Ecological Risk Assessment of Trace Metal Pollution in an Urban Agricultural Area of Yaoundé (Cameroon)

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Abstract The presence of trace metals in urban agriculture is considered as a major factor for ecological risk. The aim of this research was to determine the concentrations of metals in market garden soils in the city of Yaoundé, Cameroon, in order to assess the degree of soil pollution and evaluate potential ecological risks. Forty-five composite soil samples were taken from three market garden sites in Yaoundé. Trace metals (Cd, Cr, Cu, Mn, Ni, Pb, and Zn) were determined by inductively coupled plasma-optical emission spectrometry (ICP-OES). The geochemical background threshold values for trace metal contents were determined and the multi-element indices of pollution and ecological risk were calculated. The results showed that concentrations of selected metals in soil varied considerably from one element to another ranging from very high to low levels: Mn > Cu > Zn > Cr > Pb > Ni > Cd. The median valuesof Cd, Cr, Cu, Mn, and Zn were below the geochemical background threshold values. For the Ni and Pb metals, the median values were higher than those of the geochemical background threshold values. The Nemerow Pollution Index (NPI) indicated that 60% of the samples had a significantly high level of pollution. However, the Potential Ecological Risk Index (PERI) indicated that only 16% showed a very strong ecological risk. This study can be used as a

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baseline to develop future long-term risk assessment strategies on the potential of metal migration in agricultural soils.

Keywords Geochemical background · Pollution indices · Market gardens

1 Introduction

In Cameroon, the urban and suburban lowlands of Yaoundé city are places of emergence of urban agriculture where gardening is the main activity. This activity along urban effluents generates the use of agricultural inputs such as fertilizers and pesticides. Unfortunately, this urban farming is still tarnished by poor agricultural practices [1]. However, their irrational uses generate negative externalities, which lead to a degradation of the soil quality and the vegetables produced in market gardens [2]. According to numerous studies, anthropogenic activities such as industrial activities, mining and smelting, municipal waste disposal, sewage irrigation, fertilizer or manure application, overuse of agrochemical products contribute to soil pollution by trace metals [3–6].

Pollution of agricultural soils by trace metals has become a major concern in the world. Environmental risk assessment using different pollution indices is one of the proposed solutions in monitoring trace metals soil pollution [7]. This study aimed to determine trace metal (Pb, Cd, Cu, Zn, Cr, Ni, and Mn) contents in market gardens of Yaoundé city, and to assess trace metal pollution and ecological risk.

2 Materials and Methods

2.1 Sampling and Analytical Procedure

The present work was carried out in three market garden sites, "Nkolondom", "Ezazou", and "Nkolbisson", located in three districts of Yaoundé. Composite sampling of soils was used to reduce sampling and analytical costs. Three replicates of soil samples were collected at 0–20 cm deep in 45 sampling points. Soil samples were analyzed in the Laboratory of Soils, Plants, Water, and Fertilizers Analysis at the Institute of Agricultural Research for Development, which is accredited according to ISO 17025 standard.

The total concentrations of trace metals in the topsoil composite samples were analyzed using a mixed acid solution of HCl + HNO3 (3:1, v/v) digestion method [8], and determined by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES; Optima 8000, Perkin Elmer). In order to monitor the accuracy and precision of the analytical methods used, reference materials of soil from Interprofessional Office for Analytical Studies (BIPEA) were analyzed at the same time.

Table 1 Pollution and ecological risk Indices formulas and their criteria [11–15]

Formulas		Criteria
$NPI = [0.5\,(PI_{avg}^2 + PI_{max}^2)]^{1/2}$ [9]	PI: Pollution index ($PI = Ci/median(Bi)$) PI_{avg}: mean value of PI PI_{max}: maximum value of PI Ci: measured concentration of trace metal i median(Bi): median of background concentration of trace metal i	$NPI \le 0.7$: safe $0.7 < NPI \le 1$: low level $1 < NPI \le 2$: moderate level $2 < NPI \le 3$: high level $NPI > 3$: very high level
$PERI = \sum Er = \sum Tr{*}PI$ [10]	Er: nominal potential ecological risk factor Tr: toxic response factor for a given metal (Zn = 1, Cr = 2, Cu = Pb = Ni = 5 and Cd = 30)	$PERI < 50$: low $50 \le PERI < 100$: moderate $100 \le PERI < 200$: high $PERI \ge 200$: significantly high

2.2 Data Analysis

Based on soil samples from market gardens of Yaoundé city, a multi-element pollution index, Nemerow Pollution Index (NPI) proposed by [9], and an ecological risk, Potential Ecological Risk Index (PERI) proposed by [10], were calculated to give an assessment of the overall pollution and ecological risk status for a sample [11–15]. Formulas and criteria of different classes of these indices are presented in Table 1.

Background values were calculated using the robust or nonparametric statistical method Median ± 2MAD (median absolute deviation), for different subsets of data to calculate median values after the elimination of anomalies. MAD is a robust indicator of variation around the median [16].

3 Results

3.1 Trace Metal Concentration in Agricultural Topsoil

According to their median values, trace metals can be arranged as follows: Mn > Cu > Zn > Cr > Pb > Ni > Cd (Table 2). Exept for Ni and Pb, median values of the other trace metals (Cd, Cr, Cu, Mn, and Zn) were below the geochemical background threshold values (Table 2). The descriptive statistics of trace metal concentrations (mg/kg) in the topsoil in urban agricultural area of Yaoundé city, their geochemical background threshold value (GBTV) detected using the median absolute deviation criterion (GBTV = Median + 2*MAD), number and percentage of outliers are shown on Table 2.

Table 2 Descriptive statistics of trace metal concentrations in urban agricultural topsoil of Yaoundé city

Elements	Mean (mg/Kg)	Median	Standard deviation	Coefficient of variation (%)	Signification of Shapiro-Wilk normality test	GBTV	Number of outliers	Percentage of outliers
Cd	0.09	0.09	0.05	60.29	0.000	0.15	6	13.33
Cr	46.39	54.60	29.72	64.06	0.009	116.07	0	0.00
Cu	155.67	111.20	143.48	92.17	0.000	187.76	13	28.89
Mn	357.05	258.98	369.83	103.58	0.000	588.57	10	22.22
Ni	20.29	14.93	12.59	62.07	0.000	18.37	15	33.33
Pb	43.47	19.25	40.90	94.08	0.000	16.59	24	53.33
Zn	89.02	81.89	57.23	64.29	0.001	235.53	0	0.00

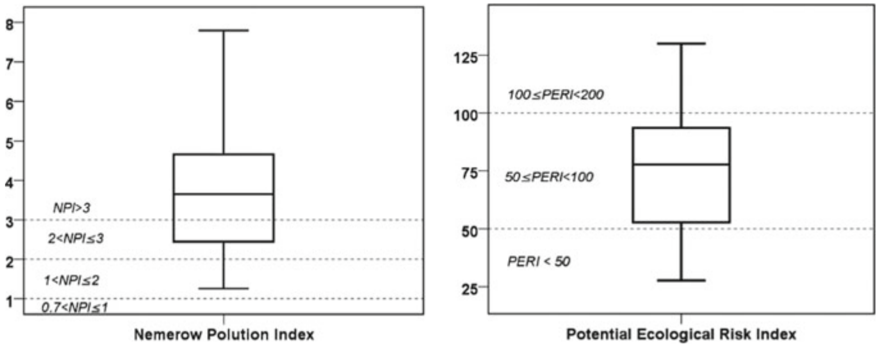

Fig. 1 Box plots of Nemerow Pollution Index (NPI) and Potential Ecological Risk Index (PERI) with horizontal lines representing threshold classes

3.2 Pollution and Potential Ecological Risk of Trace Metals

Pollution and potential ecological risk indices were used to evaluate soil pollution and potential ecological risk in urban agricultural soils. The NPI and PERI were calculated and the results are displayed in Fig. 1. Figure 1 shows that NPI values belong to high and very high pollution classes. Those of PERI belong to moderate class of potential ecological risk.

4 Discussion

Any trace metal value higher than the GBTV can be assumed as outliers coming from anthropogenic sources [15, 17]. Furthermore, with the agricultural practices developed by the market garden farmers and other urban anthropogenic activities, soil properties, in particular, trace metal concentrations can be modified [1].

For NPI, the soil samples were classified, on average, as high levels contaminated based on the mean value of 3.745. Effectively, 20% of samples were moderately polluted, 20% belong to the strong or high level of pollution, and 60% were in a very strong level of pollution.

For PERI, 24% of soil samples from our study area were in the low zone of potential ecological risk. 60% were at a moderate level, and only 16% at a high level of potential ecological risk. Taken into consideration, the PERI values demonstrated a low potential ecological risk when the local GBTV calculated was used. Indeed, the local geochemical background can be strongly influenced by anthropogenic factors [13].

5 Conclusion

Based on the pollution and ecological risk assessment results, this study can be considered as a baseline for the assessment of environmental risk in urban agricultural gardens in Yaoundé city, Cameroon. Nemerow Pollution Index (NPI) and the Potential Ecological Risk Index (PERI) indicated that more than half of our samples had a high to very high pollution level. Thereby, specific attention should be paid to anthropogenic activities that significantly influence trace metal contents in urban agricultural soils.

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