Impact of Long-term Application of Agrochemicals on the Agro-Ecology of the Lower Anambra River Basin Southeast Nigeria.

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Abstract
Information regarding the effect of application of Agro-chemicals on the soil environment of the lower Anambra River Basin is entirely lacking. A study was therefore conducted in the lower Anambra River Basin to assess the impact of long term use of Agrochemicals on the farm environment. The parameters studied were heavy metal levels [ercury (Hg), Copper (Cu), Arsenic (As), Lead (Pb), Chromium (Cr), Fe (Iron) Cadmium (Cd), Zinc (Zn), Manganese (Mn), and Nickel (Ni)] in the soil and run-off water, and soil and water microbial load. Soil and water samples were collected from the different locations of the river basin and analyzed for their content of these heavy metals. Also the microbial loads of the soil and runoff water samples were determined using the standard plate count techniques. The Results of the analysis indicated that the heavy metals in the soils and runoff water were all above the permissive levels for agricultural and domestic purposes respectively, whereas the microbiological analysis indicated a reduction in the microbial load of the soil samples compared to standards.
Key Words: Agrochemicals application; Heavy Metals; microbial load; Soil; Runoff Water; River Basin.
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1. Introduction

Many concerned with increasing agricultural productivity and food security are focused on fertilizer and other Agrochemicals as a remedy for declining soil quality and stagnant yields. There is currently world-wide concern regarding the impact of these modern farming practices on soil and water quality. Others fear that increased use will have undesirable environmental impacts (soil acidification, water pollution) that could outweigh the benefits (Pretty, 1995). Agricultural runoff often contains developed levels of heavy metals from fertilizers and other agricultural chemicals applied to the fields. These chemicals are carried with rainfall runoff into rivers and streams, reservoirs, polluting water bodies and modifying aquatic habitats. Eutrophic conditions and anoxic conditions result and accumulation of heavy metals in sediments, plants and animal tissue are known to occur. There could also be potential damage to soil microorganisms from high concentrations of Agrochemicals.

Effects of the Agrochemicals can be either direct (immediate or short-term impacts) due to harm to the organisms that come in contact with the chemical, or indirect due to changes caused by the chemical to the environment, or food source of organisms. In some cases there may be a short term but no long term effect (Angus et al 1999).The direct effects of Agrochemicals can be short; obvious in the first season after application of the fertilizer or long term; if repeated additions have taken place. Indirect effects are usually long-term; take more than one season to develop, and are due to changes in pH or changes in productivity, residue inputs and soil organic matter levels (Bune-mann and McNeill 2004). These effects become important in agriculture when nutrient availability to plants and hence crop productivity are changed due to the effect.

The lower Anambra River Basin where this study took place covers very vast areas of wet- land within the larger Anambra river basin. Large scale rice production in the area was introduced in the 1980's by the Nigerian government during the Green Revolution era. The successful agricultural development was dependent on the large-scale use of Agrochemicals. However, in recent times productivity levels have remained stagnant despite the introduction of new crop varieties and germplasms and increase in quantity of agrochemicals and fertilizer application. This situation has been attributed largely to declining soil fertility (Ogbodo *et al*, 2012)

Therefore, there is the need to verify the conditions of the environment since it has been subjected to long term application of Agrochemicals. This is important upon the reality that the use of Agrochemicals for crop production is now either limited or prohibited in most advanced countries. It appears therefore that Agrochemicals par se have detrimental effect on soil and water quality. But information regarding the impact of the application of agrochemicals and fertilizers on the soils of the lower Anambra river basin over these years is entirely lacking, hence this study.

2.Materials and methods

Location:

The study location is shown in figure 1. The study covered the entire area of land occupied by the lower Anambra River Basin Development Authority, located within latitudes 5^{o} 43^{1} N and 6^{o} 20^{1}N, and Longitude 6^{o} 36^{1} E and 7^{o} 05^{1}E of the derived savanna ecological zone of Nigeria.The area is spread across the four zones of Omor, Umumbo, Umerum and Anaku farming communities.

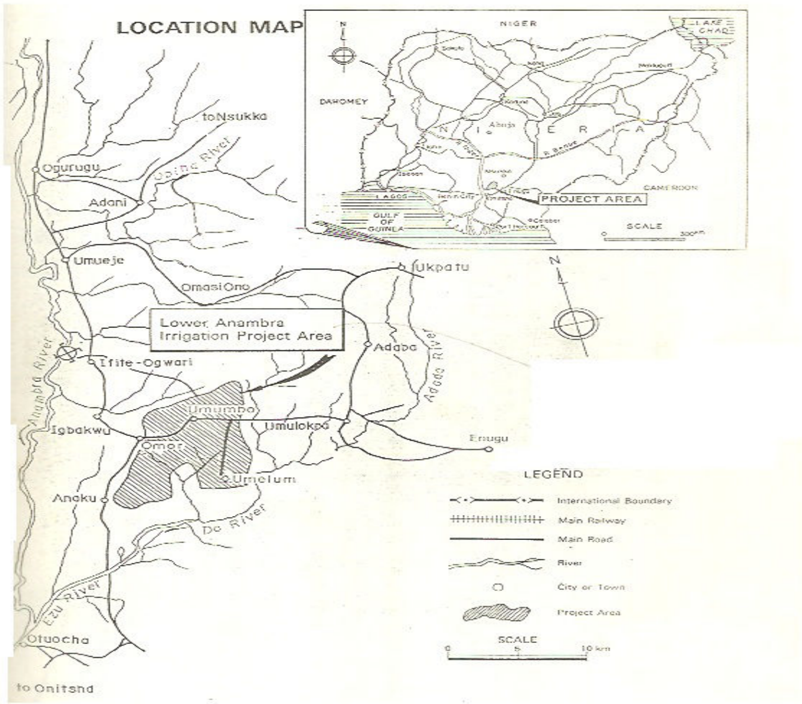

Figure 1: Location Map showing (a) Map of Nigeria indicating study area and (b) Enlarged Anambra River Basin indicating study area.

Field study

The field study started in June; the laboratory studies in July, while data analysis took place in October 2012. The work involved reconnaissance survey of the entire area, and the determination of sampling areas.

Soil-samples for heavy metal determination were randomly collected from 20 sites at the depth of 0-40 cm in each zone with soil auger, bulked together, and a sub-sample taken for analysis. These samples were analyzed separately for heavy metal count. For microbial determination, Soil samples of the different zones were collected using sterile trowels and transferred to sterile sampling bottles and labelled. About 200 grams of soil sample was collected for each sampling zone. It was then transported in an ice pack to the laboratory for analysis. Runoff water samples were collected with the aid of sterile 250ml beakers and transferred into new and clean 1 litre plastic containers with cover previously rinsed with the runoff water of the particular zone. About 400ml of the runoff water sample was collected for each sampling zone and taken to the laboratory and analyzed immediately.

Sample analysis.
The soil and water samples were analysed for heavy metal [Mercury (Hg), Copper (Cu), Arsenic (As), Lead (Pb), Chromium (Cr), Fe (Iron) Cadmium (Cd), Zinc (Zn), Manganese (Mn), and Nickel (Ni)] content, and bacteria and fungi load respectively. For the microbiological determination, standard plate count was carried out on the soil and runoff water sample according to the method as described by Harold (1998). Plate count agar was used for total bacterial count while potato dextrose agar was used for fungi count. Duplicate plating was done for all the dilutions. Plate count agar plates were incubated at 35^{o}C for 48 hours while potato dextrose agar plates were incubated at 25^{o}C for 96 hours. For the heavy metals, Total Iron(Fe), copper(Cu), lead(pb), zinc(Zn) cadmium(cd) Mercury (Hg), Arsenic(As), Chromium (Cr), Manganese (Mn), and Nickel (Ni)) content, were measured by Sp 1900 pye Unican Recording flame atomic absorption spectrophotometer at their respective wavelengths after wet digestion with a mixture of HCL and $HN0_3$.
Data analysis

The results were statistically analyzed, using coefficient of variation, and compared respectively with the World Health Organization standards.

3. Results and discussion
The effects of longterm application of Arochemicals on the soil and run-off water are presented in tables 1 and 2. Very high levels of the measured metals were detected in both the soil and water samples. The contents of these elements in the area is very alarming when compared to the world health organisation standard permissible levels, and calls for concern by the appropriate agencies, to embark on control and remediation activities.

The most frequently and currently used Agrochemicals in the area are (herbicides Atrazine, Simazine, Alachlor, Metolachlor and Trifluralin, insecticides Diazinon, Parathion methyl, and organochlorine pesticides lindane, endosulfan, aldrin, and Fertilizers Urea, Amonium Sulphate and N P K compound fertilizers. Variability in the levels of heavy metal elements among the various locations of the river basin was observed. The variability is ascribed primarily to differences in the nature of the soils and the proportion of exposure of the various locations to these agro-chemicals. Some other researchers have pointed out that the transport, persistence or degradation of these chemicals in soil is known to be dependent on their chemical properties as well as physical, chemical and biological properties of the soil (Hildebrandt et al., 2009; Jiang et al., 2009). All these factors affect sorption/ desorption, volatilisation, degradation, uptake by plants, run-off, and leaching of these chemicals. Shegunova et al., 2007; Toan *et al*., 2007; Ferencz and Balog 2010 have also shown that the Persistence of such chemicals in soil can vary from few hours to many years particularly in case of Organochlorines. These would quite adversely affect the fertility of the soils and their use for agricultural purposes. All the detected chemicals are deleterious to plants and animal life, and one should not lose sight of the fact that apart from the agricultural use to which the soil is put that the run-off water is also used for both domestic and aquaculture purposes by the inhabitants.

It was observed that Pesticides and herbicides entered the soil through spray drift during foliage treatment; wash-off from treated foliage, or from treated seeds in soil. Some pesticides such as soil fumigants and nematocides are applied directly into soil to control pests and plant diseases presented in soil. The fertilizers are applied directly to the soil either by side placement, broadcasting or incorporation during tillage.

The Agrochemicals get into water via drift during spraying, by runoff from treated area, leaching through the soil. Since many of these chemicals are not easily degradable, they persist in soil, leach to groundwater and surface water and contaminate wide environment. The primary negative impact of contituous input fertilizer applications (used without complementary liming and/or organic amendments) in the area is loss of productivity due to acidification (Ogbodo *et al 2012).* Acidification or lowering of soil pH has negative impacts on most crop growth and occurs as a direct result of application of specific types of fertilizers. Sanchez, 1976 had noted that the most serious negative impact associated with acidification is aluminium (Al) toxicity. This phenomenon causes reduced root growth and function hence hampering nutrient uptake and crop productivity. The other side effects of elevated levels of Aluminium in soil solution is the capacity to form complexes with P leading to the deficiency of the nutrient in soil, and the possibility of toxicity to micro-organisms.

Results of the aerobic bacterial count of the soil samples showed that sampling zone 3 had the least count of 4.7 x 10^{6} cfu/g followed by sampling zone 4 with 5.0 x 10^{6} cfu/g and sampling zone 1 with 1.0 x 10^{7} cfu/g. Sampling zone 2 had the highest value of 3.0 x 10^{7} cfu/g (Table 3).

The aerobic bacteria count of the runoff water samples showed that sampling zone 1 had the least count of 3.0 x 10^{5} cfg/ml followed by sampling zone 3 with 2.8 x 10^{5} cfg/ml and sampling zone 4 with 4.8 x 10^{6} cfg/ml. sampling zone 2 had the highest bacteria count of 6.3 x 10^{6} cfg/ml (Table 5).

Igba *et al* (2005) found out that the range of bacterial count of untreated soil with heavy metals ranges between 7.2 x 10^7 cfg/g to 1.1 x 10^8 cfg/g of soil, while the bacterial count of treated soil with heavy metals were below 7.2 x 10^7 cfg/g. It showed that the presence of the agrochemicals in the soil and runoff water samples affected the bacterial load of the soil in the lower Anambra River Basin. The lowest bacterial count of 4.7 x 10^6 cfg/ml by sampling zone 3 may not be unconnected to the highest presence (concentration) of Nickel and cadmium in the soil of sampling zone 3 compared to the soil of other sampled zones.

Al Gaidi (2010) showed that cadmium has much more significant effect in decreasing bacterial population than lead. He also found out that higher concentration of these metals cause decreases in total bacterial populations.

Hossain *et al* (2005) established that the relative toxicity of different metals to microbial groups/populations decreased in the order cd > cu> Zn>Pb.

Igba *et al* (2005) also found out that aerobic heterotrophic populations were more sensitive to metal groups like Nichel (Ni) and cadmium (cd) followed by Cu, Hg, Mn, Cr and Zinc. The concentrations and levels of these agrochemicals in the soil and runoff water of the lower Anambra River Basin are high enough to affect the microbial number (table 1 and table 2) and have caused a decrease in the microbial number of the soil and runoff water of the lower Anambra River Basin (Table 3-6). Besides these, Gigliotti and Allievi 2001 had found out that other bacterial species, such as nitrification bacteria, are very sensitive to pesticides influence. Inhibition of nitrification has also been shown to be toxic to nitrification and denitrification bacterial processes (Kinney et al., 2005; Lang and Cai 2009).

The fungi count of the soil samples indicated that sampling zone 4 had the least fungi count of 1.3 x 10^5 cfg/gl followed by sampling zone 3 with 4.1 x 10^5 cfg/ml and sampling zone 2 with 9.0 x 10^5 cfg/ml. Sampling zone 1 had the highest fungi count of 9.0 x 10^5 cfg/ml.

The fungi count of runoff water samples revealed that sampling zone 2 had the least fungi count of 2.1 x 10^5 cfg/ml followed by sampling zone 3 with 3.0 x 10^5 cfg/ml and sampling zone 1 with 4.0 x 10^5 cfg/ml. Sampling zone 4 had the highest fungi count of 4.1 x 10^5 cfg/ml. Fungicides had earlier been found to be toxic to soil fungi and actinomycetes and caused changes in microbial community structure (Liebich et al., 2003; *Pal et al., 2005*). Some pesticides (Benomyl, Dimethoate) can also negatively affect symbiotic mycorrhizal fungi, which facilitate plant nutrient uptake (Menendez et al., 1999[10]; Chiocchio et al., 2000). These are possible conditions that could have led to lower levels of fungal count obtainable in the soils of the lower Anambra river Basin compared to normal situation.

Overall, these soil micro-organisms are essential for maintenance of soil structure, transformation and mineralization of organic matter, making nutrients available for plants. Soil microorganisms are also known to have the capability to metabolise and degrade a lot of pollutants and pesticides and therefore are environmentally friendly. This study has therefore shown that soil microbial population are characterized by flexibility and adaptability to changed environmental condition; the application of agrochemicals (especially long-term) can cause significant variations in their population.

Countermeasures

The practice of application of organic manure and returning of crop residues to the soil could be a sure low cost measure to mop-up the excess heavy metals in the soils. The use of Soil organic manure remains the most important factor influencing sorption and leaching of chemicals in soil. Addition of organic matter to the soils can enhance sorption and reduce risk to soil and water pollution. It has been demonstrated that amount and composition of organic matter had large impact on agrochemicals sorption. For example soil rich on humus content are more chemically reactive with pesticides than nonhumified soil (Farenhorst 2006).

Conclusion

The different Agrochemicals (pesticides, Fertilizers, fungicides etc) used in Agriculture are either degraded by the soil organisms or are liable to leave toxic residues in soil and water which are hazardous to cause profound reduction in the normal microbial activity in the soil. The concentrations and levels of these agrochemicals residues in the soil and runoff water of the lower Anambra River Basin were high enough to alter the chemical composition of the soils and adversely affect their use for agricultural purposes. The elevated levels of heavy metals detected in the soils caused a decrease in the microbial number of the soil and runoff water of the lower Anambra River Basin. This definitely would lower the fertility status of the soil. It was concluded that adoption of increased use of organic manure to raise the level of soil organic matter could be a possible means of countering the menace of elevated levels of heavy metals in the soil and runoff water at the lower Anambra river Basin.

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Table 1: Levels of Heavy Metals in Soil

Sampling zone	Hg (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Cd (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Ni (mg/kg)
1	523.75	1125	1250	625	450	125	87.5	400	62.5	812.5
2	280	2750	1500	1000	75	125	62.5	525	237.5	925
3	88.75	1750	2500	125	1512.5	2125	50	937.5	262.5	2562.5
4	111.25	125	2750	1625	1275	125	37.5	900	112.5	1275
CV %	69	66	31	64	70	98	93	62	97	49
Standard	0.01	2.00	0.01	366	0.01	0.05	100	85	0.003	75

Table 2: Concentration of Heavy Metals in run-off water.

Sampling zone	Hg (ml/L)	Cu (ml/L)	Pb (ml/L)	As (ml/L)	Cr (ml/L)	Fe (ml/L)	Cd (ml/L)	Zn (ml/L)	Mn (mg/kg)	Ni (mg/kg)
1	0.02	3.40	6.40	0.70	0.47	1.40	0.10	0.22	0.11	1.12
2	0.20	0.7	6.1	0.10	0.80	1.20	0.12	0.12	0.59	0.19
3	0.04	0.1	6.6	0.70	0.67	1.10	0.17	0.44	0.13	0.62
4	0.08	3.1	7.5	0.20	0.77	0.97	0.14	0.32	0.20	1.16
CV %	98	79	73	65	19	13	19	35	74	29
Standard	0.001	0.05	0.01	0.05	0.05	90	0.01	5.00	0.05	0.05

Table 3: Aerobic bacteria count of the soil samples.

Sampling zone	**Bacteria count (cfu/g)**
1	1.0×10^7
2	3.0×10^7
3	4.7×10^6
4	5×10^6

Key: Cfu/g = colony forming units per gram.

Table 4: fungi count of the soil samples.

Sampling zone	**Fungi count (cfu/g)**
1	9.0×10^5
2	1.2×10^6
3	4.1×10^5
4	1.3×10^5

Key: Cfu/g = colony forming units per gram.

Table 5: Aerobic bacteria count of the run- off water samples.

Sampling zone	**Bacteria count (cfu/g)**
1	3.0×10^5
2	6.3×10^6
3	2.8×10^6
4	4.8×10^6

Key: Cfu/g = colony forming units per gram.

Table 6: Fungi count of the run- off water samples.

Sampling zone	**Fungi count (cfu/g)**
1	4.0×10^5
2	2.1×10^6
3	3.0×10^6
4	4.1×10^6

Key: Cfu/g = colony forming units per gram.