International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume: 09, Issue: 03 "May-June 2023"

SPATIAL VARIABILITY OF SOIL PHYSICOCHEMICAL PROPERTIES AND HEAVY METAL CONCENTRATIONS IN OWERRI MUNICIPAL DUMPSITES

[1]Osisi, A.F.; [2]Azu, D.E.O.; [3]Onwudike, S.U.; [4]Agim, L.C.;
[5]Nkwopara, U.; [6]Okoli, N.H. and [7]Egeonu, P.

[1,3,4,5,6,7]Department of Soil Science and Technology, Federal University of Technology, Owerri, Imo State.

[2]Department of Horticulture and Landscape Technology, Akanu Ibiam Federal Polytechnic, Unwana.

DOI: https://doi.org/10.51193/IJAER.2023.9301

Received: 30 Mar. 2023 / Accepted: 07 Apr. 2023 / Published: 13 May 2023

ABSTRACT

Heavy metals pose a serious threat to our environment due to the fact that majority of annual vegetable crops consumed by man and animal are produced from the polluted sites without knowing the level of it taken up by plant which revolves into food chain. This study evaluated the variability of soil physicochemical properties and heavy metals concentration in Owerri municipal dumpsites in Imo State. Samples were collected in three replicates 0, 5 and 10m away from refuge dumpsites at 0 - 30cm depth using soil auger in Ihiagwa, Avu, Abazu and Obinze. Samples were analyzed for soil properties and heavy metals-concentrations using standard methods. The concentrations of the studied heavy metals (Pb and Cr) were compared with the permissible limits of other countries. pH results from the analyzed sampled soils from the four locations were high (6.89, 6.80, 6.59 and 6.40) in Ihiagwa, Abazu, Obinze and Avu respectively while organic carbon followed the trend Ihiagwa>Avu>Abazu>Obinze. Organic carbon and total Nitrogen concentrations followed the same trend in Ihiagwa, Avu, Abazu and Obinze. Pb concentrations in the studied sites were above the standard limit recommended (0.05mg/kg) by Federal Environmental Protection Agency but within limit (100mg/kg) stipulated by European Commission. Nevertheless, Pb concentration was within the tolerance limit set by European Union but should be cautiously minimized to prevent health hazard on man and the environment. The use of refuge dumpsite for cultivation of arable crops should be avoided and lands on cultivation should be given a distance from the refuse sites.

Keywords: Contamination, Crop Plants, Environment, Heavy Metal

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INTRODUCTION

Solid waste within and around are made up of daily items from discarded materials used by the public's, they include the industrial and agriculturally produced wastes, garbage, waste wood, waste paper, plastic, rubber, steel, cement, waste oil, waste acid, liquid and gaseous waste (Aljaradinand Person 2012). According to Obaliagbon and Olowojoba (2006) reported that leachates from refuse dump sites in Nigeria pose a serious heavy metal pollution both in the soil and aquatic environment.

Municipal solid waste has some adverse effect on the environment and human health with a wide spread of offensive odors, insects, rats, smoke and gases resulting from the decomposition of waste, leachate seeping into surface and ground water system, which causes soil contamination because of the presence of heavy metals released from the waste materials (Agamuthu and Fauziah 2007; Aljaradin and Person 2012). Almost all human activities generate waste to the environment and public health because of the way it is being handled, stored, collected and disposed (Zhu *et al*., 2008). Pollution can occur when the earth is not able to recycle the waste as a result of its volume and it poses a big threat to lives. It occurs at different levels and affects all lives ranging from plants, animals to man (Skye, 2006). Some harmful substances are being released during decay of these waste materials which can affect the soil nutrient content, increase the concentration of heavy metals in the soil, altering the natural balance of nutrients available for plant growth and development and some agricultural productions. In other words, some waste materials (refuse) increases soil organic matter content and nutrients, influences soil pH, increase or decrease metal mobility in soils and profound effect on microbial and enzymatic activities (Hargreaves *et al*., 2008).

Heavy metals can accumulate in soils to toxic levels as a result of long term application of untreated waste water and fertilizers. Heavy metals can accumulate in soils gradually through the use of waste water for irrigation, and heavy metals will leach into ground water or soil solution will be available for plant uptake (Papafilippaki *et al*., 2008). Although acute poisoning from heavy metal are not common through ingestion or dermal contact , chronic exposure to even small doses can be disastrous (Sherameti and Varma, 2010). Chronic exposure to heavy metals leads to accumulation in the food chain which leads to an increased stock in the biota, therefore increasing human dose accumulated (Voet *et al*., 2008). Harmful effect from long term heavy metal exposure causes chronic problems in human beings like serious hematological and brain damage, anemia and kidney malfunctioning (Sonayei *et al.*, 2009). Lead (Pb) and Cadium (Cd) are among the heavy metals and no matter the quantity taken by plants, they are lethal. Lead has a negative influence on the somatic development, decreases the visual acuity and auditive thresholds (Simeonov *et al*., 2010).

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Acute exposure to lead causes brain damage, neurogical symptoms, brain damage and could lead to death (Simeonov *et al.*, 2010). Cho-Ruk *et al.*, 2006 also reported that the existence of Pb contaminates its environment in an insoluble form with toxic metals which cause serious human health problem like brain damage and retardation.

Due to prolific population and increasing human activities in urban areas, leading to accumulation of waste, which are dumped on open sites including water ways. There has not been enough research on soils receiving these wastes with respect to how it affects quality of agricultural produces, yet they are used for vegetable, stable and tree crop production. It becomes necessary to investigate soils from these locations in terms of its concentrations in the soil and quantity taken up by plants for growth as they affect soil properties and human health. This leads to the investigation of the soils with dump sites to ascertain the level of contamination with heavy metals within Imo State. Thus, the main objective of the study is to determine the spatial variability of the physical and chemical properties of the soil and heavy metals in soils close to dump sites, evaluate some heavy metals in the soils and correlate the physicochemical properties and heavy metals in the soils near dump sites.

MATERIALS AND METHODS

Study Area

The study was carried out in four communities in Imo State and these areas have the same parent material. The communities were Ihiagwa, Obinze, Avu and Abazu. Ihiagwa lies between Latitude 5°23' and 5° 47''N and Longitude 7°1' and 7'47''E, Obinze is located between Latitude 5°25 and 5° 2''N Longitude 6°57' and 6°24"E, Avu is also located between Latitude 5°27' and 5°1''N and Longitude 6°54' and 6°47''E while Abazu is between Latitude 5°34' and 5°26''N and Longitude 7°5' and 7°29''E. Imo state is located in a tropical forest zone with annual rainfall ranges from 2200mm – 3000mm with mean daily temperature range of 26^o -28^o and relative humidity of 78 – 85%.

Sample collection and Preparation

Triplicate samples were collected from each dumpsite location at the site, 5m and 10m away from the dump at 0-30cm depth. The samples were air dried, sieved to pass through 2mm diameter and a total of twelve (12) samples were collected and sent for routine laboratory analyses.

Laboratory Analysis

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Soil samples collected from different locations were subjected to laboratory analysis using standard methods. Particle size distribution was by hydrometer method according to Gee and Or, 2002 using calgon (sodium hexametaphosphate) as dispersant. Organic carbon was determined by wet oxidation method (Nelson and Sommers, 1982) and the values for organic matter where obtained by multiplying the organic carbon values by 1.72 (Van Bemmelen Factor). Available phosphorus was determined using Bray II solution by extraction method and determined calorimetrically on spectrophotometer (Olsens and Sommers 1982). Total nitrogen was determined by Kjeldahl digestion method using concentrated H_2SO_4 and Sodium Copper sulphate catalyst mixture was used (Bremen, 1996). Soil pH in water was determined using pH meter in sol / liquid suspension of 1:2.5 according to Hender Shot *et al.*, (1993). Exchangeable cations was determined using 1N ammonium acetate (NH4OAC) for the extraction and exchangeable K and Na using flame photometer according to Thomas, (1982). Effective Cation Exchange Capacity (ECEC) was obtained by the sum of all exchangeable cations and exchangeable acidity (Ca^{2+} + Na^{+}+ K^{+} + Mg^{2+}) as described by Udo, *et al.*, (2009). Base saturation was calculated by dividing total exchangeable base by ECEC and multiplying the quotient by 100.

Determination of Heavy Metal

10 g of soil samples were weighed into a 100 mL conical flask washed with deionized water for determination of heavy metal. 6 mL HNO_3 / $HClO_4$acid was added to each flask in the ratio 2:1 and left overnight. Each of the samples was digested at 150ºC for about 90 minutes and the temperature was increased to 230ºC for 30 minutes. HCl solution was added in ratio 1:1 to the digested sample and re-digested again for another 30 minutes. The sample digested was washed into 100 mL volumetric flask. The mixture was cooled down to room temperature to avoid formation of insoluble perchloric compounds and was made up to mark with deionized water. Heavy metals concentration in the digest was read with atomic absorption spectrometer and amount of each heavy metals was extrapolated from the prepared calibration graph.

Statistical Analysis

All data generated were subjected to analyses of variance (ANOVA). Relationship between heavy metal and soil properties were determined with correlation analysis.

RESULTS AND DISCUSSION

The Physical and Chemical Properties of the Studies Sites

Result showed that soils in the four locations were mainly sandy soil with high sand fractions in the four dump sites (Table 1) the textures of the soils were predominantly loamy sand. According

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to Uba *et al.*,(2008) soils with higher percentage of sand fraction at the top also have advantage of higher water seepage. The parent material dominant in the studied location which is coastal plain sand (Benin formation) could contribute to high sand fraction since the texture is influenced by the parent material Onwudike *et al.*, (2016) and Oguike and Mbagwu, (2009). However, the possibility of leaching of cations and anions to the deeper soil layer will increase pollution of underground water due to excessive drainage of sandy soil resulting from the nature of the soil. In contrary Brady and Weil (1999) reported that soils of humid tropics were unsuitable for waste disposal as they encourage surface flooding and pollution because of the texture of their soils. The high range of sand content around the municipal waste dump site as discovered from the result could permit the use of these wastes as land fill sites. The report of Ogbonna *et al.*, (2006) said that dump sites with low sand fractions are not suitable for waste land filling since they are highly permissible and could allow more leachate from the waste dump sites to invade the deposited refuse and down to the groundwater resources.

The bulk density was low which could be attributed to low tillage activities around the dumpsite except in Obinze which might be as a result of tillage near the dump site. The bulk densities of the studied sites ranged from 0.82g/cm^3 to 0.92 g/cm^3 and 1.06g/cm3 in Obinze. The bulk density value ranges from Obinze>Abazu>Avu>Ihiagwa respectively. However, this result agrees with the findings of Onwudike *et al.*, 2016 who observed that in areas where there is more activity the bulk density were high and lower where activities were less. Tillage operation affects the quantity of organic matter in the soil as continuous assimilation reduces its quantity thereby reduces soil bulk density as well.

The chemical properties of the studied sites are shown in Table 2. Soil total nitrogen studied ranged from Ihiagwa>Avu>Abazu>Obinze (27 cmol/kg, 24.67 cmol/kg, 23.33 cmol/kg and 20.33 cmol/kg) while organic matter followed the similar trend as total nitrogen (14.95 cmol/kg, 13.88 cmol/kg, 12.97 cmol/kg and 11.43 cmol/kg). Results showed that the soils were slightly acidic in all the dump sites. The pH of the studied soil ranged between 6.40 – 6.89 and differ from result findings of Adjia *et al.*, (2008) which reported higher pH values in Ihiagwa. According to Lee and Saunders (2003) this could be attributed to sorption capacity of metals in the soil. The high pH value recorded in all the dump sites were as a result of degradation of waste materials from the site which helps to reduce acidic content of the soil and render the alkaline condition suitable for microbial activities in the soil. The nature of parent material dominated with loamy sand could result to increase in water infiltration, run off and leaching of basic cations which result to accumulation of H^+ and Al^{3+} on the exchange complex. Soil pH affects accumulation factor of soil and it was observed that the accumulation factors for metals vary inversely with soil pH and it affects concentration of the solute and absorption in soil. The results obtained from the dump sites are contrary to report of Oluyemi *et al.*, (2005) which

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reported that at low pH, metals are more bio available to plants, and hence could constitute a problem of toxicity compared to alkaline soils.

High values of nitrogen were found in the upper horizon than the lower horizons may be due to decomposition of waste materials dumped at the soil surface (Yang *et al.,* 2004). This study recorded higher total nitrogen value in the dump sites and Ihiagwa (14.95cmol/kg) recorded highest which could also be attributed to higher soil organic matter and increased soil pH. Akanni *et al.*, 2012 recorded a good positive relationship between soil organic matter and soil pH at dump sites. Organic matter content of all the dump sites studied were slightly high and could be attributed to high rate of decomposition due to high temperature and mineralization of organic materials at the dump sites. The report does not agree with the report of FAO 2004 which states that organic carbon content of all soils studied were low. The soil organic carbon ranged from 11.88 – 15.53cmol/kg at the studied sites with the highest value in Ihiagwa which may be attributed to high organic materials also recorded from the dump site as well as high soil pH value recorded which encourages microbial activity in the soil.

The result of available phosphorus and total exchangeable bases obtained ranged from 2.93 – 5.72 mg/kg and 0.01 – 5.80 cmol/kg in dumpsites respectively. This report agreed with the report of Onwudike *et al.*, 2017 which recorded that TEB ranged from 3.96 – 4.30 cmol/kg with control value 1.26 cmol/kgal though available phosphorus had lower values. The result may be due to high organic matter and pH of the soils studied. There was a positive correlationship with the result even with available phosphorus.

Table 1: Soil Physical and Chemical Properties of the Studied Area

Dump site	Sand	Silt	Clay	BD	pH	OM	TN	Av.P	Ca	Mg	Na	K	Al	H	ECEC
	g/kg	g/kg	g/kg	g/cm^3	(H_2O)	←	Cmol/kg								→
AB	785.33	184.33	30.33	0.92	6.80	23.33	12.97	5.72	4.93	2.50	0.04	0.06	0.00	0.75	8.28
AV	780.67	144.00	75.33	0.84	6.40	24.67	13.88	3.09	5.80	4.00	0.02	0.02	0.00	0.59	10.43
OB	776.00	147.33	76.67	1.06	6.59	20.33	11.43	4.77	3.17	2.50	0.00	0.02	0.37	0.59	6.65
HD	754.67	200.67	44.67	0.82	6.89	27.00	14.95	2.93	3.53	2.50	0.01	0.01	0.11	0.69	6.85
LSD(0.5)	**46.96**	**27.54**	**27.58**	**1.52**	**0.79**	**4.30**	**2.33**	**2.07**	**1.27**	**1.29**	**0.07**	**0.03**	**0.70**	**0.26**	**3.32**

Where AB Abazu dumpsite, AV Avu dumpsite ,OB Obinze dumpsite, HD ihiagwa dumpsite, OM Organic Matter, TN total Nitrogen, AP Available Phosphorus, Ca calcium, Mg Magnesium, Na sodium, K Potassium, Al Aluminium, ECEC exchangeable cation exchange capacity.

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Heavy metal contamination and pollution in the studied dumpsites are represented in Figure 1. The result showed that the highest level of contamination/pollution was recorded in Obinze (200mg/kg) followed by Avu (193mg/kg) dump site while Ihiagwa and Abazu recorded 113 and 102 mg/kg) respectively. The order of pollution in the dumpsites was recorded as follows: OB > Av > IH > AB. The level of lead contamination / pollution in the dumpsites was slightly polluted even with the dumpsites that recorded higher level of lead. Although, according to yahaya *et al.*, (2009) that recorded higher level of Pb to be between the ranges of 35.7 to 635.31mg/kg, Ukpong *et al.*, (2013) ranged from 3.00 to 117.50mg/kg and Adelekan and Alawode (2011) ranged between 45.00 – 624.50mg/kg. The findings of the studied dumpsites recorded moderately higher level of Pb which was discovered to be above recommended limit (0.05mg/kg) of Pb in the soil by Federal Environmental Protection Agency (FEPA) 1991, but within standard limit (100mg/kg) set by European Commission (1986). FEPA (0.03mg/kg) and EU (50mg/kg) were the standard limit set for Cr concentration notwithstanding, Pb level of concentration were within the tolerance limit set by EU but should be cautiously minimized to prevent health hazard on man and the environment. Jalali and Khanlari 2007 reported that the accumulation of Pb in the soils is toxic to plants and animals in the food chain.

The result of chromium concentration in the soils were recorded in the order of increase as IH > OB>AV> AB. The mean levels of Cr in the dumpsite were 28mg/kg in Abazu, 32mg/kg in Avu, 34mg/kg in Obinze and 47mg/kg Ihiagwa refuse dumpsites. The concentration of Cr in the refuge dumpsite was lower when compared with Pb and international permissible limit. The result obtained from this study were similar to report of Amos *et al.*, (2013) that Cr concentration value were slightly greater than the results reported from Yenagoa in Nigeria which recorded lower than the critical permissible level (50mg/kg) for soils recommended for agriculture (EC, 1986). Heavy metal like Cr could be introduced into the soil through automobiles, colored polythene bags, discarded plastic materials, empty paint containers and electronic waste (Jung and Casler, 2006). The concentration of Cr reported from the study were within the range of values reported by Adelekan and Alawode (2011) being 13.15 – 75.55mg/kg. Although, the value from the study were lower than the value (212.00 – 2020.00mg/kg) recorded by Awokunmi *et al.*, 2010 and Oluyemi *et al.*, 2008 (107.50 – 181.25mg/kg).

The results of these studies were compared with international standard limits using European Union, Federal Environmental Protection Agency, United States of America etc. Pb concentration at Obinze, Avu and Ihiagwa dump sites was above EU, and US standard and Cr were below standard.

The concentration of heavy metals (Pb and Cr) passed the contamination stage and therefore will constitute negative effect on plants and soil environment in all the dump sites, according to Lacatusu (2000) findings.

Table 2: Statistical Summary of Heavy Metals Concentration (mg/kg)

SITES	AB0	AB5	AB10	AV0	AV5	AV10	OB0	OB5	OB10	IH0	IH5	IH10
Pb	0.185	0.097	0.024	0.332	0.225	0.022	0.352	0.207	0.041	0.16	0.132	0.05
Cr	0.039	0.037	0.007	0.046	0.026	0.024	0.049	0.039	0.014	0.062	0.049	0.03

Where AB-Abazu, AV-Avu, OB- Obinze and IH- Ihiagwa, 0,5 and 10cm are sampling distances

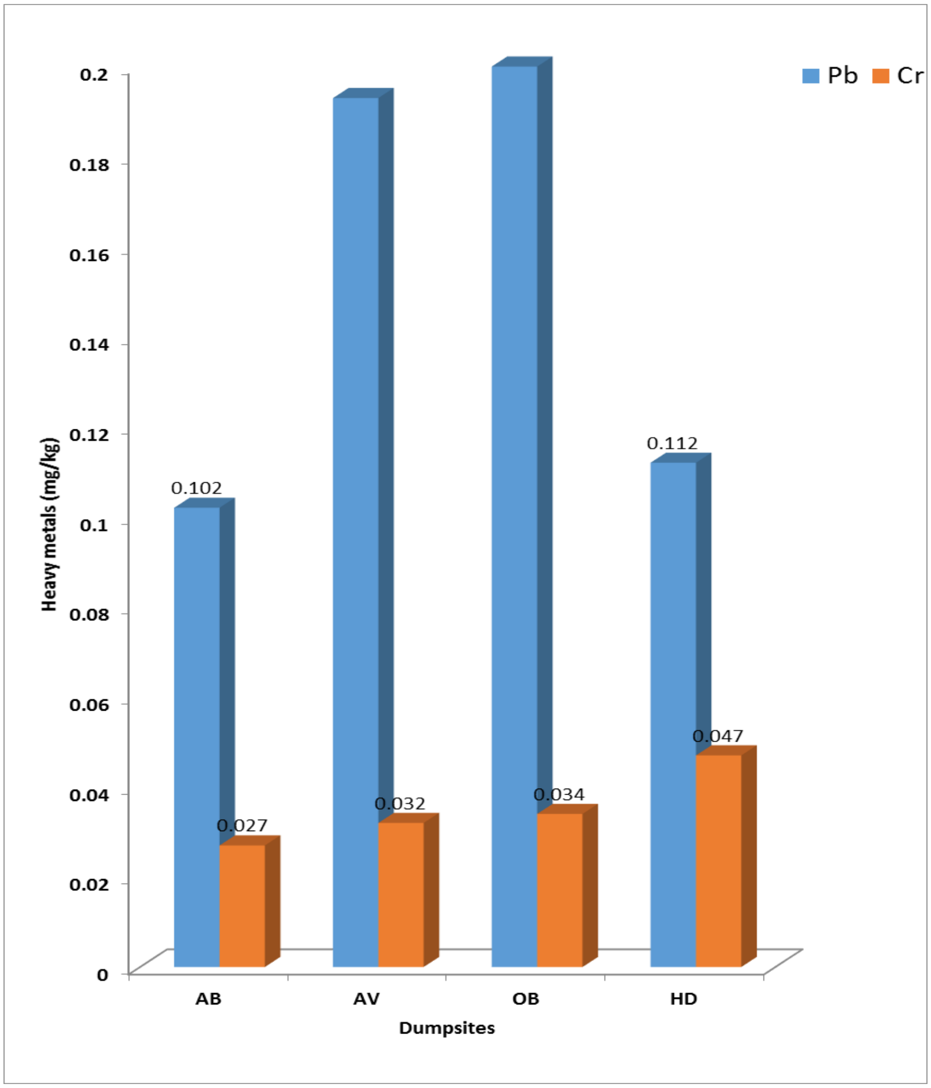

Fig 1: Distribution of heavy metals in the studied locations

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Relationship between Lead, Chronium and Physicochemical Properties

The relationship between Pb and Cr with soil properties are shown in Table 3. The results revealed that there were positive significant correlations between soil H and Pb (r= 0.7087), Cr (r=0.7144). The significant relationship between H and Pb indicated that increase in acid content boost the quantity of Pb released into the soil. On the other hand, the presence of Cr in the soil increases the acidity of the soil and vice versa. The presence of Cr in the soil affects the presence of Mg significantly (p=0.01.and p=0.05) meaning that increase of one affects the other. Similarly, Mg significantly correlated positively with Pb (r=0.8999) and Cr (r=0.6184) indicating that the increase in one affects the other. Bulk density significantly correlated negatively with Cr (r= -0.6978) which means that increase in one does not affect the other. Ca significantly correlated positively with Pb (r= 0.6751) indicating that the presence of it encourage release of Pb to the soil while total nitrogen significant correlated positively with Cr (r=0.7339) at (p=0.01) showed that increase in release of total nitrogen from the dump site increases Cr content in the soil. The result agreed with Akanni *et al.*, (2012) who reported that at high total nitrogen it could result to positive correlation with Cr.

Table 3: Relationship between Heavy Metals and Soil Properties

Soil Property	Pb	Cr
Al	-0.3183	-0.3391
BD	-0.4783	-0.6978*
Ca	0.6751*	0.4621
Clay	0.1610	-0.1524
H	0.7087**	0.7144**
K	0.2907	0.1530
Mg	0.8999**	0.6184*
Na	0.0221	-0.2200
OC	-0.0023	0.3321
AP	0.4843	0.2953
Sand	0.2227	-0.1481
Silt	-0.3166	0.2490
TN	0.4939	0.7339**
pH	0.2101	0.4056

*and ** = sig at 0.05 and 0.01 probability levels respectively

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CONCLUSION

The heavy metal distribution within Imo state (Abazu, Avu, Obinze and Ihiagwa) showed that the level of pollution / contamination in these sites for Pb and Cr were high. It was ascertained that the values analyzed were higher than the recommended level by Federal Environmental Protection Agency and European Union. All the dump sites studies passed the pollution stage. Irrespective of high value of organic matter and pH of the soil recorded at these sites it is still not conducive for agriculture or cite a bore hole based on the level of contamination. As a result of the level of contamination it is important to evaluate our soils regularly because of level of accumulation of these metals in the soil especially area for agricultural production to avoid consuming of plants with phytoxins which is not healthy to humans.

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