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Impact of Agro-Chemicals on Groundwater Quality and Soils of Irrigation Sites: A Case Study of Chanchaga Irrigation Scheme, Minna, Niger State

Mohammed B. ABDULLAHI

Department of Crop Production, Faculty of Agriculture, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria

mbabdullahi@ibbu.edu.ng

Abstract
The research work was conducted at the Chanchaga irrigation scheme aimed to identify the often-used agrochemicals by farmers and their impact on soil and groundwater in the scheme. Groundwater and soil samples were collected from the scheme and analysed for K, Cl, NO_3, and PO_4 using flame photometer and Ultra-Violet (UV) Spectrophotometer, for the heavy metals (Mn, Zn and Cr) Atomic Absorption Spectrophotometer (AAS) was used. For the survey analysis, a well-structured questionnaire and data from the municipal agriculture office were used in the data collection. A total of 113 respondents (farmers) were surveyed, most of the farmers (88.97%) were using agrochemicals and inorganic fertilisers. Correlation and ANOVA analysis were used to analyse the data. The results showed high occurrence of NO_3, PO_4, Mn, Zn and Cr in both samples. And were statistically observed to be significantly different at $p \leq 0.05$ in the soil and groundwater of the Scheme. Farmers indiscriminately used agrochemicals without consideration to dosage and rate of application. Insignificant number of the farmers applied biological control methods for crop pests and diseases. Therefore, increasing the awareness and training of farmers in sustainable agriculture and agrochemical use, within an integrated pest management approach is necessary and recommended.

Keywords: *Agrochemicals, groundwater contamination, and soil contamination.*

1.0 Introduction

Agriculture is considered amongst the pillars of Nigeria's economy in addition to oil sector exploration. For many Nigerians, agriculture is their main source of income, accounting for over one-third of the country's GDP and labour force [1,2, 3]. It is also evident that the physicochemical and the biological status of our earth are being degraded day-to-day. The damaging consequences of agrochemical application are multiplying both in rate and quantity. Natural habitat has been destroyed and biodiversity has reduced resulting from these effects. Even though we now inadequate in understanding, technology, human capacity, financial resources and the political will to remediate it, humans are working towards damaging the environment and our health in developing nations [4]. Agrochemicals are critical farming inputs that shield crops against weeds, pests, and diseases. The contributions of agrochemicals are far beyond healthy crop growth and animals, it also improves the efficiency of farm work and provides continuous supply of farm produce [5].

Herbicides play a major role in modern agriculture, it controls unwanted growth (weeds) in pastures and crops to maximise output and monetary benefits to support the growing global population. Herbicide use has increased globally due to the introduction of herbicide-resistant characteristics in some crops, including glyphosate-resistant (GR) soybean, maize, and canola [6]. In 2001, the United States consumed over 200 million kilograms, of which 20% was glyphosate. Without a question, the herbicide commonly in use worldwide is glyphosate [7]. In Argentina, where GR soybeans make up about 90% of all soybeans planted, an estimated 160 million litres of glyphosate were applied to this crop in 2004, accounting for 37% of all herbicides used in agriculture [8, 9]. Because only a small portion of the chemicals reaches the target species, the environmental fate of herbicides is currently under scrutiny due to the potential effects that leftover herbicides in water and soil may have on the health of people, animals, and crops [10].

Compared to other agrochemicals, herbicides are applied considerably more often, and many farmers and gardeners rely entirely on them to control weeds. Herbicide-resistant weeds can be encouraged to emerge when herbicides are used frequently over a long time [10]. Even though agrochemicals are useful, their improper application may be detrimental and endanger the long-term existence of foremost ecosystems by upsetting predator-prey relationships, reducing biodiversity, increasing pest resistance, and eliminating pests' natural enemies. As a result, they should only be used sparingly and safely [11]. Despite the increased usage of pesticides in developing nations, users have little to no knowledge of the environmental risks. According to [12], many consumers are not well-informed about the possible short-term and long-term hazards, and thus do not always take the appropriate precautions while using such harmful compounds.

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Due to the hazardous nature of agrochemicals and their inherent toxicity and potential to cause poisoning, it is imperative that we ensure the safety of the user, our population, and the environment [13]. It is crucial that agricultural extension workers, farmers, grain merchants, and other participants become aware with the proper application of registered agrochemicals for use and ensure that all safety measures are strictly adhered to during application. There is a dearth of information on their use, distribution, and environmental effects. Nigerian policymakers, her development partners, and agricultural specialists all agree that agricultural production can contribute significantly to the nation's prosperity [14]. Since small-scale farmers control the agricultural sector, it is widely considered that they hold the key to realizing this prospect.

The idea that a pollutant is a substance in the wrong location, at the wrong time, or in the wrong quantity is helpful to remember even while herbicides are crucial to agriculture. In some situations, they may behave as pollutants that harm surface, ground, and soil waterways. In the research region most farmers use a lot of agrochemicals. This is because farmers want to have a healthy yield while controlling weeds and shielding the crops from insects' damage. The detrimental impacts of the materials are applicable to the soil, also the surface and ground water, which are not considered during these operations. [15] reported on the effects of agrochemicals on groundwater and soils of the scheme, suggested that well depth should be 8 m in the active agricultural area, however, there was no list of agrochemicals used by the farmers in the scheme. Hence the knowledge gap here are highlights of the agrochemicals, inorganic fertilizers used and indicating their active ingredients. Therefore, the aim of this research is to evaluate the impact of agrochemicals on groundwater and soils of the scheme, and to provide information for policy and decision-making frameworks.

2.0 Materials and Methods

2.1 Study Location

The scheme (Chanchaga irrigation) came into existence in the early eighties, covering an area of about fifteen hectares of cultivable farmland with furrow and basin irrigation mostly practised. With coordinates latitude 9^{o}36'50" N and longitude 6^{o}33'25" E and located along Chanchaga river bank (Fig. 1). The scheme is among the popular irrigation sites managed by Niger Agricultural Mechanization Development Agency (NAMDA), with two different seasons, the dry and wet. The annual rainfall and duration varies from 1200 mm to 1600 mm and 150 – 210 days respectively. The area has a min. and max. average temperature of 27.6 ^{o}C and 38.2 ^{o}C. The vegetation is characterized by tall grass and the trees are sparsely distributed and are deciduous in nature. Subsistence agriculture is predominantly practiced in Chanchaga and its environs, crops such as yam, millet, melon, rice to mention a few are cultivated. Yam and Maize cultivation are prominent among the crops cultivated. The scheme mostly cultivates vegetables such as spinach, okra, roselle, eggplants, tomatoes and other necessary vegetables during the dry season [16].

2.2 Experimental Design

Primary, secondary, and other sources of data were used. The primary data sources include: questionnaires, personal interview and reconnaissance survey. Secondary sources were Journals and other records from stakeholders. Other sources were constituents of agrochemicals and their characteristics obtained from farmers, co-operate groups and organisations that are participants in agricultural practices. Multilevel factorial design was used consisting of four sample points and six months collection periods (4 x 6) with base runs of 24 and 3 replications, and a total observation of 72 x 2=144.

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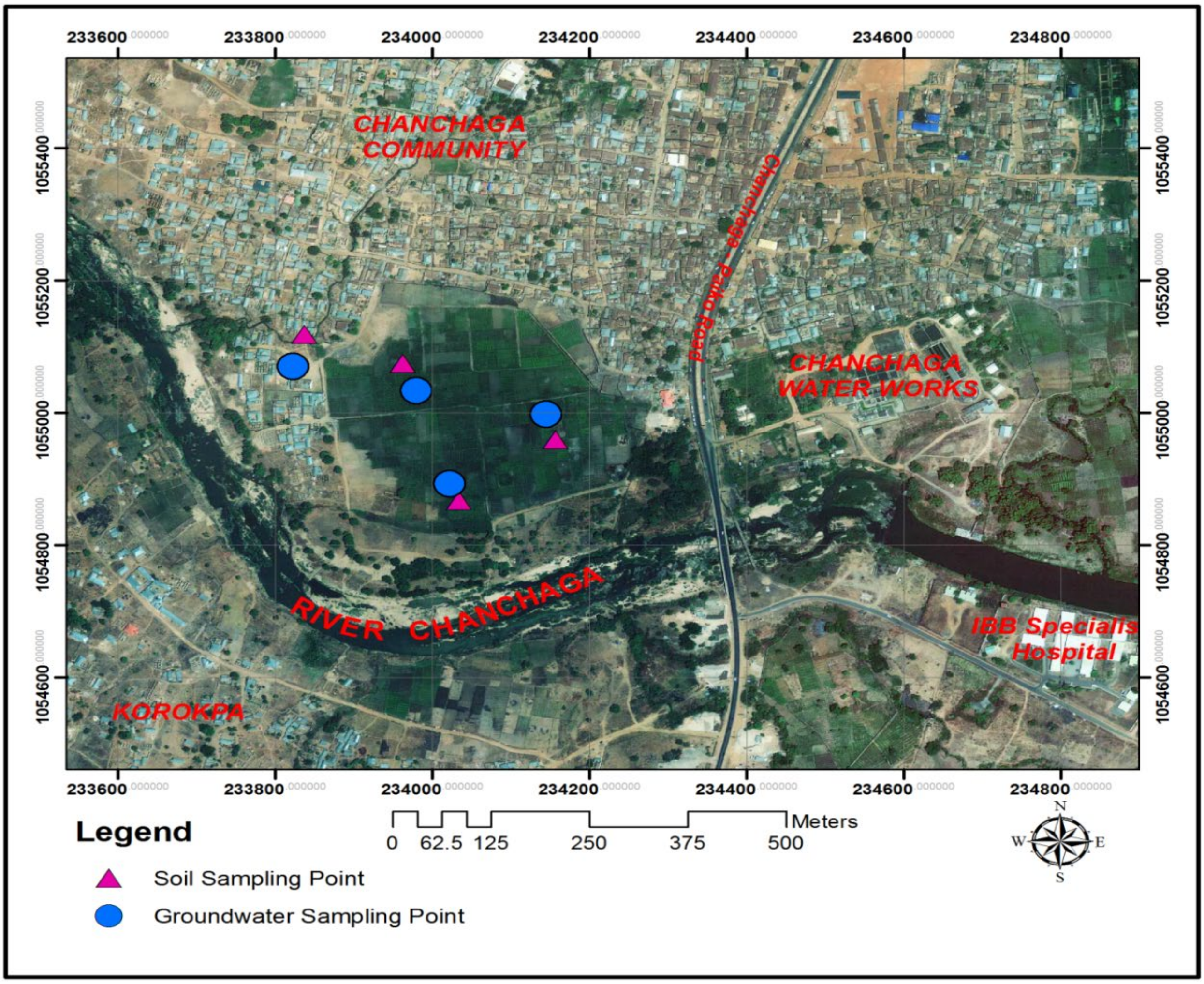

Fig.1: Study area map and the sampling points

Source: [17]

2.3 Collection of groundwater and soil samples

Plastic bottles were used to collect groundwater samples from 4 wells, with three dug within the active agricultural area and from an existing lined concrete well 100 meters away from the active agricultural area which served as the control, with coordinates GW1 N09°32’13.7”, E006°34’34.6”, GW2 N09°32’10.0”, E006°34’42.3”, GW3 N09°32’07.0”, E006°34’38.3”, GWC N09°32’15.1”, E006°34’31.8”. The water sample containers were rinsed thoroughly with the site water and labelled prior to collection. Sample bottles were sealed free of air bubbles with bottle stoppers and moved to the laboratory for analyses.

Soil samples were collected from three points at 30 cm depth in a soil sample polythene bag within the active agricultural area. In contrast, the control was 100 meters away from the active agricultural area with coordinates S1 N09°32’13.6”, E006°34’34.6”, S2 N09°32’10.0” E006°34’42.2”, S3 N09°32’07.0”, E006°34’37.9”, SC N09°32’14.7”, E006°34’31.8”. Samples were carefully sealed and moved to the laboratory for analyses.

3.0 Results and Discussion

3.1 Effect of Depth on chemical parameters

In the inter-elemental correlation at ($p<0.05$) indicated that there was a significant correlation between the depth of water and these elements: chloride, nitrate, phosphate and zinc which shows that as the depth of water reduces the elements rises in the water content, this could be due to high amount of these substances used during cultivation. This depicts that depth is important in keeping the water in the wells of active agricultural area safe, this was also reported [18].

3.2 Effect of pH on chemical parameters

From Table 1, At significant difference ($p<0.05$) NO_3, and PO_4 increases as the pH in the water reduces (-0.72* and -0.52*) which show that both NO_3, and PO_4 will thrive well in an acidic medium, while as the pH increases there was a corresponding increase in zinc and chromium in the water content (0.67* and 0.50*) which indicates that zinc and chromium will thrive well in an alkaline medium, [19] reported that this may be due to human activities, for instance: the use of chemicals and zinc based fertilizers by farmers.

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[20] also opined, that the pH of water has no direct implication on human health but suggested that high values could cause bitter taste in water and encrustation of metallic pipes and appliances. High values could also depress the effectiveness of chlorine disinfection in water. Low pH values could suggest the presence of biological life, as most organisms thrive within a quite narrow and critical pH range [21]. This has an effect on human health by serving as important life support systems that prevent illness, supply drugs, and enhance both physical and mental wellbeing.

Table 1: Pearson's Inter-Elemental Correlation among Water Samples Parameters

	Depth	*pH*	*Cl*	*NO_3*	*PO_4*	*K*	*Mn*	*Zn*	*Cr*
Depth	1								
pH	-0.26	1.00							
Cl	-0.59*	0.22	1.00						
NO_3	-0.87*	-0.72*	0.72*	1.00					
PO_4	-0.75*	-0.52*	0.39	0.84*	1.00				
K	0.34	0.04	-0.39	-0.51*	-0.08	1.00			
Mn	0.04	-0.23	0.64*	0.62*	0.63*	-0.09	1.00		
Zn	-0.82*	0.67*	0.72*	0.83*	0.66*	0.82*	0.57*	1.00	
Cr	0.31	0.50*	0.10	0.60*	-0.08	0.19	0.02	0.63*	1

***Correlation is significant at p< 0.05 (2 – tailed)**

3.3 Inter-elemental correlation in water samples parameters

Table 1 indicates significant correlation (p<0.05) between Cl, K and Mn. Chloride increases as Nitrate, Manganese and Zinc increase (0.72*, 0.64* and 0.72*). The amount of chloride needs to be checked reported by [22]. This can be attributed to the addition of chloride-based agrochemicals on the farmland. Additionally, potassium and Manganese also increases as zinc increases (0.82* and 0.57*). By implication this depict that the wells surrounding Chanchaga irrigation are not consumable except the ones with concrete lined walls because it poses threat to human health.

Table 2: Effect of seasons on chemical parameters in Groundwater

Month	Cl	NO_3	PO_4	K	Mn	Cr
Wet season						
July	41.24^{e}	50.31^{cb}	0.84^{a}	25.13^{b}	0.60^{a}	0.96^{a}
August	70.15^{b}	50.25^{cb}	0.59^{c}	25.72^{b}	0.56^{a}	0.86^{b}
September	55.16^{cd}	51.57^{a}	0.56^{cd}	62.94^{a}	0.32^{c}	0.86^{b}
SE ±	2.60	0.25	0.03	0.97	0.02	0.03
Dry season						
October	50.43^{d}	49.88^{c}	0.84^{a}	25.48^{b}	0.46^{b}	0.88^{b}
November	82.57a	50.87^{b}	0.70^{b}	23.65^{b}	0.38^{c}	0.72^{c}
December	58.90^{c}	50.79^{b}	0.50^{d}	24.61^{b}	0.36^{c}	0.84^{b}
SE ±	1.85	0.15	0.03	0.87	0.02	0.03

Values on the same column for same parameters with different superscript are significant at (p≤ 0.05), while those with the same superscript are not significantly different (p>0.05)

From Table 2 significant difference was observed between the seasons with higher average values of chloride, and phosphate recorded in dry season while, nitrate, phosphate, manganese, and chromium were recorded in wet season. The high content may be due to human activities for instance the use of agrochemicals that are high in these chemical elements.

Table 3: Results on soil and groundwater of the scheme

Variation Source	DF	pH	Cl	NO_3	PO_4	K	Mn	Zn	Cr
Month (Mo)	5	0.16NS	5185.30**	8.49*	0.52**	5796.37**	0.31**	4.09NS	0.14**
Replicate	12	0.017	2.66	1.07	0.0015	0.16	0.0019	0.81	0.0016
Medium (Me)	1	0.412*	1294.62*	29.39**	4.02**	5819.78**	5.27**	375283.86**	87.52**
Sampling points (S)	3	0.404*	8157.88**	77.02**	1.32**	260.87**	0.91**	310.60**	0.74**

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Variation Source	DF	pH	Cl	NO_3	PO_4	K	Mn	Zn	Cr
Mo x Me	5	0.130NS	1525.04**	18.23**	0.85**	7144.30**	0.45**	15.61*	0.16**
Mo x S	15	0.248*	789.43**	5.68**	0.13**	362.20**	0.069**	28.42**	0.13**
Me x S	3	1.925**	40.14NS	0.81NS	0.54**	338.26**	0.41**	238.83**	0.58**
Error	99	0.09	162.50	1.47	0.03	22.66	0.015	5.07	0.019

Values on the same column for same parameters with (*) are significantly different at ($p \leq 0.05$), while those with (**) are highly significantly different at ($p > 0.05$)

From table 3, it reveals that the months of soil sample collection and parameters differs significantly. This may be explained by the irregular pattern of rainfall during the period. Whereas, prolonged sunshine increases evaporation and, thus, the concentration of the parameters, high rainfall may dilute the concentration of the parameters. [15] noted this type of association and then suggested that samples should be collected and analysed over a period of time in order to ascertain a specific correlation of soil characteristics in a cultivated area with high agrochemicals use.

Table 4: Types of fertilisers and their active ingredients applied by the farmers

Type	Active ingredient
NPK	Nitrogen, Phosphorus, Potassium
Urea	Nitrogen
Zinc/Sulphate	Zinc, Sulphate

Source: [16]

Table 5: Types of Agrochemicals and their active ingredients applied

Common name	Active ingredient	Major element(s)	Field of action
Paraforce	Paraquat, dichloride	Cl	Herbicide
Target	Paraquat, dichloride	Cl	Herbicide
Glyspring	Glyphosate 41% sl	NO_5, P	Herbicide
Buster	Butachlor	Cl, N	Herbicide
Gobara	Glyphosate, isopropylamine salt	N, P	Herbicide
Orizo plus	2,D-Amine	Cl	Herbicide
Cypeforce	Cypermethrin 10% EC	N, Cl	Insecticide
Sting	Lambdacyhalothrin/dimethoate 315 EC	NO_3, Cl, F	Insecticide
Kombat	Lambdacyhalothrin/dimethoate 315 EC	NO_3, Cl, F	Rodenticide
Larafora	Lambdacyhalothrin/dimethoate 315 EC	NO_3, Cl, F	Rodenticide
Magic force	Lambdacyhalothrin/dimethoate 315 EC	NO_3, Cl, F	Insecticide
Perfect killer	Chlorpyriphos 20% EC	NO_3, P, S, Cl	Insecticide
Sniper	DDVP	Cl, P	Insecticide
Gramoxone	Paraquat	Cl	Herbicide
Roundoff	Glyphosate, isopropylamine	NO_5, P	Herbicide
Regent	Fipronil	N, S, F, Cl	Insecticide

Source: [16]

Paraquat, glyphosate, and cypermethrin are the common pesticides used on the site, based on the list of fertilizers and pesticides used by the irrigation community that was prepared from the interviews with the local farmers (see Tables 4 and 5 above). These residues are known to accumulate in soil and to be hazardous to aquatic life.

Total of 127 questionnaires were distributed to farmers only 113 were recovered from the respondents and analysed, which represent about 88.97 per cent. The analyses of other findings are as presented below:

3.4 Educational Background of farmers

From figure 2: it was noted that majority of the farmers have no much western education, his/her capability to assimilate professional idea is low and their ability to identify exact application dose is of great concern. Therefore, farmers with less education are likely to be less informed about the residues of agrochemicals and the significance of applying agrochemical in appropriate proportion. Resultantly, with low level of education, there is a greater possibility that farmers may apply agrochemical in large quantity, consequently, give rise to high agrochemical residues concentration on the area applied. In Chanchaga irrigation scheme, due to the inadequate knowledge regarding agrochemicals, 78% of farmers applied left over agrochemicals because they rarely paid attention to the toxic side effects of chemicals on human health.

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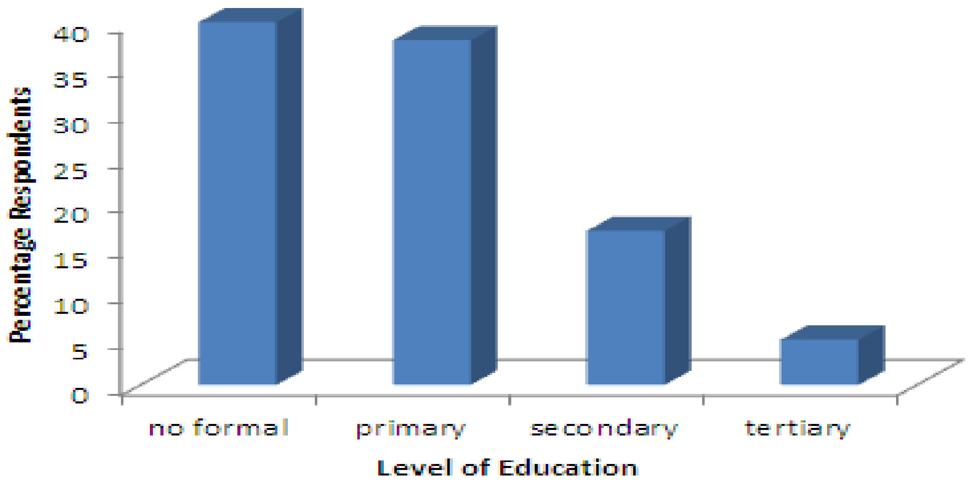

Fig.2: Farmers Educational Background

3.5 Types of agrochemicals applied

Figure 3, shows the types of agrochemicals applied by the farmers. Among these agrochemicals were insecticides, herbicides, rodenticides, as well as fertilizer. Fertilizers and insecticides were the common applied agrochemicals on the farms with 100% application whereas rodenticides and herbicides were applied only by 42% of the farmers. Broadly, farmers indicated the common names of agrochemicals used on the farm as follows (known active ingredients are indicated in italics): String (*cyhalothrin and dimethoate*), Cypeforce (*cypermethrin*), Perfect killer (*chlorpyriphos*), Compound fertilizer (*nitrogen phosphorus and potassium*), Urea (*nitrogen*), Zinc-sulphate (*zinc and sulphate*),paraforce (*paraquat*), Glyspring (*glyphosate*), Buster (*butachlor*), Kombat (*cyhalothrin and dimethoate*) reported on table 4 and 5.

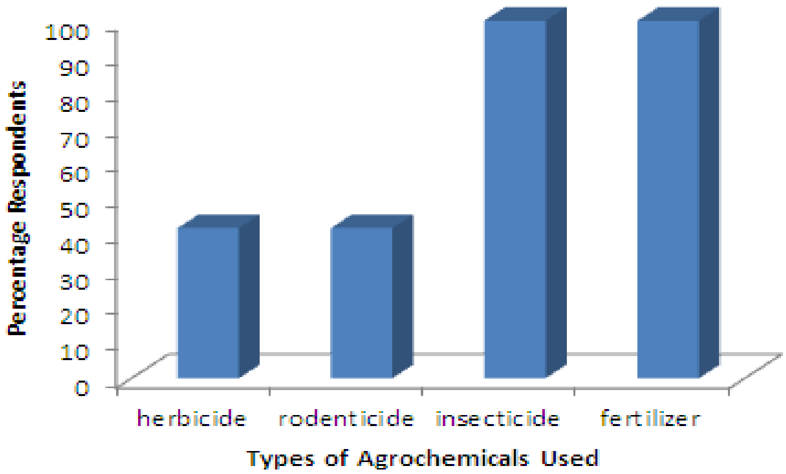

Fig.3: Types of Agrochemicals applied

3.6 Length of agrochemical application

Figure 4, shows the duration of farmland use in years. It was detected that farmers have been using these substances since the farmland had been put into use. Forty-three per cent has been cultivating and using these substances for more than 20 years, 42% over 15 years, 15% for more than 10 years and 0% for over 5 years. These quanta of substances used on the agricultural land over these durations would have led to the build-up of these substances into the groundwater and soil.

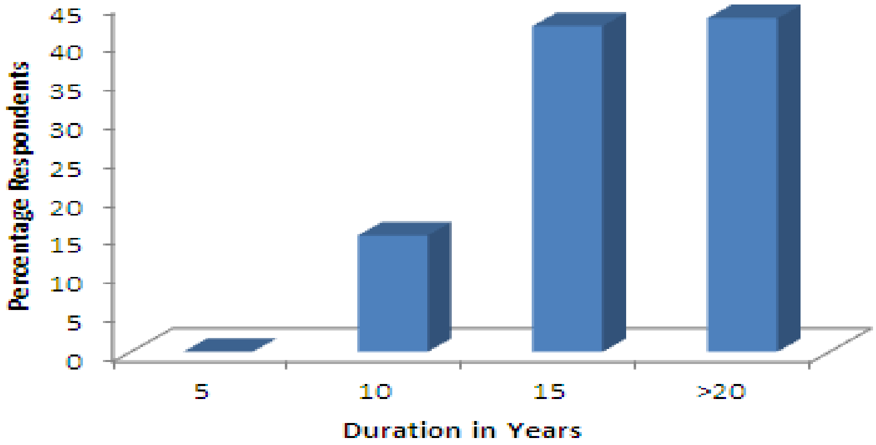

Fig.4: Length in years of agrochemical application

3.7 Amount of agrochemicals used in litres/hectare

Figure 5, shows that the amount of agrochemicals used per hectare have exceeds the standard dosage reported by [23] that is, 3 to 4 litres of liquid substance was recommended, however, 42% of the farmers used more than the approved dosage per hectare, 28% used 4 litres, 30% used 3 litres whereas zero per cent used 2 litres per hectare. These could be the reason for high concentration of the substances and contamination of the soil and groundwater of the cultivated irrigation site.

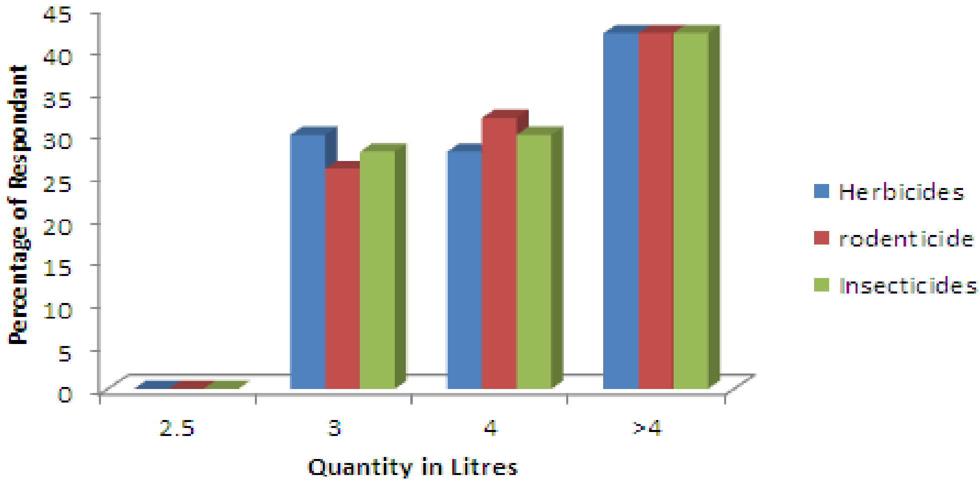

Fig.5: Amount of agrochemicals used in litres/hectare

3.8 Amount of fertilizer used per hectare

From figure 6, it was detected that 2% of the farmers used >100kg of fertilizer per hectare in their cultivated land, 9% used 200kg per hectare, 55% of the farmers used 300kg per hectare, 0% used 400kg per hectare whereas 34% used >500kg per hectare. The result reveals that high per cent of farmers used 300kg per hectare that is less than the endorsed amount per hectare reported by [19].

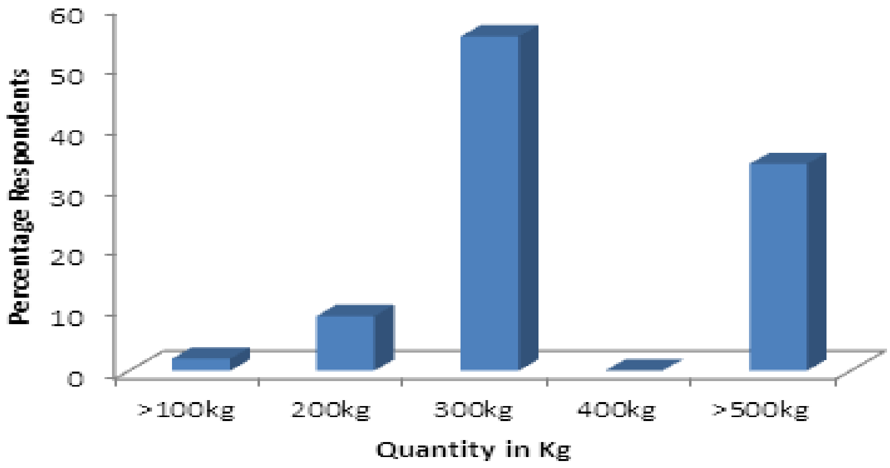

Fig.6: Amount of fertilizer used per hectare

4.0 Conclusion

The concentrations of NO_3, PO_4, Mn, Zn, and Cr were observed to be greater than the Acceptable Contaminant Level (ACL) in both soil and groundwater. It was detected that the cultivated areas had more concentration beyond the control which recorded quantities below the ACL. This has potentially lethal effects on human health, leading to neurological disorders and cancer. To lessen the excessive build-up of residual heavy metals in the soil and groundwater, farmers were advised to closely adhere to the appropriate application rate of agrochemicals per hectare. Additionally, a campaign to raise farmers' awareness of the risks connected with the overuse of agrochemicals on their farms should be planned and delivered. Lastly, research on the crops under the irrigation scheme should be conducted to determine the degree of heavy metal uptake.

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