EFFECTS OF FARMING OPERATIONS ON GROUNDWATER QUALITY IN BASAWA, ZARIA-AREA, NIGERIA

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ABSTRACT

Anthropogenic activities, mostly related to farming are some of the causes of increased dispersion of polluting substances into soil and to the subsurface water mass. Though, the interaction of water with geologic materials during movement also serves as major determinant of its chemical characteristics. Agriculture is viewed as a significant non-point source of groundwater contamination, which poses a serious challenge to the government and other stakeholders involved in environmental pollution abatement and control, on design methodologies or approach to be adopted, to prevent pollution by fertilizers and pesticides. Groundwater sources (e.g. hand dug wells, concrete wells and deep wells), in Basawa area were monitored by monthly sampling and analyses from February to September. Static water level of monitored sites varies between 0.03 and 9.0 m, with the exception of boreholes and a pH range of 5.7 to 8.1. The electrical conductivity, nitrate and phosphate concentration values are within the ranges of 46 to 1,517 µS/cm, 0.39 to 35.21 mg/L and 0.00 to 6.12 mg/L throughout the entire period of monitoring. The intensity of contamination of ground water sources due to the farming activities was found to be in decreasing order of dug wells, concrete wells, and deep wells.

Keywords: Basawa environs, farming, fertilizer, groundwater, pollution, static water level.

INTRODUCTION

Man's activities on the earth surface have drastically affected the groundwater resources with increasing rates. Therefore, polluted groundwater can be a source of serious environmental and health concern [1]. The intensification and expansion of human activities (such as farming) to meet the growing population's food demand are some of the causes of increased dispersion of polluting substances into soil surface and subsequently to the subsurface water mass [2]. Though, the interaction of water with geologic materials during movement also serves as major determinant of its chemical characters [3]. Agriculture is viewed as a significant non-point source of groundwater contamination because of the wide spread use of fertilizer and pesticides to improve crop yield, which presents a difficult problem to government and other stake holders involved in pollution prevention and control [4,5,6,7]. The possibility of ecological threat to subsurface water mass is predictable and the consequences of which may be immediate or long time phenomenon and could affect the social and economic wellbeing of the populace [8]. A number of socio-economic and environmental factors have been identified as being responsible for the vulnerability of Africa to high levels of diseases and are mostly linked to water and sanitation problems [9]. In this paper, the status of ground water quality of Basawa farming population was examined through the results of well surveys conducted in the four regions.

Study Area

The research area is located in the North-western geo-political zone of Nigeria in Zaria, Kaduna State as shown in Fig 1. The rainfall distribution is characterized by a well pronounced dry season and having high arable acreage to nearly most of the available land area than for pasture. The research study was undertaken in four regions of Basawa, Zaria, and the area investigated is presented in Figs 2 and 3. Farming is the only activity of the inhabitants of the study area, by observing both dry season and rainy season cultivation. Their farmlands are cultivated for maize, sorghum, garden-egg, cabbage, tomatoes, pepper and other vegetables. All the studied locations are within the farmlands and the water use pattern over the years is for domestic and agricultural purposes especially during dry season and drought periods.

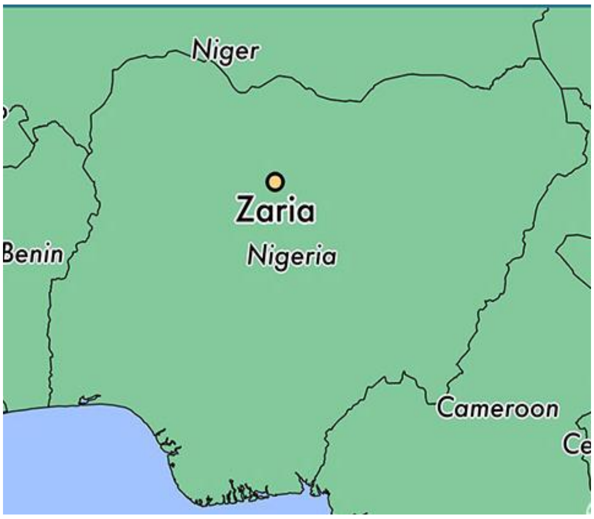

Figure 1. Map of Nigeria showing Zaria

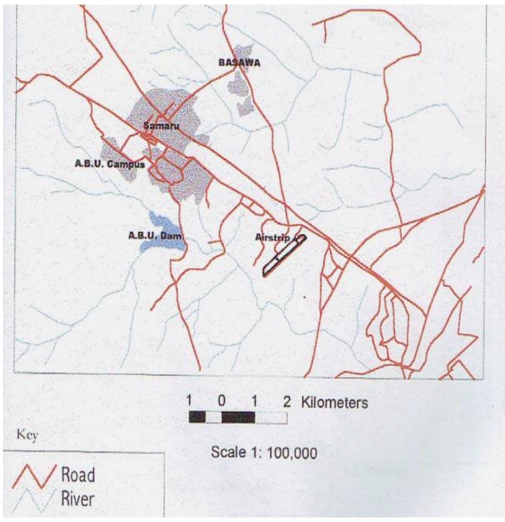

Figure 2. Map of Zaria and Environs

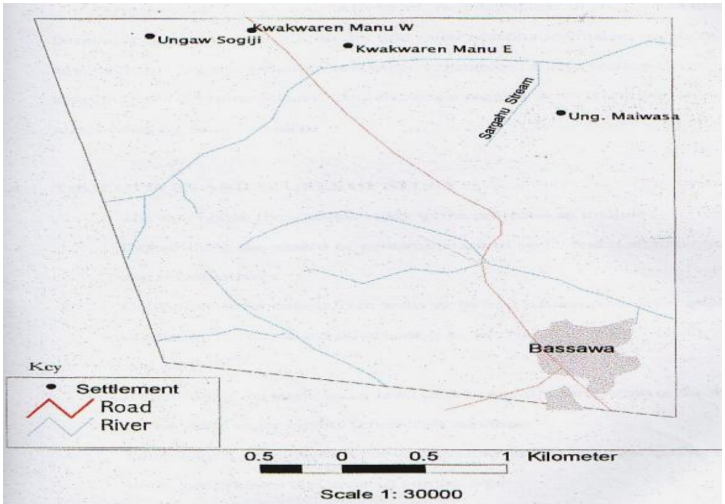

Figure 3. Map of Study Area

MATERIALS AND METHOD

Sample Collection

Samples were collected at an established monitoring site during the sampling operations. The samples were mixed to represent a grab sample for each location. Sample from each monitoring well was collected just below the static water level once every month, with the aid of groundwater sampler [10]. Sterile bottles were used to collect the water samples by slowly filling with a gentle stream to avoid turbulence and air bubbles development, then transported in cold plastic container, with ice blocks that chilled the samples during transportation to the laboratory and stored at 4 °C for 24 hrs before use. Samples from Eighteen (18) locations were collected on a monthly basis, from February to September as shown in Table 1.

Table 1. Sampling locations, sites and coding

S/N	Sampling location	Sampling site	Sample code
1.	Unguwan Maiwasa	Dan'Asabe I Dug Well	DSIDW
2.		Dan'Asabe II Dug Well	DSIIDW
3.		Dufa – Dufa Concrete Well	DDCW
4.		Dufa – Dufa Hand Pump	DDHP
5.		Yusuf Dug Well	YDW
6.	Unguwan Sogiji	Fulani I Dug Well	FIDW
7.		Sarki Mato Dug Well	SMDW
8.		Sogiji Concrete Well	SCW
9.		Sarki Mai Kudan Dug Well	SMKDW
10.	Kwakwaren – Manu West	Fulani II Dug Well	FII DW
11.		Mai Unguwa Dug Well	MUDW
12.		Saluhu Dug Well	SDW
13.		Garba Dan Fulani Dug Well	GFDW
14.		Muhammadu Sa'idu Dug Well	MSDW
15.	Kwakwaren – Manu East	Kwa Kwaren – Manu East Hand Pump	KMEHP
16.		Musa Ali Dug Well	MADW
17.		Kwakwaren – Manu East Concrete Well	KMECW
18.		Garba Mato Dug Well	GMDW

Method of Analyses

Nitrate

Nitrate content was analyzed with a modification of cadmium reduction method, using cadmium sulphanilic acid and gentisic acid in nitraver5 nitrate reagent. The colour intensity developed, is directly proportional to nitrate concentration and was measured using DR/2010 HACH spectrophotometer, at 500 nm wavelength [11].

Phosphate

Phosphate content was determined by stannous chloride calorimetric method, using ammonium molybdate. Phosver3 phosphate reagent, a modification of molybdenum blue was used after sample pretreatment. Colour intensity developed is directly proportional to phosphate concentration, and was measured using DR/2010 HACH spectrophotometer at 890 nm wavelength [11].

Field Parameters (pH, Electrical Conductivity and Static Water Level)

The field parameters, pH and electrical conductivity were measured on-site by electrometric method using NORLYLAB PM8 pH meter and NORLYLAB LM8 Electrical Conductivity Meter respectively. The static water level was measured with an electric indicator sensor using A.OTT KEMPTEN dip meter.

RESULTS AND DISCUSSION

The properties and nature of materials in a body of water would influence the quality of the water by altering its actual or original state. [12], reported that, monthly analyses of individual locations do provide an indication of the changes of substances over time and condition before, during and after assessment. This research study demonstrates that patterns and nature of the farming activities cannot be over-looked as interplay of the physico-chemical changes operating in groundwater systems of the study area. The evidence of such effects has been traced to the variation of nitrate and phosphates, which are major components of the types of chemical fertilizer intensively used during cultivation, especially the rainy season cultivation.

Some of the shallow groundwater sources (i.e. dug wells) are not only affected by fertilizer application through infiltration, but also the reinforcement through surface run-off, as some of the dug wells have no well-mouth protection. Sampling location Sarki Mato dug well (Code SMDW) dried in the months of April and May; therefore samples were not collected in this months. This caused abrupt cessation in physico-chemical trend for all the parameters at the location within the months. Sampling location Fulani II dug well (Code FIIDW) owner threatened that poison may be injected into his well during the static water level measurement. In view of the owner's resistance, this location experienced abrupt cessation in the determination of the physico-chemical trend from June to September.

Static Water Level (SWL)

The distance from ground surface to the water level varies between 0.03 and 9.0 m (Fig. 4). Rainfall reduces the distance by increasing the water volume through recharge. Though, there is the effect of withdrawal from users, such effect was negligible during rainy season, because the villagers utilize household's roof-water harvesting as their source of domestic water usage. Water infiltration through soil strata leading to groundwater recharge and subsequent lowering of the SWL especially in the month of August and September might be due to loss in matric forces as a result of high rate of rainfall.

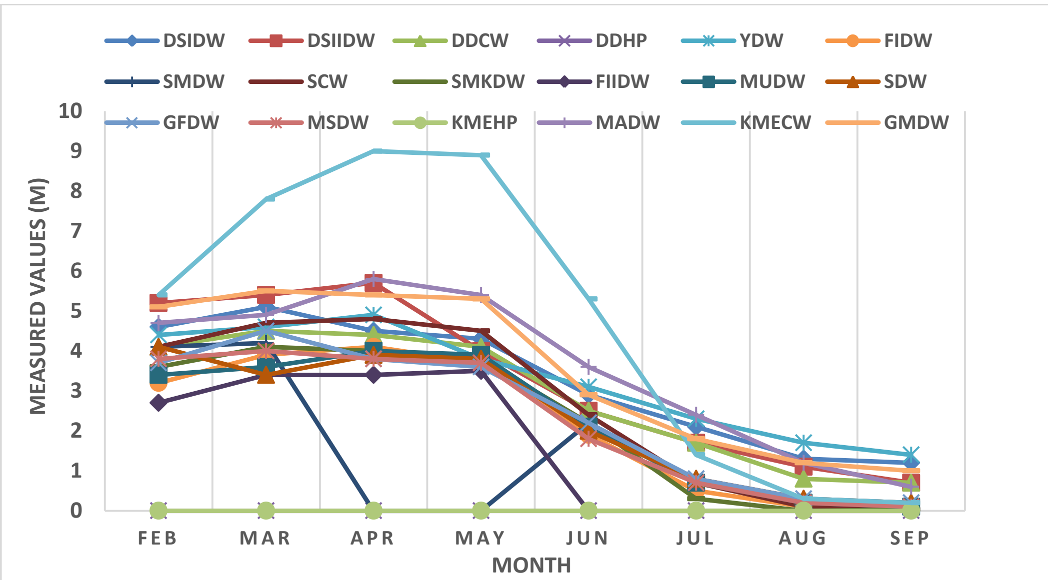

Figure 4. Static water level

pH (Measurement of Acidity or Alkalinity of Water)

The hydrogen ion concentration of water gives a measure of the acidity or alkalinity of the water. There was variation of pH from 5.7 to 8.1 during the monitoring period as shown in Fig 5. Higher pH values were mostly obtained in February during the dry season. Though, September measurements during the rainy season were high, but not as high as the values recorded in February. Some location show no appreciable variations of pH values within the assessment period. Most of the locations have pH values within the permissible limit of 6.5 – 8.5 recommended by [13] and [14, 15] for drinking water. In the overall, 51% of the monitoring exercises have pH values below the permissible limit of 6.5 – 8.5 recommended by WHO (World Health Organization) and NSDWQ (National Standard for Drinking Water Quality) MPL (Maximum Permissible Level) for drinking water and might cause gastrointestinal ulcer.

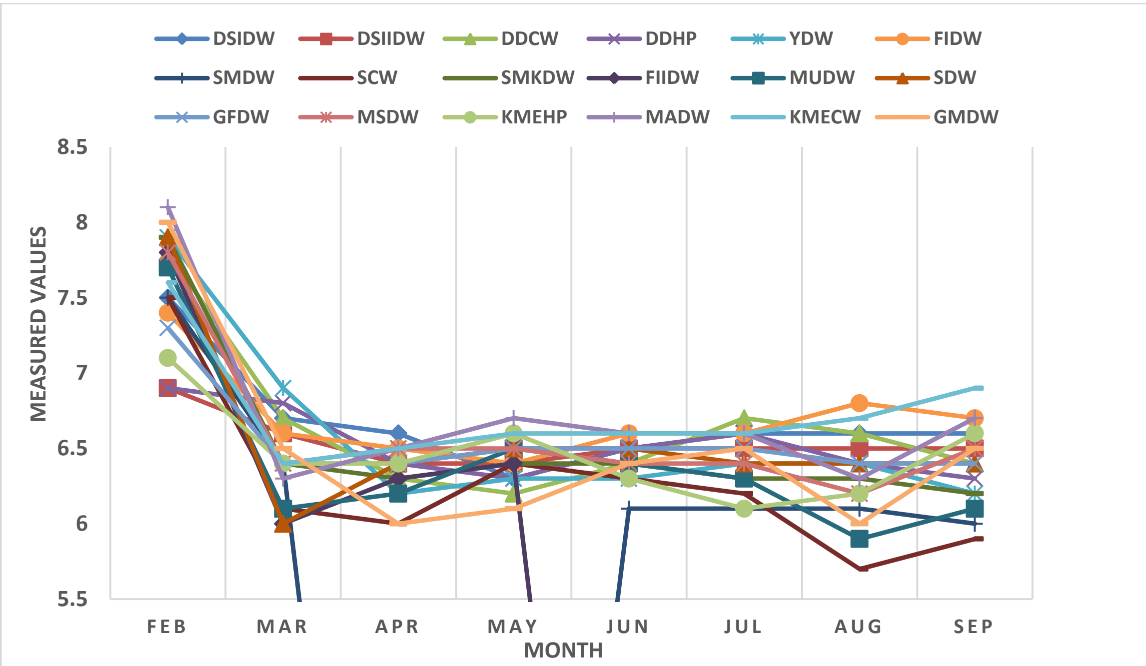

Figure 5. The pH values

Electrical Conductivity (EC)

It should be noted that, each of the basement complex layer possesses its electrical lithological as well as dimensional variations as stated by [16]. The ability to conduct electric current arises mainly from porosity, permeability and the fluid contained (water) within the matrix as reported by [17]. The presence of ions makes water conductive. The ion concentration is directly proportional to the electrical conductivity hence; the EC provides an indication of degree of ionization [18]. Electrical conductivity values monitored ranges from 46 µS/cm to 1,517 µS/cm (Fig. 6). Most of monitored locations have higher EC values in rainy season than dry season, possibly due to more salt intrusion as a result of higher dissolution rate by rainfall. There are however, very few locations with higher EC values in dry season, probably due to lower dilution effect in the dry season than rainy season. It was found that 0.7 % of the monitoring exercises records value above the 1000 µS/cm.

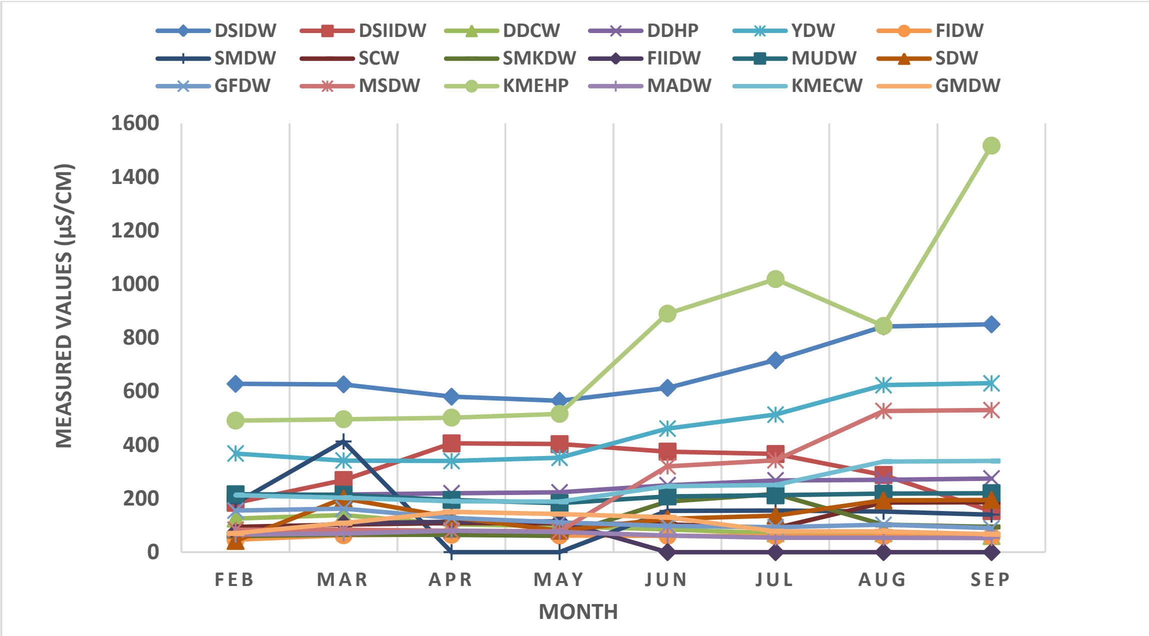

Figure 6. Electrical conductivity

Nitrate

Nitrate can gain access to water sources from variety of point, non-point and natural sources. The non-point source due to agriculture predominates in region of vast agricultural activities [5]. Monitored nitrate concentration varies between 0.39 to 35.21 mg/L, as shown in Figure 7. Higher nitrate values were mostly measured during the rainy season especially in July and this may be due to greater rate of nitrogen contained fertilizer applications, supported by high seepage due to of rainfall. During the rainy season nitrate concentration decreases from July to September and this may be not unconnected to more dilution from high rainfall intensity experienced within that period coupled with reduced rate of the nitrogenous fertilizer application in August and September.

Deep wells (the boreholes DDHP and KMEHP) have the lowest nitrate concentrations with values less than 1.00 mg/L throughout the assessment period, possibly due to depth. This is an indication that the nitrate contamination might be due to farming activities rather than from geologic composition of the region. The nitrate levels of concrete wells DDCW and SCW were fairly constant throughout the monitoring period and might be due to good concrete linings provided to the wells, coupled with lower farming activities in relation to the concrete well KMECW. Sampled locations YDW and DSIIDW had nitrate concentrations above the WHO maximum permissible level of 25 mg/L [13]. However, location SMKDW has nitrate concentrations above the level only within certain period of the measurements. The other locations though below the level, might rise above the level in future unless corrective measures are taken into consideration, because of possible cumulative effect. Changes on the type and/or rate of fertilizer application, the cropping pattern and land management may drastically reduce the nitrate concentrations in the study area. It was observed that 11 % of the monitoring exercises had nitrate concentration above the 25 mg/L recommended by WHO for drinking water and might cause methamoglobinemia (blue baby) syndrome among children consumers below 1 year of age [19].

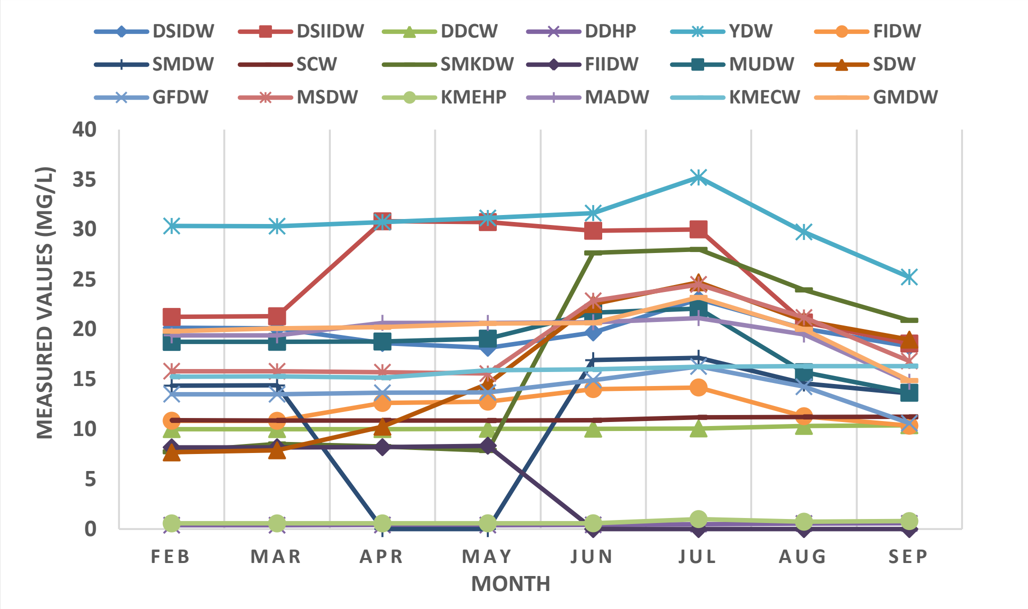

Figure 7. Nitrate concentration

Phosphate

Naturally, occurring phosphate is only released through weathering and/or erosion, since it is generally immobile. Based on reviewed data from field sites, phosphates fertilizer applications, especially where intensive irrigation is practiced are potential sources of phosphate run-off water and seeping water [20]. Phosphate concentrations within the range of 0.00 to 6.12 mg/L were obtained throughout the monitoring period (Fig 8). The lack of storm events and run-off from diffuse sources, including fertilizers could account for either low or relatively constant phosphate concentrations during the early monitoring months at most of the sampled locations. The decrease in phosphate concentration during the months of August and September is possibly due to dilution effects of the intense rainfall in the months. Nevertheless, rainy season concentrations are generally higher than dry season.

Just like for nitrate the deep wells DDHP and KMEHP have the lowest phosphate concentrations, with maximum value of 0.02 mg/L. This shows that higher values of phosphate in the project area might also not be geologically oriented. Sampled locations YDW and DSIIDW exceeded the WHO maximum permissible level of 5 mg/L phosphate in drinking water during certain periods of the monitoring [13]. The other locations may encounter same consequences in future due to cumulative effects, if corrective measures are not taken.

Results showed that 4% of the monitoring exercises have phosphate concentration above the 5 mg/L recommended by ‘WHO’ for drinking water. The health effects of drinking water with phosphates are not known but the Food and Drug Administration (FDA) has issued a report on the toxicology of inorganic phosphates as food ingredients. The FDA considers phosphates as a food additive to be generally recognized as safe [21]. However, excess phosphate will trigger eutrophic conditions, causing the water to be aesthetically objectionable and may breed microorganism that are pathogenic [22]. Both awareness creation and land use modifications will play vital role in land management.

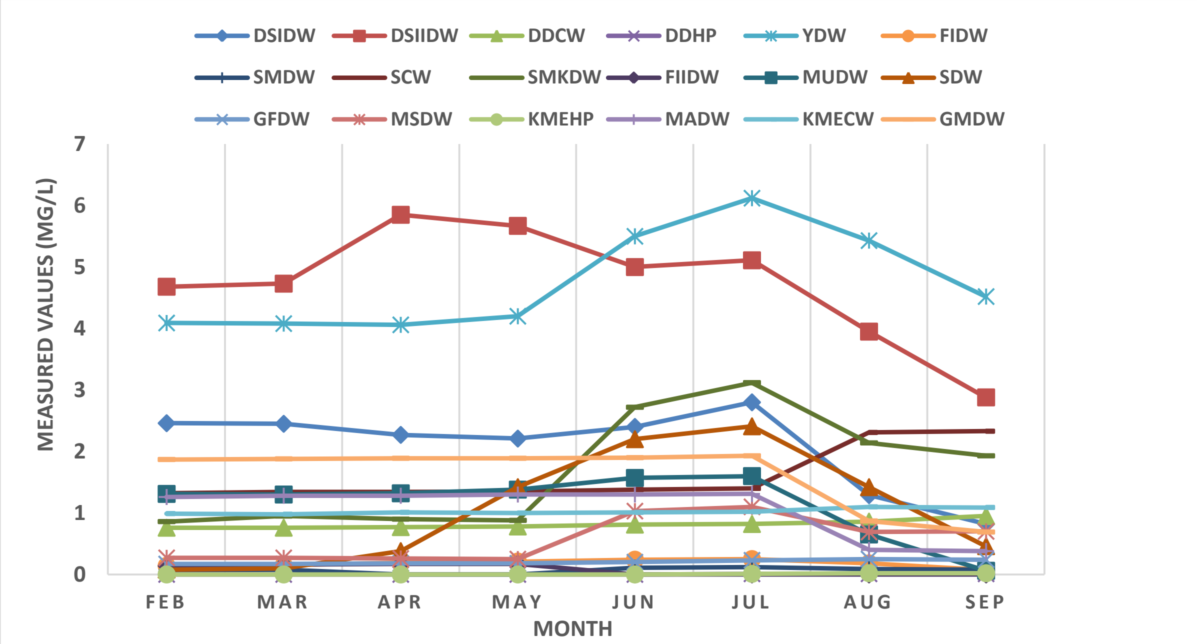

Figure 8. Phosphate concentration

CONCLUSION

The results from sampled locations indicate that, nitrate and phosphate were found in dug wells, concrete wells and deep wells (hand pumps). The intensity of contamination is in decreasing order of dug wells, concrete wells, and deep wells. It is likely that variability reflects; fertilizer application (type, quantity and time of application); differing infiltration behaviors as exhibited by similar water depth (static water level); geochemistry of the region; matric forces controlling both degree of infiltration and dilution; good lining interfering the seepage intensity; depth of water to the surface (Static water level).

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