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Spatial Volatility Analysis of Pesticides Accumulation: Indication for Toxic Exposure in Three Randomly Selected Farm Settlements in South-west Nigeria

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Abstract: Exposure to pesticides especially from farms may occur through water, soil, sediments and food. Their volatility determines changes in their accumulation in food/water and the resulting long-term and short term health effects on human. This study was conducted to predict pesticides' accumulation in 3 randomly selected farm settlements in South-west Nigeria. Seasonal composite samples (sediments, soils collected from the settlements were analyzed for pesticides. The persistence of the model was assessed using the half-life of the gamma and beta component of the model. The GARCH diagnostic returned Jack-Bera (JB) statistics ranging between 8.862 for sediment of Akufo and 1468.734 for cypermethrin in the water for Ilora. The summary statistics of the glyphosate accumulation showed that highest mean value (35.869) was obtained for glyphosate accumulated in the sediments of Ilora and the least glyphosate accumulation (8.7175) was obtained for vegetable in the same Ilora. The GARCH diagnostic returned Chi-Square Statistics that ranged between 0.1266 for sediment of Akufo and 254.71 for glyphosate in the sediment for Ilora. The analysis of the GARCH model persistence for glyphosate indicated that volatility of its accumulation can be described by the GARCH model that was neither explosive nor exponential decay model.

Key words: Volatility · Heteroskedasticity · Fluctuation · Persistent · Accumulation · Pesticide

INTRODUCTION

Possibility of spatial interconnectivity of herbicides and insecticides accumulation in farms of South-West Nigeria provide basis for viewing the study of the volatility of their accumulation as destructive. This is because the volatility of the accumulation may connote the interplay of some environmental and edaphic phenomenon with the substances. Fluctuation in the accumulation of both insecticides and herbicides was established to be as a result of differences in the edaphic and environmental conditions of each of the sites [1]. Herbicides and insecticides are commonly used farm materials (Pesticides) in cultural practices in agriculture and the duo find their ways into the surrounding water, sediments, soils and the vegetables [2,3]. The spatial connectivity of these environmental media (Water, sediment, soil and vegetables) across the different farms of selected sites prompted the question "How volatile is the presence of cypermethrin and glyphosate across both the site and the media". This would be useful in the determination of appropriate planting methods for each of the sites and would enhance the determination of their concentration in each media and as predictive tool of toxic human exposure (Of farmers and consumers).

GARCH model is one of the varieties of time series model for forecasting volatility [2] and has extensively been explored in economics. It is the general form of the Autoregressive conditional heteroskedasticity [3].

Autoregressive conditional heteroskedasticity (ARCH) model is given as

$$y_t = xt\xi + \varepsilon_t \quad t = 1, \ldots, T.$$

Where x_t = K x 1 vector of exogenous variable, ξ = k x 1 vector of regression parameters, ε_t = stochastic error.

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Engle [4] proposed the ARCH model and was further modified to the system GARCH model by Carson [5]. The modified version was used in air quality analysis by Wu and Kuo [6].

Previous works on spatial statistical analysis of environmental phenomena have focused on combining spatial statistical and ensemble information in weather forecast [7] modeling and forecasting daily average particulate matter concentration by a seasonal fractionally integrated process [8] among others. These works notwithstanding, little known works exist about the volatility of herbicide and insecticides (Pesticides) accumulation across this study area. This work consider spatial dimension in terms of time and space and volatility of the both cypermethrin (Insecticide) and glyphosate (Herbicide) across the space were studied. The goal of this work was to investigate the predictability of the volatility of the accumulation of these pesticides across the area. The general objective of the study was to model the volatility of the cypermethrin and glyphosate accumulation of the area while the specific objectives were to develop GARCH model for describing the volatility. By implication, the concentration in the media as a source of exposure of human (Farmers and consumers) to the pesticides would be assessed.

MATERIALS AND METHODS

Study Area and Analysis: The study was conducted in Oyo state, South-western Nigeria (Longitudes 4^{O} E and latitudes 8^{O} N). The state occupies 27, 249 square kilometers and has a gender distribution of 1:1 male to female population. The mainstay of a major population of the state is agriculture. The state enjoys an equatorial climate characterized by high relative humidity; wet (April to October) and dry (November to March) seasons. Ambient temperature is between 25 °C and 35 °C. The peculiar vegetation is rain forest in the south and guinea savannah further north of the state. Hence it is not unusual to see an intermingling of trees up north. This thus divides the state into three agro-ecological zone namely rainforest, savannah and derived savannah.

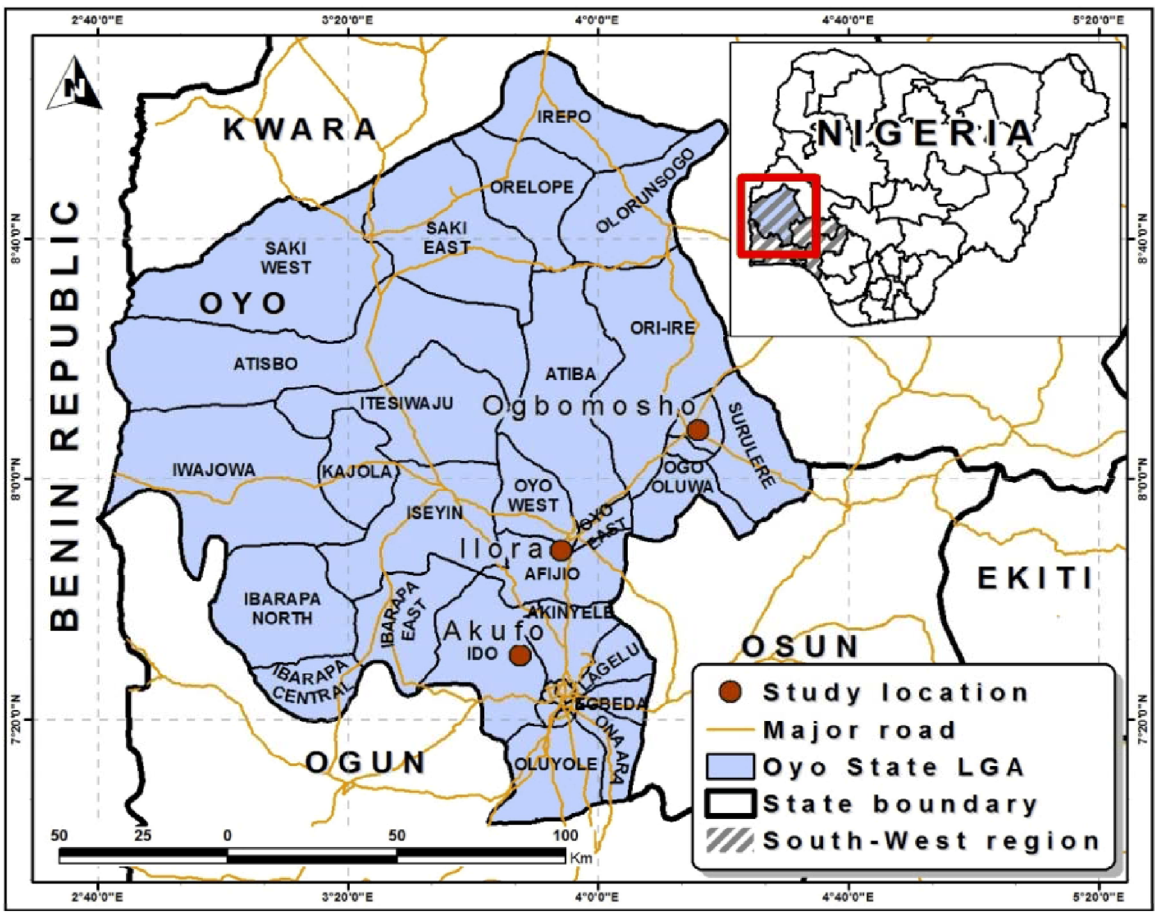

Fig. 1: Map of Nigeria Showing the Location of the study sites in the South Western Nigeria.

Three (3) farm settlements representative of the three (3) agricultural zones in Oyo state were chosen namely Akufo farm settlement, Ilora farm settlement and Ogbomoso farm settlement (Figure 1). Five (5) farms were randomly selected from each settlement making a total of fifteen (15) farms. Control samples of soil and vegetable were collected from household vegetable farms where pesticides were not being used while samples for water and sediments were collected at a distance of 10 km upstream of each study farm.

Cypermethrin and glyphosate accumulation at 5 farms per each of the 3 randomly selected locations (Ilora, Akufo and Ogbomosho) in the South West Nigeria were evaluated. The assessments were conducted for media (Water, soil sediments and vegetables) at each farm of each of the locations. Two year bi-seasonal (Dry and wet season) composite media samples collection was carried out in each location and the levels of pesticides determined by standard methods [9].

Modeling and Data Analysis: Prior to this study, a preliminary investigation of the prominent herbicides and insecticides in the South-West Nigeria was conducted and both cypermethrin and glyphosate ranked high. The data were analyzed using summary statistics (Mean and variance), time plot (Using the sample points/places as *t*) and the $GARCH_{(1,1)}$ model was obtained through maximum likelihood estimation.

The Jarque-Bera statistics of the GARCH model were computed [10] using;

$$JB = n[(\sqrt{b_1})^2/6 + (b_2-3)^2/24)]$$

Where n = sample size and $\sqrt{b_1}$ and b_2 are sample skewness and kurtosis coefficients.

RESULTS

Summary Statistics and Time Plot of Cypermethrin and Glyphosate: The summary statistics of the constituent showed that mean cypermethrin ranged between 1.365(±0.407) for water and 10.766 (±0.901) for vegetable. The variance on the other hand fell between 19.905 for water and 184.061 for soil (Table 1). Mean glyphosate ranged from 8.686(±0.613) for vegetables to 27.460(±1.663) for soil and the variance followed the trend of the mean (least = 45.088 – vegetable and highest = 331.819). It is noteworthy that quantities of Glyphosate encountered in each part were greater than those of the cypermethrin. In addition, the quantities of both substances (cypermethrin and glyphosate) were greater at dry season than the wet season (Table 1). Similarly, the cypermethrin and glyphosate recorded highest accumulation irrespective of parts at Ilora (Table 1). No regular trend was obtained for the variance however. The time plot of the cypermethrin showed an increasing regular trend over the period (Figure 2) while that of glyphosate returned a decreasing regular trend over the period. The implication of this result is that both cypermethrin and glyphosate returned a conflicting trend over the period and this conflicting rate was however not equal for all the period. The autocorrelation of both Cypermethrin and Glyphosate indicated a cyclic non – regular series for the period under study (Figure 3). The augmented Dickey-Fuller (ADF) test statistics returned for Cypermethrin test critical value of -5.120, -3.520 and -2.898 for $P < 0.01$, $P < 0.05$ and $P < 0.1$ level respectively. It is thus safe to reject the null hypothesis (of a unit root for cypermethrin). We can deduce that the cypermethrin accumulation was non-stationary. Similarly the ADF test statistics for Glyphosate produced were -5.120, -3.520 and -2.898 for $P < 0.01$, $P < 0.05$ and $P < 0.1$ level respectively. It is therefore worthy of rejecting the null hypothesis of presence of unit root.

GARCH Model: The GARCH coefficient for the sediment and water samples of glyphosate at Akufo gave higher estimates than other (Soil and vegetables) samples (Table 2). The t-test of the GARCH model components returned significant results for ?1 and ?2 for all the samples. The ?1 estimates for vegetables at Akufo (0.5019) was however not significant (P<0.05). All other model component for sediment, vegetable and water sample were not significant (P<0.05). For soil samples, the t statistics of the model components were all significant (Tables 2). The Langranger Multiplier test returned 0.127, 13.378, 3.301 and 4.294 for sediments, soil, vegetables and water respectively. All these Langranger Multiplier values were though greater than 0 but were not statistically significant except that of soil samples. Similar results were obtained for the Langranger Multiplier test for the samples at Ilora and Ogbomosho. The ARCH-LM values returned were 1.879, 1.2, 0.354 and 02.234 for sediment, soil, vegetables and water respectively at Ilora. For the sample at Ogbomosho, the Langranger Multiplier test were 4.881 (Sediment), 3.774 (Soil), 0.701(Vegetables) and 8.789 (Water). These values were though greater than zero but were not statistically significant (Table 2). The only exception was the ARCH – LM test for water at Ogbomosho which was significant (Table 2). The Jarque-Bera test 254.7109, 16.282 and 17.418 returned for sediment, vegetables and water sample respectively at Akufo were significant. The JB test obtained for the soil (4.391) was however not significant (Tables 2). In addition, the kurtosis 14.044 (Sediment), 3.900 (Soil), 4.059 (Vegetables) and 4.400 (Water) showed strong evidence of leptokurtosis. Similarly, the kurtosis for both Ilora and Ogbomosho showed evidence of leptokurtosis (Table 2). All the JB statistics 14.088, 67.973, 133.559 and 301.757 for sediments, soil, vegetables and water at Ilora as well as 38.562, 19.183 and 60.524 for sediments, soil, vegetables at Ogbomosho were statistically significant. Similarly, their kurtosis showed evidence of leptokurtosis. The implications of these results were:

The GARCH coefficient of the cypermethrin sediments and soils at Ilora gave higher estimates than all other sites while the GARCH coefficient of the cypermethrin accumulation in vegetable and water was higher at Akufo. The performances of the model components for each specimen and at each location differ from one another (Table 3). The only common peculiarities of the model components was that each of the model had at least one significant component. The LM statistics for the samples at Akufo were 4.169 (Sediments), 1.098 (Soil), 5.884 (Vegetable) and 5.136 (Water – Table 3). Also, the LM statistics for the samples at Ilora were 8.121, 2.344, 7.119 and 0.133 for sediment, soil, vegetables and water and all these LMT values were not significant (P < 0.05 – Table 3).

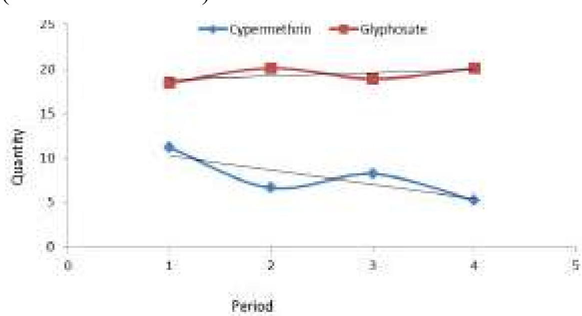

Fig. 2: Time Plot of Cypermethrin and Glyphosate

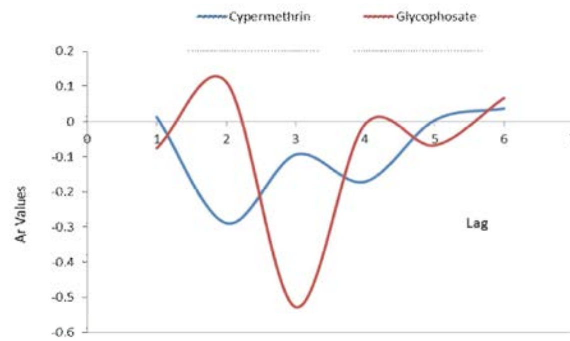

Fig. 3: Autocorrelation (r_k) of the Herbicides (Cypermethrin and Glyphosate).

Analysis of Model Persistence and Volatility: The analysis of the GARCH model persistence for glyphosate indicated that volatility of its accumulation can be described by the GARCH models that were neither explosive nor exponential decay model (Table 2). This was because the sum of gamma and $beta_{(1)}$ in all the cases were less than 1. The half-life for

GARCH model of cypermethrin persistence analysis also showed that the entire GARCH model accurately captures the persistence of the volatility. This was hinged on the fact that none of the half-life values gave infinity value even in spite of the bogus beta value of vegetable at Akufo (Table 3). Similar result was obtained for Akufo, the half-life of the models ranged between -0.115 (vegetable at Akufo) and 8.616 (vegetable at Ilora) model persistence for cypermethrin. The implication of this persistence of the models is that the GARCH models would present good predictions of the cypermethrin and glyphosate accumulation.

Table 1: Summary Statistics of the Parameters for Cypermethrin and Glyphosate

		Cypermethrin			Glyphosate		
Parameters	Options	Mean+SE	Variance	Kurtosis	Mean+SE	Variance	Kurtosis
Parts	Sediments	9.856±1.218	177.904	6.352	25.595±1.474	260.672	1.898
	Soil	9.144±1.238	184.061	17.398	27.460±1.663	331.819	3.467
	Vegetable	10.766±0.901	97.487	4.082	8.686±0.613	45.088	3.949
	Water	1.365±0.407	19.905	91.309	15.706±1.470	259.355	8.021
Season	Dry	9.661±0.828	164.584	12.642	18.649±1.031	255.271	2.688
	Wet	5.905±0.630	95.247	11.816	20.074±1.130	306.669	5.135
Places	Akufo	5.660±0.555	49.275	6.729	21.293±1.204	231.956	3.999
	Ogbomosho	5.304±0.745	88.848	16.089	14.732±1.233	243.292	9.933
	Ilora	12.385±1.202	231.054	7.548	22.059±1.454	338.322	2.250

Table 2: GARCH Model coefficient and Model Statistics for Glyphosate

		sediment		Soil		vegetable		Water	
Location	Variable	Coefficient	t-statistics	Coefficient	t-statistics	Coefficient	t-statistics	Coefficient	t-statistics
Akufo	intercept	500.6828	0.28562	200.7112	0.01191	9.7656	0.20688	300.0589	0.90546
	gamma	0.16427	0.13375	0.54104	0.01698	0.0624	0.28383	0.8324	1.77234
	beta(1)	0.04608	0.0189	0.2573	0.00869	0.5019	0.08859	0.0014	0.00383
	beta(2)	0.00301	0.00126	0.4948	0.01393	0.0103	0.00232	0.00069	0.00224
	Test (ARCH-LM)	0.1266		13.378**		3.301		4.2936	
	F - statistics	0.0318		5.3224**		0.9085		1.2188	
	Test (Jarque-Bera)	254.7109**		4.3945		16.282**		17.4177**	
	Kurtosis	14.0444		3.8996		4.059		4.400	
Ilora	intercept	500.9615	0.09443	200.2379	0.15588	7.0396	0.13651	7.1383	0.13122
	gamma	0.09237	0.1725	0.1384	0.41324	0.0895	0.33785	0.04271	0.14259
	beta(1)	0.01669	0.00364	0.0012	0.00073	0.0181	0.00547	0.82402	0.11449
	beta(2)	0.04867	0.13769	0.6435	0.44521	0.2912	0.06312	0.01779	0.00186
	Test (ARCH-LM)	1.8787		1.200		0.3539		2.234	
	F - statistics	0.4955		0.3104		0.0894		0.5953	
	Test (Jarque-Bera)	14.0881**		67.973**		133.559**		301.757**	
	Kurtosis	4.4936		7.653		10.288		14.7945	
Ogbomosho	intercept	200.2109	0.33965	700.9821	0.17484	2.2119	0.15495	7.7891	0.31821
	gamma	0.06267	0.18475	0.0649	0.27209	0.0777	0.15143	0.0634	0.34896
	beta(1)	0.51976	0.1255	0.0052	0.00138	0.5134	0.05235	0.5042	0.1079
	beta(2)	0.001887	0.00047	0.2391	0.07194	0.0139	0.00186	0.0424	0.00998
	Test (ARCH-LM)	4.8812		3.774		0.7011		8.789*	
	F - statistics	1.4117		1.054		0.1788		2.907*	
	Test (Jarque-Bera)	38.5617**		19.183**		60.5241**		4.006	
	Kurtosis	6.0395		5.0885		7.9018		2.778	

Table 3: GARCH Model coefficient and Model Statistics for Cypermethrin

		Sediment		Soil		vegetable		water	
Location	Variable	Coefficient	t-statistics	Coefficient	t-statistics	Coefficient	t-statistics	Coefficient	t-statistics
Akufo	intercept	7.3374	0.11269	2.476119	0.25654	6.0064	0.34294	0.3582	0.18417
	gamma	0.0648	0.26364	0.07001	0.38695	400.9614	0.47242	0.03563	0.14722
	beta(1)	0.00529	0.00251	0.009285	0.00449	6.4759	0.10152	0.6682	0.10092
	beta(2)	0.76692	0.32635	0.54933	0.27022	0.2377	0.00388	0.007793	0.00141
	Test (ARCH-LM)	4.169		1.098		5.884		5.136	
	F – statistics	1.179		0.2831		1.758		1.498	
	Test (Jarque-Bera)	4.960		8.862		28.418**		86.594**	
	Kurtosis	1.636		3.100		5.255		8.515	
Ilora	intercept	100.1843	0.15713	8.5318	0.25469	1.2932	0.04938	0.2286	0.09829
	gamma	0.05161	0.76004	0.0684	0.98309	0.0383	0.06191	0.00209	0.04414
	beta(1)	0.0073	0.00191	0.013	0.00742	0.8844	0.06058	0.0818	0.00642
	beta(2)	0.6788	0.19021	0.78285	0.47432	0.03909	0.00292	0.5121	0.04854
	Test (ARCH-LM)	8.121		2.3441		7.119		0.1327	
	F – statistics	2.622*		0.6268		2.218		0.0333	
	Test (Jarque-Bera)	22.806**		81.792**		30.258**		1468.734**	
	Kurtosis	5.027		8.481		5.476		30.793	
Ogbomosho	intercept	0.2841	0.00216	2.4101	0.12206	1.24833	0.2234	0.1231	0.13878
	gamma	0.05998	0.89026	0.05289	0.62928	0.61767	0.55032	0.06224	0.7302
	beta(1)	0.09572	0.08468	0.0146	0.00686	0.02139	0.00137	0.01497	0.02015
	beta(2)	0.82604	0.68015	0.6662	0.26417	0.6867	0.44913	0.8149	1.60846
	Test (ARCH-LM)	8.117		3.1311		8.127		1.9121	
	F – statistics	2.620*		0.8574		2.624*		0.5048	
	Test (Jarque-Bera)	76.053**		22.050**		15.706**		26.914**	
	Kurtosis	8.022		4.996		4.271		5.0573	

Table 4: The Persistence of the GARCH Model

		Parts		Cypermethrin		Glyphosate	
Site		alpha (1)	beta (1)	½ life	alpha (1)	beta (1)	½ life
Akufo	Sediment	0.0648	0.00529	0.26078	0.164	0.046	0.444141
	Soil	0.07001	0.009285	0.273476	0.541	0.257	3.071825
	Vegetable	400.9614	6.4759	-0.11533	0.0624	0.502	1.211813
	Water	0.03563	0.6682	1.97355	0.8324	0.001	3.803453
Ilora	Sediment	0.05161	0.0073	0.244777	0.092	0.017	0.312735
	Soil	0.0684	0.013	0.276333	0.138	0.001	0.351266
	Vegetable	0.0383	0.8844	8.615755	0.09	0.018	0.311439
	Water	0.00209	0.0818	0.279692	0.043	0.824	4.856819
Ogbomosho	Sediment	0.06	0.096	0.373081	0.063	0.52	1.284633
	Soil	0.053	0.015	0.257844	0.065	0.005	0.260654
	Vegetable	0.618	0.021	1.547719	0.078	0.513	1.317922
	Water	0.062	0.015	0.270344	0.063	0.504	1.221629

DISCUSSIONS

The goal of the present study has been to study the volatility of the compound (Cypermethrin and glyphosate) distribution across the site. None of the coefficient of both cypermethrin and glyphosate returned negative values and the sum of the $\acute{a}_1$ and $\hat{a}_1$ is less than 1. This implied that cypermethrin and glyphosate accumulation at any of the sites and parts were dominated by pure positive shocks and none of the GARCH model returned explosive or exponential decay model. From this study, it is apparent that the volatility of herbicides and insecticides accumulation can be predicted using the GARCH model. This is similar to Wang *et al*. [11] and Gourdarzi and Ramanarayanan [12]. GARCH model was established to test and Model Stream flow process.

Also, the disparity in the coefficient of the GARCH model in addition is in order. This is because, the locations though may fall within the same climatic zone and have common regional features but some edaphic and other weather characteristics (like rainfall) could still bring about these disparities. Our finding was similar to that of He *et al.* [13] where disparities were experienced among 42 cities of 9 regions of China. From our study, the samples (Water, soil, sediment and vegetables) worked on could be categorized into primary or direct accumulator and secondary or indirect accumulator. Soil is the example of direct or primary accumulator because it is usually the direct recipient of the herbicides. Sediment, vegetables and water are examples of indirect or secondary accumulator. The materials (Herbicides and insecticides) are usually transported to these materials through erosion, absorption and others. The Engle Langranger Multiplier effect results confirm the natural partition of the samples. The direct or primary accumulator returned the highest mean while the secondary accumulator returned the least values.

Implication for Environmental Conservation: The predictability of herbicides and insecticides accumulation in all the samples and across the different spatial locations provides the impetus for sustainable use of the materials without environmental degradation. Also, it guides the manufacturer on the expected improvement required of the products to make them more environmentally friendly. The effects of herbicides and insecticides accumulations can be mitigated by the withdrawal system usually practiced in agriculture. Through this work, appropriate withdrawal period is recommended.

It serves as a vital tool in predictive accumulation of pesticides in soil, water and sediment over time after discontinue use. This serves as potential source of contamination. Prediction of presencce of pesticides in vegetable consumed by human. This may be of value in toxicology study and forensic science. The report of this work can serve as planning reference for envinronmental conservation, regulation and pollution control.

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