ConcentrationWeathering of Agrochemicals in Runoff and Soil Interface on the National Centre for Agricultural Mechanization (NCAM) Farm, Ilorin-Nigeria

Abstract

Agrochemicals are applied to boost agricultural productivity. These agrochemicals are not completely absorbed by the targeted plants and ample quantity are transported into surface and groundwater at varying concentrations thereby affecting aquatic and human lives. This study aimed at investigating the level of dissipation of agrochemical elements and compounds as they moved along the furrow. Four experimental fields - NPK fertilizer, urea fertilizer, pesticides (glyphosate) and herbicides (organochlorine) were prepared for this study. The selected agrochemicals were applied on the experimental field and the concentration of chemical elements (electrical conductivity, pH, nitrogen, phosphorus, manganese, zinc, magnesium, potassium, glyphosate and organochlorine) along the furrow were measured at intervals (1 m on a 20 m row) using standard techniques. The maximum and minimum values obtained for electrical conductivity, pH, nitrogen, phosphorus, manganese, zinc, magnesium and potassium concentrations were (175.61 and 95.25 µS/cm; 186.54 and 176.102 µS/cm; 285.725 and 112.45 µS/cm; 380.508 and 342.18 µS/cm), (7.585 and 5.225; 7.6875 and 7.09; 7.865 and 6.45; 7.9085 and 6.535), (0.866 and 0.2035%; 0.479 and 0.205%; 1.215 and 0.112mg/kg; 0.5805 and 0.2885 mg/kg), (0.3705 and 0.0765%; 0.4175 and 0.203%; 0.2295 and 0.02%; 0.1945 and 0.0475 %), (0.4925 and 0.1 mg L^{-1}; 0.661 and 0.34 mg L^{-1}; 1.957 and 0.4025 mg L^{-1}; 0.952 and 0.65 mg L^{-1}), (0.67 and 0.2475 mg L^{-1}; 0.4995 and 0.214 mg L^{-1}; 2.6185 and 0.409 mg L^{-1}; 1.535 and 0.802 mg L^{-1}), (7.946 and 4.491 mg L^{-1}; 7.8725 and 5.313 mg L^{-1}; 13.31 and 5.153 mg L^{-1}; 14.845 and 12.44 mg L^{-1}) and (16.35 and 7.1 mg L^{-1}; 10.65 and 7.95 mg L^{-1}), respectively for the runoff samples of NPK fertilizer, urea fertilizer, herbicides and pesticide fields. The concentration of agrochemical elements and compounds disintegrate along the furrows on all agrochemical fields except in the case of pH.

Keywords: Agrochemicals, concentration dissipation, runoff and chemical elements

1 Introduction

Agrochemicals is defined as any substance used in the management of an agricultural ecosystem; including fertilizers, pH adjusting agents, soil conditioners, pesticides, herbicides and crop-growth regulator (Catarino *et al.,* 2019). In order to significantly improve agricultural productivity and to meet the ever-increasing food and fibre needs of the world, the use of agrochemicals has increased globally (Sharma and Singhvi, 2017). It has been reported that, the widespread use of agrochemicals in modern irrigation techniques in combination with improved seeds has largely increased agricultural productivity. However, their effects on the environment and agricultural sustainability are of concern. However, their effects on the environment and sustainability of agriculture are of great concern (Jimoh *et al.*, 2003). For instance, Sharma and Singhvi (2017) reported that larger percentage of the agrochemicals applied affects soil chemical and biological properties. Sebio*et al.* (2012) and Singh (2014) in their respective studiesfound out that higher concentration of herbicides decreases the concentration of both micro and macro nutrients in the soil as they have very low degradation effect especially at higher temperature, while medium and lower concentration increases certain chemical elements like N, P, K, Cu, Mn, Zn and Fe in the soil. Bhardwaj and Sharma, 2013 reported that, in each application of agrochemicals especially pesticide, only about 0.1% of the applied quantity is used by the target while the remaining 99.9% are left in the environment. Meftaul*et al.* (2020) reported that most of these chemical elements left in the soil are either ingested by insects, worms or microorganisms; exported to surface water bodies or leached to groundwater after certain quantities would have evaporated or drift off. According to Geyikci (2011) agrochemicals applied on farms, either dissolved or suspended in water, are transported via runoff (surface flow or interflow), and with some of the suspended elements lost to soil particles while in transit. Some of these agrochemical elements after application are transformed into metabolites, most of which are found to be of higher concentration than the original elements (Guzzella*et al.*, 2006).

Environmental awareness on the effects of agricultural chemicals in Nigeria and some other parts of Africa is still low, especially in places where agricultural chemicals are used over the years without comprehensive Environmental Impact Assessment (EIA) or programmes. The need for detailed environmental study of such practices so as to have a comprehensive view of the environmental impacts of these chemicals in such countries is germane towards providing detailed and comparative analyses for proper environmental management and sustainability. Although, several studies (Jimoh *et al.*, 2003; Guzzella*et al.*, 2006; Hotton *et al.*, 2010; Geyikci, 2011;Seibo *et al.*, 2012; McKinlay *et al.*, 2012; Ogbodo and Onwa, 2013; Adeoye *et al.*, 2013; Bhardwaj and Sharma, 2013; Singh, 2014; Wimalawansa and Wimalawansa, 2014; Biswas *et al.*, 2014; Bhandari, 2014; Maton *et al.*, 2016; Caldas, 2019; Meftaul*et al.*, 2020) revealed that various levels of agrochemical concentrations have been found in air, sand dust, soils, surface and groundwaters, blood, breast milk, semen and urine of farmers, there is dearth of information on the level of dissipation (of such agrochemicals) along their flow paths particularly in Southwestern and North-central Nigeria.

The continuous application of agrochemicals over the years has been a thing of admiration due to the remarkable increase in yield associated with it. Though, recently researches have highlighted some negative effects of agrochemicals application on the soil, water, animal and fish, including man as the final consumer (Singh, 2014; Sebio*et al.*, 2012; Obiri-Danso *et al.*, 2011). Toxic chemical elements resulting from agricultural chemicals applied on soil to boost crop yield are subsequently transferred from plant that absorb them into animals that feed on the plant, including human beings. This process of chemical element transfer through food chain has resulted in terminal illness such as cancer, kidney and liver failure (Guzzella*et al.*, 2006; Sall and Vanclooster, 2009; Obiri-Danso *et al.*, 2011). However, the rate at which these chemicals move from the point of application to other places (surface and groundwater) had not been fully studied. This research determines the concentration of applied agrochemicals along their pathways from the point of application.

2 Materials and Methods

2.1 The study area

The study was carried out at the National Centre for Agricultural Mechanization (NCAM) farm. The farm was established within the premises of National Centre for Agricultural Mechanization (NCAM) headquarters Idofian**,** in 1978 with a land area of 1000 ha. NCAM is about 20 km from Ilorin metropolis along Ilorin – Omuaran road. It is situated on Longitude 4°39´ E and Latitude 8°23´ N (Ibikunle, 2021; Abioye, 2022). Figure 1 shows the location map of the study area.The altitude of the study area is369 m above sea level. The soil in the area is predominantly sandy loam. The area is drained by an annual stream named Odo-omu (Figure2). The climate is generally influenced by the Inter-Tropical Convergence Zone (ITCZ) which results in wet and dry seasons. The wet season usually starts in April and lasts till late October, with the peak rainfall occurring between June and September while the dry season lasts between November to March (Abubakar *et al.*, 2019). The mean annual rainfall of the area is 1700 mm while the mean monthly maximum and minimum temperatures within the area are 31℃ and 29℃, respectively. Highest temperatures are usually recorded in the months of February, March and April, and the potential evapotranspiration of the area is between $1500 - 1700$ mm per annum (Metrological Report, 2009).

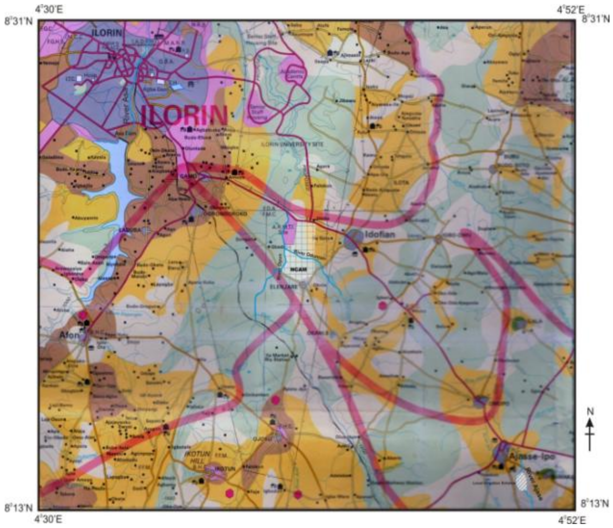

Figure 1: Location map of the study area

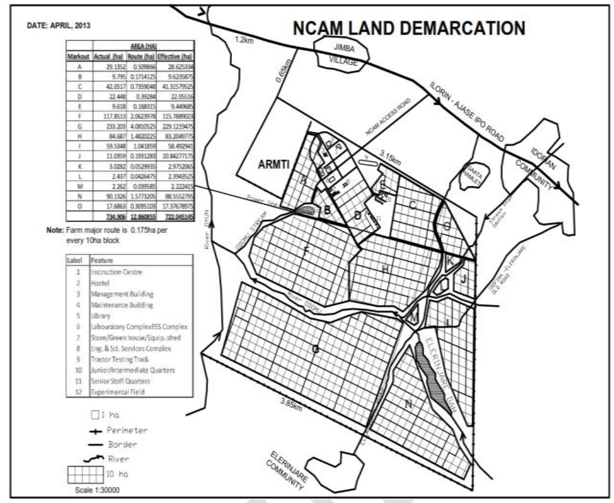

Figure 2: Area and Land demarcation of the study area

2.1.1 Description of the Experimental field

An undulating field was developed to assume a natural farmland conditions with a height difference of 2, 1, 0.5 and 0.25 m in a rectangular box of 20 m length and 4 m breadth (Figure 3). The experimental field was developed in four forms of equal measurements, with four furrows on each, running along the length of the four fields. The furrows are divided at 1 m interval along the 20 m length, taking their reference points from a rectangular block of 20 m length.

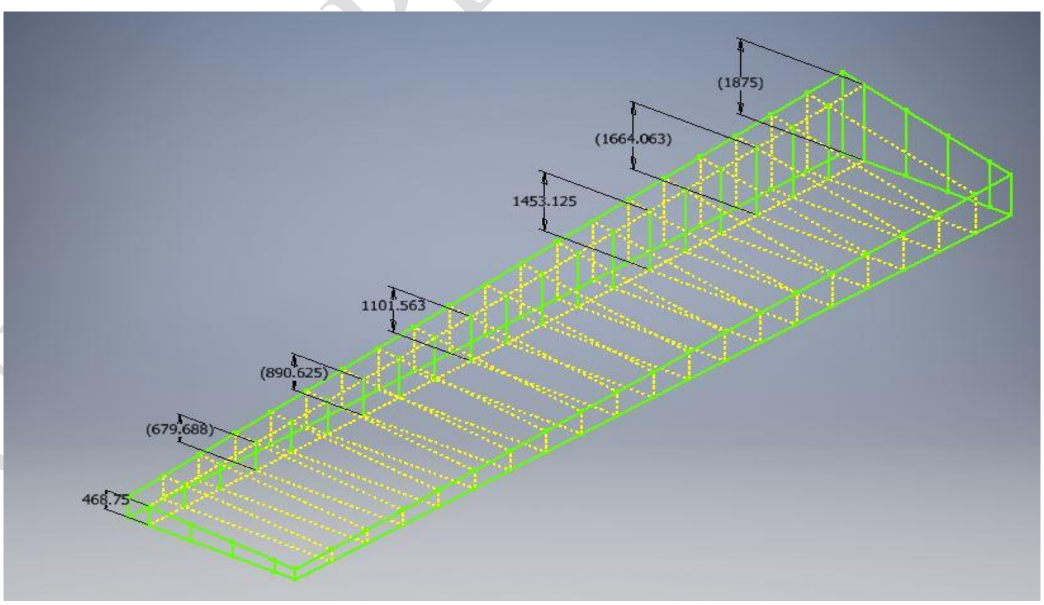

Figure 3:Model of runoff experimental field showing height difference (mm).

2.2 Experimental procedure and sample collection

One gram (1 g) each of NPK (15:15:15) and urea fertilizers, 3 ml each of herbicide (glyphosate) and pesticide (organochlorine) were mixed with 1000 ml ofwater to form solution based on the manufacturer's specification as itemized in Table 1.Two hundred millilitre (200 ml) of each prepared agrochemical was applied on the field. Shower head was used to simulate rainfall at the rate of 2 mm/h into the furrows to imitate runoff from actual rainfall.

Runoff samples were collected at 1 m interval along the 20 m furrow and at different heights of the furrowson the four experimental fields. The collected samples were filtered using 0.45 μm filter paper (Whatman Grade 602 h) to remove physical contaminants (e.g. papers, debris, twigs silts) and the filtratewere placed in a well labelled plastic bottle in preparation for lab analysis. Soil samples were randomly collected at eight different points across the four-furrow height and distances on all the fields. Same samples of the soil were air-dried at between$20 - 25℃$ and at relative humidity of between 20 and 60% according to Jackson (1992) for three days. After drying, the soil was milled and sieved using 2 mm standard mesh. The sieved soil samples were bagged for analysis.

Table 1: Agrochemical sample preparation

S/N	**Type of Agrochemical**	**Quantity of Agrochemical**	**Quantity of Solute (H_2O) (ml)**	**Sample size Applied (ml)**
1	NPK	1 g	1,000	200
2	Urea	1 g	1,000	200
3	Herbicide (Glyphosate)	3 ml	1,000	200
4	Pesticide (Organochlorine)	3 ml	1,000	200

2.3 Analysis of soil and Runoff samples

The nitrate nitrogen (NO_3^--N) content in the runoff and soil samples were determined by ion chromatography (HJ 84- 2016) method as described by Li *et al.* (2020). Colorimetric methods were used to determine Potassium (K^+)using Pallintest photometer 7100 according to APHA (2008) as described by Adebayo*et al.* (2021).

Atomic Absorption Spectrophotometer (AAS) was used to determine the concentrations of the Mn^{2+},$Ca^{2+}$$Mg^{2+}$, and Na^+in the runoff samples.A calibration of the AAS machine was done for each element to be determined using separate standards prepared with different cathode lamp for each element and corresponding wavelength are introduced to the AAS as described in APHA (2008). The concentration of each element was calculated using Equation 1.

$$\text{Metal}\ (mg\ L^{-1})\ =\ \frac{\text{Gradient of slop}\ \times \text{absorbance}\ \times 100 \times \text{D}}{10} \qquad 1$$

Where:

D = dilution factor

In the case of soil samples, 10 g of soil samples were weighed into a conical flask, and 100 ml of 1M ammonium acetate and 0.1M HCl was added for digestion (Jackson, 1992). The mixture is stirred on mechanical shaker for 1 h and then filtered. The filtrate was analysed using AAS as explained above. The pH and electrical conductivity (EC) were measured *in situ*. pH was measured with pH meter (PHS-3c) while TDS and EC with a multi-parameter Analyzer (DZS-706).

3 Results and Discussion

The results of the changes in concentrations of the NPK, Urea, glyphosate and organochlorine in runoff and soil samples along the furrow (definite parts) are discussed in the following sections.

3.1 Chemical elements in runoff and soil from NPK fertilizer field

The concentrations of the chemical elements as they move along the furrow on NPK fertilizer field are presented in Figure 4a-e and Figure 5a-e for runoff and soil, respectively.From the Figures, concentrations of chemical elements for the runoff demonstrate an inverse relationship with distance from point of application except for pH which increased as the solution move along the furrow. The maximum and minimum values of 175.61 & 95.25 µS/cm, 7.59 & 5.23, 0.87 & 0.20%, 0.37 & 0.08%, 0.49 & 0.1 mg L^{-1}, 0.67 & 0.25 mg L^{-1}, 7.95 & 4.49 mg L^{-1} and 16.35 & 7.1 mg L^{-1} were obtained for electrical conductivity, pH, nitrogen, phosphorus, manganese, zinc, magnesium and potassium constituents, respectively in the runoff samples of NPK fertilizer field. The corresponding values in the soil sample are 125.59 & 110.23 µS/cm, 7.31 & 6.09, 0.749 & 0.22%, 0.53 & 0.12%, 0.55 & 0.11 mg L^{-1}, 0.85 & 0.32 mg L^{-1}, 8.16 & 4.79 mg L^{-1} and 17.0 & 8.35 mg L^{-1}, respectively.

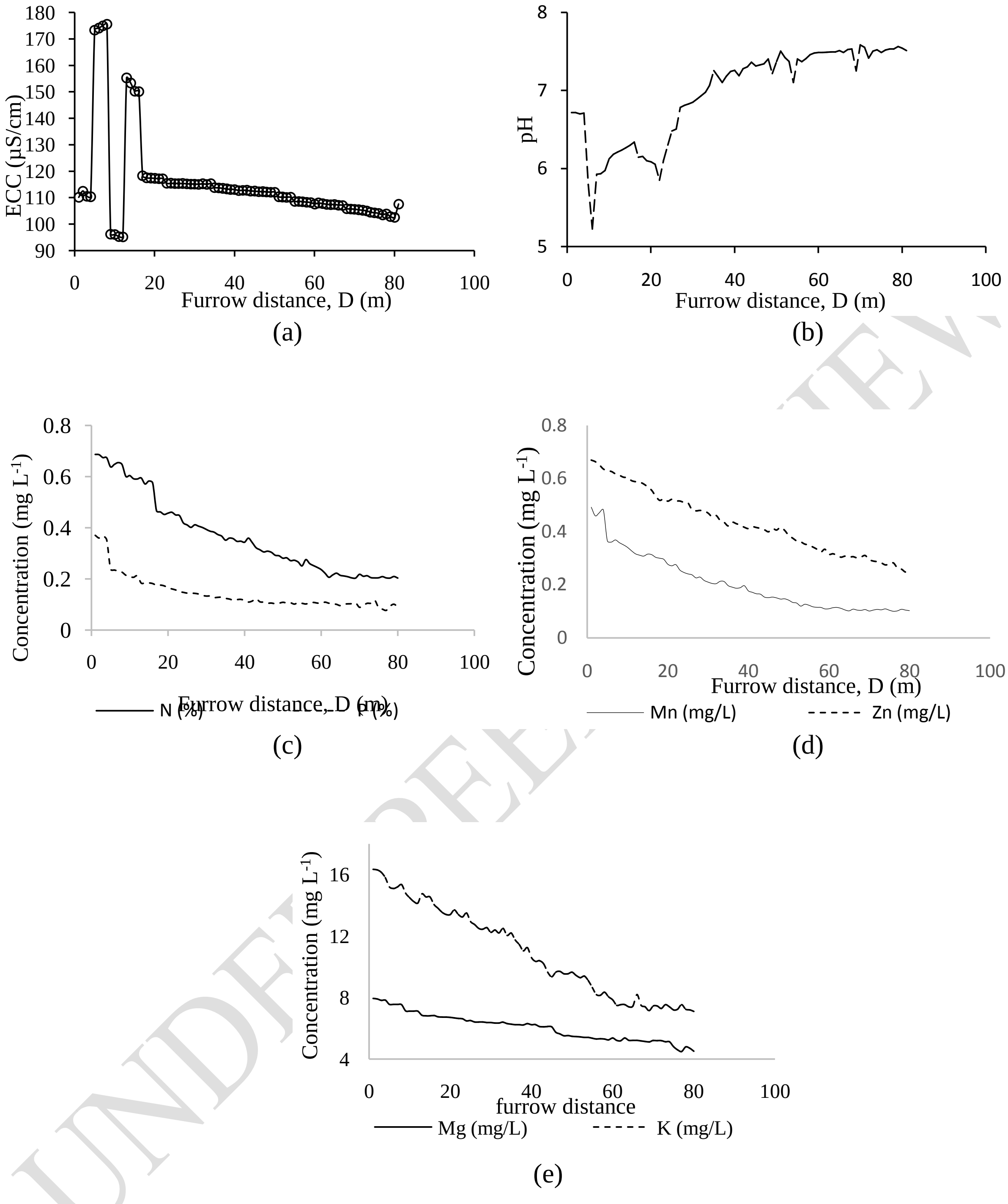

Figure 4: Change in concentration of agrochemicals in from runoff on NPK fertilizer field: (a) electrical conductivity (b) pH (c) nitrogen and phosphorus (d) manganese and zinc (e) magnesium and potassium

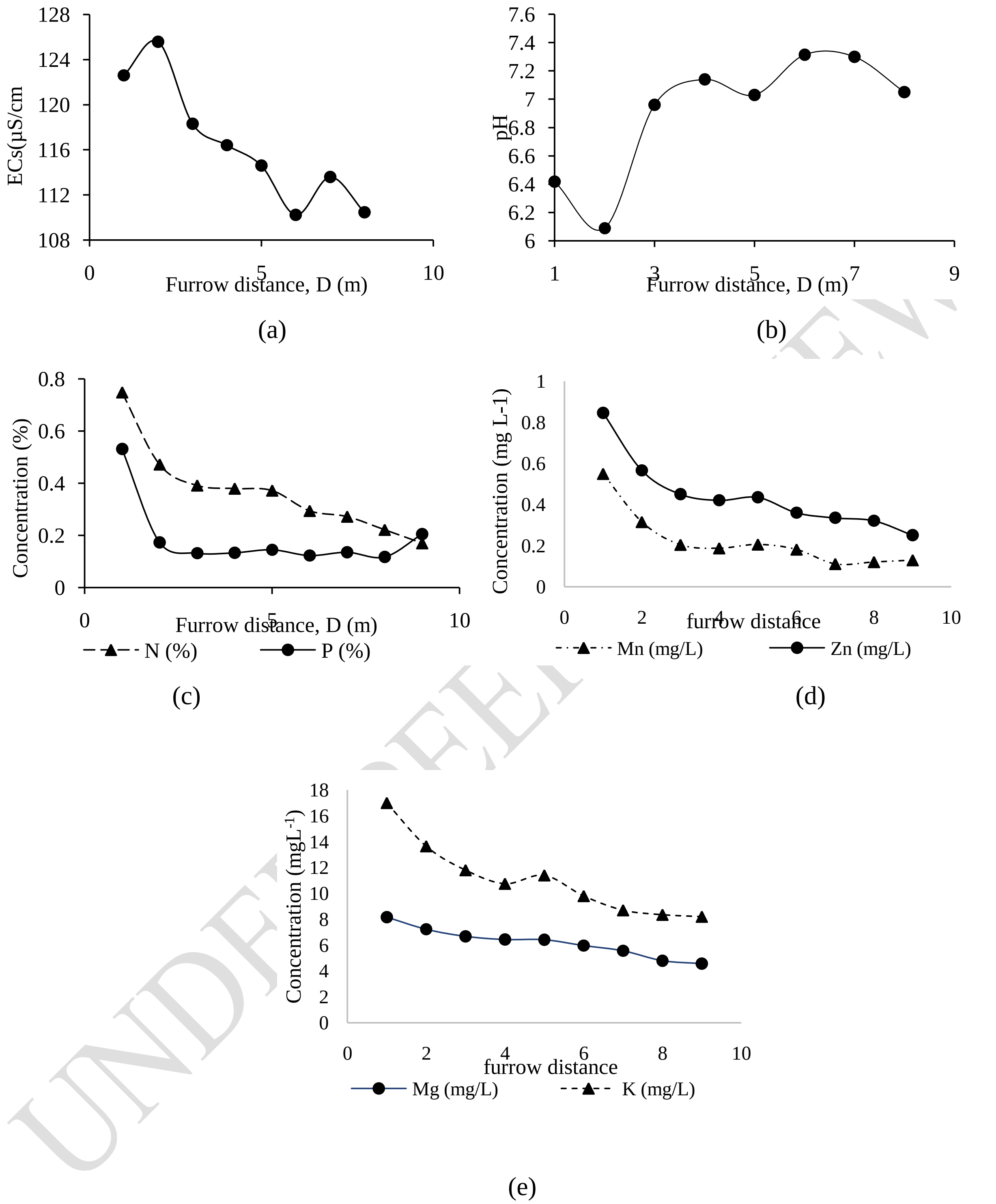

Figure 5: Change in concentration of agrochemicals in soil on NPK fertilizer field: (a) electricalconductivity (b) pH(c) nitrogen and phosphorus (d) manganese and zinc (e) magnesium and potassium

The maximum values of chemical elements in the runoff samples were obtained at the application point except in the cases of electrical conductivity and pH, this could be due to the influence of the initial EC of the soil as stated by Shi *et al.* (2017). The maximum value of electrical conductivity was recorded at a furrow distance of 8m with a difference of 65.5 µS/cm from the value obtained at the point of application. The high value of EC may be related to the previous agricultural activities or soil texture of the soil between the point of application and 18 m furrow distance which tends to retain more chemical from the irrigation water(Sharma, 2019). The values of pH obtained were found to increase as the distance from the point of application (of the chemicals) increases along the furrow, this could be attributed to the initial soil pH (Chen *et al.*, 2018) and organic matter contents of the soil as corroborated from the findings of Chen *et al.* (2020). The highest value recorded for pH was at 80 m furrow distance with a difference of 1.493 compared with the value atthe point of application. This variation may be as a result of the presence of other chemicals in the sample area which may have caused other chemical reactions, thereby increasing the pH in the runoff at the point (Mandal *et al*, 2020).

Tables 2a and b present the summary of relationships between the concentrations of the agrochemical elements and compounds and the furrow distance for the runoff and soil, respectively on the NPK field. The R^2values from the table provide information on the extent of influence the furrow distance has on the changes in concentration of the agrochemicals. From the table, it is shown that furrow distance account less (for about 26.3%) of the variation in ECC concentration in runoff from NPK fertilizer field, suggesting that other factors such as residual soil chemical elements and compounds not considered in this study may have greater influence on the variation of ECC concentration than the furrow distance. In contrast, while variation in the concentration of P is moderately (64.9%) influenced by the furrow distance, the variation in concentration of Zn is largely (97.9%) influenced by furrow distance. In Table 2b on the other hand, furrow distance can account for about 82.5% of the variation in concentration of ECC in the soil of NPK fertilizer field while only 26.2% of the variation in the concentration of P could be explained by furrow distance.

Table 2a: Summary of the relationship between concentration and furrow distance in NPK(15:15:15) field runoff

Elements	Trend equations	R^2
ECC	ECC = -0.375D+130.620	0.263
pH	pH = 0.022D+6.070	0.756
N	N = -0,002D+0.623	0.919
P	P = -0.002D+0.233	0.649
Mn	Mn = -0.004D+0.374	0.874
Zn	Zn = -0.005D+0.636	0.979
Mg	Mg = -0.037D+7.577	0.958
K	K = -0.124D+15.975	0.973

Table: 2b: Summary of the relationship between concentration and furrow distance in NPK field soil

Elements	Trend equations	R^2
ECC	ECC = -2.036D+125.630	0.825
pH	pH = 0.136D+6.300	0.589
N	N = -0.057D+0.652	0.827
P	P = -0.025D+0.312	0.262
Mn	Mn = -0.041D+0.428	0.668
Zn	Zn = -0.057D+0.727	0.778
Mg	Mg = -0.407D+8.230	0.958
K	K = -0.971D+15.926	0.864

3.2 Chemical elements in runoff and soil from urea fertilizer field

The concentrations of chemical elements in runoff and soil from urea fertilizer field as they move along the furrow are presented in Figures 6a-e and Figures 7a-e, respectively. The maximum and minimum values of EC, pH, nitrogen, phosphorus, manganese, zinc, magnesium and potassium are 186.54 &176.10 µS/cm, 7.69 & 7.09, 0.48 & 0.21%, 0.42 & 0.20%, 0.66 & 0.34 mg L^{-1}, 0.49 & 0.21 mg L^{-1}, 7.87 & 5.31 mg $L^{-1}$and 10.65 & 7.95 mg L^{-1}, respectively. The corresponding values for soil samples are 197.18 & 183.68 µS/cm, 7.39 & 6.99, 0.51 & 0.40%, 0.50 & 0.36%, 0.85 & 0.55 mg L^{-1}, 0.58 & 0.41 mg L^{-1}, 9.82 & 7.21 mg $L^{-1}$and 13.75 & 11.3 mg L^{-1}, respectively.

Tables 3a and b present the summary of relationships between the concentrations of the agrochemical elements and compounds and the furrow distance for the runoff and soil respectively on the Urea field. From Table 3a, it is shown that furrow distance account more for ECC concentration (R^2=0.93 and less for pH (0.18) Other chemicals were moderately accounted for by furrow distance. Table 3b on the other hand show that furrow distance can account for about 85.5% of the variation in concentration of Mn in the soil of Urea fertilizer field while 45.4% of the variation in the concentration of pH could be explained by furrow distance.

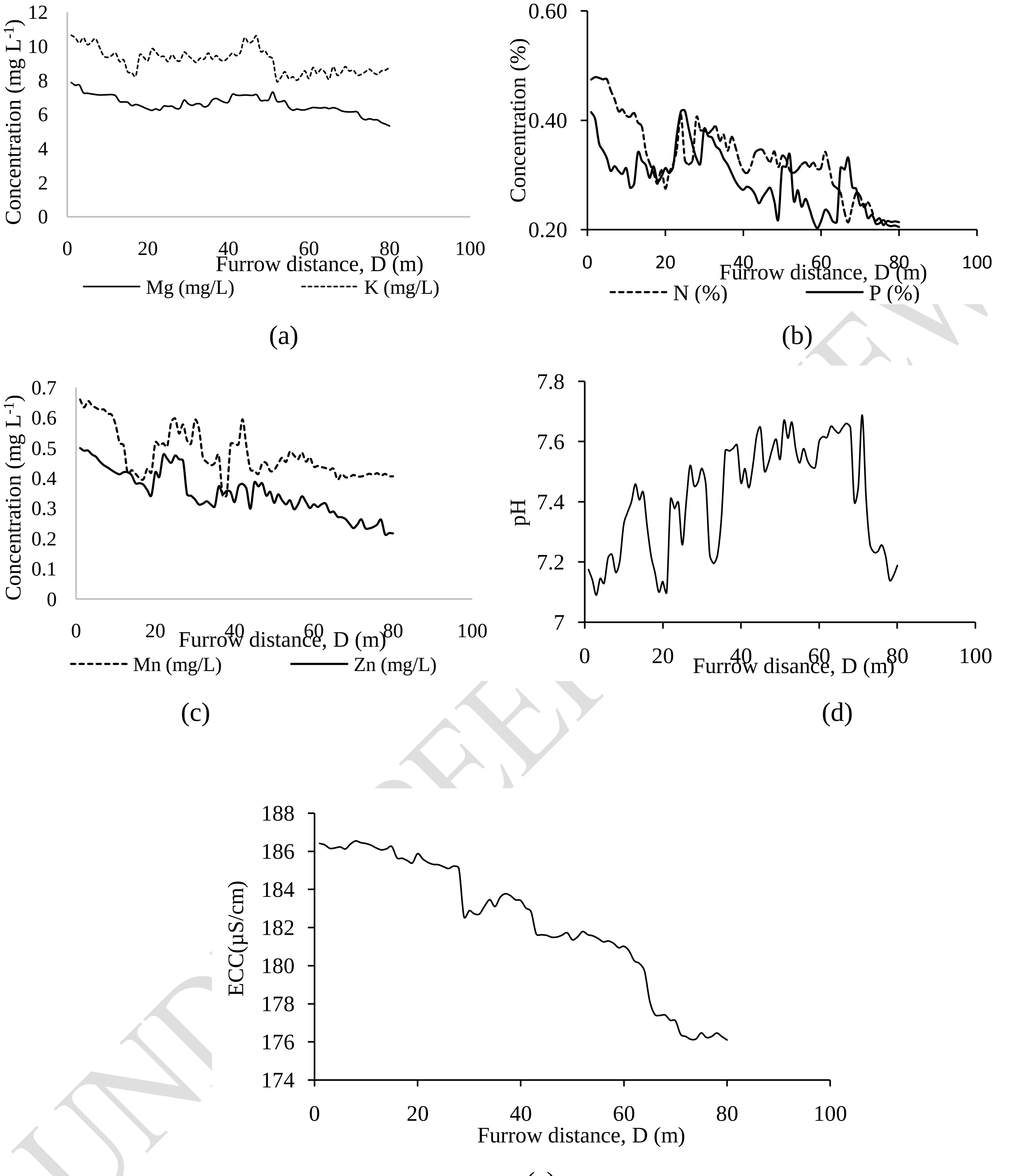

Figure 6: Change in concentration of agrochemicals on urea fertilizer field runoff; (a) electrical conductivity (b) pH (c) nitrogen and phosphorus (d) manganese and zinc (e) magnesium and potassium

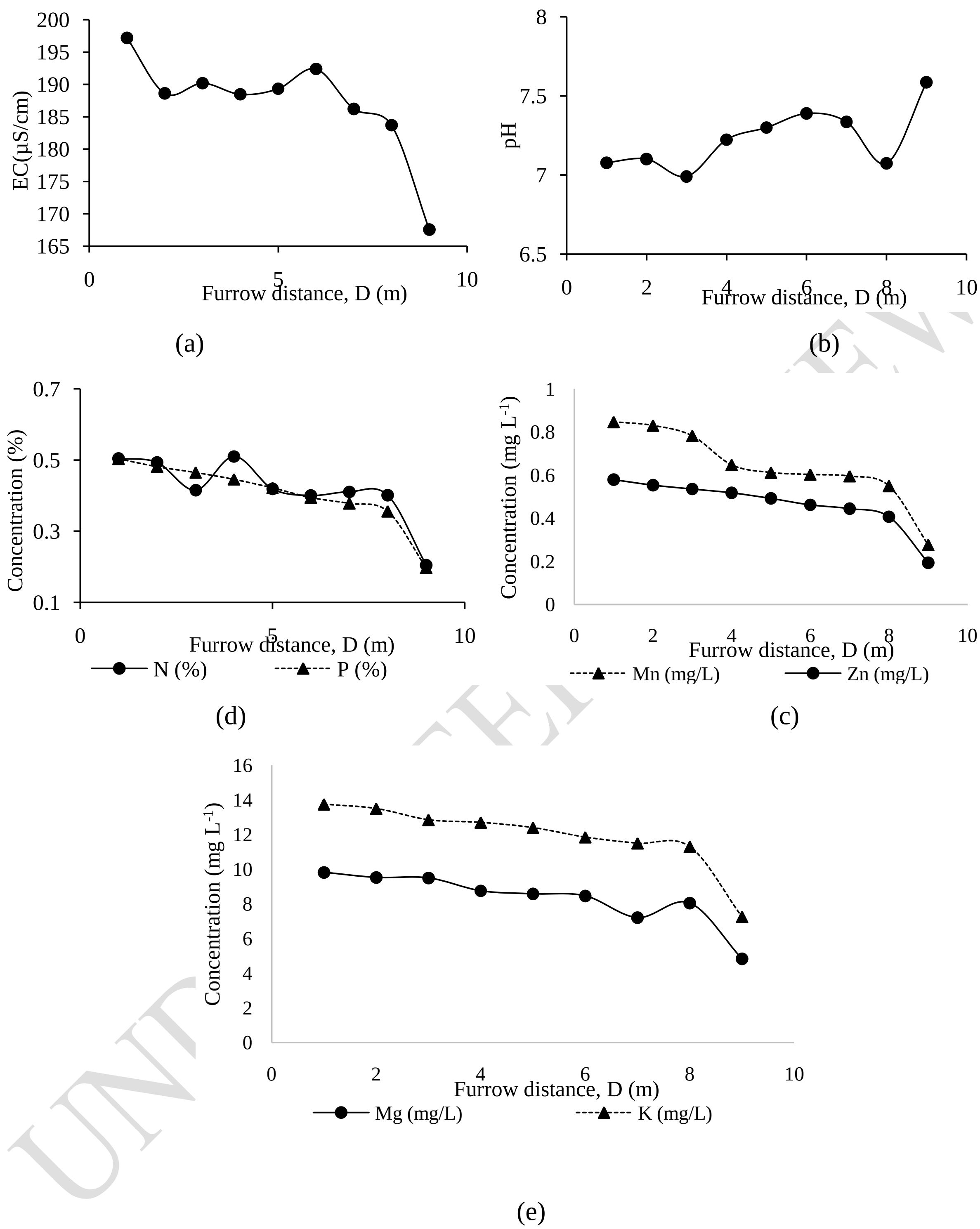

Figure 7: Change in concentration of agrochemicals in soil of urea fertilizer field: (a) electrical conductivity (b) pH (c) nitrogen and phosphorus (d) manganese and zinc (e) magnesium and potassium

Table 3a: Summary of the relationship between concentration and furrow distance in urea field runoff

Elements	Trend equations	R^2
ECC	ECC = -0.141D+188	0.929
pH	pH = 0.003D+7.278	0.179
N	N = -0.003D+0.435	0.719
P	P = -0.002D+0.361	0.510
Mn	Mn = -0.002D+0.572	0.451
Zn	Zn = -0.003D+0.468	0.796
Mg	Mg = -0.015D+7.225	0.493
K	K = -0.002D+9.960	0.428

Table 3b: Summary of the relationship between concentration and furrow distance in urea field soil

Elements	Trend equations	R^2
ECC	ECC=-2.290D+198.510	0.579
pH	pH= 0.047D+6.996	0.454
N	N= -0.027D+0.550	0.623
P	P= -0.030D+0.557	0.823
Mn	Mn= -0.059D+0.933	0.858
Zn	Zn= -0.037D+0.650	0.769
Mg	Mg= -0.488D+10.743	0.757
K	K= -0.603D+14.913	0.728

3.3 Chemical elements in runoff and soil from herbicide (glyphosate) field

The respective variation in concentrations of chemical elements in runoff and soil as they move away from the point of application on the herbicide field are depicted in Figures 8 (a - e) and9 (a - e), respectively. On the average, the maximum and minimum values of 285.73 & 112.45 µS/cm, 7.87 & 6.45, 1.22 & 0.11mg/kg, 0.23 & 0.02%, 1.96 & 0.40 mg L^{-1}, 2.62 & 0.41 mg $L^{-1}$and 13.31 & 5.15 mg L^{-1}were recorded for electrical conductivity, pH, nitrogen, glyphosate, manganese, zinc, and magnesium, respectively. The corresponding values for soil sampleswere 306.41 & 250.11 µS/cm, 7.69 & 6.36, 0.52 & 0.26 mg/kg, 0.19 & 0.09%, 1.52 and 0.62 mg L^{-1}, 2.88 & 1.25 mg $L^{-1}$and 15.19 & 9.70 mg L^{-1}.

Tables 4a and b present the summary of relationships between the concentrations of the agrochemical elements and compounds and the furrow distance for the runoff and soil respectively on the herbicide field. Table 4a shows that pH and EC are significantly influenced by furrow distance accounting for 97% and 94%of variation in pH and ECC, respectively. However, distance along the furrow accounted for only 26% and 18% of glyphosate and N concentrations, respectively. On the other hand, furrow distance moderately influenced the concentrations of Mn and Zn, accounting for 78% and 72%, respectively. Table 4b shows that furrow distance account for about 94.9 and 91.8% of the variation in the concentrations of N and pH, respectively in the soil of urea fertilizer field while 64.4% of the variation in the concentration of ECC could be accounted for by furrow distance.

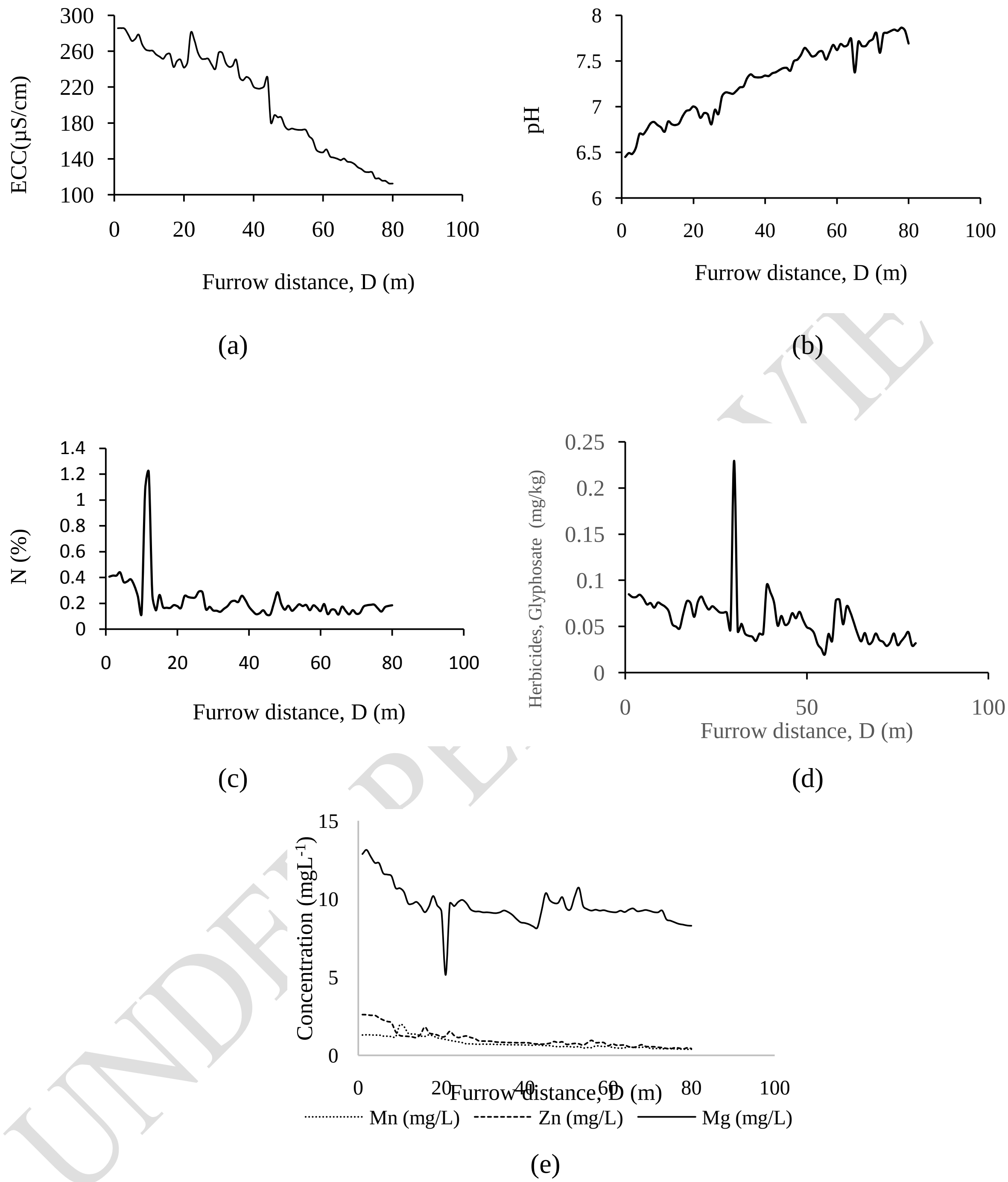

Figure 8: Change in concentration of agrochemicals on Herbicide field runoff;(a) electrical conductivity (b) pH (c) nitrogen(d) Glyphosate (e) manganese, zinc and magnesium

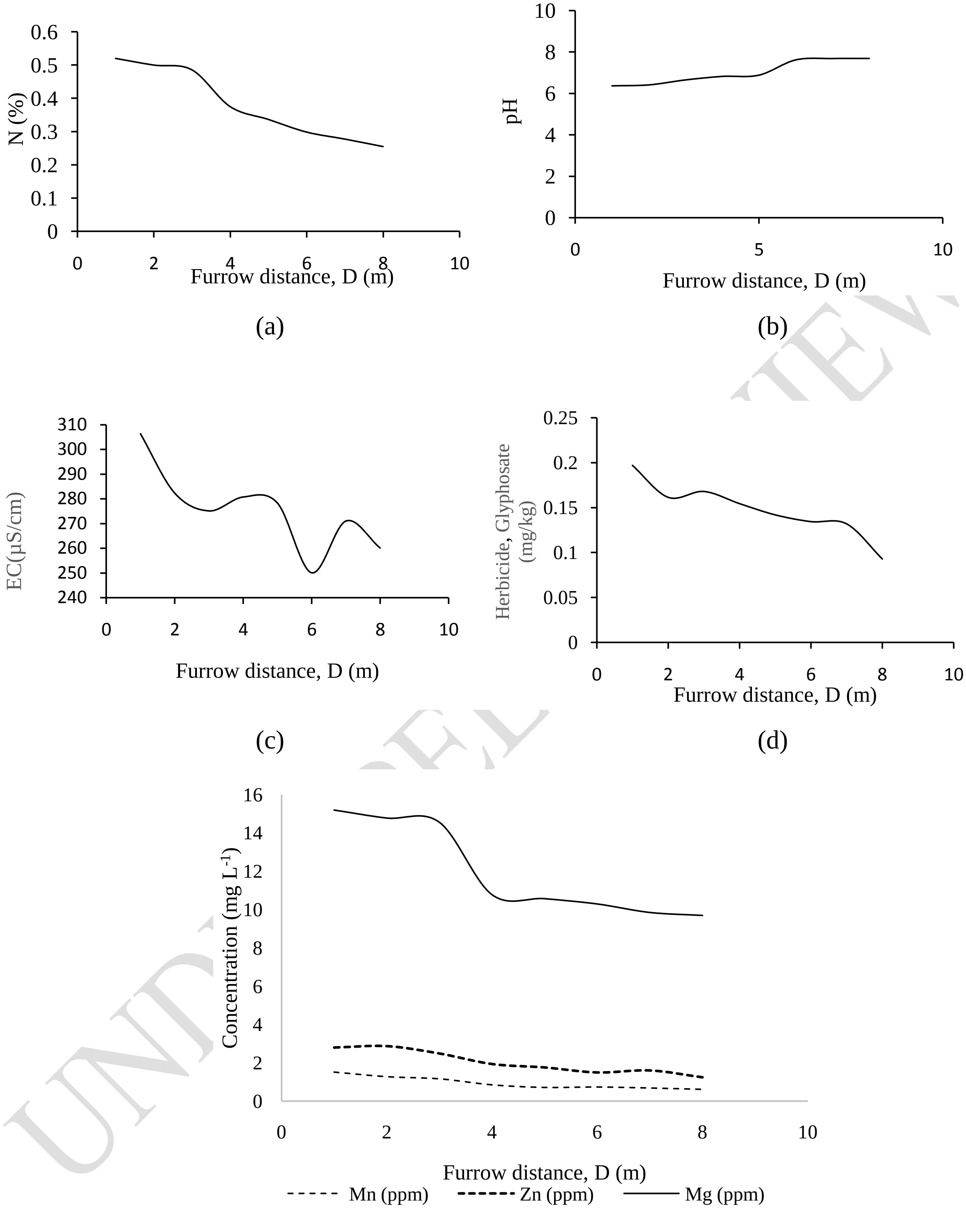

Figure **9**: Change in concentration of agrochemicals on Herbicide field soil; (a) nitrogen (b) pH (c) electrical conductivity (d) Glyphosate (e) manganese, zinc and magnesium

Table 4a: Summary of the relationship between concentration and furrow distance in herbicide (glyphosate) field runoff

Trend equati
ECC = -2.35(
pH= 0.017D+
N= -0.003D+
Mn= -0.013D
Zn= -0.620D-
Mg= -0.028D
Gly= -0.001D

Gly = Glyphosate

Table 4b: Summary of the relationship between concentration and furrow distance in herbicide (glyphosate) field soil

Trend equat
ECC = -5.45(
pH= 0.0223D
N= -0.043D+
Mn= -0.127D
Zn= -0.243D-
Mg= -0.905D
Gly= -0.012D

Gly = Glyphosate

3.4 Chemical elements in runoff and soil from pesticide (organochlorine) field

The variations in the concentration of the chemical elements as they move away from the point of application along the furrow on the pesticide field are presented in Figures 10 (a – e) and 11 (a – e). The maximum and minimum values obtained for electrical conductivity, pH, nitrogen, organochlorine, manganese, zinc and magnesium in the runoff were 380.51 & 342.18 µS/cm, 7.91 & 6.54, 0.58 & 0.29 mg/kg, 0.19 & 0.05 %, 0.95 & 0.65 mg L^{-1}, 1.54 & 0.80 mg $L^{-1}$and 14.85 & 12.44 mg L^{-1}, respectively. The corresponding values obtained in soil samples are 392.76 & 356.27 µS/cm, 7.58 & 6.47, 0.62 & 0.36 mg/kg, 0.40 & 0.31%, 1.17 & 0.87 mg L^{-1}, 1.57 & 0.95 mg L^{-1}.

The summary of relationships presented in Tables 5a and b revealed that concentration of different parameters measured in the runoff varied significantly with the furrow distance. Furthermore, furrow distance account for only about 53% of the ECC concentration and can explain as much as 93% of the variation in the concentration of the Mn (Table 5a). In contrast, only about 0.1% of the variation in the concentration of organochloride in the soil is accounted for by furrow distanceand a high 96% of the variation in Mg concentration (Table 5b) this suggested that other factors (such as soil physical and chemical properties as well as chemical reactions) that were not considered in this study has influence on the variation of the concentration of the agrochemicals along the furrow (Komissarov and Klik, 2020).

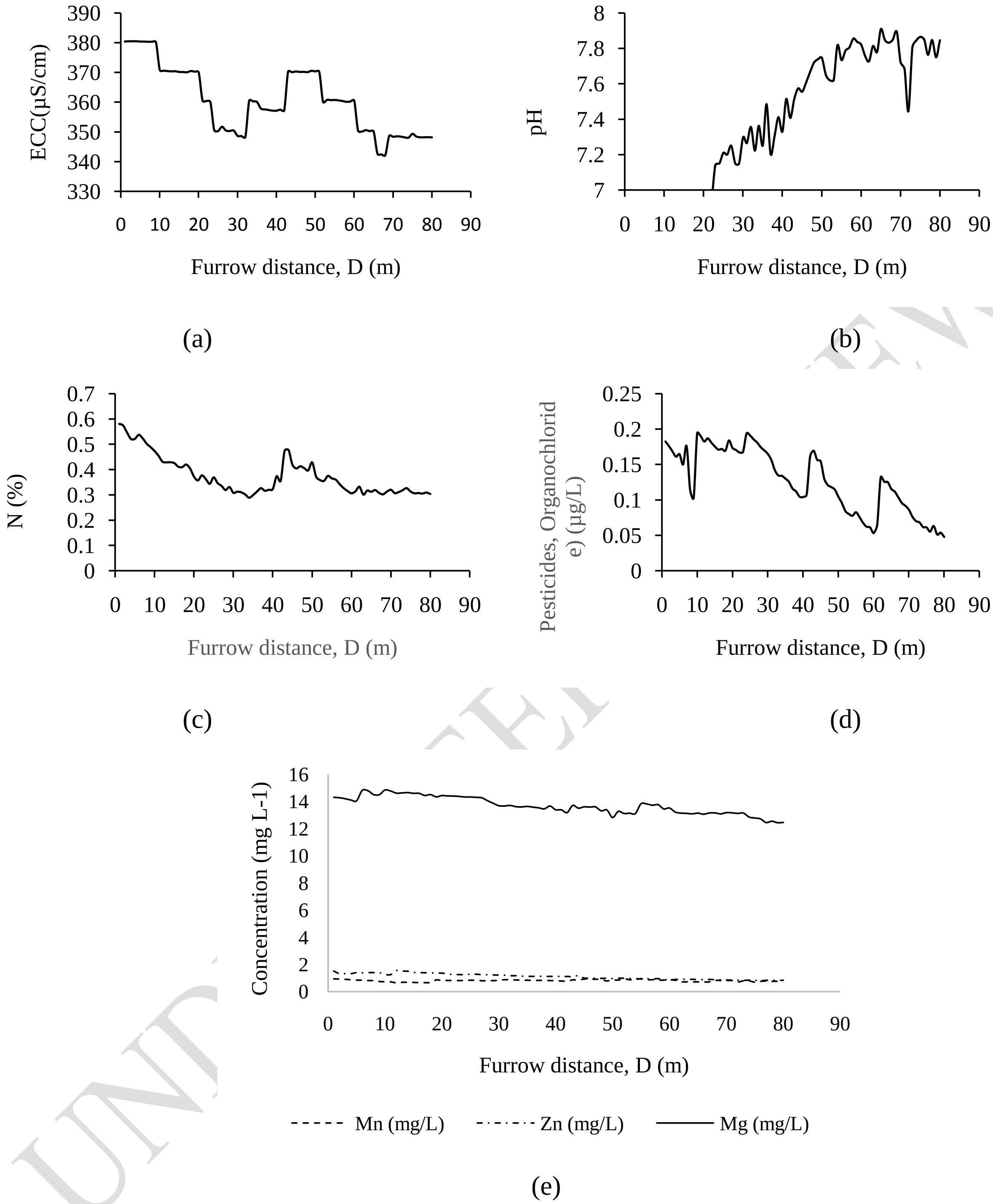

Figure 10: Change in concentration of agrochemicals on pesticide field runoff; (a) electrical conductivity (b) pH (c) nitrogen (d) organochlorine (e) manganese, zinc and magnesium

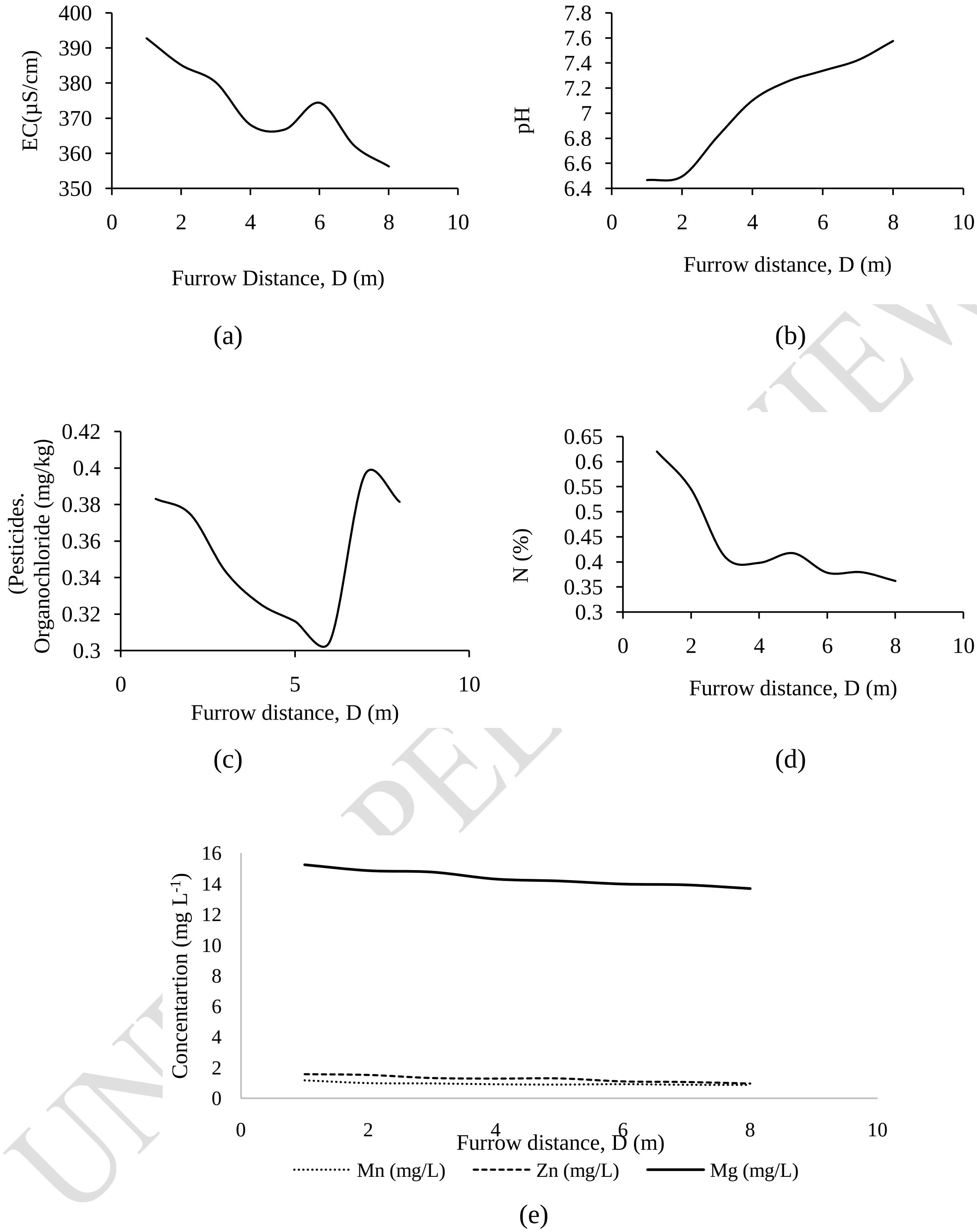

Figure 11: Change in concentration of agrochemicals on PESTICIDE field soil; (a) electrical conductivity (b) pH (c) nitrogen (d) organochlorine (e) manganese, zinc and magnesium

Table 5a: Summary of the relationship between concentration and furrow distance in pesticide (Organochlorine) field runoff

Elements	Trend equations	R^2
ECC	ECC = -	0.528
pH	0.349D+374.720	0.902
N	pH= 0.017D+6.698	0.516
Mn	N= -0.002D+0.467	0.925
Zn	Mn= -0.009D+1.458	0.003
Mg	Zn= -0.0002D+0.815	0.825
Organochlorine	Mg= -0.025D+14.715	0.704
	OC= -0.002D+0.193	

OC = Organochlorine

Table 5b: Summary of the relationship between concentration and furrow distance in pesticide field soil

Elements	Trend equations	R^2
ECC	ECC = -4.630D+394.070	0.858
pH	pH= 0.169D+6.299	0.954
N	N= -0.032D+0.584	0.726
Mn	Mn= -0.088D+1.654	0.956
Zn	Zn= -0.033D+1.101	0.695
Mg	Mg= -0.216D+15.328	0.963
OC	OC= -0.001 D+0.355	0.001

OC = Organochlorine

4 Conclusions

The concentration of chemical elements and compounds in the runoff and soil samples are found to reduce at varying rates along the furrow runs in all the experimental fields. While some parameters in the agrochemical degenerated continuously with furrow distance, some fluctuated, possibly due to soil properties. The research has given an insight on the movement, concentration level and extent of coverage of the excess chemical elements in surface water with respect to the point of application.

References

Abioye, T. A. (2022). Impacts of Biochar Supplemented with Poultry Manure on Growth of *Amaranthus caudatus*(L.)Nutrient Uptake and Soil Properties. An *Unpublished Doctoral dissertation*, Kwara State University, Nigeria.

Abubakar, M. I., Adeshina, I., Abdullahi, A. M., Hamza, F. O., Abdulraheem, I. and Musa, A. M. (2019). Occurrence of fungi in frozen Titus fish (*Scomberscombrus*) sold in some areas in Ilorin metropolis. *Journal of Agriculture and Environment*, *15*(2), 117-131.

Adeoye, P. A., Abubakar, Sani Kazaure, A. S. and Adeolu, A. F. (2013). Effect of Agrochemicals on Groundwater Quality: A Review. *Scientia Agriculturae.* 1(1). www.pscipub.com/SA.

APHA (2008). "Standard Methods for the Examination of Water and Wastewater". 21st ed. American Public Health Association/American Water Work Association (APHA/AWWA) Washington D.C.

Bhardwaj, T. and Sharma, J. P. (2013). Impact of pesticides application in agricultural industry: An Indian scenario. *International Journal of Agriculture and Food Science Technology*, 4(8), 817-822.

Black, C.A. (Ed) (1995). Methods of Soil analysis. Agronomy No 9 (2) America Society of Agronomy. Madison Wisconsin.

Bouyoucous, G.J. (1992). Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal*, 54: 464 – 465.

Caldas, E. D. (2019). Toxicological aspects of pesticides. *Sustainable agrochemistry: A compendium of technologies*, 275-305.

Catarino, R., Bretagnolle, V., Perrot, T., Vialloux, F. and Gaba, S. (2019). Bee pollination outperforms pesticides for oilseed crop production and profitability. *Proceedings of the Royal Society B*, *286*(1912), 20191550.

Chen, H., Cao, J., Huang, G., Zheng, H. and Han, F. (2018). Transport of pH in runoff from agricultural fields: effects of land use, slope and rainfall intensity. *Water, Air* and *Soil Pollution*, 229(8), 273

Chen, Z., Zhang, H., Wang, H. and He, X. (2020). Transport and transformation of pH in soil and sediment: a review. *Journal of Soils and Sediments*, 20(4), 1664-1677

Geyikci, F. (2011). Pesticide and Their Movement in Surface and Groundwater. OndokuzMayis University, Chemical Engineering Department, Turkey, Paper No. 22.

Guzzella, L., Pozzoni, F. and Guiliano, G. (2006). Herbicide Contamination of Surficial Groundwater in Northern Italy. *Journal of Environmental Pollution*, **142** (2006).

Gödeke, S. H., Malik, O. A., Lai, D. T. C., Bretzler, A., Schirmer, M. and Mansor, N. H. (2020). Water quality investigation in Brunei Darussalam: investigation of the influence of climate change. *Environmental Earth Sciences*, *79*: 1-15.

Hotton, A., Barminas, J. I. and Osemeahon, S. A. (2010). Pesticide Umnary Metabolite and Deposit on Agro-chemicals Retail Outlets in Taraba Nigeria. *European Journal of Scientific Research*, **46**(4): 584-591.

Ibikunle, R. A. (2021). Investigating municipal solid waste generation and management in Ilorin for possible integrated waste-management system. *Journal of Material Cycles and Waste Management*, *23*, 1239-1257.

Jackson, M.L. (1992). Soil Chemical Analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Jimoh O. D., Ayodeji, M. A. and Mohammed, B. (2003). Effects of Agrochemicals on Surface Waters and Groundwaters in the Tunga-Kawo (Nigeria) Irrigation Scheme. *Journal of Hydrological Sciences*, **48** (6): 1013-1023.

Komissarov, M. A., and Klik, A. (2020). The impact of no-till, conservation, and conventional tillage systems on erosion and soil properties in Lower Austria. *Eurasian soil science*, *53*, 503-511.

Li, Y., Abegunrin, T. P., Guo, H., Huang, Z., Are, K. S., Wang, H. and Wei, L. (2020). Variation of dissolved nutrient exports by surface runoff from sugarcane watershed is controlled by fertilizer application and ground cover. *Agriculture, Ecosystem and Environment*, 303, 107121.

Mandal A. and Madhab, C. M. (2020) Impact of agrochemicals on soil health: Agrochemicals Detection, Treatment and Remediation: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/agrochemical retrieved on 12/04/23

Maton, S. M., Dodo, J. D., Nesla, R. A. and Ali, A. Y. (2016). Environmental Impact of Pesticides Usage on Farmlands in Nigeria. *International Journal of Innovative Research & Development*5(4).

McKinlay, R., Dassyne, J., Djamgoz, M., Plant, J. A., Voulvoulis, N., Ragnarsdottir, K., and Voulvoulis, N. (2012). Agricultural pesticides and chemical fertilisers. *Pollutants, human health and the environment: a risk-based approach, 1st edition. Wiley, West Sussex*, 181-206.

Meftaul, I. M., Venkateswarlu, K., Dharmarajan, R., Annamalai, P. and Megharaj, M. (2020). Pesticides in the urban environment: A potential threat that knocks at the door. *Science of the Total Environment*, *711*, 134612.

MSR (2009). Metrological Station Report (MSR). Ilorin International Airport Meteorological Station yearly report, Ilorin, Kwara State.

Musselman, R. (2012). Sampling procedure for lake or stream surface water chemistry. Res Note RMRS-RN-49. Fort Collins, CO: *US. Department of Agriculture, Forest Service, Rocky Mountain Research Station*. 11 p

Obiri-Danso, K., Adonadaga, M. G. and Horgarh, J. N. (2011). Effect of Agrochemical Use on the Drinking Water Quality of Agogo, a Tomato Growing Community in Ashanti Akim, Ghana. *Bull Environmental Contamination Toxicology,* **87**: 71-77.

Ogbodo, E.N. and Onwa, N.C. (2013). Impact of Long-term Application of Agrochemicals on the Agro-Ecology of the Lower Anambra River Basin Southeast Nigeria. *Journal of Environment and Earth Science*. 3(5).

Sall, M. and Vanclooster, M. (2009). Assessing the Well Water Pollution Problem by Nitrates in the Small-Scale Farming System of the Niayes Region, Senegal. *Journal of Agricultural Water Management*, **96**(2009):1360-1368. www.elsevier.com/locate/agwat.

Sebio, A., Ogundero, V. W. and Bankole, S. A. (2012). The Impact of Four Herbicide on Soil Minerals. *Research Journal of Environmental and Health Sciences,* 4(6): 617-624. ISSN: 2041-0492.

Sharma, B., Vaish, B., Monika, Singh, U. K., Singh, P. and Singh, R. P. (2019). Recycling of organic wastes in agriculture: an environmental perspective. *International journal of environmental research*, *13*, 409-429.

Sharma, N. and Singhvi, R. (2017). Effects of chemical fertilizers and pesticides on human health and environment: a review. *International journal of agriculture, environment and biotechnology*, *10*(6), 675-680.

Shehani A. Wimalawansa, S. A. and Wimalawansa, S. J. (2014). Agrochemical-Related Environmental Pollution: Effects on Human Health. *G.J.B.A.H.S.* 3(3): 72-83.

Shi, Z., Chen, X., Zhang, X., Qiu, J. and Cai, Z. (2017). Transport of antibiotics and antibiotic resistance genes in runoff and soil from an agricultural field under aerobic and anaerobic conditions. *Environmental Pollution*, 231(Pt1), 157-165.

Singh, R. (2014). Soil Major (N, P, K) and Micro (CU, Mn, Zn and Fe) Nutrients as Influenced by Different Herbicides in Presence of Fertilizer (NPK) in Field Condition of Aligarh Soil under Wheat Cultivation. *International Research Journal of Environment Science*,**3**(10), 84-93. ISSN: 2319-1414.

Sudhangshu Kumar Biswas, S. K., Rahman, s., Kobir, S.M.A., Ferdous, T. and Banu, N.A. (2014). A Review on Impact of Agrochemicals on Human Health and Environment: Bangladesh Perspective. *Plant Environment Development.* 3(2):31-35.

Yadav, A. N. (2020). Plant microbiomes for sustainable agriculture: current research and future challenges (pp. 475-482). Springer International Publishing.