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Assessment of Municipal Solid Waste Compost Used In Urban Agriculture and Its' Potential Public Health Impacts In Katsina City, Nigeria.

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ABSTRACT
This research assessed the potential ecotoxicological impacts of municipal solid waste compost (MSWC) as soil fertility improvement material on soil, plants and humans in urban Katsina. MSW Compost samples were collected from different dump sites and mixed with sand and kaolin into 2:2:1 ratio respectively. Maize and beans were planted on the mixture for phytotoxicity assessment as describe by Zucconi et al., 1981. Both the mixture and plant vegetative biomass were tested in the laboratory for non-biodegradable chemicals of Zn, Pb, Mn, Fe, Cd, Cr and pH using Atomic Absorption Spectrophotometer and pH meter methods respectively. In phytotoxicity assessment, Bean show high phytotoxicity while maize considers MSWC as phytonutrients. Paired t-test reports no statistical difference of non-biodegradable substances concentrations in soils and in plants vegetative biomass. Single factor pollution index values range from clean to slightly polluted. Ecological risk index (ERI) values indicate low risk for all the heavy metals. Estimated daily intake of contaminants in beans and maize plants are far below the maximum allowable limits of WHO/FAO while Target hazard quotients (THQ) values are likely to cause non-carcinogenic effects to the ecosystem. This finding is promising particularly to the maize farmers. Both beans and maize farmers should ensure quality standard and regulations such as source separation and matured composting to remove harmful non-biodegradable chemical substances before application.

Keywords: Municipal Solid Waste Compost, Soil, Beans, Maize, Ecological risk.

I. INTRODUCTION

Soil as a life support system, plays a crucial role in supporting life on Earth, as it acts as a reservoir, mediator of nutrients and its cycle. It stores, release and regulates water flow and its availability to plant. Increase in urbanization, population, industrialization, advancement in science and technology, and transportation have led to the increase in generation of municipal solid waste (MSW). World bank estimated global average MSW generation rate at 1.3 billion tons per annum (1.2 kg/person/day) and it will rise to 2.2 billion tons per annum (1.42kg/person/day) by 2025 (Ferro, 2021). MSW generation in Sub Saharan Africa is 62 million tons per year and spans a wide range from 0.09 to 3.0 kg per person per day with an average of 0.65 kg–1 capita/day (Yimenu, 2023). Nigeria produced 32 million tons of MSW each year only 20-30% is recycled and the remaining end in open dump site (Bakare, 2022). Municipal solid waste composting is a process that transforms organic waste from households, businesses, industrial and commercial activities and institutions into nutrient-rich compost (Alshehrei and Ameen 2021). This process divert organic waste from landfills, reduces methane emissions, and produces a valuable soil amendment. Compost supplied both macro and micro soil nutrients for improved soil functioning (Musbauet al., 2021). Farmers use MSW compost for several reasons, primarily to improve soil fertility and enhance agricultural productivity, availability of MSW compost, inadequacy and high cost of chemical fertilizer. However, MSW compost inevitably contain non-biodegradable chemicals which are harmful to the ecosystem, as it can be absorbed by plants and may cause carcinogenic, mutagenic, teratogenic effects to humans who consumed them

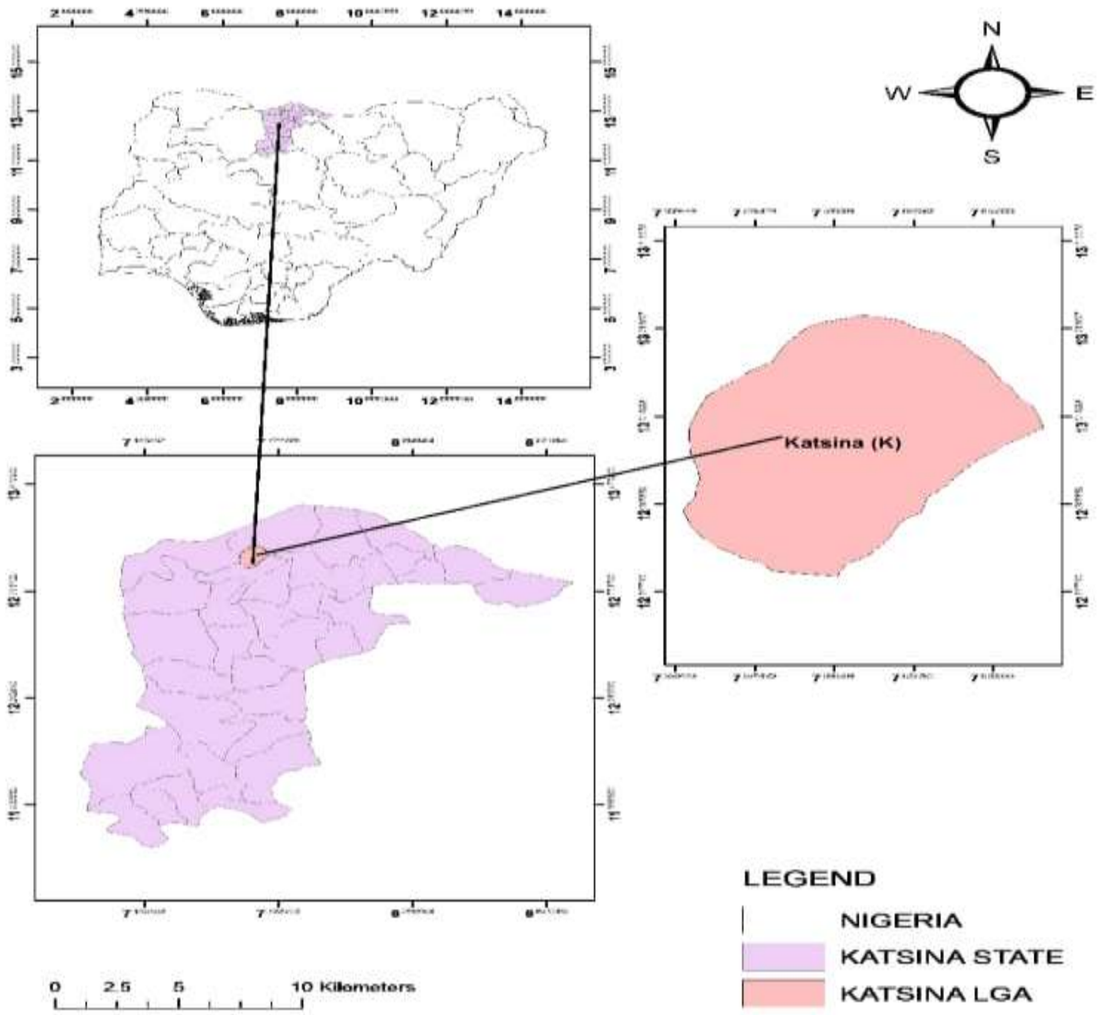
(Agegnehu, et al., 2017). Human exposure to heavy metals rich-crops above maximum permissible limits may led to toxicity, mental lapse, kidney failures, gastrointestinal disorder, liver disorder, lung cancers, central nervous system disorder with carcinogenic, teratogenic and mutagenic effects (Khan et al., 2020).

Soil ecotoxicological assessment is an interdisciplinary field that combines principles from ecology, toxicology, and environmental science to evaluate the potential toxic effects of contaminants and substances on soil-dwelling organisms and ecosystems (Pereira et al., 2018). It helps in environmental monitoring and making informed decisions about soil, plants and environmental management (Powlsonet al., 2011). It is of paramount importance to assess the municipal solid compost used in farmlands to ensure that the non-biodegradable chemical do not go beyond maximum permissible limits and for general ecosystem health.

II. MATERIALS AND METHODS

Study area

Municipal solid waste compost (MSWC) used by farmers as amendment material was collected from different dumpsites in urban Katsina. It is located between Latitude 12^0 $45^'$ and Latitude 13^0 $15^'$N, and Longitude 7^0 $30^'$ and 8^0 $00^'$E.



The continental sediments of Katsina plains consist of Feldspatic clayey sandstones and grits with small basal pebble beds. The sediments have maximum thickness of about 100 meters and the plain stands at an elevation of about 505m above sea level (Ologe, 1985). The climate is characterized as humid tropical. The Ginzo and Tille rivers drain the excess water from the city while the soil is typically alfisol, generally loose and sandy (Abdullahi, 2024). The vegetation is dominated by fine-leaved Acacia spp. and their associates Asanarimam, et al. (2015).

Materials

GPS was used to get the sampling plot locations, pH meter was used to determine the soil pH values, polythene bags in conveying soil and compost samples, marker was used to mark the soil containing polythene bags while Atomic Absorption Spectrophotometer (AAS Machine) was used for the determination of soil non-biodegradable chemicals concentrations while maize and beans were used as planting material for the phytotoxicity experiment.

Research Design

Experimental research design was employed whereby two population were used from municipal solid waste compost amended and animal dung amended plots

Different experiments were conducted to test the phytotoxicity of the municipal solid waste compost using the widely cultivated crops (maize and beans) in the study area as describe by Zucconi et al., (1981).

Soil sampling techniques

Municipal solid waste compost was collected from different locations of the urban Katsina. a composite compost sampling techniques was used whereby 5 different samples were collected from each location, mix properly to form a single bulk sample. In each bulk sample, 2 kg of compost was kept inside polyethylene bag, properly label and moved to the experiment site. Sand, MSW compost and kaolin were mixed at 2:2:1 ratio respectively. Half kg of each mixture was collected before planting and the samples were moved to laboratory for further treatment and analysis.

The2:2:1 Sand;’: MSW compost:kaolin mixtures were then placed in a plastic bowls and water it for two days before planting maize and bean seeds. The plants were harvested after 21 days of planting, the vegetative biomass of the plants was weighed before and after drying for phytotoxicity analysis.

LABORATORY ANALYSIS

Determination of Soil pH

Soil pH was determined using electrode pH meter method (Black, 1965).

Twenty gram (20g) of air-dried soil was weighed into a 50ml beaker. Twenty millilitres (20ml) of distilled water were then be added and it was allowed to stand for 30 minutes and stirred with a glass rod; the electrode of the soil pH meter was inserted into the partly settled suspension and measures the pH; and the observed pH was recorded as soil pH measured in water (Bates, 1954).

Determination of Soil Non-biodegradable chemicals

The collected soil samples were analysed for the following non-biodegradable chemicals of lead (Pb), Cadmium (Cd) chromium (Cr), Zinc (Zn), Iron (Fe) and Manganese (Mn). The soil samples were air dried to constant weight and sieved using a 2mm mesh. For each sample, one gram of air dried was weighed into a boiling tube which has been washed with concentrated nitric acid (HNO_3) and distilled water. Fifteen millilitres (15ml) of a ternary mixture were added to each weighed soil sample in the boiling tube. The samples were then be digested using a block digester under fume hood for 24 minutes. The solutions were then allowed to cool, and then distilled water was added to each and filtered into a 100ml Pyrex volumetric flask using a Whatman No. 42 filter 9cm. It was then made up to the mark with distilled water. The solutions were then stored for heavy metal determination using AAS (Perkin Elmer 400 Atomic Absorption Spectrophotometer). Phytotoxicity experiments was carried out as described by Zucconi et al., (1981).

ECOTOXICOLOGICAL ASSESSMENT

This involves the use of different toxicity assessment indices aimed at evaluating the concentrations of toxic substances and its possible impacts to the ecosystem.

SINGLE FACTOR POLLUTION INDEX

$$Px = {}^{Cx}/_{Sx}$$

Where Px= Pollution Index of metal x, Cx= Measured heavy metal value of metal x in the target area and Sx= Background level of metal x in the target area. (Hong et al., 2013).

Table:1 Single factor index Grading System

S/N	Index Value	Description
1	Px<1	Clean
2	1≤Px<2	Potential pollution
3	2≤Px<3	Slightly polluted
4	3≤Px	Highly polluted

Adopted from Muhammad, 2017.

ECOLOGICAL RISK INDEX (ERI)

This express the potential risk posed by a contaminant to the ecosystem quantitatively and is represented by:

ERI=TR*CF

Where TR= Toxicity response and CF=Contamination Factor Ecological Risk Factor. The toxic response of some heavy metals are As =10, Cr=2, Cd=30, Cu=5, Pb=5, Ni=5, Zn=1 (Hakanson, 1980).

Table: 2 Ecological Index Value and its Description

Ecological Risk Index Value	**Ecological Risk Index Value Description**
40<ERI	Low Risk
40≤ERI<80	Medium Risk
80≤ERI<160	Significant Risk
160≤ERI<320	High Risk
ERI≥320	Very High Risk

Hakanson, 1980.

Table: 3 Maximum permissible limits of heavy metals in crops and vegetables

Heavy metals	Zinc	Lead	Manganese	Iron	Cadmium	Chromium
Maximum limits	99.4	0.3	500	425.5	0.2	2.30

Source: WHO/FAO, 1989, Report of 33rd meeting, Joint FAO/WHO Joint ExpertCommittee on Food Additives, Toxicological evaluation of certain food additives and contaminants

Table:4 Target Hazard Quotient (THQ) Value and its Description

THQ Index value	THQ Index value Description
THQ<I	Free from non-carcinogenic effects
THQ≥1	Likelihood of non-carcinogenic effects

Source: Gebeyehu and Bayissa, 2020.

III. RESULT AND DISCUSSION

Municipal Solid Waste (MSW) Compost Toxicity Assessment Using Test Plants

Compost Toxicity from Bean (Phaseolus Vulgaris) Plant Experiments

Table:5 Bean Phytotoxicity Value

S/N	**SAMPLING LOCATION**	**BEAN TOXICITY VALUE**	**VALUE RANKING**
1	**TUDUN MATAWALLE**	24.21%	High Phytotoxicity
2	**KWADO**	3.29%	High Phytotoxicity
3	**KOFAR MARUSA**	16.24%	High Phytotoxicity
4	**GRA**	45.39%	High Phytotoxicity
5	**TUDUN LIHIDDA**	13.31%	High Phytotoxicity
6	**JANBANGO**	56.41%	Moderate Phytotoxicity

Source: Field Experiments, 2024.

This finding shows the highest and lowest phytotoxicity 0f **3.29%** and **56.41%**(Table 5) was recorded at Kwado and Janbango respectively. All sampling locations reveals high phytotoxicity except Janbango with moderate phytotoxicity. This result obtained corroborate the findings of Bozym 2022 and slavikovaeta l. 2022 using municipal solid waste compost on garden cress and lettuce

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respectively. Bean plant has high sensitivity to municipal solid waste compost. Compost quality standards and regulation to minimize toxic substances and soil nutrients need assessment need to be ensured on beans production fields.

Compost Toxicity from Maize (Zea Maize) Plant Experiments

Table: 6 Maize Phytotoxicity Value

S/N	SAMPLING LOCATION	MAIZE TOXICITY VALUE	VALUE RANKING
1	**TUDUN MATAWALLE**	306.62%	CompostBecomes Phytonutrients
2	**KWADO**	661.70%	Compost Becomes Phytonutrients
3	**KOFAR MARUSA**	81.47%	Absence Of Phytotoxicity
4	**GRA**	858.28%	Compost Becomes Phytonutrients
5	**TUDUN LIHIDDA**	395.76%	Compost Becomes Phytonutrients
6	**JANBANGO**	1541.92%	Compost Becomes Phytonutrients

Source: Field Experiments, 2024.

The highest and lowest value of 1541.92% and 81.47% table 6 was recorded at kofarmarusa and Janbango respectively. This result obtained corroborate the findings of Roca et al., (2023) using municipal solid waste compost on Barley. This finding shows that maize plant is less sensitive to harmful substances in compost and therefore municipal solid waste compost is relatively safe to be used on maize production fields.

HEAVY METALS TOXICITY ASSESSMENT

The results obtained from the laboratory analysis of Zinc (Zn), Lead (Pb), Manganese (Mn), Iron (Fe), Cadmium (Cd) and chromium were presented in table7.

Table:7 Mean values of pH non-biodegradable chemicals in soil and plant vegetative biomass

Heavy metal	MSWC amended soil	Animal dung amended soil	Beans treatment	Maize treatment
Zinc (Zn) mg/kg	78.25	23.75	155.50	169.00
Lead (Pb) mg/kg	-133.75	58.75	165.75	-8.75
Manganese (Mn) mg/kg	5.50	5.50	121.75	2.00
Iron (Fe) mg/kg	160.50	216.75	2850.50	1084.75
Cadmium (Cd) mg/kg	11.80	16.30	94.30	33.50
Chromium (Cr) mg/kg	6.75	5.75	4.25	3.00
pH	7.4	7.6		

Source: Laboratory work (2024).

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The distribution of non-biodegradable chemicals in soil amended with MSWC, reveals that, iron (Fe) recorded highest value of 160.50 mg/kg and lead (Pb) recorded the lowest of -133.75. In animal dung amended soil, iron (Fe) recorded the highest value of 216.75 mg/kg while manganese recorded the lowest value of 5.50 mg/kg. The soil pH which is a critical factor controlling the transfer of heavy metals within the soil matrix, its values are within the neutral class, as such, the non-biodegradable chemicals might be unavailable for plant consumption when the pH value is not within the acidic range.

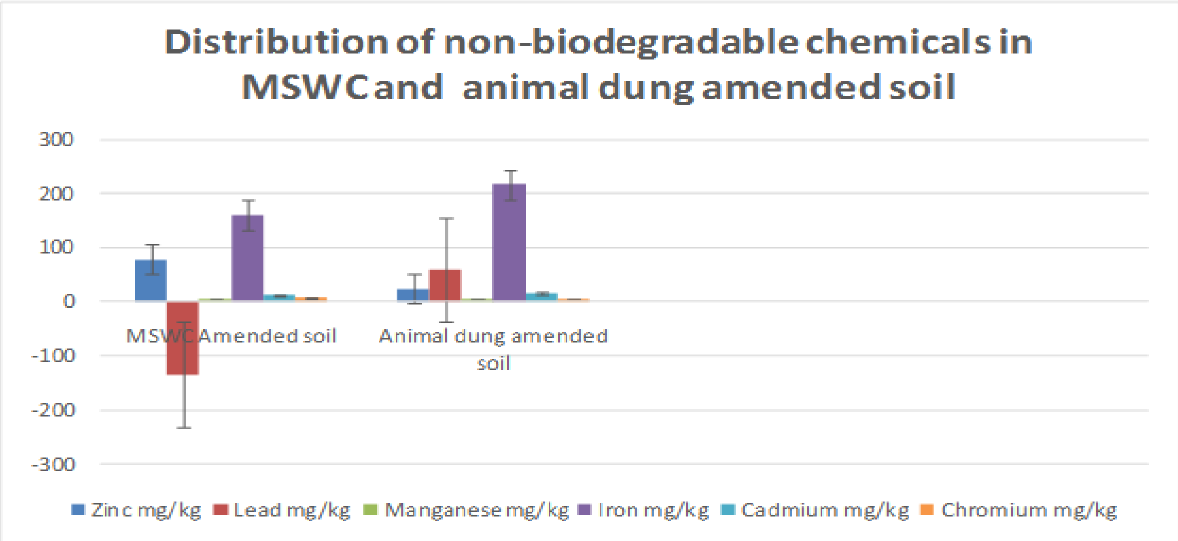

Figure: 2 Distribution of non-biodegradable chemicals in MSWC and animal dung amended soil

In plant vegetative biomass, iron appears to be the most abundant heavy metal with value of 2850.50mg/kg and 1084.75mg/kg in beans and maize respectively while the lowest chromium value of 4.25mg/kg and -8.75mg/kg of lead (Pb) were recorded for beans and maize respectively.

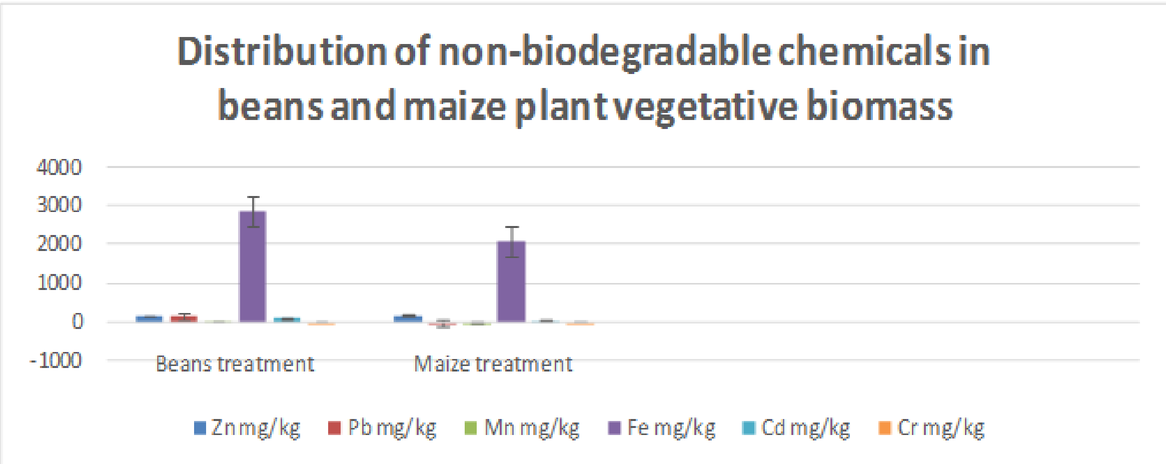

Figure: 3 Distribution of non-biodegradable chemicals in beans and maize plant vegetative biomass

Table: 8 Paired t-test of soil and test plants

Variables	Standard deviation	Mean	P-value
MSWC Treated and Control Soil	85.66	-32.95	0.38
Beans and Maize plants on MSWC Treated soil	768.53	-88.24	0.79

Source: Laboratory work (2024).

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Results of paired t-test shows P-value of **0.38** and **0.79** for MSWC Treated & Control Soil andBeans & Maize plants on MSWC Treated soil respectively.These findings indicate no statistical difference in all the experiments, therefore, with proper MSW compost quality control mechanisms, MSWC can be incorporated into soil fertility management strategies within the study area.

Single Factor Pollution Index

The single factor pollution index values report Zinc with slightly polluted value of (3.29mg/kg), Manganese and chromium with potential pollution while lead, iron and cadmium were reported as clean (Table 8).

Table:9 Single Factor Pollution Index

Non-biodegradable Chemical	Zn mg/kg	Pb mg/kg	Mn mg/kg	Fe mg/kg	Cd mg/kg	Cr mg/kg
Pollution Index Value	3.29	-2.25	1.0	0.74	0.72	1.17
Value Description	Slightly polluted	Clean	Potential pollution	Clean	Clean	Potential pollution

Source: Laboratory work (2024).

Ecological Risk Index(ERI)

The ecological risk index values (Table 9) show that, all heavy metals fall within the low-risk index value. This indicates that, the MSW compost contains relatively low harmful waste materials with ecological risk potentials.

Table: 10 Ecological Risk Index (ERI)

Non-biodegradable Chemicals	Zn	Pb	Mn	Fe	Cd	Cr
Ecological Risk Index value	3.29	-11.35	5.00	3.7	21.60	2.34
ERI Value Description	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk

Source: Laboratory work (2024).

Estimated Human Daily Intake (EDI) of Contaminants in Beans and maize plants

Table: 11 Estimated Human Daily Intake (EDI) of Contaminants in Beans plant

Non-biodegradable Chemicals	Zn	Pb	Mn	Fe	Cd	Cr
EDI Values	2.84	-1.96	0.07	11.71	0.38	0.03
Maximum allowable limit	99.4	0.3	500	425.5	0.2	2.30

Source: Laboratory work (2024).

The estimated human daily intake of contaminants in vegetative biomass of beans plant shows that all the non-biodegradable chemicals values are far below the maximum allowable limit except cadmium with an increase of 47.37% above the maximum allowable limit.

Table: 12 Estimated Human Daily Intake (EDI) of Contaminants in maize plant

Non-biodegradable Chemicals	Zn	Pb	Mn	Fe	Cd	Cr
EDI Values	3.00	-0.11	0.01	8.57	0.13	0.02
Maximum allowable limit	99.4	0.3	500	425.5	0.2	2.30

Source: Laboratory work (2024) and WHO/FAO, 1989

The estimated human daily intake of contaminants in vegetative biomass of maize plant shows that all the non-biodegradable chemicals values are far below the maximum allowable limit.

therefore, maize grown on fields amended with similar MSWC are relatively safe for human consumption.

Table:13Target Hazard Quotient (THQ)

Non-biodegradable Chemicals	Zn	Pb	Mn	Fe	Cd	Cr
THQ Values	9.46	560	1.48	1642.85	76	60

Source: Laboratory work (2024).

Table 12 shows target hazard quotient values for the heavy metals and all the values are above one which signifies likelihood of non-carcinogenic effects within the ecosystem.

IV. CONCLUSION AND RECOMMENDATION

Based on the results obtained, the single pollutionindex values description ranges from clean to slightly polluted, ecological risk index value description reveals low risk for all the metals while human daily intake of non-biodegradable chemicals in beans and maize plants vegetative biomass are below maximum allowable limit for all the metals except cadmium in beans. Target hazard quotient report values above one which have likelihood to cause non-carcinogenic effects within the ecosystem.

To improve the quality of compost and reduce its toxicity impacts, Municipal solid waste compost used in agriculture must be subjected to quality standards and regulations to ensure it meet specific criteria for nutrients content and absence of harmful substances.

RECOMMENDATION

Based on the result obtained the following recommendation were made

1) Source separation of MSW need to be put in place to remove all materials with toxicity potentials
2) Farmers should apply only matured MSW compost
3) Beans farmers should look for non-MSWC as alternatives
4) Maize farmers are encouraged to effectively use MSWC
5) Stakeholders should develop environment-friendly operational guidelines to guide the use of MSW compost in agricultural operations.

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