of the used pesticides in the selected fields on the basis of EIQ Field Use Rating (EIQFUR). WHO classified hazardous level of pesticides was also looked into the selected fields. Fifty percent of the fields found with low EIQFUR (25-50), 19 percent with very low EIQFUR (<25), 31 percent with moderate EIQFUR (50-100). No field was found with high (>100) or very high (>150) category.Eight pesticides were found with sixteen varied doses form the organophosphate group including*Fipronil* and *Imidacloprid* as non-organophosphates. Among the four sample sites as villages, maximum values of EIQFUR as 78.6 found at Site 3 in three fields (F65, F66& F70) followed by EIQFUR 75.3 at Site 4 in two fields(F84 & F94), EIQFUR as 65.1 at Site 1 in one field (F4) and EIQFUR as 64.5 at Site 2 also in one field (F36). Pesticides used in the study region found were from four hazardous class as per WHO recommended classification of pesticides by hazard namely Ia, Ib, II and III receptively for extremely hazardous (12.5%), highly hazardous (12.5%),moderately hazardous (62.5%) and slightly hazardous (12.5%). No pesticide found as U class for unlikely to present acute hazard. Mean values of EIQFUR found at four sites as 40, 41, 43 and 43 suggest the low level of pesticide effect on the environment in the study region.

Keywords: EIQ, contamination, EIQFUR, hazardous,organophosphates, pesticide, rice

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ISSN- 2394-5125 Vol 7, Issue 16, 2020

1. Introduction

The agricultural sector has been witnessing a tremendous pressure and expectation to produce more form the limited available land resources mainly in the tropical climatic areas where human population is excreting a pressure too on the shrinking resources. Producers of the agricultural commodities have been using chemical inputs to safeguard their crops from insect pests and diseases to incur least losses due to such pests.They apply number of chemical sprays and basal doses of chemical inputs mainly as pesticides and make the immediate environment polluted and adversely affected which increases the risk of health hazard for the humankind and brings in many associated health problems for everybody. No fragment and strata of the population is completely protected against the side effects of pesticides leading to potentially serious health effects, though a disproportionate burden, is shouldered by the people of developing countries and by high risk groups in each country along with the hazardous pesticides classified(WHO, 2019 and Arora, 2009).

The worldwide deaths and chronic diseases due to pesticide poisoning number about 1 million per year (Environews, 1999).Chemicals do pose a potential risk to humans and other life forms and unwanted side effects to the environment (Forget et al., 1993; Igbedioh, 1991 and Jeyaratnam, 1985).Ninety-seven percent of rice samples indicated contamination (Singh and Dhaliwal, 2002) during the comparison of pesticide residues in food products for understanding the pesticides contamination of the environment in Punjab.Utilization of commercially available synthetic pesticides in huge magnitude has led to their bioaccumulation in the environment causing increased resistance and reduction in soil fauna and flora. Further, 90% of the applied pesticides enter the various environmental resources as a result of run-off, exposing the farmers as well as consumers of the agricultural produce to severe health issues (Chaudhary*et al.*, 2017).The unthinking use of pesticides leads to contamination of air, water and soil(Muhammetoglu, 2007). The flip side is that the assessment of the impact of the pesticide used can be calculated by several pesticide risk indicator models developed and available for the concerned researches.

Producers are really under great pressure to produce and provide food commodities for the ever increasing numberassociated with the ever increasing demands and needs in a continuous manner. The existing increase in demands for food, fiber and fuel to be met from the ever shrinking operational agricultural fields poses the compulsion on the producers to protect the losses caused by crop pests, and protecting the crops by applying synthetic chemicals indiscriminately leaves many unwanted and harmful elements as poison behind in soil and water, and thus affecting the immediate environment. Application of pesticides decides the production of about one-third of agricultural products.Edwards (1973) stated that large amounts of pesticides reach the soil, either as direct applications, from fall-out from aerial spraying, in rain or dust or from plant or animal remains which become incorporated with the soil. Misunderstanding the contamination level and magnitude of chemical pesticides in soil and water may pose serious threat to environmental pollution. Once the ground water is polluted with toxic chemicals, it may take many years for the contamination to dissipate or be cleaned up (Johnson and Ware, 1991; USEPA, 2001). Estimated results indicated that only about one percent of the pesticides reach the target organisms and the remaining bulk contaminates the surrounding environment (Carriger*et al*., 2006).Punjab covers 2.5 per cent of land in India, it uses almost 18 per cent of total pesticides in India (Chaudhry, 2009).Punjab ranks first in productivity in the country. There are 563 districts in the country growing rice crop. Ludhiana district in Punjab state ranks first in productivity (4439 kg/ ha) in the country (Directorate of Rice Development, 2009).Currently, an about one kg technical grade pesticide per hectare is being used in the state of Punjab against the all-India average of 350g per hectare.Universally pesticides pollutes the ground water as a problematic feature worldwide.Rice crop (*Oryza sativa* L.) being the most important cereal crop among all food crops in terms of geographical extent of cultivated area providing food for maximum population in the country, was selected for the study to look into the environmental effect of pesticide use in this important crop to understand the pertinent problem of chemical inputs used.

Ludhiana district, therefore, was selected to conduct the study to analyze and understand the impact on environment by the chemical pesticides used in the region. Four sites as Site 1- Dhande village, Machchhiwara Block, Site 2-Ghuman village, Sudhar Block, Site 3- Nizampur village, Khanna Block and Site 4- Selioni village, Jagraon Block were taken for the study. Twenty five fields selected from each site including four IPM fields from four blocks through a grid sampling plan. The eight pesticides namely Acephate, Chlorpyrifos, Fipronil, Imidacloprid, Malathion, Phosphamidon, Quinalphos and Triazophos used by the farmers in the study area with sixteen varied doses form the organophosphate group including*Fipronil* and *Imidacloprid* as non-organophosphates were considered for calculating Environmental Impact Quotient and Field Use rating of the used pesticides in all the selected one hundred fields.

2. Material and methods

2.1 Sampling Design

Systematic sampling design on grid basis was adopted in the selection of 25 sampling fields from the cells of the grid representing a cell (280x180m) as the sampling field. The same grid pattern adopted in selecting all the 100 fields from the four selected sites as villagesfromthe rice growing area of the study area in Ludhiana district. The cells with settlement area and where cropped area was not available were discarded and avoided as a sample field, besides care was also taken to select an alternate cell from the created grid for each site representing and covering the entire area of the selected village as a site. The study region of theses villages was selected on the basis of combination of consumption of chemical inputs especially pesticides used and substantial cultivated area as percentage of rice crop area to net sown area for each of the selected locations as the sampling village containing the sampling fields. The pattern of pesticide usage in India is different from that for the world in general. And in India 76% of the pesticide used is insecticide, as against 44% globally (Mathur, 1999).. The per hectare pesticide use is highest in Punjab (923 g/ha) as compared to other agriculturally advanced states like Haryana, Andhra Pradesh, Tamil Nadu, Karnataka and Gujrat (Tiwana et al., 2009). Punjab state was selected as the state exhibiting the maximum consumption of chemical pesticides.It has only 1.5 percent landmass of the country, while its pesticides consumption comes around 17 percent of the country.

2.2 Study Region

Ludhiana district with Sudhar, Raikot, Machhiwara and Doraha blocks selected taking four villages as Sites namely Dhande (30.858829N, 75.136613E) in Machhiwara (Site 1),Ghuman (30.781901N,75.660682E) in Sudhar (Site 2), Nizampur (30.654590N, 75.024303E)in Doraha (Site 3) and Siloani (30.670569N, 75.553125E) in Raikot block(Site 4).Four villages taken with one hundred rice growing fields as twenty five fields from each site including four IPM fields from four blocks through a grid sampling plan.

2.3 Selection of Pesticides

Pesticides considered for calculation of Environmental Impact Quotient (EIQ) and Field Use Rating (FUR) in the study were from organophosphate group *viz*. *Acephate*, *Chlorpyrifos*,*Phosphomidon*, *Quinalphos*, *Triazophos*. Besides, *Malathion*, *Fipronil*, *Imidacloprid* as being the popular and common among the farmers.The selection of pesticide was undertaken based the mostly consumed pesticides in the country as per Chemicals and Petrochemicals Statistics(CPSG,2018), and the recommended pesticides mentioned in the Package of Practices for *Kharif*, Punjab, 2020, including a pre-study rapid survey of the region.

2.4 Collection of field data

All the required information for this study have been collected through visiting the selected sampling fields with the help of the concerned farmers by personal interview through the structured questionnaire. Primary data and information on the application of pesticide, their class, doses, application, and number of sprays were collected twice from the fields in two phases *viz*. transplanting stage and harvesting stage with an interval of three and a half months in the *Kharif* season 2020. Additionally, pesticide specific information like active ingredient also collected.

2.5 Environmental Impact Quotient (EIQ) and EIQ Field Use Rating (EIQFUR)

Environmental Impact Quotient (EIQ) model (Kovach *et al*., 1992)was used to understand the environmental impact of the used pesticides in the selected fields on the basis of EIQ Field Use Rating (EIQFUR). Using this model, pesticidesused in the study region were evaluated for their effect on the environment. The evaluation was based on dosage, frequency, and percent active ingredients present in the pesticide formulations.

This rating is calculated by multiplying the EIQ value for the specific chemical by the percent active ingredient in the formulation and by the rate used, usually in pints or pounds of formulated product per acre (Kovach *et al*., 1992).

EIQFUR = EIQ xpercent Active Ingredient x Rate of application

The lower the EIQFUR, the lower the environmental impact. This method allows comparisons of the environmental impact among pesticides used in managing and controlling of the concerned pests.

EIQ Field Use Rating(Kovach *et al*., 1992):

<25: Very low; <50: Low; 50-100: Moderate; >100: High >150: Very high

2.6 WHO Recommended Classification of Pesticides by Hazard

The classification distinguishes between the more and the less hazardous forms of each pesticide in that it is based on the toxicity of the technical compound and on its formulations (WHO, 2019).

Class	Level
Ia	Extremely hazardous
Ib	Highly hazardous
II	Moderately hazardous
III	Slightly hazardous
U	Unlikely to present acute hazard

The mentioned classes for the attributed hazardous level were utilized for looking into chemical pesticides used in the study region and see their distribution among all the selected fields to understand the classes of pesticideswere in use at the different sites selected.

3. Results and Discussion

The in depth interviews with the rice growing farmers in the study region for the collection of information revealed that eight pesticides were used by the farmers in the study area with sixteen varied doses form the organophosphate group including*Fipronil* and *Imidacloprid* as non-organophosphates. The farmers were found using Acephate, Chlorpyrifos,Fipronil, Imidacloprid, Malathion, Phosphamidon, Quinalphos and Triazophosas per mentioned doses in *Table 1*in rice crop with slight variation. As per WHO classification of pesticides by their hazardous level Phosphamidon belongs to Extremely Hazardous Class (Ia); Triazophos belong to Highly Hazardous Class (Ib); Acephate, Chlorpyriphos, Fipronil, Imidacloprid, and Quinalphos are fromModerately Hazardous Class (II) while Malathion comes under Slightly Hazardous Class (III).

It was found that the farmer of the study area used chemical pesticides namely Acephate, Chlorpyrifos, Fipronil for managing and controlling Yellow Stem Borer, Leaf Folder, Plant Hoppers, Green Leaf Hopper; Triazophos for Stem Borer, Leaf Folder, Hispa, Green leaf hopper, Brown plant, hopper, White back plant hopper; Quinalphos for Stem borer, Leaf borer, Green leaf hopper, Brown plant hopper, White backed plant hopper; Phosphamidon for Stem borer, Leaf borer, Green leaf hopper, Brown plant hopper, White backed plant hopper; Malathion for Gundhi Bug. The famers were found using these pesticides as per recommended use against the concerned pests.

***Table 1.* Farmer using chemical pesticides in rice crop**

Pesticide	Active Ingredient	Dose*
Acephate	75% SP	700-1000g/ha
Chlorpyrifos	20% EC	1250 ml/ha
Chlorpyrifos	50% EC	800 ml/ha
Fipronil	5% SC	1500 ml/ha
Imidacloprid	30.5% M/M	75 ml/ha
Imidacloprid	70% WG	35g/ha
Malathion	50% EC	1150ml/ha
Monocrotophos	36% SL	625-1250 ml/ha
Phosphamidon	40% SL	875-1250 ml/ha
Quinalphos	25% EC	1000-2000 ml/ha
Triazophos	40% EC	1250-2500/ha

**Farmers were found using these chemical pesticide in rice crop for managing and controlling the pests*

Fifty percent of the fields found with low EIQFUR (25-50), 19 percent with very low EIQFUR (<25), 31 percent with moderate EIQFUR (50-100). No field was found with high (>100) or very high (>150) category (*Table 2*).

***Table 2.* Distribution of Fields EIQFUR Category wise**

	No. of Fields at all the sites			
Code	Site 1	Site 2	Site 3	Site 4
Very Low	5	5	5	4
Low	11	10	13	16
Moderate	9	10	7	5
High	0	0	0	0
Very High	0	0	0	0

Among the four sample sites as villages, maximum values of EIQFUR as 78.6 found at Site 3 in three fields (F65, F66 & F70) followed by EIQFUR 75.3 at Site 4 in two fields (F84 & F94), EIQFUR as 65.1 at Site 1 in one field (F4) and EIQFUR as 64.5 at Site 2 also in one field (F36) (*Table 3*). Pesticides used in the study region found were from four hazardous class as per WHO recommended classification of pesticides by hazard namely Ia, Ib, II and III receptively for extremely hazardous (12.5%), highly hazardous (12.5%), moderately hazardous (62.5%) and slightly hazardous (12.5%). No pesticide found as U class for unlikely to present acute hazard. Mean values of EIQFUR found at four sites as 40, 41, 43 and 43 suggest the low level of pesticide effect on the environment in the study region.

The recommended doses were slightly found varied in some fields for few pesticide namely *Chlorpyrifos*,*Imidacloprid*, *Malathion*, *Phosphamidon*and*Quinalphos*respectively in 22, 97, 42 and 42 fields in all the site together. In these fields *Chlorpyrifos*(20% EC)was used 1400 ml/ha against the recommend dose 1250 ml/hac, recommended to be used as 1400ml per ha, similarly Imidacloprid (70%WG) 50g/ha against 35g/ha, Phosphamidon(40% SL) 1300ml/ha against 1250 ml/ha.

***Table 3*. EIQ FUR at all Sites 1-4 with Fields (F1-F100)**

Site 1		Site 2		Site 3		Site 4	
F1	35.5	F26	33.4	F51	19.2	F76	52.2
F2	40.9	F27	52.2	F52	25	F77	47.1
F3	38.9	F28	47.1	F53	28.4	F78	41.6
F4	65.1	F29	47.1	F54	45.4	F79	11.5
F5	12.9	F30	12.2	F55	18.1	F80	12.2
F6	64.5	F31	35.5	F56	33.4	F81	12.6
F7	56.7	F32	40.9	F57	52.2	F82	12.6
F8	51.0	F33	38.9	F58	47.1	F83	35
F9	33.2	F34	60.5	F59	47.1	F84	75.3
F10	53.6	F35	12.2	F60	11.5	F85	45.4
F11	12.6	F36	64.5	F61	42	F86	45
F12	12.6	F37	56.7	F62	12.6	F87	45.4
F13	35.0	F38	51	F63	12.6	F88	45
F14	64.4	F39	33.2	F64	35	F89	41.6
F15	54.4	F40	53.6	F65	78.6	F90	45
F16	56.4	F41	12.6	F66	78.6	F91	41.6
F17	13.3	F42	12.6	F67	53.6	F92	75.3
F18	42.0	F43	35	F68	63.2	F93	68.5
F19	41.6	F44	64.4	F69	41.6	F94	75.3
F20	63.2	F45	54.4	F70	78.6	F95	41.6
F21	19.2	F46	56.4	F71	41.6	F96	45.4
F22	25.0	F47	13.3	F72	45.4	F97	45
F23	28.4	F48	42	F73	45	F98	41.6
F24	45.4	F49	42	F74	78.6	F99	41.6
F25	45.0	F50	58.5	F75	41.6	F100	41.6
Mean	40		41		43		43
Total Mean 42.02		Mode value 41.60			Median 42		
STDEV 18.12		Average Deviation13.85					

The mean of EIQ FUR at all sites for all the fields found was in the range of 40-43, these values were at very low level at all the four IPM fields selected for calculation of EIQ values. The values found for these field were 12.9 in F5 at Site 1, 12.2 in F30 at Site 2, 18.1 in F55 at Site 3 and 12.2nin F80 at Site 4 (*Table* 4). These fields were found using *Chlorpyrifos*(50% EC) as 800ml/ha, *Imidacloprid*(30.5% M/M SC) as 80ml/ha at Site 1, *Chlorpyrifos* (20% EC) as 1400ml/ha,*Imidacloprid* (30.5% M/M SC) as 80ml/haand*Fipronil* (5% SC) as 1500ml/ha atSite 2, *Chlorpyrifos*(50% EC) as 800ml/ha, *Imidacloprid*(30.5% M/M SC) as 80ml/haat Site 3 and at Site 4 *Chlorpyrifos* (20% EC) as 1400ml/ha, *Fipronil* (5% SC) as 1500ml/ha and *Imidacloprid* (30.5% M/M SC) as 80ml/ha.

The mean EIQ FUR at the different sites found as40, 41, 43 and 43 respectively for Site 1, Site 2, site 3 and site 4 which indicated their Field Use Rating as of low <50, which is a good sign and a positive finding for saving the environment from chemical pesticides used in agricultural crop especially organophosphates in rice for managing and controlling the pests of this crop in the study region.

***Table 4.* EIQ FUR in IPM Fields**

Site 1	12.9	F5
Site 2	12.2	F30
Site 3	18.1	F55
Site 4	12.2	F80

The statistical test values for entire regions for all 100 fields in all sites indicted the mean of EIQFUR as 42.02, while the Mode values as 41.60 for mostly repeated impact affecting magnitude with a median value as 42. The calculated standard deviation for the entire fields found to be 18.12. The results evidenced the lower usage of chemical pesticides especially of organophosphates in the studied fields having lower impact on environmental concerns, and no field from all the site found with high or very high values impacting the environment. The variability of impacting values calculated using EIQ model for all the fields together found as low as around 18 evidenced from deviation values of SD while average deviation from the mean was found 13.85 (*Table 3*).

***Table 5*. Variability Statistics for EIQFUR for Sites 1-4**

Sites	*No. of Fields*	*Sum*	*Mean*	*Variance*
Site 1	25	1010.8	40.43	304.82
Site 2	25	1030.2	41.21	297.40
Site 3	25	1076	43.04	435.45
Site 4	25	1085	43.40	324.07

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Sites	153.15	3	51.05	0.15	0.93	2.70
Within Sites	32681.81	96	340.44			
Total	32834.96	99				

Statistically it was also confirmed through ANOVA,the non-significant variability of the observed EIQFUR for all the Sites (1-4), as calculated F value (0.15) for between sites variation was far less than the critical value (2.7) with 3 degree of freedom supported by the non-significant of P-values as 0.93with alpha 0.05 (*Table* 5). Results clearly indicated the similar magnitude with nominal variability of the calculated values of EIQFUR meant for impacting the environment among the observed sites in the study region, and it could be stated with ninety five percent confidence level as per statistics obtained. It showed that farmers followed the kind and quantity of pesticides in almost in same similar fashion without much variation to be stated.

4. Conclusion

The EIQ model is quite useful in bringing out the values needed for understanding the environmental impact by the chemical pesticides. The values calculated through this model indicated the dosages of the chemical pesticides at safer side with no field crossing the magnitude beyond the category of moderate values for impacting the environment adversely. Indication of the similar magnitudes of chemical pesticides used with nominal variability meant for impacting the environment among the observed sites in the study region advocates that farmers followed the kind and quantity of pesticides in almost in same similar fashion without much variation. Findings also indicated the application of chemical pesticides carefully and in need based mode with proper doses as per recommendations. Indeed it isa positive and a good sign and gesture to save the environment eliminating the adverse effects of the chemical pesticides besides incurring higher input cost to cultivation causing the reduced cost benefit ratios in terms of agricultural income.Overuse of the chemical pesticides, on the other hand, kill or harm soil invertebrates like earthworms, ants, beetles and ground-nesting bees. The use of chemical pesticide in agricultural crops ought to be considered with the output values using EIQ. Selection of safer pesticides with the optimum doses needed is greatly helped by this model. It is to be used by every concerned agency and famers in selecting the best option of safer pesticide among the available ones to suit to the environment. The chemical pesticide are essential part in agriculture in managing and controlling the crop pests, but their need based and judicious use must be popularized for safer pesticides without affecting the environment.

It is also argued by Webster et al. (1999) that minimal use of chemical pesticides including bio formulation applied in agricultural crops to safeguard the crops from the attack of pests may not pose threat to the environment. Moreover, in the environment most pesticides undergo photochemical transformation to produce metabolites which are relatively non-toxic to both human beings and the environment (Kole et al., 1999).

Muhammetoglu *et al*. (2007)also supported the EIQ model being an easily applied and very helpful tool for pest management practitioners and agricultural specialists. It can be used efficiently to compare different agricultural pest management strategies or programs. Judicious use and need based application of chemical pesticides are required to safeguard the crops and produce the yields with minimal impact on the environment. Therefore, pesticides play a critical role in reducing diseases and increasing crop yields worldwide. Evaluation of the chemical pesticides used in agricultural crops need to be frequently monitored for any adverse effect on environment using impact assessment tools and models to suggest the corrective measures owing to the primary concern for the health of the man and his environment.

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