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Quantitave Analysis Of Heavy Metals In Soil From Niakhene Site In Senegal Using Xrf

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Abstract
The study investigates heavy metal concentration in soil samples from Senegal's Niakhene site using X-ray fluorescence (XRF) analysis. It addresses the global challenge of soil pollution due to Nickel (Ni), Arsenic (As), Zinc (Zn), Chromium (Cr), Lead (Pb), and Cadmium (Cd), and mercury (Hg). These metals originating from various sources, pose threats to ecosystems and human health.
XRF, a non-destructive method precisely evaluated heavy metal presence and distribution Nikel (Ni), Arsenic (As), and Zinc (Zn) displayed varying concentration across samples ranging from 0-47.30 ppm for Ni, 0 – 5.67 ppm for As and 0- 29.49 ppm for Zn. In contract, Lead (Pb), Chromium (Cr), and Mercury (Hg) were either undected or found below detection limits. The text highlights the toxicity of these metals, emphasizing potential health risks and environmental damage, necessitating source identification and effective management strategies. Detailed tables present heavy metal concentrations at various sampling points, offering insights for future investigations. Comparisons with international guidelines and reference site averages reveal notable differences in Zn and Ni levels between sites, suggesting potential influences from environmental factors or human activities. The study's implications stress the continuous monitoring of heavy metal levels, comprehensive assessments for environmental and health impacts, and the implementation of suitable measures.
***Keywords**: X-ray fluorescence, soil samples, Heavy Metals*

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I. Introduction

The significant upsurge in soil pollution by heavy metals, notably Nickel (Ni), Arsenic (As), Zinc (Zn), Chromium (Cr), Pb (lead), Cadium (Cd) and Mercury (Hg) poses a major environmental challenge on a global scale. Stemming from from various industrial, mining, agricultural, and urban activities, these metals infiltrate the environment and endure in soils, thereby threatening terrestrial ecosystems' integrity and human health [1,2]. In this study, the assessment of these metals' levels in soils was conducted using a non-destructive X-ray fluorescence (XRF) analysis technique. Renowned for its precision and capability to identify heavy metal concentrations without altering samples, this method comprehensively evaluated the presence and distribution of these elements in the studied soils [**3**].

Due to their toxocity to degradation these heavy metals are recognized for their devastating effects on biodiversity soil fertility alteration and and contamination of water resources [**4,5**]. For instance, arsenic and mercury, even at low concentrations, can inflict severe health consequences on humans, leading to neurological issues and respiratory disorders [**6,7]**

Considering the pressing concerns regarding global warming and the increased need for expertise in agroecology, the investigation into the resilience of agricultural systems takes on a pivotal role. Consequently, a comprehensive soil characterization campaign was executed on the rural campus of niakhene aimed at assessing contamination levels and contributing to this crucial evaluation. The objective of this study was to evaluate the concentrations of various heavy metals in soil samples gathered from the Nainkhene site in Senegal specificity during the summer season of 2020.

II. Materials and Methods

Site and Sample collection

Soil samples were gathered in triplicate during the summer season of December 2020.The sampling locations encompassed in the Niakhène site, which 37 soil samples were collected. The coordinates of the sample points in the site as outlined in Table 1. Topsoil samples were collected from a depth of 0–20 cm and carefully preserved in sterile bags. Subsequently, the soil samples were air-dried at room temperature before the heavy metal analysis commenced.

Table 1 : UTM coordinates of the sampling points in the study site.

Points	X	Y
S1	354386,509	1667363,51
S2	354486,510	1667263,508
S3	354436,510	1667263,508
S4	354586,510	1667263,508
S5	354436,510	1667313,508
S6	354436,510	1667413,508
S7	354386,509	1667163,507
S8	354386,509	1667313,508
S9	354486,510	1667313,508
S10	354436,510	1667513,509
S11	354486,510	1667213,507
S12	354536,510	1667213,507
S13	354536,510	1667163,507
S14	354286,509	1667213,507
S15	354636,510	1667363,508
S16	354436,510	1667213,507
S17	354486,510	1667463,508
S18	354436,510	1667163,507
S19	354636,510	1667263,508
S20	354636,510	1667413,508
S21	354586,510	1667213,507
S22	354336,509	1667263,508
S23	354636,510	1667313,508
S24	354536,510	1667363,508
S25	354436,510	1667463,508
S26	354336,509	1667313,508
S27	354586,510	1667413,508
S28	354636,510	1667213,507
S29	354586,510	1667163,507
S30	354536,510	1667313,508
S31	354636,510	1667313,508
S32	354336,509	1667213,507
S33	354536,510	1667413,508
S34	354486,510	1667413,508
S35	354336,509	1667263,508
S36	354586,510	1667363,508
S37	354386,509	1667213,507

Heavy Analysis

The concentrations of various heavy metals, namely Nickel (Ni), Arsenic (As), Zinc (Zn), Chromium (Cr), Lead (Pb), Cadmium (Cd), and Mercury (Hg), were evaluated in soil samples using X-ray fluorescence (XRF) analysis.

X-ray fluorescence principe :

The X-ray fluorescence analysis method functions by subjecting a sample to intense X-radiation, causing the ionization of atoms by dislodging electrons near the nucleus. As a result, the atom stabilizes by reconfiguring its electron cloud [**8,9**]. Specifically, when an electron is expelled, another electron from an outer layer fills the vacancy, inducing a radiative transition that emits an X-ray fluorescence photon. This emitted photon possesses energy equivalent to the disparity in energy levels between the initial and final states of the recombined electron, thereby serving as a distinctive signature for the emitting atom. Measuring the fluorescence intensity at each energy level generates an X-ray emission line spectrum reliant on the sample's composition. This process allows for the determination of the total content of elements in the sample with an atomic number above a specific threshold, contingent upon the excitation energy [**10**]. It's important to note that this phenomenon mainly affects elements with higher atomic numbers as low atomic number atoms exhibit lower fluorescence yield, which is less pertinent to heavy metals [11].

Soil samples are directly presented to the X-ray fluorescence analyzer with a silver Ag anode as excitation source and an optimized large-geometry detector with multiple filters as secondary sources.

In Table 2, we outline the specifications and operating conditions of the Niton XLT900s spectrometer with various types of filters.

Table 2: Niton XLT900s Spectrometer specification and operating conditions.

Resolution	178 eV@ Mn Kα
Window thickness	12.7 μm Be
Excitation Tube	50KV, 40 A maximum power 2W
Beam diameter	7mm
Filters	List of targeted elements
Excitation Source Ag	Sb, Sn, Cd, Pd, Ag, Mo, Nb, Zr, Sr, Rh, Bi, As, Se, Au, Pb, W, Zn, Cu, Re, Ta, Hf, Ni, Co, Fe, Mn, Cr, V, Ti, Th, U
Sandwich of Al, Ti and Mo	Ba, Sb, Sn, Cd, Pd, Ag
Filter of Cu	Cr, V, Ti, Ca, K
No Filter	Al, P, Si, Cl, S, Mg

III. Resultats and discussions

Table 3 displays the concentrations identified at the study site. Nickel (Ni), Arsenic (As), and Zinc (Zn) were detected in certain collected samples from the site. Their concentration ranges were as follows : Nickel (Ni) : 20.2 - 47.30 ppm, Arsenic (As) : 0 - 5.67 ppm, Zinc (Zn) : 0 - 29.49 ppm. Furthermore, Lead (Pb), Chromium (Cr), and Mercury (Hg) were noted as not detected' in the soil samples from the site. This information indicates specific concentration ranges for Nickel, Arsenic, and Zinc in all samples, while Lead, Chromium, and Mercury were either absent or below the detection limit (LOD) in this particular site's soil samples. Arsenic was detected in several samples, although generally at low concentrations, suggesting a moderate presence in the study soil. The results reveal varying concentrations of heavy metals such as Nickel (Ni), Arsenic (As), and Zinc (Zn) in the collected soil samples, showing significant concentration ranges. These metals might originate from diverse sources like industrial activities, waste, or natural processes such as rock erosion. Notably, Lead (Pb), Chromium (Cr), and Mercury (Hg) were undetected in the soil samples. This promising information implies that these heavy metals are either absent or present below the detection limit. These findings emphasize the significance of monitoring heavy metal levels in soils, as even relatively low concentrations can potentially impact human health, biodiversity, and surrounding ecosystems.

Table 3 : Concentrations of heavy metals for the differents samples points.

SAMPLE	Pb	Hg	As	Cd	Zn	Cr	Ni
S1	< LOD	< LOD	< LOD	< LOD	21,35	< LOD	31,29
S2	< LOD	< LOD	5,14	< LOD	29,49	< LOD	30,33
S3	< LOD	< LOD	< LOD	< LOD	8,54	< LOD	27,47
S4	< LOD	< LOD	3,26	< LOD	10,55	< LOD	37,2
S5	< LOD	< LOD	< LOD	< LOD	9,74	< LOD	37,47
S6	< LOD	< LOD	< LOD	< LOD	14,57	< LOD	35,6
S7	< LOD	< LOD	< LOD	< LOD	7,75	< LOD	27,18
S8	< LOD	< LOD	2,57	< LOD	20,5	< LOD	30,78
S9	< LOD	< LOD	< LOD	< LOD	14,47	< LOD	20,02
S10	< LOD	< LOD	4,82	< LOD	8,18	< LOD	35,65
S11	< LOD	< LOD	3,79	< LOD	10,51	< LOD	40,05

S12	< LOD	< LOD	3,27	< LOD	12,68	< LOD	28,47
S13	< LOD	< LOD	3,63	< LOD	11,01	< LOD	37,12
S14	< LOD	< LOD	3,65	< LOD	27,25	< LOD	34,43
S15	< LOD	< LOD	2,83	< LOD	13,35	< LOD	34,6
S16	< LOD	< LOD	3,88	< LOD	13,03	< LOD	22,67
S17	< LOD	< LOD	< LOD	< LOD	12,03	< LOD	32,06
S18	< LOD	< LOD	2,55	< LOD	8,66	< LOD	31,67
S19	< LOD	< LOD	2,91	< LOD	10,93	< LOD	33,53
S20	< LOD	< LOD	4,94	< LOD	8,88	< LOD	30,18
S21	< LOD	< LOD	3,35	< LOD	9,05	< LOD	26,08
S22	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	27,4
S23	< LOD	< LOD	4,21	< LOD	9,43	< LOD	32,27
S24	< LOD	< LOD	< LOD	< LOD	13,6	< LOD	39,2
S25	< LOD	< LOD	2,73	< LOD	11,29	< LOD	31,08
S26	< LOD	< LOD	2,51	< LOD	9,14	< LOD	36,86
S27	< LOD	< LOD	2,5	< LOD	13,45	< LOD	37,01
S28	< LOD	< LOD	2,78	< LOD	10,21	< LOD	25,19
S29	< LOD	< LOD	5,67	< LOD	8,57	< LOD	35,14
S30	< LOD	< LOD	3,1	< LOD	8,67	< LOD	28,11
S31	< LOD	< LOD	2,5	< LOD	6,56	< LOD	27,45
S32	< LOD	< LOD	3,13	< LOD	21,05	< LOD	41,9
S33	< LOD	< LOD	2,46	< LOD	11,84	< LOD	34,21
S34	< LOD	< LOD	4,57	< LOD	11,93	< LOD	34,07
S35	< LOD	< LOD	3,78	< LOD	25,43	< LOD	47,3
S36	< LOD	< LOD	2,79	< LOD	9,05	< LOD	36,74
S37	< LOD	< LOD	2,84	< LOD	11,42	< LOD	38,95

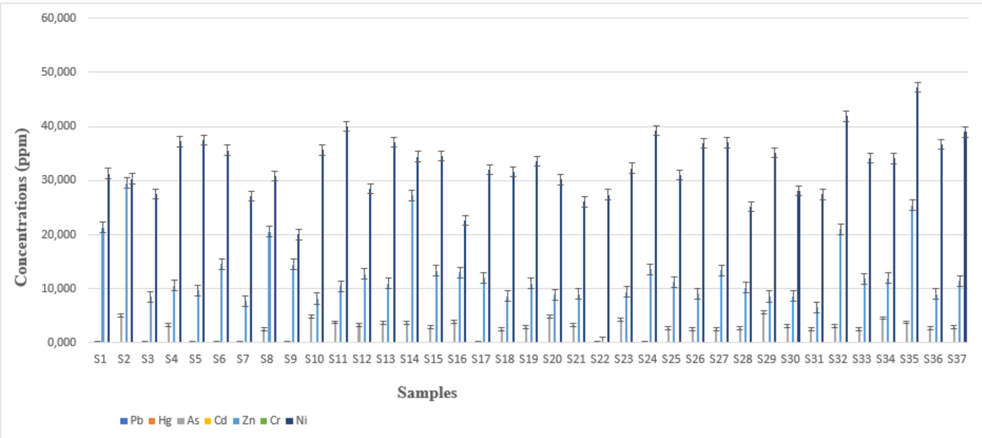

Figure 1 : Concentration of the heavy metal in the sampling points

Previous Previous studies have shown the deleterious impacts of these metals on human health, such as neurological issues, respiratory disorders, and even long-term cancers [**12,13**]. The non-detection of certain metals might be interpreted positively, but it also highlights the need to understand potential sources of contamination in the studied area. Further research is often required to assess potential risks to human health and the environment, as well as to implement appropriate management measures [14,15].

The absolute values of heavy metal contamination hold particular significance, especially during remediation efforts. However, these figures do not capture the relative toxicity of individual metals present at each site. This relative toxicity is taken into consideration in establishing the Maximum Permissible Limits (MPL) set by various governmental regulatory agencies. The authorized maximum levels for Pb, Cd, As and Hg in agricultural soil are outlined in table 4 [16].

Table 4 : Guidelines for the maximum permissible limit (MPL in ppm) values of selected heavy metals in agricultural soil.

Heavy	FAO/ WHO[a]	EC[b]	US[c]	France[d]	Germany[d]	Austria[d]	SEPA chine (grade III)	Arab-German coop projet	Average value
Pb	90-400	50-300	50-300	70-150	100	100	500	100	166.25
Cd		1-3	1.6	1-3	1.5-3	5	1	1	2.12

As	-	20	14	20	50	50	-	-	32.8
Hg	1	1	0.5	1	2	5	1.5	-	1.71

The were no specific universal international Maximum Permissible Limits (MPL) for nickel (Ni), zinc (Zn), and chromium (Cr) in agricultural soils. For elements (Zn, Cr, and Ni) that do not have established maximum permissible limits, we compared the values obtained at the study site to the average concentrations found at the reference site. The average was calculated at three depth points : 0-20 cm. The averages found are repesented in the table 5.

Table 5 : Average cncentrations (ppm) of the samples ponits in control soil

Heavy metals	Average concentrations in ppm of the points in the soil control
Zn	8.68
Cr	-
Ni	29.16

The figure 2 shows the distribution of concentrations of heavy metals and thier average in the control soil. An analysis of zinc (Zn), chromium (Cr), and nickel (Ni) concentrations in the soil reveals significant differences between the reference site and the study site. Notably, the absence of defined limits set by the World Health Organization (WHO) for these elements complicates the assessment of soil pollution. However, using alternative references and comparing with naturally occurring background values can aid our understanding. At the reference site, the average Zn concentration measures 8.68 ppm, serving as a baseline for comparison. Contrastingly, at the study site, concentrations vary substantially, ranging from 6.56 ppm to 29.49 ppm. This significant range suggests potential contamination sources or environmental influences on Zn distribution. Despite the lack of specific WHO limits for Zn in agricultural soil, these variations necessitate thorough investigation to identify causes and evaluate potential implications on soil quality and surrounding ecosystems. The absence of detectable chromium concentrations at both sites is a positive finding, indicating no detectable contamination by this potentially harmful element.

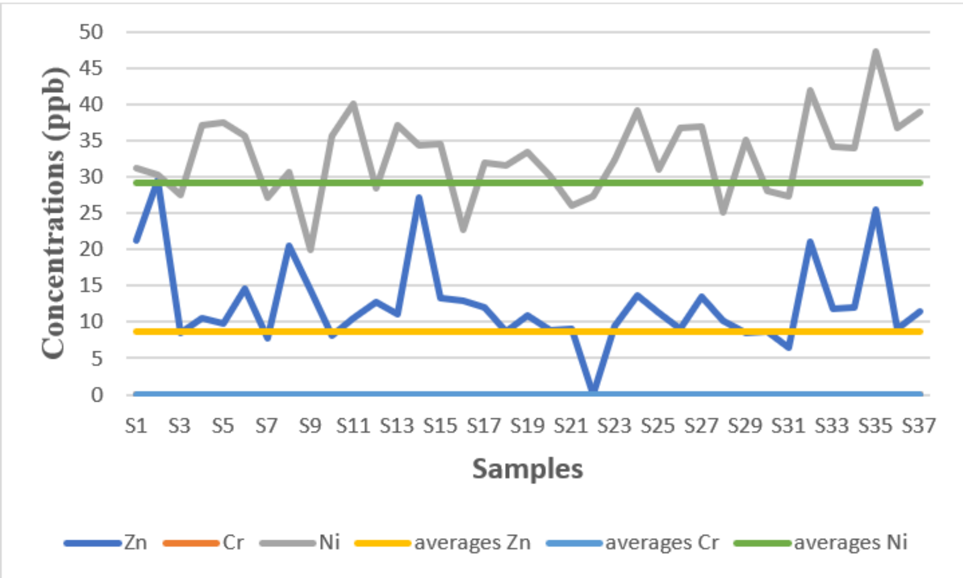

Figure 2 : Distribution of concentrations and average of heavy metal

This observation aligns with environmental safety standards, reassuring the soil quality in terms of chromium. Regarding nickel, the average concentration at the reference site stands at 29.16 ppm, setting a baseline for natural Ni levels. However, at the study site, concentrations range widely from 20.02 ppm to 47.3 ppm. This considerable variation highlights potential influences from human activities or geological factors on Ni levels. Despite the lack of specific WHO limits for Ni in agricultural soil, the broad range necessitates a comprehensive assessment to determine sources and potential environmental or health implications.

IV. Conclusion

The quantitative analysis of heavy metals in the soil of Niakhène, Senegal, using X-ray fluorescence (XRF), reveals varying concentrations of nickel (Ni), arsenic (As), and zinc (Zn). The study highlights potential contamination sources based on the refernce site, with arsenic consistently present at low concentrations in several samples. The absence or minimal presence of lead (Pb), chromium (Cr), and mercury (Hg) is reassuring for soil quality. The studied area has limited industrial, mining, or other anthropogenic activities that release these metals into the environment, which could explain the absence or low presence of Cr, Pb, and Hg. However, the absence of universal international limits for Ni, Zn, and Cr complicates the assessment. The study emphasizes the need for ongoing monitoring, comprehensive assessments, and proactive measures to address heavy metal contamination and its potential impacts on the environment and human health.

References

[1]. Smith, S. L., & Macdonald, B. C. (2018). Metal Contamination Of Food Crops : Mechanisms Of Uptake And Translocation. Environmental Monitoring And Assessment, 190(12), 645. Doi: 10.1007/S10661-018-7100-2.

[2]. Alloway, B. J. (2013). Heavy Metals In Soils : Trace Metals And Metalloids In Soils And Their Bioavailability (3rd Ed.). Springer Science & Business Media.

[3]. Jones, A. B., & Smith, C. D. (2017). Xrf Analysis Of Soil Samples. Journal Of Environmental Analysis, 5(3), 112. Doi: 10.4172/2380-2391.1000177.

[4]. Kabata-Pendias, A., & Pendias, H. (2001). Trace Elements In Soils And Plants (3rd Ed.). Crc Press.

[5]. Li, Z., Ma, Z., Van Der Kuijp, T. J., Yuan, Z., & Huang, L. (2014). A Review Of Soil Heavy Metal Pollution From Mines In China : Pollution And Health Risk Assessment. Science Of The Total Environment, 468-469, 843-853. Doi: 10.1016/J.Scitotenv.2013.08.090.

[6]. Rahman, M. A., Hasegawa, H., & Lim, R. P. (2012). Bioaccumulation, Toxicity, And Adaptation Of Arsenic In Aquatic Organisms. In Arsenic Pollution (Pp. 257-278). Springer, Dordrecht.

[7]. Clarkson, T. W., & Magos, L. (2006). The Toxicology Of Mercury And Its Chemical Compounds. Critical Reviews In Toxicology, 36(8), 609-662. Doi: 10.1080/10408440600845619.

[8]. Robinson. A.. Harroun. S.. Bergman. J.. Brosseau. C.. 2012. Portable Electrochemical Surface-Enhanced Raman Spectroscopy System For Routine Spectroelectrochemical Analysis. Analytical Chemistry 84. 1760-1764.

[9]. Malik. L.A.. Bashir. A.. Qureashi. A.. Pandith. A.H.. 2019. Detection And Removal Of Heavy Metal Ions: A Review. Environmental Chemistry Letters 17. 1495-1521.

[10]. Gopinath. K.P.. Vo. D.-V.N.. Gnana Prakash. D.. Adithya Joseph. A.. Viswanathan. S.. Arun. J.. 2021. Environmental Applications Of Carbon-Based Materials: A Review. Environmental Chemistry Letters 19. 557-582.

[11]. Plassard. C.. Robin. A.. Le Cadre. E.. Marsden. C.. Trap. J.. Herrmann. L.. Waithaisong. K.. Lesueur. D.. Blanchart. E.. Lardy. L... 2015. Améliorer La Biodisponibilité Du Phosphore: Comment Valoriser Les Compétences Des Plantes Et Les Mécanismes Biologiques Du Sol. Innovations Agronomiques 43. 115-138.

[12]. Taylor, V.F. Et Al. (2016). Heavy Metals In Human Hair Samples From The Industrial Area Of Milazzo-Valle Del Mela (Northern Sicily). International Journal Of Environmental Research And Public Health.

[13]. Smith, E. Et Al. (2019). A Review Of Arsenic Poisoning And Its Health Effects In The Bangladesh Population. Journal Of Environmental Science And Health, Part A.

[14]. Nriagu, J.O. (1996). A History Of Global Metal Pollution. Science

[15]. Alloway, B.J. (2013). Heavy Metals In Soils : Trace Metals And Metalloids In Soils And Their Bioavailability (3rd Ed). Environmental Pollution

[16]. Jamilah. B,. ,Manal. E. J., Lobn. Y., Rawan. K.,1 And Diane. A. B. (2020). Quantitative Analysis Of Heavy Metals And Organic Compounds In Soil From Deir Kanoun Ras El Ain Dump, Lebanon. The Scientific World Journal. Volume 2020, Article Id 8151676, 10 Pages.