Effect of Chemical Fertilizers on Groundwater Quality in an Unconfined Aquifer

Conference Paper · December 2020

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ABSTRACT
The use of fertilizer on soil in order to improve agricultural yield has been practiced for years. While fertilizers and manures greatly improve crop yield, it is also important to consider the corresponding and devastating effects. In this study, the fertilizers application rate was varied and their effects on groundwater quality with soil depths of 30 cm and 60 cm was observed. Two fabricated lysimeters was used to collect soil samples undisturbed and taken to the laboratory for analyses. The samples in the lysimeters was made saturated and varying quantities of fertilizers from 87.37 g and 100 g were applied. The saturation of the samples was done through an improvised rainfall simulator which was set up in such as a way that a constant discharge was adopted. Water samples were collected at 30 cm and 60 cm depths and analyzed for fertilizer residues and physico-chemical characteristics such as temperature, pH, total chloride, total dissolved solids, dissolved oxygen, conductivity, free ammonia, total phosphate, urea, zinc and iron. The results showed that the more the quantities of fertilizers applied on the soil, the more it affects the physico-chemical properties of the water and renders it toxic and unsuitable for drinking purposes except treated. The results, however revealed that the concentrations of the fertilizers in the groundwater decreases with soil depths

Keywords: *Fertilizers, Nitrates, Unconfined aquifer, Water Pollution*

1 INTRODUCTION

Soil of application of agro chemicals such as fertilizers plays a major role in enhancing the fertility of the soil for agricultural productivity in recent times. This, therefore, means the primary purpose of applying fertilizers to the soil is mainly to improve the crop yield in order to enhance profitability of the farming enterprise. But the adverse environmental effects of these chemicals on soil and groundwater body in the case of fertilizer overdose has over shadowed the merits of this practice. In recent decades, changes from traditional agriculture practices to modern agriculture practices have led to the overuse of chemical fertilizers which, in turn, has resulted in higher groundwater contamination. Some fertilizers, such as nitrate, play a more important role in the contamination of water and soil due to their physical and chemical characteristics, especially in agricultural lands. Therefore, what influences the mobility of these contaminants through soil to groundwater like soil, hydrogeological conditions, land use systems and climate differ from one location to another (Adeoye et al., 2017). Collin and Melloul (2003) also pointed out that this may be as a result of different soil and hydrogeological settings offering different vulnerability and different degrees of protection to the underlying aquifer. Rainfall influence on the contaminants transport cannot be overemphasized. According to Pérez et al, (2003), in regions with high rainfall, such with average precipitation of 700 mm/year, nitrogen-based fertilizer residues left unused by plants may be leached away thereby contaminating groundwater. The contamination may occur several days even months after the fertilizers have been spread. The speed at which the contamination occurs, according to Pérez et al, (2003), depends on the nitrogenous compound concentration in the unsaturated zone of the soil, on input from atmosphere and on the hydrology of the aquifer. The precipitation influence on the fertilizers leaching to the groundwater body has been corroborated by Gunatilake (2016). There has always been a link between fertilizers leaching (in areas with a dryer climate) and intensive irrigation as well (Djaman et al., 2018).

Use of lysimeter to study migration of contaminants to groundwater has also been recognized for many years because it has been of major importance in the development of understanding of soil water and contaminants dynamics in the subsurface. Earliest lysimeter consisted of a container filled with soil repacked to a similar bulk density of that in the fields. Ehler and Goss (2003) and Goss et al. (2010) developed a non-weighing drainage lysimeters and tension lysimeter by placing a wick in contact with the soil body to carry water down into the collecting vessel. Goss and Ehlers (2009) developed a hybrid weighing lysimeter which allows the contaminant load entering unconfined shallow groundwater to be identified. Kartikeyan et al. (2008)

studied the migration of faecal matter through soil with a drainage non-weighing lysimeters. The results from all these studies and more show fast movement of these bacteria as a result of very permeable nature of the vadose zone soil. The concentrations of these chemicals seem to be reducing as they move through the soil mass

Several cases of water borne diseases have been documented in Minna over the years Chukwu et al. (2004) reported nine years water borne diseases in Minna and also reported that major water borne diseases affecting Minna inhabitants are typhoid, diarrhea, cholera, amoebiasis and blue baby. It was concluded form his study that majority of people affected by these diseases are people living in the suburb and close to area where there are intensive farming activities like dairy, slaughters house and poultry activities. Some groundwater sampling campaign in North central Nigeria and Minna (Jimoh et al., 2003; Salami et al., 2008; Isikwue et al., 2011) have reported presence of nitrates, phosphates and biological parameters especially inside the poultry farms as a result of indiscriminate dumping of poultry manure. However, a mechanism guiding the transport of the pollutants through the vadose zone into the groundwater has not been adequately studied. There is therefore a need to ascertain behaviour of chemical fertilizer contaminants through the soil profile to be able to predict and describe the danger posed to groundwater aquifers by continuous and excessive application of chemical fertilizer to agricultural lands.

2 METHODOLOGY

2.1 DESCRIPTION OF STUDY AREA

The study area will be Gidan Kwano Inland Valley located between Latitude 9o 5000’ and 9o 5625’ N and Longitude 6o 373’ and 6o 4375’ E. The valley is located at the western end of Minna, a North-Western town in Niger State, Nigeria within the permanent site of Federal University of Technology, Minna. The catchment area of the basin 30.79 km2. The soil type on the study area was in a textural class of gravelly sand up to the depth of 80 - 90 cm. The area is characterized with low and erratic rainfall of between 1000 to 1200 mm as total annual rainfall with peaks in July and August.You can simply download the template and replace the content with your own material. This section describes various methods adopted in your paper.

2.2 EXPERIMENTAL METHOD AND DATA COLLECTION

Two different agricultural zones within the study area were selected in this study. Metal lysimeters of 0.3m diameter and 1m length with openings for water collection at 30. 60 and 90 cm (Figure 1) were pushed into the soil at the locations in order to collect the soil samples undisturbed. The lysimeters were pushed into the soil profile with little disturbance to the soil mass. The lysimeters was extracted from the soil and transported to the laboratory for laboratory experimental set up. The two lysimeters were left for 2 weeks to allow for stabilization of soil mass inside the lysimeters before the experimental analysis (application of fertilizers). For the experimental analysis, the NPK fertilizer particles were applied at the rate of 5.74 kg/ha according to Matsumoto and Yamano (2011), prior to the application of water through the rainfall simulator. The rainfall intensity was simulated using an improvised rainfall simulator with constant discharge at the rate of 1 litre/m2 = 1 mm of rainfall FAO (1986). Hydraulic conductivity was carried out at two (2) different depths of 30 and 60 cm soil depths.

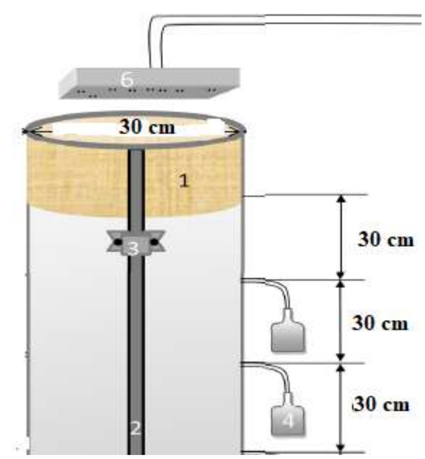

Figure 2: Lysimeter with the openings at different depths

The first experimental analysis started with the application of 87.37 g particles of NPK fertilizers (approximately at the rate of 5.74 kg/ha) on the lysimeters after which the water was then applied to them through rainfall simulator. At the end of rainfall simulation, water samples were collected using sterilized cans at the soil depths of 30 cm and 60 cm. The same procedures were repeated with the application of 100 g of NPK fertilizers on the soil columns in the lysimeters. Water samples were also collected at the different depths of 30 cm and 60 cm. The collected samples were refrigerated and sent to the laboratory for further analysis. Analysis will be done in the laboratory for the determination of the following parameters: **pH, EC, TA, TH, CO_3^{2-}, HCO_3^-, Ca^{2+}, Mg^{2+}, Fe, Cl^-, COD, NO_3^-, PO_4^3.**

3 RESULTS AND DISCUSSION

The results of physico-chemical parameters of the water samples for the EXPERIMENT 1 where 87.37 g of NPK fertilizers were applied on the first soil column is as presented in Table 1. From Tables 1 and 2, six (6) water samples were analysed; three (3) samples at each depths of 30 cm and 60 cm. From the tables, it was observed that most of these parameters reduces in values with depths. The same trend was observed in EXPERIMENT 2 where 100 g of NPK fertilizers were applied on the second soil column. The results of the analysis for the EXPERIMENT 2 analysis were presented in Table 2.

TABLE 1: RESULTS OF PHYSICO-CHEMICAL ANALYSIS OF GROUNDWATER FOR EXPERIMENT 1

SAMPLE ID	pH	EC (µS/cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	CO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
A1 30cm	7.6	1001	45	112	16.82	17.08	221	2460	20.61	19.38	7.5	6.78	5.22
A2 30cm	7.64	752	40	86	21.86	7.66	194	2384	18.04	16.95	6.38	6.87	4.85
A3 30cm	7.65	613	36	120	20.18	16.98	204	2077	15.97	15.02	6.75	7.03	5.5
A4 60cm	7.05	535	24	180	42.05	18.3	15.86	26.88	9.79	9.2	1.11	4.67	1.35
A5 60cm	7.08	472	24	176	31.95	23.47	13.55	29.25	9.79	9.2	1.38	2.31	1.51
A6 60cm	7.06	506	26	136	28.59	15.76	15.6	31.4	10.82	10.17	1.29	2.34	1.48

TABLE 2: RESULTS OF PHYSICO-CHEMICAL ANALYSIS OF GROUNDWATER FOR EXPERIMENT 2

SAMPLE ID	pH	EC (µS/cm)	TA mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	COD mg/l	HCO3 mg/l	CO3 mg/l	Fe mg/l	PO4 mg/l	NO3 mg/l
B1 30cm	6.87	4100	50	132	28.59	16.83	185.22	3700	28.35	11.14	6.25	6.35	3.38
B2 30cm	6.77	3960	60	168	26.07	24.08	196	3600	20.1	12.11	6.3	6.6	3.5
B3 30cm	6.78	4360	65	164	40.37	29.76	162.68	3400	9.79	9.2	6.27	6.47	1.94
B4 60cm	6.83	549	45	100	25.23	6.97	196	1350	11.85	26.64	3.5	3.65	0.15
B5 60cm	6.78	706	44	94	27.75	7.05	140.14	1200	12.88	18.89	1.75	3.4	0.1
B6 60cm	6.66	459	30	98	16.82	7.01	123.48	1275	12.88	12.11	4	3.75	0.15

From Table 1, there is no significant variation in the pH values of the water samples collected at both depths. The pH values obtained at both depths range between 7.05 at 60 cm and 7.65 at 30 cm. However, the pH values at both depths were all within the permissible of 6 – 8. The same trend was observed in EXPERIEMENT 2 though with lower pH values which ranged from 6.66 at 60 cm depth to 6.87 at 30 cm depth. From Table 1, highest nitrates and phosphates values were recorded at depths 30 cm compared to the values obtained at 60 cm. This could be attributed to the reduction in concentration of these particles as they migrate deeper into the soil mass. And it also means that fertilizer particles are being taken up in the soil mass as they move downward into the soil column. For nitrates, the values declined from 5.22 mg/L at 30 cm to 1.35 mg/L at 60 cm. The phosphate values recorded declined from 6.87 mg/L at 30 cm to 2.31 mg/L at 60 cm. The indication of this is that nitrates and phosphates contents of the applied NPK fertilizers could not leach up to a depth of 60 cm and beyond of the soil within the period of the study. The same pattern was observed in EXPERIMENT 2 as phosphate and nitrate values declined from 30 cm depth to 60 cm depth. Nitrate values in EXPERIMENT 2 declined from 3.38 mg/L at 30 cm depth to 0.1 mg/L at 60 cm depth.

The electrical conductivity EC values followed a declining pattern as the fertilizer particles migrate down into the soil mass. From Table 1, the highest value recorded was 1001 µS/cm at 30 cm soil depth compared to the lowest of 472 µS/cm at 60 cm soil depth. The same trend was observed in EXPERIMENT 2, though with higher values of EC, which could be as a result of higher quantity of NPK fertilizers applied. The value recorded was as high as 4100 µS/cm at 30 cm depth compared to 459 µS/cm obtained at 60 cm. Electrical conductivity has been explained (Nkandawire, 2008) as an indication of dissolved elements (metallic and non-metallic) in water and the increase in values may be attributed to the fact that infiltrating rain that was simulated on the soil core and applied poultry waste might have dissolved some organic and inorganic constituent of poultry was which are capable of raising EC values of the water samples

(Adeoye et al., 2017). The total alkalinity obtained in the two experimental set up showed that the total alkalinity (TA) varied between 65 mg/L at 30 cm in EXPERIMENT 2 to 24 mg/L at 60 cm in EXPERIMENT 1. The values of TA fall within the allowable limit for TA in drinking water which is 20 – 200 mg/L.

4 CONCLUSION

The Effect of Chemical Fertilizers on Groundwater Quality in an Unconfined Aquifer has been studies. This study has showed that the soil on the experimental plots have ability to take in fertilizer particles as they migrate deep down into the soil mass. Nitrates and phosphates generally decline in concentrations as they move with soil depths. They were able to leach up to 60 cm of soil depth of the undisturbed soil column. These observations were attributed to high porosity of the soil and high hydraulic conductivity which ranged from 0.489 – 0.81m/day according to hydraulic parameters analysis carried out on the soil of the area. The results obtained in this study can be used as baseline to know the precise application of fertilizers needed for optimum crop productivity with little negative effects on human consumption of groundwater bodies. The results of this study can also help in modelling the fertilizers particles movement in the soil columns. This information from this study can also be used as input parameters into modern software and models for predicting contaminant fate, transport and persistence in unconfined aquifer.

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