ISSN : 0974 - 7451 Volume 9 Issue 9

Environmental Science
An Indian Journal
Current Research Paper

ESAIJ, 9(9), 2014 [308-319]

Assessment of insecticide residues in eggplant farm soils and water

Jinky Leilanie Lu
Institute of Health Policy and Development Studies, National Institutes of Health, University of the Philippines Manila, (PHILIPPINES)
E-mail : jinky_lu@yahoo.com

ABSTRACT

This study aimed to investigate the insecticide residues in agricultural soil and water in Pangasinan which is the largest eggplant producing community in the Philippines. A total of 24 soil and water samples with replicates from 24 farms were collected. Eleven (45.8%) samples were found positive with insecticide residues. Soil samples were collected and delivered to the laboratory for insecticide residue analysis using gas chromatography. The positive residues were cypermethrin, chlorpyrifos, profenofos, triazophos, and malathion which exceeded the maximum allowable concentration (MAC) set by the Environmental Protection Agency (EPA) and the European Commission (EC). Profenofos at 0.10ppm exceeded the MAC at 0.05ppm. Average triazophos residue detected in five farms registered at 0.02ppm in three farms, 0.04 in one farm, and 0.05ppm in another farm, all exceeding the Limit of Detection (LOD) of EC at 0.01ppm. Chlorpyrifos and cypermethrin residues were minimal and within MAC. None of the water samples was found with insecticide residues. However, the active ingredients of the latter two insecticides have high bioaccumulation potential. This study showed soil contamination by insecticide residues. Necessary actions by the local government should be carried out to prevent the hazards posed by these insecticide residues in soil.

KEYWORDS

Insecticide residues;
Residues in soil and water samples;
Environmental assessment of insecticides;
Environmental health.

INTRODUCTION

Due to the increasing demand for food due to increasing population, modern agriculture has been widely adopted worldwide. Green revolution in agriculture is the utilization of fossil fuels in cultivation, fertilization, pesticide application, irrigation, and harvesting as well as in hauling, cold storage, and processing of farm products. Modern agriculture has successfully increased the crop yields and food supply, however, this has caused disadvantageous impacts to the environment such as soil erosion, contamination of surface and ground waters from pesticides and nitrate-based fertilizers, loss of diversity, and increased pest resistance[23,34,36,38,40,41,44,51].

As a result of modern agriculture, excessive use of pesticides has caused contamination in soil, water, and biota[8]. According to Pimentel[40], most of the pesticides applied contaminate soil, water, and air, thereby, posing risks to the non-target organisms. Only very small amount of pesticide applied on crops, which Pimentel[40] estimated at about less than 0.1% reaches the target organisms. The 99.9% moves throughout the environment, compromising the public health. Pesticides move through the food chain affecting the consumer's health, most especially humans. Health problems, accounted by the hazardous effects of pesticides include cases of breast and prostate cancer and problems on the endocrine system[2,30].

Soil health is also disadvantageously affected by the misuse of chemicals. Soil health, as defined by Doran and Zeiss[12] and Karlen et al.[27] is the continued soil capacity to serve as a vital living system due to its biological elements within land-use boundaries. Soil degradation happens due to the use of agrochemicals, thus affecting soil health[35]. Pesticide residues left in the previous planting season can affect the growing of the next crops[3].

Eggplant, *Solanum melongena L.* is an important vegetable crop in the Philippines. In 2007, the Philippines was one of the top ten countries in terms of area, production, and productivity related to eggplant (TABLE 1). One of the top producing provinces of eggplant is Pangasinan. Of the total eggplant production of the country in 2009, 30% was accounted coming from Pangasinan[9].

In the Philippines, the field site has been the top eggplant producing province. In 2009 (latest data), Pangasinan produced 60,069.65 metric tons of eggplants followed by Quezon province with only 26,564.94 metric tons (TABLE 2).

On the other hand, eggplant cultivation, like other vegetable crops, has the potential to degrade the environment due to the misuse of pesticides applied on these crops. The destructive insect pest of eggplant, namely the eggplant fruit and shoot borer (EFSB) is a concern among farmers who then rely extensively on the use of pesticides to eliminate the pest[6]. In India, the farmers practiced more frequent times of spraying and indiscriminately used cocktails of pesticides and higher dosages to keep their eggplants free from damage caused by EFBS. They sprayed their crops an average of 20-30 times in a single crop season and used 26.7 litres of pesticides per hectare. They used cocktails of pesticides such as chlorpyrifos, cypermethrin, monocrotophos, and dimethoate[10].

Due to massive and widespread use of pesticides, determination of residues in all the environmental matrices (i.e., soil, water, and air) has been widely conducted[53]. This study was done to assess the pesticide residues in soil samples in eggplant farms in Sta. Maria Pangasinan. Specifically, the objectives were: 1.) to look into the nature of insecticides used in the farm soil; and 3.) to evaluate the insecticide residues found in relation to the maximum allowable concentration (MAC) set by the Environmental Protection Agency (EPA) and the European Union Commission (EC).

METHODOLOGY

Study area and sampling

The target site was Pangasinan as it is the largest eggplant producing province in the Philippines. The unit of analysis consisted of farms. This study was pursued as a continuing investigation of the previous insecticide

TABLE 1 : Worldwide distribution of eggplant by area, production, and productivity of eggplant in 2007: Selected top ten countries

Country	Area (ha)	Production (tons)	Productivity (tons/ha)	%World production share
China	1,200,000	18,000,000	15.00	56.2
India	512,800	8,450,200	16.47	26.4
Bangladesh	57,747	339,795	5.80	1.1
Indonesia	53,000	390,000	7.35	1.2
Egypt	43,000	1,000,000	23.25	3.1
Turkey	30,000	791,190	26.37	2.5
Iraq	22,000	380,000	17.27	1.2
Philippines	21,000	198,000	9.42	0.6
Italy	12,059	271,358	22.50	0.8
Japan	12,000	375,000	31.25	1.2

Source: Choudhary B and Gaur K. 2009. The Development and Regulation of Bt Brinjal in India (*Eggplant/ Aubergine*). ISAAA Brief No.38. ISAAA: Ithaca, NY

TABLE 2 : Top ten eggplant producing provinces in the Philippines in 2009 (latest data)

Province	Volume of production (in metric tons)
Pangasinan	60,069.65
Quezon	26,564.94
Iloilo	9,782.84
Isabela	9,342.16
Cagayan	7,885.04
Nueva Ecija	6,881.25
Tarlac	6,298.43
North Cotabato	5,399.76
Ilocos Norte	4,969.52
Cebu	4,574.20

Source: Bureau of Agricultural Statistics (BAS) CountryStat. 2009. Other Crops: Volume of Production by Crop, Geolocation and Year. Available from http://countrystat.bas.gov.ph/ selection.asp. .Accessed on May 13, 2011

residues in eggplant in the same area.

The study was a cross sectional design of randomly selected farms in Sta Maria, Pangasinan. Based on the equation below for sample size and the number of farms in Sta Maria, Pangasinan, 24 farms were selected randomly.

$$n=\frac{NZ^2 x p(1-p)}{Nd^2+Z^2.p(1-p)}$$

Z= the value of the normal variable for a reliability level; this was set at 90 % reliability in this study considering budget and feasibility; p=.20 (the proportion of getting a positive sample based on previous studies; 1-p=.80 (the proportion of getting a negative sample based on previous studies); d= sampling error, set at.1; N= population size *, 128 based on available data in Pangasinan; n= sample size

Sample collection

Based on the sample size calculation and sampling procedure, the average distance of the target farms from each other was 1,388.2 meters. One kg of soil was taken from the various plottings within the farm. The average size of the farm was 1.15 has. The various 1 kg soil samples in one farm were mixed together from where the final 1 kg was taken for analysis in the laboratory. A soil auger was used to unearth the soil from soil surface to a depth of one foot The soil sample was placed in an opaque plastic bag. One liter of water sample was also taken from each farm.

Two samples/replicates of the soil samples were taken. The samples were placed in an icebox, and delivered to the laboratory within 24 hours. The samples were stored in a refrigerator at 5 degrees Celsius. The samples were analysed using gas chromatography (GC) (TABLE 3).

Sample analysis and quality control

A standard procedure was used to analyze samples upon receipt by the Bureau of pLant Industry (BPI). Briefly, the insecticide residues were desorbed from the samples and analyzed using gas chromatography (GC) operated in a split mode. Major chromatogram peaks were identified in samples based on a comparison of retention times and mass spectra to peaks from a calibration method.

The sample underwent three stage clean up to remove particulates and impurities in the sample. The first clean up stage was C18, then the use of carbon graphite, and finally, the use of flourisil. Gas chromatography was used for the analysis of multi-insecticide residues in soil. Two detectors were used- nitrogen phosphorous and electron capsule detectors.

The elements in the oven program such as the

TABLE 3 : Sample collection and analytical method

Analyzing method	Specifics
Soil and water samples	Gas chromatography was be used in analyzing multi-pesticide residue in the samples. Two detectors were used- nitrogen phosphorous and electron capsule detectors. Solid phase extraction was done using acetonitril. The soil sample underwent three stage clean up to remove particulates and impurities in the sample. The first clean up stage was C18, then the use of carbon graphite, and finally, the use of flourisil. The elements in the oven program such as the temperature programming, retention time of various pesticides, and temperature of the detector e were previously determined and will depend on each type of pesticide. The recovery method will be about 70-120%. The coefficient of variation will be about less than 10%. A blank control matrix will be used in the laboratory.

temperature programming, retention time of various pesticides, and temperature of the detector were previously determined depending on each type of insecticide. During sample transfer, the oven temperature was maintained between 30 °C below and 20 °C above the solvent's atmospheric boiling point. After the sample had been transferred, the oven temperature was programmed up and chromatography was started. The inlet temperature program consisted of 40 °C (4.2 min), and 200 °C/min to 320 °C (2 min). The oven temperature program included 50 °C (6.13 min), 30 °C/min to 150 °C (2 min), 3 °C/min to 205 °C (0 min), and 10 °C/min to 250 °C (20 min).

The spiked calibration standard data was done. Data review was conducted on a single midpoint standard. The midpoint standard was used as a reference to process the remaining 5 points of the calibration curve. Assessment of all peak assignments, integrations, and calibration curve linearity was done. Analysis of the insecticides exhibited correlation coefficient values of greater than 0.9900.

The recovery was 70-120%. The coefficient of variation was less than 10%. A blank control matrix was used in the laboratory. Two trials were done for each sample. There was no residue detected at the limit of determination (LOD) which was 0.02 mg/kg for organophosphates, and 0.005 mg/kg for organochlorines and pyrethroids.

Data were analyzed using descriptive statistics for pesticide residue concentration in samples. Comparison with national and international standards for maximum residue level was done.

The study was registered with the Research Grant Administration Office of the University of the Philippines Manila. The research study does not involve human subjects or vulnerable populations, and risk to humans was nil as this involved environmental samples of soil and water.

RESULTS

Pesticide use in the farm

In all farm, the following were used- Prevathon® (chlorantraniliprole). Malathion® was used by 88% in the farms, followed by Lannate® (methomyl) at 83%. The insecticide with the highest amount used in L was Brodan® (chlorpyrifos) at 0.26L, followed by Malathion® at 0.188L, then, Siga® (chlorpyrifos) at 0.183L. The average amount used per application was 0.081 (s.d. 0.075) (TABLE 4).

The average spraying time was 2 (s.d. 0.39) hours/day, 3 (s.d. 0.60) days/week, 1 (s.d. 0.26) weeks/month, 7 (s.d. 1.41) months/years and 1 year/cropping season. The insecticides with the highest liter-years of exposure were Brodan (chlorpyrifos) and Siga (chlorpyrifis) at 3.04 and 2.95 liter-years, respectively. (TABLE 5).

TABLE 6 is the summary of the average spraying factors in the farms. It includes the number hours of spraying per day, number of days of spraying per week,

TABLE 4 : Distribution of farms by type and amount of insecticides use

Brand Name	Active ingredient	Type of pesticides	Toxicity class	Freq.	%	Amount used/ application (in L)
Prevathon®	Chlorantranili-prole	Anthranilic diamide	Insecticide 4	24	100	0.073
Malathion®	Malathion	Organophosphate	Insecticide 4	21	88	0.188
Lannate®	Methomyl	Carbamate	Insecticide 2	20	83	0.144
Tamaron®	Methamidophos	Organophosphate	Insecticide 1	14	58	0.123
Hosthathion®	Triazophos	Organophosphate	Insecticide 2	14	58	0.129
Decis®	Deltamethrin	Pyrethroid	Insecticide 4	13	54	0.023
Solomon®	Imidacloprid + betacyfluthrin + cyclohexane	Neonicotinoid + Pyrethroid + Petroleum derivative	Insecticide 2	13	54	0.135
Mospilan®	Acetamiprid	Neonicotinoid	Insecticide 3	12	50	0.136
Selecron®	Profenofos	Organophosphate	Insecticide 2	12	50	0.144
Magnum®	Cypermethrin	Pyrethroid	Insecticide 4	11	46	0.156
Padan®	Cartap hydrochloride	Carbamate	Insecticide 3	10	42	0.030
Brodan®	Chlorpyrifos	Organophosphate	Insecticide 2	10	42	0.264

TABLE 5 : Distribution of farms by percentage, amount and years of insecticide use

Brand name	Active ingredient	Percentage	Amount used/ Application (in L)	Mean number of years of usage
Prevathon®	Chlorantraniliprole	100	0.073	3.04
Malathion®	Malathion	88	0.188	10.00
Lannate®	Methomyl	83	0.144	15.35
Tamaron®	Methamidophos	58	0.123	14.29
Hosthathio®n	Triazophos	58	0.129	12.29
Decis®	Deltamethrin	54	0.023	15.77
Solomon®	Imidacloprid + betacyfluthrin + cyclohexane	54	0.135	2.15
Mospilan®	Acetamiprid	50	0.136	4.67
Selecron®	Profenofos	50	0.144	5.50
Magnum®	Cypermethrin	46	0.156	13.36
Padan®	Cartap hydrochloride	42	0.030	4.30
Brodan®	Chlorpyrifos	42	0.264	11.50

TABLE 6 : Distribution of farm by spraying factors

Spraying Factors	Mean	Standard deviation
Number of hours of spraying per day	2.14	0.39
Number of days per week	2.87	0.60
Number of weeks per month	1.43	0.26
Number of months per cropping season	6.66	1.41
Number of cropping season per year	1.00	0
Number of years	8.24	5.63
Amount of insecticide used in liters per usage	0.081	0.075
Dose Exposure to Insecticides (liter-years)	0.82	0.98

number of weeks per month, and the number of months per cropping season. It also includes the average number of years of pesticide usage and the amount of pesticide used per application.

Result of insecticide residue analysis in soil and water samples

There were 11 farms out of the 24 farms (45.8%) found positive with insecticide residues in soil. None was found positive in the water samples.

For the soil samples, the insecticide residues found were cypermethrin, chlorpyrifos, profenofos, triazophos, and malathion. Seven pesticide residues (29%) exceeded the maximum residue level (MRL). Profenofos residues, detected in 3 farms were assessed based on the MAC set by Environmental Protection Agency (EPA). Triazophos, found in 5 farms were evaluated based on the default LOD MAC of the European Commission under the Regulation 396/2005. Chlorpyrifos, found in 2 farms was assessed based on the MAC set by EPA. Cypermethrin, detected in 2 farms was also evaluated using the MAC set by EPA. Malathion, found in 2 farms was also assessed using the MAC set by EPA (TABLE 7).

A total of 24 samples with replicates from 24 farms were collected. Eleven (45.8%) samples were found positive with insecticide residues. Nineteen positive residues (79%) were found in 11 farms out of the 24 farms. Five of these farms (20.8%) exceeded values of insecticide residues. Six insecticide residues or 25% exceeded the MAC set by the above-mentioned international agencies (TABLE 8). No pesticide residue was found in water samples.

DISCUSSION

The fate of insecticides and their transformation products (TPs) on the soil depend on the properties of

TABLE 7 : Insecticide residues found in the soil samples

Farm Code	Positive insecticide Residues	Actual reading	Maximum residue Level	Evaluation	Reference
Farm 3	Chlorpyrifos	0.02ppm	0.03ppm	Within MRL	EPA*
	Chlorpyrifos	0.02ppm	0.03ppm	Within MRL	EPA*
Farm 6	Triazophos	0.02ppm	0.01ppm	Exceeded	EC*
Farm 7	Chlorpyrifos	0.03ppm	0.03ppm	Within MRL	EPA*
	Chlorpyrifos	0.01ppm	0.03ppm	Within MRL	EPA*
Farm 8	Triazophos	0.02ppm	0.01ppm	Exceeded	EC*
	Triazophos	0.05ppm	0.01ppm	Exceeded	EC*
Farm 9	Cypermethrin	0.02ppm	0.05ppm	Within MRL	EPA*
Farm 10	Cypermethrin	0.03ppm	0.05ppm	Within MRL	EPA*
	Cypermethrin	0.02ppm	0.05ppm	Within MRL	EPA*
Farm 11	Profenofos	0.10ppm	0.05ppm	Exceeded	EPA*
	Triazophos	0.02ppm	0.01ppm	Exceeded	EC*
Farm 12	Profenofos	0.01ppm	0.05ppm	Within MRL	EPA*
	Triazophos	0.01ppm	0.01ppm	Within MRL	EC*
Farm 13	Triazophos	0.04ppm	0.01ppm	Exceeded	EC*
Farm 14	Malathion	0.01ppm	0.05ppm	Within MRL	EPA*
Farm 15	Malathion	0.04ppm	0.05ppm	Within MRL	EPA*
	Profenofos	0.01ppm	0.05ppm	Within MRL	EPA*
	Triazophos	0.01ppm	0.01ppm	Within MRL	EC*

***EPA stands for environmental protection agency and EC for european commission. Regarding on the maximum residue level (MRL) used in this study, the limit of analytical determination (LOD) of EPA method 8141A for soils and waters and the default LOD MRL of EC were adapted**

TABLE 8 : Summary of insecticide residues found in soil samples

Sample	No. of samples	Positive residues		Residues exceeding MRL	
		Farms	Insecticides Found	Farms	Insecticides Found
Soil	24 with replicates	11 (45.8%)	19 (79%)	5 (20.8%)	6 (25%)

the active ingredients of the insecticides and the degree of interaction with the soil particles or adsorption. The parameters such as the water solubility, soil-sorption constant (Koc), the octanol/water partition coefficient (Kow), and half-life of insecticides in soil (DT50) as well as the properties such as chemical functions, polarity, polarizability, and charge distribution of both soil and insecticide molecules are all the characteristics that measure the persistence and movement of insecticides and their TPs in the soil[4,5,39,48]. In this study, insecticide residues with low polar characteristics and found to be existent in the soil samples were chlorpyrifos, cypermethrin, traizophos, profenofos and malathion.

The persistence and mobility of insecticides in soil are also controlled by several processes. The persistence of insecticide in the soil is affected by chemical degradation (i.e. photolysis, hydrolysis, oxidation and reduction) and microbial degradation with the aid of soil microorganisms. The degradation process ranges from the formation of transformation products (TPs) to decomposition of inorganic products. Mobility of insecticides includes sorption, plant uptake, volatilization, wind erosion, run-off and leaching. Furthermore, the fate of insecticides varies depending on the type of soil, agricultural practices, and climate[4]. In this study, farms were sprayed on the average of 2 hours per day, and 3 days per week, and 8 years. The average amount of insecticide used per application in the farm was 81 ml. All these factors contributed to the persistence of insecticides in the soil in this study[4]. The results in this study reveal more insecticide residue reading in soil compared to the previous study[32] since more varies communities and farm sampling was included (TABLE 9).

TABLE 9 : Classification of insecticides in relation to the study

Pesticide Class*	Description*	Results of insecticide residue in this study
Hydrophobic, persistent, and bioaccumulable pesticides	These insecticides strongly bound to the soil. Examples are organochlorine DDT, endosulfan, heptachlor, endrin, lindane and their TPs. Majority of the pesticides included in this group were already banned but still their residues existed in the environment.	None found in the soil samples in this study.
Polar pesticides	These insecticides moved from soil by means of run-off and leaching thus may possibly contaminate groundwater. Insecticides that belong to this group are the carbamates, fungigicides, some organophosphates and their TPs.	These insecticide residues were found in this study namely chlorpyrifos, cypermethrin, traizophos, profenofos and malathion.

***Source of data: Andreu V and Pico Y. 2004. Determination of pesticides and their degradation products in soil: critical review and comparison of methods. Trends in Analytical Chemistry 23 (10–11) : 772-789**

Each insecticide varies in toxicity, persistence and mobility, thus, pesticides also differ to the degree of environmental risks they posed[7]. According to Andreu and Pico[4], if a insecticide has a low sorption coefficient, long half-life, and high water solubility, then it has the potential to contaminate groundwater through leaching. Moreover, according to Barnard et.al.[7], the active ingredients of pesticides differ widely in terms of persistence. Half-life, which is the typical measurement for persistence, has ranged to 10 to 100 days for modern pesticides. Also, the longer the active ingredient left in the environment, the more danger it poses to other non-target organisms[7,11,18,47,54,55].

Chlorpyrifos residues were found positive in soil samples in two farms. The reading was 0.02 ppm. Chlorpyrifos is non-mobile, has low leachability, moderately persistent in soil, and volatile. These properties of the compound can be most likely explained why it was found positive in soil samples. This is similar to the study of Laabs et al.[31] wherein chlorpyrifos remained within the top 15 cm of the soil. They noted that chlorpyrifos showed extremely rapid dissipation and this was attributed to the high vapor pressure of the compound and also to the tropical weather conditions. The immobility through and over the soil profile of the compound was accounted by the high level of Koc. It has an average of soil and sediment sorption coefficient (Koc) of 8498[43]. Other studies also showed the same result such that of Fermanich and Daniel 1991; Kathpal et al. 1997. In addition, chlorpyrifos, which is a non-polar molecule, has a low water solubility. It has not been found and proved to contaminate groundwater. Although, small amount of chlorpyrifos residue was found in this study, this can still pose risk to the health of humans since it has high rate of bioaccumulation potential.

Residues of profenofos were found positive in soil in three farms, and one exceeded the MRL. This compound is moderately volatile, non-persistent in soil, has low leachability and slightly mobile. The positive residue found can be accounted to these properties of the compound.

Triazophos residues were found positive in five farms and four exceeded the default LOD MRL set by EC, which is 0.01ppm. The residues that exceeded MRL had a reading between 0.02- 0.05ppm. Triazophos is moderately volatile, moderately persistent in soil, and moderately mobile. No researches yet were done regarding on the positive residues of triazophos in soil.

Cypermethrin residues were found positive in two farms but within the MRL set by EPA. Cypermethrin is moderately volatile and moderately persistent in soil. It is non-mobile and has low leach ability. Malathion residues were found positive in two farms but within the MRL set by EPA. Malathion has low leach ability thus its movement is limited only in superficial surface of the soil. This may explain why malathion residues were positive in soil samples.

TABLE 10 presents the properties of the positive insecticide residues, namely, chlorpyrifos, profenofos, triazophos, cypermethrin, and malathion. Chlorpyrifos, cypermethrin, and triazophos are moderately persistent in soil while profenofos and malathion were non-persistent. Cypermethrin, triazophos and profenofos are moderately volatile based on their Henry's Law of Con-

TABLE 10 : Physico-chemical properties of the active ingredients of insecticides

Active ingredient	Water solubility	Vapour pressure	Henry's law of constant (dimensionless)	Koc - organic-carbon sorption constant	GUS leaching potential index*	Soil (typical aerobic) Half life	Bio-accumula Tion potential	Charac teristics	Results in the study
Chlorpyrifos	1.05 at 20^{o}C (mg l^{-1})	1.43 at 25^{o}C (mPa)	2.80 X 10^{-04} at 20^{o}C	8151 ml g-1	0.15	50 days	High	Low water solubility Volatile(based on Henry's Law of Constant) Moderately persistent in soil Low leachability Non-mobile	Positive in two farms at 0.01-0.03 ppm; none exceeded MRL
Profenofos	28 at 20oC (mg l-1)	2.53 at 25oC (mPa)	1.39 X 10-05 at 20oC	2016 ml g-1	0.59	7 days	Low	Low water solubility Moderately volatile(based on Henry's Law of Constant) Non-persistent in soil Low leachability Slightly mobile	Positive in three farms (0.01, 0.4ppm), and one exceeded MRL(0.10 ppm)
Triazophos	35 at 20oC (mg l-1)	1.33 at 25oC (mPa)	1.30 X 10-06 at 20oC	358 ml g-1	2.38	44days	Moderate	Low water solubility Moderately volatile(based on Henry's Law of Constant) Moderately persistent in soil Transition state Moderately mobile	Positive in five farms, and four exceeded MRL (0.02-0.05 ppm).
Cypermethrin	0.004 at 20oC (mg l-1)	0.00034 at 25oC (mPa)	1.75 X 10-05 at 20oC	57889 ml g-1	-1.18	35days	High	Low water solubility Moderately volatile(based on Henry's Law of Constant) Moderately persistent in soil Low leachability Non-mobile	Positive in two farms but none exceeded MRL (0.02-0,03 ppm)
Malathion	148 at 20^{o}C (mg l^{-1})	3.1 at 25^{o}C (mPa)	4.80 X 10^{-05} at 20^{o}C	217ml g^{-1}	-1.28	0.17 days	Low	Moderate water solubility Volatile(based on Henry's Law of Constant) Non-persistent in soil Low leach ability Moderately mobile	Positive in two farms but none exceeded MRL (0.01-0,05 ppm)

Source of data: International Union of Pure and Applied Chemistry (IUPAC). 2011. Global Availability of Information on Agro-chemicals. Available from http://sitem.herts.ac.uk/aeru/iupac/index.htm. Accessed on March 22, 2011

stant while chlorpyrifos and malathion are volatile. Chlorpyrifos, malathion, cypermehrin, and profenofos have low leaching potential whereas triazophos is in transition state. Chlorpyrifos and cypermethrin are non mobile, profenofos is slightly mobile, and triazophos and malathion are moderately mobile. Chlorpyrifos and cypermethrin has high rate of bioaccumulation potential, profenofos and malathion have low rate of potential and triazophos has moderate rate of bioaccumulation potential. The higher Koc, the lower the leaching potential, therefore, the compound is limited from movement throughout and over the soil profile and so less potential for groundwater contamination. Almost all of the residues detected have low leach ability thus groundwater contamination is unlikely to occur in the area.

Fate of insecticides in soil

According to Aharonson et al.[1] the soil serves as a "purifying filter" and as such contamination of groundwater is unlikely to happen. However, Hamilton et al. 2003 noted that there newer studies show pesticide compounds, specifically herbicides, detected in surface and ground waters. Due to modernization, pesticides being developed are more water-soluble, thermolabile, and more polar and have longer persistence to enable effective pest control[4,7]. Perhaps, this serves as an inkling to the possibility of pesticide contamination in water.

For groundwater contamination, the soil profile plays a significant role in determining the potential of pesticides to leach to groundwater. As mentioned earlier, the more organic content of the soil, the greater the persistence of the pesticide in the soil. For this study, no residues were found in groundwater samples.

The type of soil used in growing eggplants is sandy, loam soil with a pH ranging from 5.5 to 6.5. This type of soil used in eggplant cultivation is rich, well-drained, and has high organic matter[33,52]. Thus, according to Harper[22], the very low tendency for insecticide to leach can be accounted by the high organic matter content of the soil. As such, no insecticide residues were found in surface and groundwater samples in this study due to the high organic matter of the type of soil used in eggplant cultivation.

Risk exposure to contaminated soil

Detectable concentrations of insecticide residues in soil, water (both groundwater and surface water), air, and even commodities pose health risks to the human health and the environment[15,29]. Simcox et al.[49] investigated the pesticide exposure of children to soil-contaminated pesticides and household dust. The farms were within 200 feet away from their houses and the pesticides investigated were organophorous pesticides including chlorpyrifos, parathion, phosmet, and azinphosmethyl. It was found that higher concentrations were detected in household dust than in soil. In this study in Pangasinan, there is potential for the communities to be exposed to household dust- and soil-contaminated insecticides since houses are very close to the farms.

Effect of insecticide contaminated soil to vegetation

Residues that originate from pesticides and used in agriculture are called bound residues[45]. Studies have shown that bound residues present in the soil could be taken up by vegetation[19]. The mustard plants, for example, was studied by Suss and Grampp[50], took up minimal amounts of bound 14C-monolinuron residues in soil. Other studies have also shown that bound residues such as [methyl-14C]parathion in the study of Fuhremann and Lichtenstein[17], 14C-cypermethrin in Roberts and Standen[46], and 14C-hydroxymonolinuron in Hague et al.[20]. All these pesticides were taken up by plants. It has also been shown that portions of these residues have the tendency to bound within plant tissues[17,25].

CONCLUSION

This study showed that soil contamination due to insecticides is evident in Pangasinan which is the largest eggplant producing community in the Philippines. Eleven farms were found positive with pesticide residues in soil, and 5 farms exceeded the MAC. The study has shown that several factors such as farming practices, amount and duration of insecticide used, soil type and characteristics of the insecticides all affect the persistence of insecticides in the soil. Even for the insecticide residues that were within MAC, this could still pose risk to the health of the community since some insecticide residues found in the study have the potential of bioaccumulation. Thus, based on the findings of this study, it is suggested management programs be developed to minimize the adverse effect of contaminated soils and remediation practices for the contaminated soils.

For future studies, it is recommended to do more extensive research on the transformation products (TPs) of the insecticides and their fate in the soil, the bonding forces between the soil and active ingredient, as well as the chemical structure of each active ingredient.

Acknowledgement is cited to International Service for the Acquisition of Agri-biotech Applications funding support extended for this study.

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