Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI: 10.21474/IJAR01/9789
DOI URL: http://dx.doi.org/10.21474/IJAR01/9789

RESEARCH ARTICLE

ASSESSMENT OF NATURAL OCCURRING RADIONUCLIDES (^{40}K, ^{226}RA, ^{232}TH) AND HEAVY METALS IN A DISTURBED AND UNDISTURBED SOIL IN THE REGION OF DAKAR, SENEGAL.

Mamadou Lamine Sané[1], Modou Mbaye[1], Alassane Traoré[1], Djicknack Dione[1], Mamoudou Sall[2], Ababacar Sadikh Ndao[1] , Papa M. N'diaye[3] and Ahmadou Wagué[1].

1. Institute of Applied Nuclear Technology, Department of Physics, Faculty of sciences and techniques, University of Cheikh Anta Diop, Dakar, Senegal.
2. Laboratory of X-ray, Department of Physic, Faculty of sciences and techniques, University of Cheikh Anta Diop, Dakar, Senegal.
3. Department of Geology, University of Cheikh Anta Diop, Dakar, Senegal.

Manuscript Info

Manuscript History
Received: 16 July 2019
Final Accepted: 18 August 2019
Published: September 2019

Key words:-
Natural radioactivity, Heavy metals, gamma spectrometry, XRF, dose assessment, radiological risk, pollution risk.

Abstract

Radiometric study of natural radioactivity from soil has been carried out to estimate the concentration of gamma-induced radioisotopes and their associated radiological risk in two sampling sites, an uncultivated (undisturbed) and an agricultural site located near an industrial zone. A High Purity Germanium (HPG) detector was used to measure natural gamma emitting radionuclides of ^{40}K, ^{232}Th and ^{226}Ra. With a portable X-ray fluorescence equipment, elemental concentration of several major elements (*Ca, Fe, Ti and K*) and minor element (*Mn, Zn, As, Zr, P, Cu, Cr and Ni*) were measured. The assessment of soil contamination was made by determining the geoaccumulation index, the enrichment factor, the contamination factor and the pollution load index of the various metals targeted in this study. The results indicate moderate soil pollution at the Bargny site by heavy metal As. But also, that this same soil of the Bargny study site was significantly enriched with arsenic and chromium. Levels of radiological hazard indices associated with the measured radioisotopes were inferred. The average of the radium equivalent activity calculated is 65.76 ±3.40 Bq.Kg^{-1} (disturbed) and 57.25 ± 5.76 (undisturbed); while the mean of the total absorbed gamma dose rate was 30.20±1.56nGy.h^{-1} (disturbed), and 26.64 ± 2.67 (undisturbed). The External hazard ranged between 0.17 and 0.19 in the disturbed sampling site and 0.12 and 0.17 (Undisturbed).

Introduction:-

Naturally gamma-emitting radioisotopes are the principal source of outdoors exposition and it is responsible for approximately between 80% and 85% gamma radiation received by humans (Daryouch and al., 2013). Exposition, mainly, arises from ^{238}U, ^{232}Th and ^{40}K decay daughters (radium and radon). Based on UNSCEAR, on average ^{40}K contributes 13.8%, ^{232}Th 14% and ^{238}U to 55% to the worldwide terrestrial gamma dose of 60 nGyh^{-1} (UNSCEAR, 2000). Nowadays environmental monitoring of radioactivity in soils, rocks, air and superficial water, as well as their

Corresponding Author:-Mamadou Lamine Sané.
Address:-Institute of Applied Nuclear Technology, Department of Physics, Faculty of sciences and techniques, University of Cheikh Anta Diop, Dakar, Senegal.

fate in the environment, is an increasing demand for policymakers; and more importantly, it has been demonstrated that quantification of background levels of radionuclides is necessary to evaluate the potential environmental risk (ICRP, 1993).

The content of heavy metals in the soil is often not constant, especially at the level of industrial and agricultural areas. Heavy metals come from natural processes but also from anthropogenic processes. It is estimated that the contribution of metals from anthropogenic sources to the soil is greater than that of natural metals (Nriagu and Pacyna., 1998). Heavy metals, which are not biodegradable, accumulate in the soil and, depending on biogeochemical conditions, pass through the soil solution (Mench et al., 2000). These metals can be absorbed by plants but also found at the water table; entering the food chain (Loska and Wiechula, 2003). However, their effects on human health or the environment, in general, are dangerous when exposed to higher than normal concentrations.
According to existing literature, measurement of concentration of naturally occurring radionuclides and the concentration of chemical elements in the environment have been performed in several countries all around the world (El-kameesy and al., 2015) (Ajayi and al., 2018). However, there are very few data available of occurring radionuclides and elemental concentration in soil from developing countries. This study was conducted with the aim of assessing the specific activities of natural radionuclides, determining the concentration of some chemical elements and assessing the risks of radiological and pollution at ground level of the cities of Dakar and Bargny.

Study area
The disturbed site is in Bargny about 20 km east of Dakar. It lies between 14°43'1.99N//14°41'8.99N and 17°15'1.44W//17°11'35.68W. Its geological cover includes an alternation of marl and limestone. In addition, this eastern part of the Dakar region includes a set of hills and plateaus with altitudes below 50m. Local temperature varies substantially between 18°C to 39°C. This study area soil texture was predominately sandy 63%, with 17% of silt and clay 19% with average organic matter of 76%, with a pH of 6.9 on average. The National cement factory used soil material in Bargny. The second study site is in the central zone of the western end of the Dakar region, which is a local undisturbed area since many decades. The GPS coordinates of this site are between 14°44'30.64N//14°38'57.76N and 17°26'5.16W//17°26'3.49W. This zone has an altitude of less than 10 m and consists soil texture was predominately sandy 66%, with 13% of silt and clay 20% with average coarse fragment of 18%. The soil bulk density was about 1.4 and acidic pH of 6.8.

Materials and Methods:-

Gamma spectrometry Analysis
The sample collector equipment is a motorized core drill for the soil column. The samples were dried for 24 h at a temperature of 100° C, crushed, screened (2 mm) and homogenized. A representative part of each sample is taken and placed in a cylindrical plastic container. The whole is sealed for 4 weeks for the realization of the secular equilibrium. The analysis of the samples is carried out by a gamma spectrometer equipped with a high purity germanium detector. The detector is coaxial p-type, which is characterized by an energy resolution of 1.8Kev at 1332Kev with excellent peak symmetry and a relative efficiency of 30%. The detector is calibrated using a certified multi-gamma source and two reference materials (IAEA 327, IAEA 375). The samples are analyzed with duration of 86000 s. The activity calculation, using the spectra, made it possible to determine the content of the radionuclides in each sample. Since secular equilibrium is achieved, radium ^{226}Ra is obtained from Bismuth ^{214}Bi (609 Kev); thorium ^{232}Th from actinium ^{228}Ac (911Kev); and ^{40}K potassium from her energy 1461Kev. The activity of a radionuclide is calculated by the following equation:

$$A\left(\frac{Bq}{kg}\right) = \frac{N}{\varepsilon * I * m * t}$$

Where
N: Net peak area of the gamma photo peak.
ε: efficiency of the detector
I: branching ratio
m: masse (Kg) of the sample
t: time of counting

Calculation of the radiological effects
Naturally occurring radionuclides are well known to cause significant increase in public exposition. In this study 4 radiological hazard indices associated with the presence the measured naturally occurring radioactive materials were computed using conversion factors. Equation 1 to 6 expressed the following radiological risk index :

1. The total absorbed dose rate in air
2. The radium equivalent index
3. The external and internal hazard index
4. The annual effective dose equivalent for outdoor and indoor

The absorbed dose rates in at radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) were calculated by using Equation (1) on the guidelines provided by (UNSCEAR, 2000)

$$D(nGyh^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (1)$$

Where A_{Ra}, A_{Th}, A_K are the average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively.0.462, 0.604 and 0.0417 are the dose conversion factors for converting the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K into dose rate. Radium equivalent activity (Raeq) and External and Internal Radiation hazards (Hex and Hin) were calculated according to Equation (2) and Equations (3) and (4) (Beretka and Mathew, 1985), respectively

$$Raeq(Bq.kg^{-1}) = A_{R_a} + 1.43A_{Th} + 0.077A_K \quad (2)$$

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (3)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (4)$$

Where A_{Ra}, A_{Th}, A_K are the average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq.kg^{-1} respectively.
The value of H_{ex} and H_{in} indices must be less than 1mSv.y^{-1} in order to cause any harmful effect to population. (Quindos, Fernandez and Soto 1987).
The outdoor and indoor annual effective dose equivalent are calculated by the equations (5) and (6):

$$AEDE_{out}(\mu Sv.y^{-1}) = D(nGy.h^{-1}) \times 8760h \times 0.2 \times 0.7(Sv.Gy^{-1}) \times 10^{-3} \quad (5)$$

$$AEDE_{in}(\mu Sv.y^{-1}) = D(nGy.h^{-1}) \times 8760h \times 0.8 \times 0.7(Sv.Gy^{-1}) \times 10^{-3} \quad (6)$$

Where D(nGy.h^{-1}) is the absorbed dose rate; 0.2 and 0.8 are the outdoor and indoor occupancy factors, respectively and 0.7(Sv.Gy^{-1}) is the conversion coefficient from absorbed dose in air. (UNSCEAR, 2000)

XRF Analysis

XRF was performed with 100% normalization and full fundamental parameter quantification techniques. The metal content of sodium was determined by ICP-AES to be 0.4, 0.470, 5.14 and 4.12% in ultrabasite (UB), granodiorite-mylonite (D155), granodiorite (D153), and granite (D141A), respectively.

Resolution	178eV at Mn Kα
Window Thickness	12.7μm Be
Rating	50kV, 40μA maximum power of the tube 2W
Beam diameter	7mm
Filter	Element analysis
Ag excitation source	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, and U
Sandwich of Al, Ti and Mo	Ba, Sb, Sn, Cd, Pd, Ag
Cu Filter	Cr, V, Ti, Ca, K
No Filter	Al, P, Si, Cl, S, Mg

Table 1:-Spectrometer specification and operating conditions

Calculation of the pollution index

In this study four techniques to assess metal contamination were used to check the contamination of the soils of Bargny and Dakar city:

1. Index of geo-accumulation I_{geo}
2. Enrichment factor (EF)
3. Contamination factor (CF)
4. Pollution load index (PLI)

Using the equation (7) of (Muller., 1969) the values of the geo-accumulation index of the metals studied were calculated:

$$I_{géo} = log_2(\frac{C_n}{1{,}5B_n}) \quad (7)$$

Where C_n is the measured concentration of element-n in the soil sample, B_n is the geochemical concentration of the background of a soil element-n (Turekian and Wedepohl; 1961) and 1.5 is a factor in correcting possible variations due to the effects lithogenic. (Muller; 1981) gave, according to Igeo's value the ranking as below:

Class	Igeo	Soil Quality
0	$I_{géo} \leq 0$	Unpolluted
1	$0<I_{géo}<1$	Unpolluted to moderately polluted
2	$1<I_{géo}<2$	Moderately polluted
3	$2<I_{géo}<3$	Moderately to strongly polluted
4	$3<I_{géo}<4$	strongly polluted
5	$4<I_{géo}<5$	strongly to extremely polluted
6	$5>I_{géo}$	Extremely polluted

The formula established by (Simex and Helz, 1981) on the calculation of the enrichment factor is:

$$EF = \frac{(\frac{C_x}{C_{ref}})_{sample}}{(\frac{B_x}{B_{ref}})_{Background}} \quad (8)$$

Where C_x is the concentration of the element x of the soil sample of the study site, C_{ref} is the concentration of the reference element, B_x is the background concentration of element x and B_{ref} is the Background concentration of the reference element. In this study Iron was used as a reference metal. Iron is distributed independently of other metals and is abundant in the soil. Five categories of contamination are recognized based on the enrichment (Sutherland , 2000) factor:

EF<2	Deficiency to minimal enrichment
2<EF<5	Moderate enrichment
5<EF<20	Significant enrichment
20<EF<40	Very high enrichment
EF>40	Extremely high enrichment

The measurement of contamination is also carried out by the contamination factor which assesses the anthropogenic contribution of soil pollution by metals. The evaluation is carried out using the formula of (Hakanson, 1980):

$$CF = \frac{C_x}{B_x} \quad (9)$$

Where, C_x is the measured concentration of element x in the sample and, B_x is the concentration of element x of the geochemical background. A classification of contamination according to the value of CF is established by (Hakanson, 1980; Loska, 2004)

CF<1	Low contamination factor indicating low contamination
1≤CF<3	Moderate contamination factor
3≤CF<6	Considerable contamination factor
6≤CF	Very high contamination factor

The pollution load index includes pollution from various heavy metals and directly reflects the level of pollution of all heavy metals at a sampling point (Cao et al., 2016). The PLI was determined by the equation (Tomlinson et al., 1980):

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)^{1/n} \quad (10)$$

Where CF is a factor of contamination and n the number of items studied.

According to the pollution load index, pollution is divided into six levels (Liu, et al., 2018):

First	=0	Backgroung concentration
Second	1~2	Unpolluted
Third	2~3	Middly polluted
Fourth	3~4	Moderately polluted
Fifth	4~5	Highly polluted
Sixth	>5	Very highly polluted

Résultats and Discussion:-

Activity concentration of radionuclides

The descriptive statistics (mean, minimum, maximum and standard error) of naturally occurring radionuclides are given in Table 2. Correlation Analysis was study the relationship between activity concentrations between sampling sites. In addition, a comparative analysis was conducted across undisturbed and disturbed soil sample by using t.test. Prior to application of statistical inference, the activity concentration data were submitted to a statistical test for homogeneity of variance (F-test) and for normally (Shapiro-Wilk test). Whenever both conditions were satisfied, a parametric t-test was applied otherwise; a non-parametric Wilcoxon-Mann-Whitney test was used. The level of significance of test was set to 5%.

Table 2:-Descriptive statistics (mean, standard deviation (sd), Minimum (Min), Maximum (Max) and range) of Activity concentration in Bq.kg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K in the field sampling of disturbed (dist) and undisturbed (Und) soil

	^{226}Ra			^{232}Th			^{40}K		
	Und	Dist		Und	Dist		Und	Dist	
Mean	23.08	25.57		14.85	19.83		168.08	153.7	
Sd	2.63	2.76		2.34	2.55		26.57	14.89	
Min	19.05	22.52		12.34	16.12		124.09	138.03	
Max	28.18	30.95		18.03	23.82		206.35	174.2	
Range	9.13	8.44		5.69	7.70		82.26	36.10	

The activity concentration of ^{232}Th in soil between sampling sites was significantly different ($p<0.01$), which indicated different behavior of the radionuclide beside similar physicochemical soil properties. The average activity $\pm$ standard error for ^{232}Th (disturbed site) was 19.83 $\pm$2.55 Bq.kg^{-1} that is statistically higher to the concentration activity of ^{232}Th (14.85 $\pm$2.34 Bq.kg^{-1}) in the non-disturbed area. Alternatively, the mass concentration of ^{226}Ra and ^{40}K in both site areas was similar. No significant differences were found between the undisturbed site and the disturbed agricultural sampling site, with of p-value>0.5, however the null hypothesis of equality of mean activity on radium-226 was stronger compared to ^{40}K between sites. The reason why ^{40}K mass concentration was not statistically different may be found in the topsoil organic carbon content at the study sites, while soil texture and lithographical similarity may explain the similarity of the site on ^{226}Ra concentration. Both sites have an acidic soil pH, similar annual rainfall and relatively similar soil organic carbon. The measured activity of ^{226}Ra ranged between 22.52 $\pm$ 1.16 Bq.kg^{-1} and 30.95 $\pm$ 1.76 Bq.kg^{-1} in disturbed site and 19.05 $\pm$ 1.07 Bq.kg^{-1} and 28.18 $\pm$ 1.54 Bq.kg^{-1} in the undisturbed area; while the mean activity of ^{40}K was 153.7 Bq.kg^{-1} and 168.08 Bq.kg^{-1} in the disturbed and undisturbed site respectively.

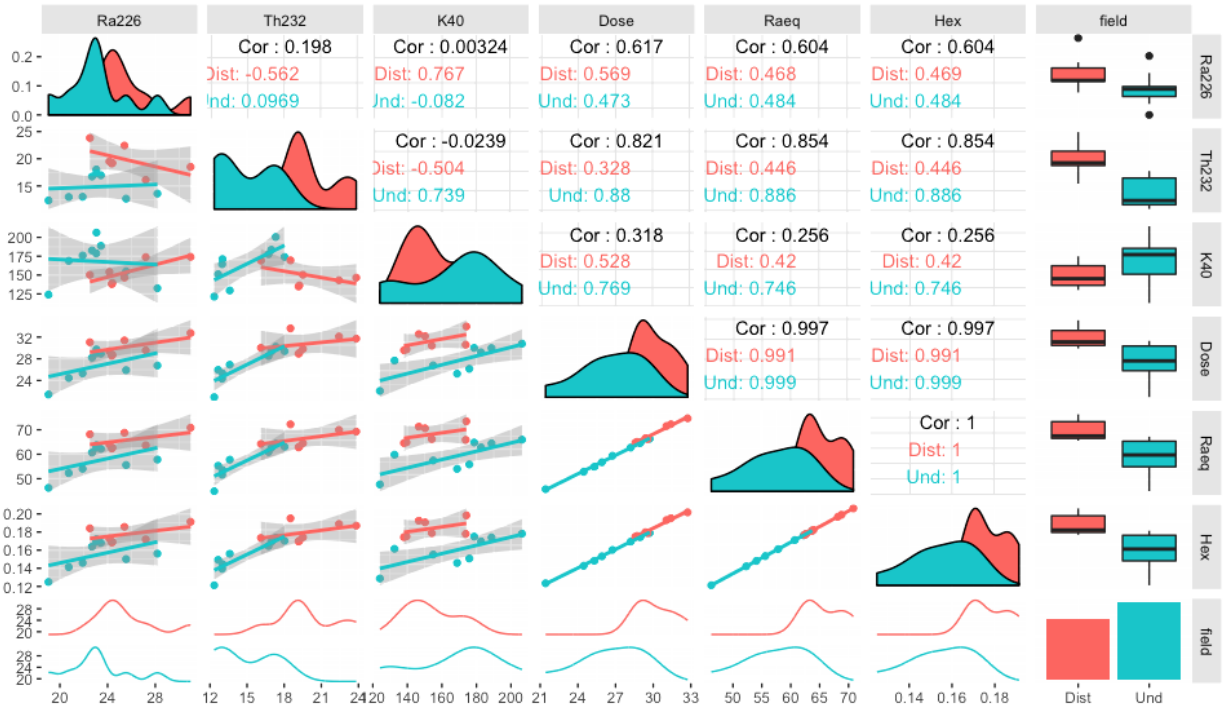

Figure 1: summarizes the statistical correlation, kernel density distribution and comparative boxplot of measured naturally occurring radionuclides and their associated radiological hazard indices. A positively strong correlation was found between ^{40}K(und) and ^{232}Th(Und). In addition, the correlation study between sites results shows non-correlation among radionuclides.

Radiological hazards

Assessment of the radiological hazards includes the calculation of the radium equivalent index (**Ra_{eq}**), external and internal hazard index (**H_{ex} and H_{in})**, the dose absorbed, the indoor annual effective dose and the outdoor annual effective dose. All the results are indicated in **Table 1**. In this table we noted the range of radium equivalent from minimum to maximum was 62.38 Bq.kg^{-1} to 70.83 Bq.kg-1 for Bargny and 46.26 Bq.kg^{-1} to 63.72Bq.kg^{-1}for Dakar city. The means values for each site of study; 65.76Bq.Kg^{-1} for Bargny and 57.26Bq.kg-1 for Dakar city; are smaller than the upper recommended value of 370 Bq.kg^{-1}. The calculated values of external hazard index (H_{ex}) for the samples in the studies area was in the range of 0.12 to 0.17 in Dakar city and 0.17 to 0.19 for Bargny. Their average, 0.15 for Dakar city and 0.18 for Bargny, is lower than unity. It is the same thing, inferior a unit, for the average internal hazard index for the both studies area, 0.25 for Bargny and 0.22 for Dakar city. The internal hazard index various form 0.23 to 0.25 for Bargny and from 0.18 to 0.23 for Dakar city. According to **Table 1**, the gamma absorbed dose rates for soil samples in Dakar city lie from 21.43 to 29.72 nGy.h^{-1} and his mean is 26.64 nGy.h^{-1} and for the soil samples in Bargny, 28.58nGy.h^{-1} to 32.74nGy.h^{-1}and his mean is 30.20nGy.h^{-1}. Based on the report by UNSCEAR, the dose rate from terrestrial gamma rays under normal conditions is approximately 60 nGy.h^{-1} for a population-weighted value. The both means values in the studies area are lower than the worldwide average limit value. The minimum and maximum value of the indoor annual effective dose and the outdoor annual effective dose were found to vary from 140.10 µSv.y^{-1} to 160.62 µSv.y^{-1} and 35.05 µSv.y^{-1} to 40.15 µSv.y^{-1} for Bargny, respectively. And for Dakar City, the indoor annual effective dose and the outdoor annual effective range, respectively, from 105.13 µSv.y^{-1} to 145.79 µSv.y^{-1} and from 26.25 µSv.y^{-1} to 36.45 µSv.y^{-1}. The mean values are 32.67 µSv.y^{-1} and 130.69 µSv.y^{-1} for undisturbed site (Dakar City) respectively for the outdoor annual effective dose and the indoor annual effective dose. Nevertheless, the mean values of the outdoor annual effective and the indoor annual effective dose for Bargny are 37.04 µSv.y^{-1} and 148.15 µSv.y^{-1}, respectively. These values in the present work satisfy the safety criterion for the general public.

	D (nGy.h^{-1})	R_{aeq} (Bq.kg^{-1})	Hazard Index		AEDE (µSv.y^{-1})	
			H_{ex}	H_{in}	Outdoor	Indoor

	Dist	Und	Dist	Und	Dist	Und	Dist	Und	Dist	Und	Dist	Und
Mean	30.20	26.64	65.76	57.26	0.18	0.15	0.25	0.22	37.04	32.67	148.15	130.69
Sd	01.56	02.67	03.40	05.76	0.01	0.02	0.01	0.02	01.91	03.27	07.65	13.09
Min	28.58	21.43	62.38	46.26	0.17	0.12	0.23	0.18	35.05	26.28	140.20	105.13
Max	32.74	29.72	70.83	63.72	0.19	0.17	0.27	0.23	40.15	36.45	160.62	145.79
Range	04.16	08.29	08.45	17.46	0.02	0.05	0.04	0.05	05.1	10.17	20.42	40.66

Table 3:-Descriptive statistics (mean, standard deviation (sd), Minimum (Min), Maximum (Max) and range) of radiological hazard assessment including the Radium equivalent index (Ra_{eq}), the External and Internal Hazard index (Hex and Hin), the gamma absorbed dose (D) and the outdoor and indoor Annual effective dose equivalent (AEDE) in the disturbed (Dist) and undisturbed reference site (Und).

Elément compositions

The analysis of soil samples from the Bargny site by X-ray fluorescence allowed the determination of the concentrations of some chemical elements. The average concentrations of the major elements showed the following classification Ca>Fe>K>Ti whereas those of the minor elements it is to be noted that their average concentrations followed the following decreasing order P>Zr>Cr>Ni>Mn>As>Zn>Cu. The Calcium Ca is the most present element in the soil of the study area of Bargny. The Calcium concentration ranges from 3.28 to 29.12g/kg, while the least common major element, tritium Ti, ranges from 0.11 to 0.30g/kg. (**Table 4**). Calcium contributes to the growth of plants and plays an important role in the health of the human body. The concentration of Ca needed for plant growth ranges from 2000 to 4000mg/kg (Steven, 1995). The average Ca concentration in this study, 16.76 g/kg, is above 4,000mg/kg. The geological cover of the study site includes alternating marls and limestones. Copper is not abundant in Bargny's samples. The concentration found was 1.03mg/kg. Perhaps this is since it is very intensely absorbed by plants, essential for their growth. But also, other facts may be responsible for this observation. The highest average concentration at the level of minor elements was for phosphorus P, 479.21mg/kg. It ranges from 277.07 to 589.86 mg/kg. The phosphorus detected in this site has natural but also anthropogenic origins, the use of fertilizers. The average concentration of arsenic As is 12.43mg/kg. In general, the increase in the content of arsenic as in the environment is due to industrial activities, pesticides and fertilizers.

	Eléments majeurs (g/kg)				Eléments mineurs (mg/kg)							
	Ca	**Fe**	**Ti**	**K**	**As**	**Zn**	**Mn**	**Zr**	**P**	**Cu**	**Ni**	**Cr**
Mean	16.76	2.94	0.20	1.09	12.43	3.00	14.98	109.3	479.21	1.03	18.6	52.97
Sd	10.96	0.38	0.07	0.25	17.15	1.90	5.64	28.00	108.06	-	5.10	40.11
Min	3.28	2.21	0.11	0.53	5.06	2.00	10.03	69.2	277.07	1.03	6.8	20.76
Max	29.12	3.39	0.30	1.30	54.79	7.50	21.78	154.1	589.86	1.03	23.5	112.25
Range	25.83	1.18	0.20	0.77	49.74	5.50	11.75	84.90	312.79	-	16.7	91.49

Table 4:-Descriptive statistics (mean, standard deviation (sd), Minimum (Min), Maximum (Max) and range) of elementals concentrations in the field sampling of disturbed (dist) soil

The average concentrations of the elements of the Dakar city soil samples could be ranked in descending order as follows: Fe>Ca>K>Ti>P>Zr>Mn>Zn>Cr>Cu>Ni>As. (**Table 5**) The average concentrations of the elements determined on the undisturbed site of Dakar city are lower than those of Bargny for Ca, As, Zr and P. The site of Bargny is in an industrial zone, moreover, the market gardening culture which is led there maintain the content of these elements. The concentrations of the elements in the soil are the sum of the concentrations of the elements of natural and anthropic origins. On the other hand, Zn and Cu are more abundant in the study area of Dakar city than in the Bargny study area. This can be attributed to their uptake by plants but also to soil characteristics. Among the minor elements the phosphorus is more abundant then for the major elements the Fe was more abundant.

	Eléments majeurs (g/kg)				Eléments mineurs (mg/kg)							
	Ca	**Fe**	**Ti**	**K**	**As**	**Zn**	**Mn**	**Zr**	**P**	**Cu**	**Ni**	**Cr**

Mean	1.82	4.29	0.24	1.25	2.05	9.74	21.10	54.20	119.57	2.79	2.17	4.57
Sd	0.20	0.77	0.04	0.18	0.29	12.97	5.01	14.80	47.47	-	0.21	1.62
Min	1.59	2.88	0.20	0.98	1.48	4.09	12.47	31.08	44.14	2.79	1.85	1.99
Max	2.14	5.10	0.31	1.54	2.32	39.12	28.19	80.01	174.25	2.79	2.39	6.18
Range	0.55	2.22	0.11	0.56	0.84	35.03	15.72	48.93	130.11	-	0.54	4.19

Table 5:-Descriptive statistics (mean, standard deviation (sd), Minimum (Min), Maximum (Max) and range) of elementals concentrations in the field sampling of undisturbed (Und) soil

The correlation between the concentrations of natural radionuclide activities and the concentrations of chemical elements belonging to the same samples was calculated. Table 7 indicates that the Ca and P have a low and negative correlation with ^{226}Ra and ^{232}Th. The correlation between Ca and ^{40}K is positive low to zero while the correlation between P and ^{40}K is negative low to zero. The K and Zn are moderately and negatively correlated with the ^{232}Th. As and Zn have a strong positive correlation with ^{226}Ra. Compared to ^{40}K, the As and Zn have positive but average correlations for As and strong with Zn. The Zr has a strong negative correlation with ^{226}Ra. So, when ^{226}Ra decreases in the soil the amount of Zr increases. The correlation of Cu to the three radionuclides is low to zero negative except for ^{40}K which is positive. Table 8; ^{232}Th has an average positive correlation with the Ca, Ti, and Zr elements. The correlation of this same radionuclide is positive and strong with Fe. Also, with the ^{232}Th, the correlation with the K, the As, and Mn is positive and weak while it is with the Zn and cu is negative and weak. Elements K and Zr are correlated with the ^{40}K radioactive element in a positive and medium way. With the Fe, Zn and P elements the correlation is low and negative except for the Fe which has a positive correlation with the ^{40}K. Radium 226 has an average negative correlation with Cu, a weak positive correlation with Zn, a low negative correlation with K and Zr.

	^{226}Ra	^{232}Th	^{40}K	Ca	Fe	Ti	K	As	Zn	Mn	Zr	P	Cu	Ni	Cr
^{226}Ra	1.00														
^{232}Th	-0.56	1.00													
^{40}K	0.77	-0.50	1.00												
Ca	-0.29	-0.28	0.14	1.00											
Fe	0.13	-0.34	-0.09	-0.01	1.00										
Ti	0.05	0.18	-0.15	-0.43	0.77	1.00									
K	0.22	-0.67	0.37	0.32	0.74	0.43	1.00								
As	0.88	-0.24	0.61	-0.41	0.35	0.42	0.20	1.00							
Zn	0.94	-0.43	0.79	-0.19	0.28	0.25	0.33	0.95	1.00						
Mn	0.36	-0.08	-0.04	-0.85	0.42	0.63	0.18	-0.61	0.28	1.00					
Zr	-0.88	0.80	-0.79	-0.07	-0.05	0.28	-0.34	-0.61	-0.75	-0.01	1.00				
P	-0.37	-0.30	-0.09	0.78	0.55	0.15	0.69	-0.33	-0.19	-0.43	0.13	1.00			
Cu	-0.23	-0.05	0.01	0.21	0.07	-0.06	0.23	-0.19	-0.25	0.07	-0.05	0.20	1.00		
Ni	0.08	-0.67	0.31	0.61	0.65	0.20	0.94	0.02	0.19	-0.13	-0.31	0.86	0.27	1.00	
Cr	0.82	-0.71	0.88	0.25	0.11	-0.14	0.45	0.62	0.84	-0.12	-0.85	0.09	-0.27	0.44	1.00

Tableau 6:-Pearson correlation for radionuclide concentrations and heavy metal and heavy metal and heavy metal disturbed site

	^{226}Ra	^{232}Th	^{40}K	Ca	Fe	Ti	K	As	Zn	Mn	Zr	P	Cu	Ni	Cr
^{226}Ra	1.00														

^{232}Th	-0.18	1.00													
^{40}K	-0.68	0.61	1.00												
Ca	0.01	0.65	0.21	1.00											
Fe	-0.02	0.76	0.29	0.55	1.00										
Ti	0.08	0.73	0.15	0.56	0.94	1.00									
K	-0.47	0.41	0.53	-0.08	0.65	0.60	1.00								
As	-0.02	0.48	0.08	0.42	0.92	0.83	0.59	1.00							
Zn	0.34	-0.46	-0.34	-0.53	-0.83	-0.74	-0.68	-0.87	1.00						
Mn	0.24	0.31	-0.12	0.36	0.81	0.68	0.39	0.92	-0.75	1.00					
Zr	-0.28	0.72	0.53	0.20	0.88	0.79	0.88	0.77	-072	0.59	1.00				
P	0.06	-0.21	-0.41	0.05	0.27	0.45	0.35	0.45	-0.47	0.33	-0.22	1.00			
Cu	-0.52	-0.36	-0.002	-0.06	-0.22	-0.31	-0.13	0.09	-0.13	-0.03	-0.22	0.14	1.00		
Ni	0.24	0.79	0.14	0.72	0.81	0.73	0.12	0.69	-0.49	0.69	0.55	-0.11	-0.19	1.00	
Cr	-0.07	0.84	0.41	0.59	0.97	0.94	0.67	0.79	-0.79	0.66	0.88	0.23	-0.37	0.75	1.00

Tableau 7: Pearson correlation for radionuclide concentrations and heavy metal and heavy metal and heavy metal undisturbed site

Pollution Level

With the average concentrations of heavy metals contamination indicators such as the geo-accumulation index, the enrichment factor, the contamination factor and the pollution load index were calculated (see Table 9). The Zn, Mn, Cu, Ni and Cr metal geo-accumulation indices are negative, implying the absence of metal pollution at the two study sites. In contrast, the Arsenic has an Igeo equal to about 2 for the disturbed site and 0.07 for the undisturbed site. This would indicate that moderate pollution by arsenic metal had occurred at the disturbed site and no pollution at the Dakar city study site. This result was confirmed by the enrichment factor. The soil of the Study Area of Bargny was significantly enriched by the metal As, the EF was 15.37, while the soil of the study area of Dakar city had an enrichment factor that ranked it among the sites whose enrichment by Arsenic is Minimum. Arsenic is a toxic and carcinogenic element. Increased risks of lung and bladder cancer, as well as skin changes, have been reported in people exposed to high levels of arsenic (WHO, 2015). The Cr enrichment factor was 9.46 at the disturbed Bargny site, indicating the significant enrichment of chromium in the study area. There is no enrichment by the Cr on the ground of the Dakar city site. Chromium can cause health problems in humans. It attacks the airways and leads to gastric problems and stomach ulcers (Reichl, 2004; Klaassen, 2008). Metal enrichment factors Zn, Mn and Cu indicated deficient enrichment at both sites (see Table 9). The EF being between 0 and 1 show that they were of natural origin i.e. earthly crust. Arsenic, Ni and Cr, whose EF values were higher than one in the Bargny site, indicated anthropogenic origins (Zsefer et al., 1996). The CF contamination factor for all heavy metals measured at the two study areas was less than one, which may suggest no contamination at both sites. The PLI values at both sites were much lower than the unit, indicating a lack of pollution for all heavy metals combined.

Heavy metals	Igéo		EF		CF	
	Dist	Und	Dist	Und	Dist	Und
As	2.67	0.07	15.37	1.73	0.96	0.16
Zn	-5.57	-3.87	0.51	1.13	0.03	0.10
Mn	-6.41	-5.92	0.28	0.27	0.02	0.02
Cu	-9.04	-4.59	0.05	0.68	0.002	0.06
Ni	-2.45	-5.55	4.40	0.35	0.27	0.03
Cr	-1.34	-4.88	9.46	0.56	0.59	0.05

Table 8:-Geo-accumulation index (Igeo), Enrichment factor (EF) and Contamination factor (CF) of heavy metals measured in the field sampling of disturbed (dist) and undisturbed (Und) soil

Conclusion:-

The results reported on this paper show that radionuclide activities in both study areas are below the global activity average 35 $Bq.kg^{-1}$; 30$Bq.kg^{-1}$ and 400$Bq.kg^{-1}$ ^{226}Ra; $^{232}Th$and ^{40}K respectively (UNSCEAR, 2000). The average value of doses absorbed in Bargny and Dakar city are below the global average. The same is true for the equivalent radium activity as well as the external and internal hazard index all below their respective global average. The soils of Bargny and Dakar do not present any risk of radiological exposure to population health.

Regarding the assessment of the risks of heavy metal pollution, measurements of geo-accumulation and enrichment factor set to light significant enrichment on the part of elements such as arsenic and chromium at the Bargny's disturbed. The CF and the PLI did not indicate any contamination at the two sites. Concentrations of chemical elements at both sites show similar orders of magnitude for concentrations of major elements except for calcium, which is more abundant in Bargny. The values of global average concentrations of certain elements found in this paper are higher than the concentrations measured in this paper except for the arsenic ace at the Bargny site, which has a concentration almost double that of the global average. The concentration of chromium at the disturbed Site of Bargny is close to the global average concentration of chromium. The global average concentrations of the elements are 7038, 267, 59.5, 29, 488, 6.83, 70 and 38.9mg/kg respectively for Ti, Zr, Cr, Ni, Mn, As, Zn and Cu.(Kabata-Pendias, 2011). This work can serve as a reference on the follow-up to the evolutionary state of natural radioactivity and heavy metal content at both study sites.

Références:-

1. Ajayi, O. S., Dike, C. G., & Balogun, K. O. (2018). Elemental and radioactivity analysis of rocks and soils of some selected sites in southwestern Nigeria. Environmental Forensics, 19:2, 87-98 DOI: 10.1080/15275922.2018.1448906.
2. Beretka, J., & Mathew, P. J. (1985). Naturel radioactivity of Australian building materiels, industrial wastes and by-products. Health Phys, 48:87-95. https://doi.org/10.1097/00004032-198501000-00007.
3. Cao, L. W., Hu, S. Y., Erwin, A., Shi, S. L., & Yin, G. (2016). The spatio-temporal variation of magnetic properties of tree leaves in Linfen, China and its indication to the atmospheric pollution of heavy metals. . Chin. J. Geophys., 59, 1729-1742.
4. Daryouch, G., Mehrdad, G., & Samaneh, S. (2013). A review on natural background radiation. Adv, Biomed Res., 2, 65.
5. El-kameesy , S. U., Afifi, S. Y., & Hamidalddin, A. e. (2015). Elemental and radioactivity concentration of stream sediments in Abu-Rusheid, Nugrus Area-South Eastern Desert, Egypt. American Journal of Physics and Applications, 3 (6):, 183-189.
6. Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentalogical approach. Water Res, 14:, 975-1001.
7. ICRP. (1993). International commission on radiological protection ICRP publication 65 Annuals of the ICRP Oxford. Pergaman Press.
8. Kabata-Pendias, A. (2011). Trace elements in soils and plants, Fourth edition. Taylor and Francis.
9. Klassen, R.. A.; Garrett, R. G.,; Dilabio, R. N., W;. (2008). Sources naturelles de contaminants à l'état de traces. In Environnement Canada. Menaces pour les sources d'eau potable et les ecosystemes aquatiques au Canada.
10. Liu, Y., Li, S., Sun, C., Qi, M., Yu, X., Zhao, W., & Li, X. (2018). Pollution Level and Health Risk Assessment of PM2.5-Bound Metals in Baoding City Before and After the Heating Period. Int. J. Environ. Res. Public Health, 15, 2286.
11. Loska, K., Wiechulsa, D., & Korus, I. (2004). Metal contamination of farming soils affected by industry. Environ. Int., 30:, 159-165.
12. Loska, K.; Wiechula, D. (2003). Application of principal componet analysis for the estimation of source heavy metal contamination in surface sediments from Rybnik Reservoir. Chemosphere, 51, 723 - 733.
13. Mench, M. J., Manceau, A., Vangronsveld, J., Clijsters, H., & Mocquot, B. (2000). Capacity of soil amendments in lowering the phyto availability of sludge-borne Zinc. Agronomics, 20, 383-397.
14. Muller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. Geology Journal, 2:, 109-118.
15. Muller, G. (1981). Die Schwermetallbelastung der Sedimenten des Neckars und Seiner Nebenflusse. Chemiker Zeitung, 6:, 157-64.
16. Nriagu, J. O., & Pacyna, J. M. (1988). Quantitative assessment of worldwide contamination of air, water and soil by trace metals. Nature, 333, 134-9.

17. Quindos, L. S., Fernandez, P. L., & Soto, J. (1987). Building material as source of exposure in houses. Indoor Air. 87(2), 365.
18. Reichl, F. -X. (2004). Guide pratique de toxicologie. Bruxelles. De Boeck Université, 348 p.
19. Simex, S. A., & Helz, G. R. (1981). Regional geochemistry of trace elemnts in Chesapeake Bay. Environmental Geology, 3:, 315-323.
20. Steven, C. H. (1995). Soil Fertility Basics, Soil Science Extension North Carolina State University Crop Advisor Training. 2-75.
21. Sutherland , R. A. (2000). Bed sediment-associated trace metals in an urban stream, Oahu, Hawaii. Environ Geol, 39:, 611-27.
22. Tomlinson, D. C., Wilson, J. G., & Harris, C. R. (1980). Problems in the assessment of heavy metals in estuaries and the formation pollution index. Helgoland Marine Research, 33:, 566-575.
23. Turekian, Y. Y., & Wedepohl, K. H. (1961). Distribution of the elements in some major units of the earth's crust. Geological Society of America, 72:, 175-192.
24. UNSCEAR, U. N. (2000). Report to the General Assembly, with Scientific Annexes,. New york: United Nations,.
25. WHO, W. (2015). Toxicity of Arsenic in soil. Available on : http:/www.who.int/mediacentre/factsheets/fs372/en/.
26. Zsefer, P., Glasby , G. P., Sefer, K., Pempkowiak, J., & Kaliszan, R. (1996). Heavy metal pollution in superficial sediments from the southern Baltic Sea off Poland. J Environ SCi Health A, 31:, 2723-2754.