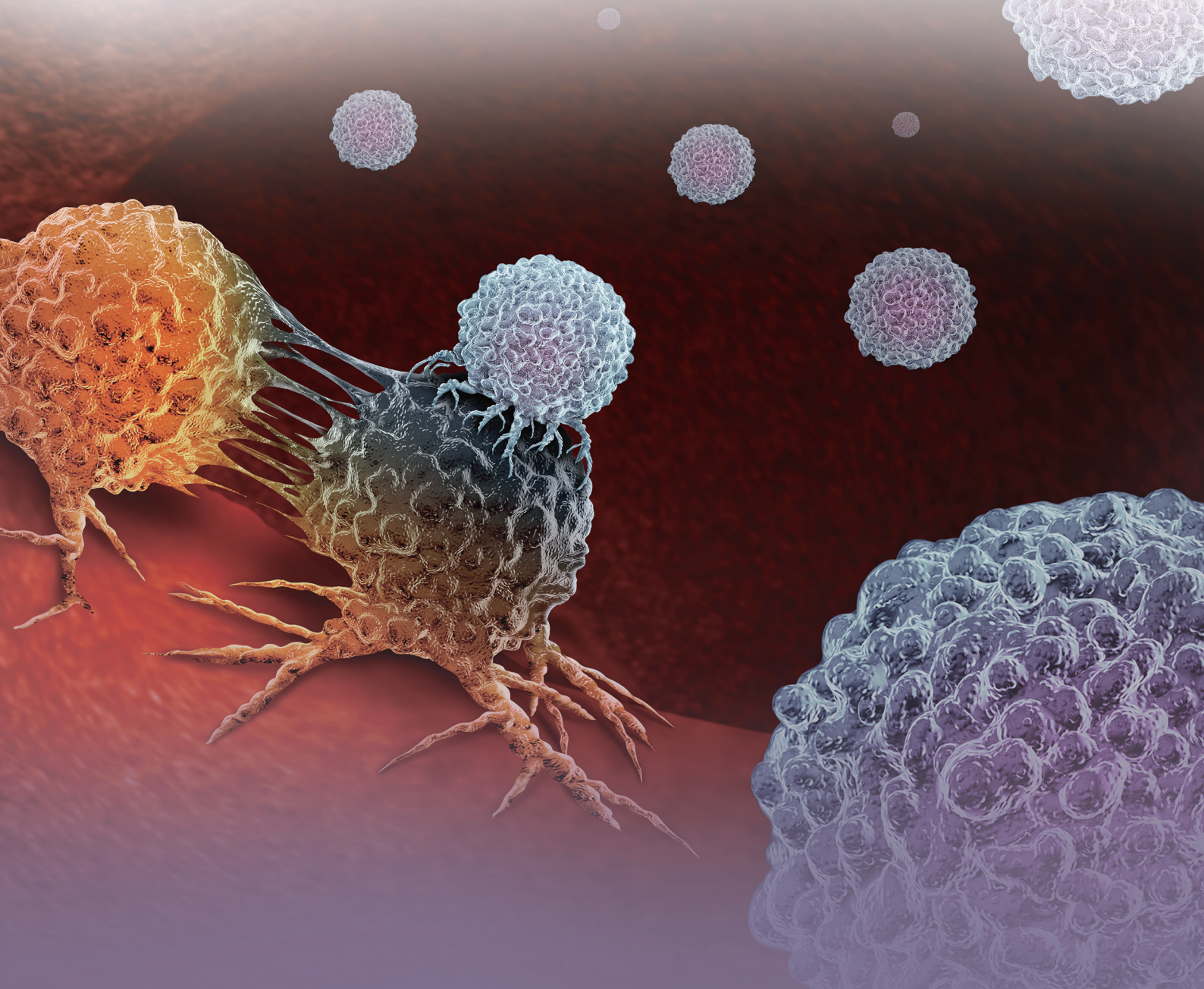
BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Oncology Research

Volume 4 · Issue 2 · July 2022 ISSN 2630-5267 (Online)



Volume 4 Issue 2 • July 2022 • ISSN 2630-5267 (Online)

Journal of Oncology Research

BILINGUAL PUBLISHING CO.

Pioneer of Global Academics Since 1984

BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Volume 4 | Issue 2 | July 2022 | Page1-37
Journal of Oncology Research

Contents

Articles

BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Oncology Research
https://ojs.bilpublishing.com/index.php/jor

ARTICLE

Relationship between D90 and D100 with Biochemical and Local Failure in Low-risk Prostate Cancer Treated with Low-rate Brachytherapy (LDR)

Marta Domínguez Morcillo* **Carmen Ibáñez Villoslada** **Joaquín Navarro Castellón** **Paula Sáez Bueno** **Eliseo Carrasco Esteban** **Andrea Matas Escamillas** **Zigor Zalabarría Zarrabeitia** **María Concepción López Carrizosa**

Department of Radiation Oncology, Hospital Central de la Defensa, Universidad de Alcalá de Henares, Madrid, Spain

ARTICLE INFO

Article history
Received: 17 May 2022
Revised: 6 July 2022
Accepted: 12 July 2022
Published Online: 19 August 2022

Keywords:
Brachytherapy
Prostate
Cancer
Dose
Failure
Biochemical
Local

ABSTRACT

Low dose rate brachytherapy (LDR) is an accepted, effective treatment with few local side effects, used as monotherapy in patients with low-risk prostate cancer (PC). The aim of this paper is to analyse 245 patients treated with LDR in the Radiation Oncology Department of the Hospital Gómez Ulla, from 2004 to 2016, evaluating the relationship of dosimetric parameters with biochemical and local recurrence as well as genitourinary and gastrointestinal toxicity derived from the technique. The results obtained show a clear relationship between the dose used and biochemical and local failure.

1. Introduction

There are strong data showing similar local control and survival rates when comparing LDR to other techniques such as external radiotherapy or radical surgery with lower risk of genitourinary and gastrointestinal side effects. Few studies in the literature analyse the relationship between the dose received by 90 and 100 percent of the prostate and the development of biochemical and local failure. This study offers some important insights in this regard, with the main objective of this paper being: *"To*

*Corresponding Author:
Marta Domínguez Morcillo,
Department of Radiation Oncology, Hospital Central de la Defensa, Universidad de Alcalá de Henares, Madrid, Spain;
Email: martadominguezmorcillo@gmail.com

DOI: https://doi.org/10.30564/jor.v4i2.4721

demonstrate the relationship between D90 and D100 and biochemical and local failure."

2. Material and Methods

2.1 Design

This is a longitudinal observational survival study.

2.2 Study Population

Patients from the districts of Carabanchel and Latina, Military Health patients (ISFAS) from the Community of Madrid or from other Autonomous Communities or from another district in whose reference hospital the technique is not performed.

2.3 Sampling

Patients who met the criteria to be candidates for this treatment were selected by non-probabilistic consecutive sampling. Patients included adhere to the RTOG patient selection criteria [1].

2.4 Inclusion Criteria

- Males;
- No age limit. Life expectancy greater than 10 years;
- Diagnosed with low-risk prostate cancer, with which they must meet:
  - Gleason ≤ 6
  - PSA < 10
  - Clinical stage T1c-T2a

2.5 Exclusion Criteria

- Patients who have already received previous treatment with Brachytherapy or External Radiotherapy.
- Previous transurethral resection (TUR), in which a significant prostate volume has been resected (relative contraindication).
- Prominent median lobe.
- Pubic arch precluding seed insertion.
- Glandular size > 60 cc.

2.6 Sample Size

A total of 245 patients were recruited between 2004 and 2016. All of them signed the corresponding informed consent for the technique.

2.7 Material

- Computer with specific planning software.
- Stabiliser (stepper) fixed to the table with connectivity to the ultrasound machine.
- A template (template for needle placement) with a matrix of 13 Å~ 13, with 5 mm distance between the needle holes with a gauge of 17 and 18.
- Stabilising needles and specific brachytherapy needles with stylet with markings every 5 mm and radioactive seeds.
- Cutter or seed binding system with loading system when using needles preloaded with stranded, linked, or loose seeds and/or a Mick applicator or similar device to load seeds into the prostate and seed cartridges for this system.
- A source or needle holder with radiological protection where the loaded needles and/or carriers should be deposited until implantation.
- Ionisation chamber for calibration and control of the implant seeds.
- Radiation detector.
- Usual material for anaesthesia and surgical technique.

2.8 Method

2.8.1 Pre-implant

On the day of the first consultation, all the patient's clinical data is collected and a complete clinical examination and a transrectal ultrasound scan is performed to determine the prostate volume. The number of seeds required, and their activity, is requested on an individual basis, based on knowledge of the patient's prostate volume and anatomical characteristics.

2.8.2 Implant

On the day of the operation, the procedure is as follows:

Positioning

Once the anaesthesia (spinal anaesthesia or general anaesthesia) has been administered, the patient is placed in the lithotomy position.

Planning

The implant technique is carried out with intraoperative planning; ultrasound images are obtained every 0.5 cm from the base to the apex. The images are transferred to the planner. The images are processed, and the prostate, urethra and rectum are delimited in each of the slices and intraoperative dosimetric planning is performed. Seeds are inserted with pre-loaded needles. Evaluation of dose-volume histograms, limiting doses in organs at risk [2].

Dose prescription to target volume

If GTV is visible on imaging, it should be covered by

the 150% isodose [3]. For CTV, the dosimetric parameters should be:

- V100 ~ 100 %
- D90, CTV > 100% DP
- V150 < 50%

Organs at risk

Rectum (Dmax < 200 Gy, D100≤ 100% of dose prescription, D2 cc < 145 Gy) and urethra (D10 < 150% of dose prescription, D30 < 130% of dose prescription).

Despite previous recommendations, The Royal College of Radiologists in the UK, due to the historical experience of many centres, also considers V100prostate > 98% and V150prostate = 40%-65% acceptable. Post-implant dosimetry should be performed, and the following parameters should be analysed:

- Target volumes: D90%, V100%, and V150%.

Organs at risk: D10% and D30% for the urethra, and D2 cc and D0.1 cc for the rectum.

2.9 Statistical Method

2.9.1 Descriptive Statistics

Indices of central tendency and dispersion for quantitative variables were the arithmetic mean and standard deviation $\bar{x}$(SD) or the median and interquartile range Md (IQR), depending on the assumption of normality as determined by the Kolmogorov-Smirnov (K-S) test, respectively.

For categorical variables, absolute and relative percentage frequencies were used.

As graphical representations, bar diagrams were used for categorical variables, and box plots for quantitative variables assuming or not, respectively, the assumption of normality (K-S or S-W).

2.9.2 Analytical Statistics

The measure of association between two categorical variables was performed using Pearson's χ^2, or Fisher's exact test if both were dichotomous, in which case the assessment of the effect was performed.

To determine the association between a dichotomous independent variable and a quantitative dependent variable with a parametric distribution, the Student's t-test for independent samples was used. The effect was assessed by the mean difference, and precision by the 95% confidence interval.

The measure of association between a polytomous independent variable and a quantitative dependent variable was estimated with Snedecor's F-test (one-way ANOVA) or the Kruskal Wallis test, depending on whether it was Gaussian or not, respectively.

The survival study was performed using the Kaplan Meier method. In all cases, a value of $p<0.05$ will be used as the degree of statistical significance and the statistical application will be the SPSS® package version 25.

3. Results

3.1 Sample Characteristics

In Table 1, the following sample characteristics are listed. The mean age was 68 years (49 years - 82 years). The mean Karnofsky index was 99.43 (4.1).

At diagnosis, 16.3% (40 patients of the total sample) had perianal pathology, such as external haemorrhoids: 13.5% (33 patients), anal fissures: 1.6% (4 patients), anal fistulas: 1.2% (3 patients).

Table 1. Characteristics of the patient sample

	Total N: 245 n (%)
Age	68 (6.2)
IK	99.43 (4.1)
Haemorrhoids n (%)	33 (13.5)
Anal Fissure n (%)	4 (1.6)
Anal Fistula n (%)	3 (1.2)
Oncological background n (%)	24 (9.8)
Previous pelvic surgery n (%)	89 (36.3)

Of the entire sample, 24 patients (9.8%) had been diagnosed with a previous oncological process.

In Table 2, patients with previous surgeries are classified by type, frequency and percentage:

Table 2. Type of previous surgery

	Frequency	Percentage (%)
Prostatic adenectomy	5	2.0
Inguinal Hernia	46	18.8
Appendectomy	15	6.1
Renal transplant	1	0.4
Lithotomy	1	0.4
Nephrectomy y lymphadenectomy	2	0.8
Right hemicolectomy	4	1.6
RTU	5	2.0
Total Surgery	79	32.2
Total Patients	245	100

The median time to PSA Nadir was 3.75 years (2.2) and the median PSA Nadir value was 0.2 ng/mL.

3.2 Biochemical Recurrence-free Survival

Biochemical Progression Free Survival is defined as the time from implantation to biochemical relapse according to the Phoenix criteria described above.

Of the total patients in the sample, 36 (14.69%) failed biochemically during follow-up and one third of the patients, 10 patients (4.08%) failed within the first two years after brachytherapy.

The biochemical progression-free survival at 5 years was found to be 88% and 78% at 10 years.

Half of the patients (46.8%) did not progress biochemically at 13.4 years of follow-up, as can be seen in Figure 1.

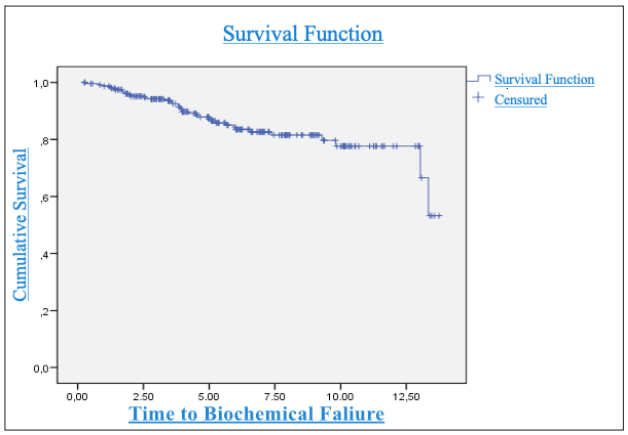


Figure 1. Graph of biochemical recurrence-free survival.

3.3 Relationship between Target Volume Dosimetry and Biochemical Recurrence

The possible relationship between D90 (dose received by 90% of the prostate) and D100 (dose received by 100% of the prostate) with biochemical recurrence has also been studied.

3.3.1 For D90

The mean dose at D90 of patients with biochemical recurrence was 149.5 (21.9).

The mean dose on D90 for patients who did NOT experience biochemical recurrence was 159.4 (12.5).

Thus, patients who did NOT have biochemical recurrence received 9.8 Gy more (95% CI 4.7 - 15) with a $p<0.001$.

The precision of the 95% confidence interval for the extra Gy for those with biochemical recurrence is quite wide, possibly more precise if the number of patients with biochemical recurrence were increased in a subsequent study.

We can therefore conclude that there is a statistically significant relationship between D90 and biochemical recurrence, in the sense that patients with a D90 of 149.52 Gy on average (21.91) relapsed more, $p<0.001$, as seen in Table 3:

3.3.2 As for D100

The mean dose on D100 for patients with biochemical recurrence was 94.8 (19.6).

The mean dose on D100 of patients who did NOT have biochemical recurrence was 106.2 (13).

Thus, patients who did NOT have biochemical recurrence received 11.4 Gy more (95% CI 6.2 - 16.6) with a $p<0.001$, as seen in Table 4.

The precision of the 95% confidence interval for the extra Gy for those with biochemical recurrence is quite wide, possibly made more precise by increasing the number of patients with biochemical recurrence in a subsequent study.

3.4 Local Recurrence-free Survival

The number of local recurrences observed during the study period was 18 cases (7.4%). All these patients had previous biochemical recurrence.

Table 3. Relationship between D90 and biochemical relapse

	Biochemical recurrence	N	Mean	Standard Deviation	Deviation Mean Error
Dose in 90% of the prostate	yes	36	149.5290	21.90853	1.56092
	no	197	159.3511	12.47962	2.07994

Table 4. Relationship between D100 and biochemical recurrence

	Biochemical recurrence	N	Mean	Standard Deviation	Deviation Mean Error
Dose in 100% of the prostate	yes	191	94.7461	19.63371	1.42065
	no	36	106.1517	13.01777	2.16963

The first one appeared at 1.5 years and the last one at 13.7 years.

At 5 years 95.3% were free of local recurrence and at 10 years 89.2% were free of local recurrence.

Slightly more than half of the patients (51.8%) had local recurrence at 12.1 years with a 95% CI (11.4 years and 12.6 years) as can be seen in Figure 2.

3.5 Relationship between Target Volume Dosimetry and Local Recurrence

We have also studied the possible relationship between D90 (Dose receiving 90% of the prostate) and D100 (Dose receiving 100% of the prostate) with local recurrence.

3.5.1 As for D90

The mean dose at D90 of patients with local recurrence was 150.47 (21.24).

The mean dose at D90 for patients who did NOT experience local recurrence was 157.9 (17.11).

Thus, patients who did NOT have local recurrence received 7.43 Gy more (95% CI 1.47 -16.32) with a p: 0.097, as seen in Table 5.

The precision of the 95% confidence interval for the extra Gy for those with local recurrence is quite wide (1.47 - 16.32), possibly more precise if the number of patients with local recurrence was increased in a subsequent study.

We can therefore conclude that there is NO statistically significant relationship between D90 and local recurrence, although there is a clear tendency for patients with higher D90 doses to have less local recurrence.

3.5.2 As for D100

The mean dose on D100 for patients with local recurrence was 95.72 (19.29).

The mean dose on D100 of patients who did NOT have local biochemical recurrence was 106.16 (15.03).

Thus, patients who did NOT have local recurrence received 10.44 Gy more (95% CI 1.23 -19.63) with a p: 0.026, as seen in Table 6.

The precision of the 95% confidence interval for the extra Gy for those with local biochemical recurrence is, as in the previous results, quite wide and would possibly be more precise if the number of patients with local recurrence were increased in a subsequent study.

Therefore, we can conclude that there is a statistically significant relationship between D100 and local recurrence, in the sense that patients with a higher mean dose of 106.16 Gy (15.03) relapsed less. 95% CI (95% CI 1.23 - 19.63) with a p: 0.026.

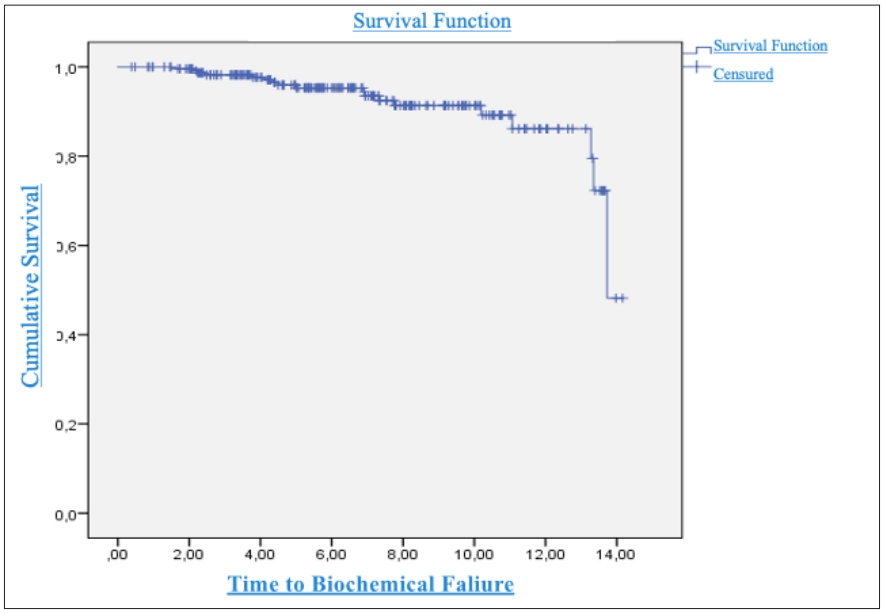


Figure 2. Time to local recurrence

Table 5. Relationship between D90 and local recurrence

	Local Recurrence	N	Mean	Standard Deviation	Deviation Mean Error
Dose in 90% of the prostate	yes	215	150.4727	21.24236	1.44872
	no	18	157.9017	17.11992	4.03520

Table 6. Relationship between D100 and Local Recurrence

	Local Recurrence	N	Mean	Standard Deviation	Deviation Mean Error
Dose in 100% of the prostate	yes	209	95.7276	19.29846	1.33490
	no	18	106.1611	15.03660	3.54416

4. Discussion

Prostate cancer is the second most diagnosed cancer in men with an estimated 34,394 cases in 2019, it has a high prevalence and although in terms of mortality it is not at the forefront, it is essential for a cure to choose the best therapeutic strategy, individualising each case according to risk groups and patient characteristics.

Despite the advances made in recent years in the treatment of localised prostate cancer with robotic surgery and new external radiotherapy techniques, this work focuses on demonstrating that low-dose rate (LDR) prostate brachytherapy is an excellent technique for the treatment of low-risk prostate cancer, with excellent results in terms of disease control and survival, while offering a good quality of life for the patient with acceptable genitourinary and gastrointestinal toxicity results.

Brachytherapy has rapidly gained popularity as an accepted, effective, and safe therapy for localised prostate cancer. There is strong follow-up data beyond 10 years showing similar biochemical control rates to radical prostatectomy and external beam radiotherapy [4,5] with lower risk of incontinence and impotence compared to surgery and better preservation of healthy tissues compared to EBRT [6,7].

The aim of this work is to analyse the 245 patients diagnosed both in our hospital centre and in others, in the community of Madrid or outside the EU, who were treated with low dose rate brachytherapy in monotherapy in our service from 2004 to 2016.

The data obtained in the analysis of results have been compared with data obtained from publications from specialised centres worldwide and it has been found that both the primary and secondary objectives are consistent with what has been published in the last ten years.

However, we have focused on analysing in more depth the most recent publications, specifically since 2014.

In recent years numerous groups have reported medium- and long-term results, however, many of these studies were multicentre and had variable patient selection criteria (such as including not only low-risk patients, but also unfavourable intermediate-risk patients in combination with ETN).

Furthermore, few of these studies were European, the first results published by Prada et al. in 2010 [8] were very encouraging, although the patient sample was very heterogeneous.

Given this context, we present in this paper our experience over 14 years in the treatment with low-rate brachytherapy for patients with low-risk prostate cancer in monotherapy with a homogeneous sample of patients treated in a single institution, the Defense Central Hospital.

The characteristics of our series are very similar in terms of median age (67 to 69 years) to most publications [9,10], as well as the maximum prostate volume which in all cases has been less than 50cc or the number of seeds and needles used with a median very similar to that of our series [11,12].

However, there is a very important aspect that differentiates us from other publications and that is that in our study we only included patients with low-risk prostate cancer and did not use other treatments such as androgen derivation therapy (ADT), which is a factor that in some studies may be related to the results of local control; nor was combined treatment with external radiotherapy carried out in any of the cases. All the published studies include a lower percentage of patients with intermediate risk prostate cancer with a good prognosis to whom ADT treatment [13] was added and some studies even publish results for high-risk prostate cancer [14], which is why the results must be evaluated taking these aspects into account.

4.1 Survival Free of Biochemical Recurrence.

To calculate this, we have considered the date of implantation and the date of biochemical recurrence, defined by the PHOENIX criteria [15] (3 consecutive elevations that are two points above the PSA Nadir figure).

Of the 245 patients in our study, 38 patients relapsed biochemically, giving a 5-year biochemical recurrence-free survival rate of 88% and a 10-year survival rate of 78%.

We have seen that these data are slightly below the survival rates of other studies (we will look at the most relevant ones, because of their similarity to our study, because they have a large sample size, because they are published in high impact journals and finally because they are very recent publications).

The study by Chao et al. [16] (Australian Study) published in 2018, analyses overall survival and biochemical recurrence-free survival in 371 patients all treated with LDR brachytherapy in monotherapy, reports 5-year data of 95%. This study included 33% of patients with intermediate-risk prostate cancer; subgroup analysis found a higher rate of biochemical recurrence in the intermediate-risk group. The dose administered was the same as ours, 145 Gy, and the median D90 was 144 Gy with an SD (64-215).

Another very interesting study looking at possible factors associated with biochemical recurrence and survival in 974 patients treated with LDR brachytherapy is Routman et al. [9] (Mayo Clinic) published in 2018.

In this study the baseline characteristics of the patients are very similar to ours but as in the previous study, 20% of the patients were intermediate risk of which 30% received ADT.

The 5-year biochemical recurrence-free survival results were 96% at 5 years and 88% at 10 years; however, analysing only those in the intermediate-risk group, the 10-year survival rate dropped to 74%.

The most significant conclusions of this study were the following:

- The use of ADT reduced the risk of biochemical recurrence with statistical significance. In our study, no patients were treated with ADT, so our poorer results may be partly related to this fact.

- Gleason (4 +3) was the variable most frequently associated with biochemical recurrence and reached statistical significance.

The third most relevant study is that of Rasmusson et al. [10] (Swedish study) published in 2016, whose primary objective is to study the relationship between D90 and biochemical recurrence.

In this study only 10% of the 195 patients were intermediate risk and a percentage of the low-risk patients received ADT to reduce prostate volume. The 5-year biochemical recurrence-free survival was 95.7%.

Older series with similar patient characteristics also show biochemical recurrence-free survival rates of around 90% at 5 years.

The fact that we were below these values led us to wonder about the possible causes. Upon close observation of the sample, we saw an abnormal PSA evolution in some patients who relapsed biochemically in the first months after treatment, even presenting extreme PSA values at the third- and sixth-month post-implantation, in all cases it was ruled out that it was a PSA rebound and biochemical recurrence was confirmed according to the Phoenix criteria. This can be seen in Figure 1. PSA evolution over time up to 40 ng/mL.

Therefore, we wondered whether there might have been a diagnostic failure, among other causes, and these patients really had a more aggressive cancer and hence the poor outcome.

Of the 36 patients who relapsed biochemically during the entire follow-up period, 18 patients were diagnosed in our centre and the other 18 outside, both in the community of Madrid and in other autonomous communities, making it impossible for us to access samples from other centres for reanalysis.

Given the accessibility we had with the Anatomical Pathology Service, we asked them to review the samples from our hospital. Thus, all the crystals were removed again to re-evaluate the cases with an observer who would either ratify the diagnosis or perform new sections stained with haematoxylin-eosin or with immunohistochemistry techniques as required.

The results of this reassessment showed that of the 18 patients referred, 15 were understaged and corresponded to a Gleason 7 (4+3).

There were several explanations for the variation in the results. Firstly, the lack of homogeneity in the samples received by the Urology Department. Some containers contained only fragments of cylinders separated into left and right, with minimal thickness which, when processed, was reduced to a quantity of tissue that might not be representative of the entire lesion. At the time when these diagnoses were made, there was a shortage of technicians and pathologists in the Anatomical Pathology Department. The technicians cut the cylinders, stained them with haematoxylin-eosin, and the pathologists, lacking sub-specialisation in uropathology, reported the case.

In the cases in which cylinders with little tissue were observed, they were deepened to obtain a larger study surface. In the new observation, tumour areas of the same diagnosed grade appeared but the percentage changed in some of the patients. In others, a higher grade that had not initially been diagnosed appeared. In doubtful cases, immunohistochemical techniques (Racemase, p. 63) were used to establish the diagnosis.

Therefore, the fundamental cause of the variation in grading was insufficient devascularisation of the cylinders.

Given these findings, we wondered whether the rest of the patients diagnosed in our centre, even if they had not had a poor clinical course, were correctly staged, so we re-evaluated the biopsies of 110 patients (the rest had been diagnosed in other centres); all of them were correctly staged (Gleason 6 or less).

Therefore, the statistical analysis was redone excluding those 15 patients who, because they were Gleason 7

(4+3) and this factor was considered intermediate risk, brachytherapy alone would not have been the treatment of choice.

As for the 18 patients who relapsed biochemically and were diagnosed outside the centre, we left them in the initial sample as we were unable to access the biopsies and re-evaluate them.

Thus, 5-year survival free of biochemical recurrence, excluding the 15 intermediate-risk patients, would be 91.8% at 5 years and 87.2% at 10 years. This represents an improvement of 4% and 9% respectively with respect to the initial sample. These results are more in line with those reported in the literature.

We can conclude that in our procedure, several factors may have contributed to biochemical recurrence-free survival rates slightly below the mean of other studies.

Perhaps the most significant, as it is the one, we have been able to verify, was the Gleason understaging of the 15 patients at our centre and perhaps of a high percentage of patients diagnosed at other centres.

It is also a factor to consider that our patients did not receive ADT and as concluded in the study by Routman et al., the use of hormonal treatment reduced the risk of biochemical failure reaching statistical significance.

From the study by Prada et al. [17] published in 2016, we can also draw results that are like those of our series, even though it is a smaller sample of patients, 57 patients were studied, all with previous TUR, from which results were obtained for Survival free of biochemical recurrence, Overall Survival and Survival free of local recurrence. The sample included patients with low and intermediate risk and 40% received hormone therapy for 3 months.

Biochemical recurrence-free survival was 94% at 5 years and 91% at 10 years.

The most important finding of this study that differentiates it from others previously described is that Cox proportional hazards regression revealed NO statistically significant association for clinical T stage, Gleason value, pre-treatment PSA, age, brachytherapy dose (D90) and ablative hormonal treatment with biochemical recurrence. Although this is a very comprehensive study, the sample size is small.

In 2016 the results of a multicentre study in Italy were also published by Fellin et al. [13]. This is a very relevant study as it includes 2,237 patients from 11 hospitals in Italy in whom low dose rate brachytherapy was performed with a median D90 of 149 Gy, very similar to that obtained in our study.

The largest percentage of patients was low risk (66.4%) but patients with intermediate risk prostate cancer (26%) and even 1.8% of high-risk patients were also included. Hormone therapy was given to 39.4%.

In this study the 5-year and 7-year biochemical recurrence-free survival results were 91.8% and 88.7% for the total sample, and the results improved in the subgroup analysis, being worse as expected in the intermediate risk group.

The results of this study are very similar to ours, perhaps because we also included a percentage of patients with intermediate risk of worse prognosis (Gleason 4+3) which, although not considered at the time of implantation, has been confirmed a posteriori.

A very complete and relevant study in our setting was published in 2015 by Martínez et al. [14] from the Catalan Institute of Oncology (ICO) in which the results of brachytherapy in monotherapy were presented for 700 patients, 91% of whom were low risk, which represents a very high percentage of the total; the characteristics of the patients in terms of median age, prostate volume, recurrence criteria, follow-up, implant dosimetry and evaluation of toxicity is practically the same as that carried out in our centre.

The results obtained for biochemical progression-free survival at 5 years and 10 years were 95% and 85%, respectively.

In 2014, the Department of Radiation Oncology at Cleveland University, Ohio, published a very interesting study led by Kittel et al. [18], with a large sample size (1,989 patients from a single institution) that mainly evaluated the efficacy and toxicity of low-dose rate brachytherapy in all prostate cancer risk groups.

Importantly, in multivariate analysis, biochemical progression-free survival decreases significantly as we increase in risk groups, as seen on Figure 3.

Thus:

- For Low risk at 5 and 10 years the bRFS is 95.3% and 86.7%.

- For Intermediate Risk of good prognosis at 5 years and 10 years the bRFS is 90% and 79.3%.

- For Intermediate Poor Prognostic Risk at 5 years the bRFS is 80.9%.

- For High 5-year risk the bRFS is 67.5%.

Intermediate-risk prostate cancer with a good prognosis is defined as having only one intermediate risk factor excluding Gleason 7 (4 +3) and a PSA greater than 15 ng/mL.

Although in our work we did not perform a multivariate study as such since it was only a posteriori that we were able to verify that 15 of our patients were understaged and would currently be classified as intermediate risk prostate cancer with worse prognosis, Gleason 7 (4 +3), we can conclude that in the second outcome analysis

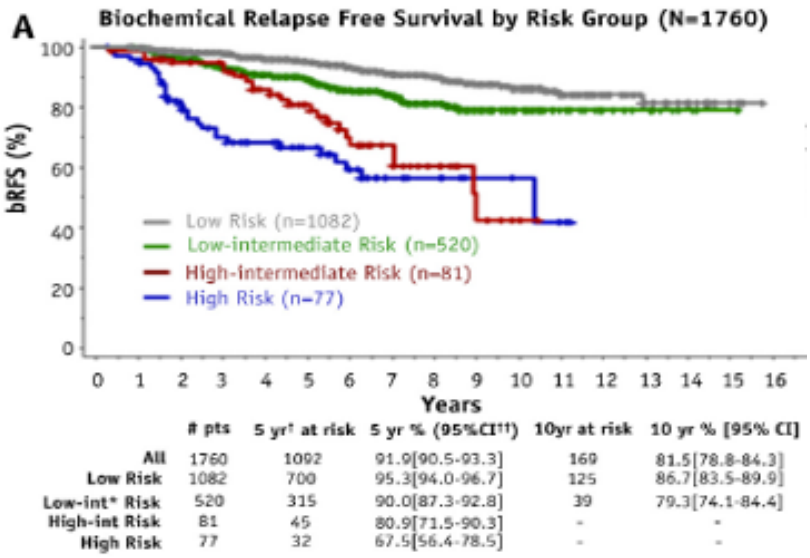


Figure 3. Biochemical recurrence-free survival by risk groups

we performed, our 5-year bRFS rate was similar to the one presented in this study, 91.8% vs 95.3% for low risk.

However, at 10 years we were slightly above 87.2% vs. 86.7%.

In our study we would most probably have obtained higher rates if we had been able to analyse the biopsies of patients with a poor outcome diagnosed outside our centre.

Finally, other renowned authors in the treatment of prostate cancer, such as Zelefsky et al. [19], who published in previous years (2007) very satisfactory results in terms of biochemical recurrence in the treatment of low-risk prostate cancer as monotherapy.

The most relevant data in this aspect can be seen summarised in Table 7, which shows that the 5-year biochemical progression-free survival percentages vary from 86.9% to 98% depending on the study.

Table 7. List of studies with prostate cancer treated with brachytherapy as monotherapy

Author (yr)	Low-risk patiens/total no.	PSA relapse definition	Median folloup month	% BRFS (yr)
Ellis et al. (2007)	110 (239)	Phoenix	47.2	86.5 (yr)
Zelefsky et al. (2012)	840 (1466)	ASTRO	49	98 (5 yr)
Zelefsky et al. (2007)	319 (367)	ASTRO	63	96 (5 yr)
Henry (2010)	575 (1298)	ASTRO, Phoenix	4.9 yr	86.4, 72.3 (10 yr)
Zeleksy et al. (2007)	1444 (2693)	ASTRO, Phoenix	63	82 (8 yr), 74
Prada et al. (2010)	487 (734)	Phoenix	55	92 (10 yr)
Potters et al. (2005)	481 (1449)	ASTRO	82	89 (12 yr)
Sharkey et al. (2005)	723 (1177)	ASTRO	36	89 (3 yr)
Sylvester et al. (2011)	128 (215)	Phoenix	11.7 yr	89.5 (15 yr)
D'Amico et al. (2003)	196 (322)	ASTRO	3.95 yr	95 (5 yr)
Dickinson et al. (2013)	1038 (1038)	ASTRO, Phoenix	60	94.1 (ASTRO) (5 yr), 94.2 (Phoenix) (5 yr)
Martin et al. (2007)	273 (396)	ASTRO, Phoenix	60	91.5 (5 yr), 94.6
Merrick et al. (2005)	Not available (202)	ASTRO	5.2 yr	93.2 iodine-125 (8 yr)
Lubbe et al. (2012)	341 (341)	Phoenix	41.6	91.1 (6 yr)
Hinnen et al. (2012)	262 (975)	Phoenix	69	90 or 70 (bounce vs. no bounce) (6 yr)
Martinez et al. (2015)	664 (700)	Phoenix	63	94 (5 yr), 84 (10 yr)

4.2 Relationship between D90 - D100 and Biochemical Recurrence

As already mentioned, there are several studies whose primary objective is the logical study of the possible relationship between the dose received by 90% or 100% of the prostate and possible biochemical recurrence or, in other words, whether increasing the dose to D90 can have a benefit in terms of biochemical control of the disease.

In our work this objective has also been studied both in the whole cohort of initial patients (245 patients) and in the second analysis carried out excluding anatomopathological understaged patients, and we have found that for the total (245 patients), there was a statistically significant relationship between D90 and biochemical recurrence in the sense that patients with D90 of 149.52 Gy (21.91) relapsed more than those who received an average of 159.35 Gy (12.48).

The same is true when comparing the mean D100 of the entire cohort. Patients without biochemical recurrence received 11.4 Gy more on average (95% CI: 6.2 - 16.6) with a $p < 0.001$.

In the second analysis with the 230 patients:

- The mean for D90 was 149.43 Gy with a SD (21.92) in those who DID have biochemical recurrence.
- The mean for D90 was 160.4 Gy with a SD (12.39) in those who did NOT have biochemical recurrence.
- The mean for D100 was 94.61 Gy with a SD (19.54) in those who DID have biochemical recurrence.
- The mean for D100 was 106.24 Gy with a SD (11.10) in those who did NOT have biochemical recurrence.

We can conclude that a higher mean dose for D90 or D100 in either group is related to better biochemical control.

Regarding the results of other studies:

- Routman et al.:

A 10 Gy increase in D90 (Dose receiving 90% of the prostate) correlated with a decrease in local recurrence due to increased target volume coverage but did not reach statistical significance in this respect.

- Rasmusson et al.:

This study begins by introducing the existence of many studies relating biochemical control to the dose received by 90% of the prostate. The first was a study from Mount Sinai in 1998 [11] that suggested a D90 in the range of 140 Gy-160 Gy using the AAPMTG guidelines 43 [3].

In a large study conducted by Morris et al. (Canadian group) in 2014; D90 was not a predictor of disease-free survival in the entire cohort; however, for the subgroup of low-risk patients without ADT, increased dose was associated with improved disease-free survival.

They conclude by stating that although there should logically be a dose threshold for which response is optimal, these remain unknown and, in their study, they could not confirm a correlation between prostate D90 and biochemical failure.

Returning to the study by Rasmusson et al., in their analysis of study results they conclude that: Median D90: 174 Gy with a SD (155 Gy-190 Gy).

The study concludes that D90 was an important predictor for biochemical recurrence reaching statistical significance (HR 0.90 95% CI 0.83 to 0.96 p less than 0.002) suggesting an optimal cut-off level of 167 Gy.

These results agree with those obtained in our study, where we obtained a mean D90 of 159.35 Gy (12.45) in the first analysis and 160.46 Gy (12.4) for the second analysis, reaching statistical significance.

The Kaplan-Meier survival table for D90 = 167 Gy is shown in the figure below in Figure 4.

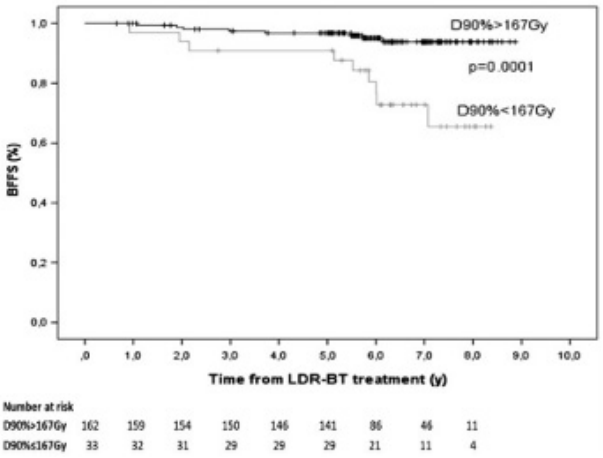


Figure 4. Kaplan-Meier survival for D90 = 167 Gy

- Prada et al.:

Increasing the dose received by 90% of the prostate volume (D90) of > 160 Gy was not associated with better biochemical control (P = 0.37).

- Kittel et al.:

Although it was not their aim to study the relationship between D90 and possible biochemical or local recurrence. The median was like that of our study, 146 Gy with an SD (24.48 Gy).

- Martinez et al.:

No statistically significant relationship was found between dose at D90 and a decrease in biochemical recurrence-free time.

4.3 Local Recurrence-free Survival

Local recurrence-free survival is not an objective that has been analysed in most of the studies reviewed. In our

work we have obtained the following results for the whole sample (245 patients):

- 5-year local recurrence-free survival rate: 95.3%.
- 10-year local recurrence-free survival rate: 91.3%.

For the sample excluding intermediate risk patients (230 patients), the same results were obtained as for the entire initial cohort. Surprisingly, local recurrence-free survival is an objective that has not been studied in most of the studies reviewed, but not in the Spanish studies.

- Prada et al.:

Local recurrence-free survival at 5 and 10 years was 96% and 96(+/-2) respectively.

- Martinez et al.:

5- and 10-year local recurrence-free survival was 95% and 85%, respectively.

We can conclude that our results are practically the same at 5 years and even better at 10 years than in the most relevant Spanish studies in recent years.

4.4 Relationship between D90 -D100 and Local Recurrence

As is logical, the probable relationship between the dose received by 90% and 100% of the prostate and local recurrence has been studied both for the initial sample of 245 patients and for the second sample in which we excluded the 15 patients who were found to be under-staged.

In all cases except for the relationship of prostate D90 and local recurrence for the first sample, we obtained statistical significance.

Thus, for the sample of 245 patients:

- Patients with NO local recurrence received 7.43 Gy more (95% CI 1.47 -16.32) with a p: 0.097 at D90.
- Patients with NO local recurrence received 10.44 Gy more (95% CI 1.23 -19.63) with a p: 0.026 at D100.

For the sample of 230 patients:

- Those with NO local recurrence received 10.35 Gy more (95% CI 1.9 - 18.79) with a p: 0.019 at D90.
- Those who did NOT have local recurrence received 13.8 Gy more (95% CI 6.7-20.8) with a p: 0.001 at D100.

It is important to note that if we were to balance the sample, we could possibly verify that the patients who received higher mean doses at D90 in the sample of 245 patients relapsed less locally.

Also striking is the width of the Confidence Interval, which could possibly be reduced by increasing the sample size of the patients who did not relapse locally.

We have not found any publication in which the relationship between local recurrence and dosimetry to target volume has been studied, so we can conclude that the data obtained are encouraging and are related to those described above.

When we administer higher dose averages to the D90 and D100 of the prostate we obtain a significant reduction in biochemical recurrence and consequently also in local recurrence.

5. Conclusions

The results obtained in our series in terms of local and biochemical failure-free survival are comparable to those published in the literature with patients with similar characteristics. We found better results when intermediate-risk patients were excluded from the sample. In subsequent studies, it would be interesting to see if with average doses at D90 of 160cGy (12.4) we improve the results of biochemical and local control.

Authors Contribution

All participants have contributed by updating and including data for the study in our database. María Concepción López Carrizosa (editor of the journal) has directed this work.

Conflict of Interest

There is no conflict of interest.

References

[1] RTOG, 2021. RTOG Foundation. Available: https://www.rtog.org/About-Us.

[2] Nag, S., Beyer, D., Friedland, J., et al., 1999. Recommendations for permanent transperineal brachytherapy of prostate cancer. 44(4).

[3] Rivard, M.J., Coursey, B.M., Dewerd, L.A., et al., 2004. Response to Comment on Update of AAPM Task Group No. 43 Report: A Revised AAPM Protocol for Brachytherapy Dose Calculations.

[4] Gerber, G., Thisted, R., Chodak, G., et al., 1997. Results of radical prostatectomy in men with locally advanced prostate cancer: multi-institutional pooled analysis. 32, 385-390.

[5] Pollack, A., Zagars, G., Smith, L., et al., 2000. Preliminary results of a randomized radiotherapy dose-escalation study comparing 70 Gy with 78 Gy for prostate cancer. 18, 3904-3911.

[6] Ferrer, M., Guedea, F., Suarez, J., 2013. Quality of life impact of treatments for localized prostate cancer: cohort study with a 5 year follow-up. 108, 306-313.

[7] Ferrer, M., Suárez, J.F., Guedea, F., 2008. Health-related quality of life 2 years after treatment with radical prostatectomy, prostate brachytherapy, or external

beam radiotherapy in patients with clinically localized prostate cancer. 72, 421-432.

[8] Prada, P., Juan, G., Gonzalez-Suarez, H., 2010. Prostate-specific antigen relapse-free survival and side-effects in 734 patients with up to 10 years of follow-up with localized prostate cancer treated by permanent iodine implants. 106, 32-36.

[9] Routman, D., Funk, R., Stish, B., et al., 2018. Permanent prostate brachytherapy monotherapy with I-125 for low and intermediate risk prostate cancer: outcome in 974 patients. Brachytherapy.

[10] Rasmusson, E., Gunnlaugson, A., Kjellen, E., et al., 2016. Low-dose rate brachytherapy in I-125 has an excellent 5-year outcome in patients with low risk prostate cancer. Acta Oncologica. 55(8), 1016-1021.

[11] Stock, R., Stone, N., Tabert, A., et al., 1998. A dose response study for I-125 prostate implants. 41, 101-108.

[12] Nath, R., Anderson, L., Luxton, G., et al., 1995. Dosimetry of intestitial brachytherapy sources. Recommendations of the AAPM Radiation Therapy Committee Task Group No 43. 22, 209-234.

[13] Fellin, G., Mirri, M., Santoro, L., et al., 2016. Low dose rate brachytherapy as monotherapy for early stage prostate cancer in Italy: practice and outcome analysis in a series of 2237 patients from 11 institutions. 89.

[14] Martinez, E., Daidone, A., Gutierrez, C., et al., 2015. Permanent seed brachytherapy for clinically localized prostate cancer: long-term outcome in a 700 patient cohort.

[15] Roach, M., Hanks, G., Thames, H., et al., 2006. Defining biochemical failure following radiotherapy with or without hormonal therapy in men with clinically localized prostate cancer: recommendations of the RTOG-ASTRO Phoenix Consensus Conference. 65, 965-974.

[16] Chao, M., Spencer, S., Guerrieri, M., et al., 2018. A single institution analysis of low dose rate brachytherapy: 5 year reported survival and late toxicity outcomes. 10, 155-161.

[17] Prada, P., Anchuelo, J., Blanco, A., et al., 2016. Low dose rate brachytherapy for patients with transurethral resection before implantation in prostate cancer. Long-term Results. 42, 47-52.

[18] Kittel, J., Chandana, A., Kristin, L., et al., 2015. Long-term Efficacy and Toxicity of low dose rate I-125 Prostate Brachytherapy as Monotherapy in low, intermediate and high risk prostate cancer. 1-10.

[19] Zelefsky, M., Yamada, Y., Cohen, G., et al., 2007. Five-year outcome of intraoperative conformal permanent I-125 interstitial implantation for patients with clinically localized prostate cancer. 67, 65-70.

BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Oncology Research
https://ojs.bilpublishing.com/index.php/jor

ARTICLE

Transfer Factor of Heavy Metals due to Mining Activities in Some Parts of Plateau State, Nigeria (Health Implications on the Inhabitants)

J. Waida[1] U. Ibrahim[2] N.G. Goki[3] S.D. Yusuf[2] U. Rilwan[4*]

1. Department of Physics, Borno State University, Maiduguri, Borno State, Nigeria
2. Department of Physics, Nasarawa State University, Keffi, Nasarawa State, Nigeria
3. Department of Geology and Mining, Nasarawa State University, Keffi, Nasarawa State, Nigeria
4. Department of Physics, Nigerian Army University, Biu, Borno State, Nigeria

ARTICLE INFO

Article history
Received: 2 March 2022
Revised: 18 July 2022
Accepted: 20 July 2022
Published Online: 1 August 2022

Keywords:
Heavy metals
Soil-Plant
Soil-Water
Transfer Factor
Water
Soil
Edible plant

ABSTRACT

Accumulation of heavy metals in agricultural soils is instigated by industrial and other human activities such as mining, smelting, cement-pollution, energy and fuel production, power transmission, traffic activities, intensive agriculture, sludge dumping and melting operations. Plants received heavy metals from soils through ionic exchange, redox reactions, precipitation-dissolution, and so on, which implies that the solubility of trace elements based on factors like minerals in the soil (carbonates, oxide, hydroxide etc.), soil organic matter (humic acids, fulvic acids, polysaccharides and organic acids), soil pH, redox potential, content, nutrient balance, other trace elements concentration in soil, physical and mechanical characteristics of soil, soil temperature and humidity, and so on. In this study, the soil-edible plant and soil-water Transfer Factor (TF) for various metals showed that the TF values differed slightly between the locations. On soil-edible plant transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: As (0.6) mg/kg > Cd (0.1) mg/kg > Cr (0.06) mg/kg > Pb (0.003) mg/kg > Ni (0.001) mg/kg. The total TF for different locations decreases in the following order: Barkin Ladi (1.0) mg/kg > Jos South and Jos East (0.7) mg/kg > Bassa and Mangu (0.6) mg/kg. On soil-water transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: Cd (0.001) mg/L > As (0.0007) mg/L > Cr (0.0005) mg/L > Pb (0.0001) mg/L and Ni (0.0001) mg/L. The total TF for different locations decreases in the following order: Jos South (0.003) mg/kg > Barkin Ladi, Bassa, Jos East and Mangu (0.002) mg/kg. Based on the findings of this study, it can be concluded that the water and edible plants in the study area are good for public consumption, even though, regular checking of heavy metals in the study area is recommended.

*Corresponding Author:
U. Rilwan,
Department of Physics, Nigerian Army University, Biu, Borno State, Nigeria;
Email: rilwan.usman@naub.edu.ng

DOI: https://doi.org/10.30564/jor.v4i2.4490

1. Introduction

Accumulation of heavy metals in agricultural soils is instigated by industrial and other human activities such as mining, smelting, cement-pollution, energy and fuel production, power transmission, traffic activities, intensive agriculture, sludge dumping and melting operations [1-7]. Plants received heavy metals from soils through ionic exchange, redox reactions, precipitation-dissolution, and so on. Which implies that the solubility of trace elements based on factors like minerals in the soil (carbonates, oxide, hydroxide etc.), soil organic matter (humic acids, fulvic acids, polysaccharides and organic acids), soil pH, redox potential, content, nutrient balance, other trace elements concentration in soil, physical and mechanical characteristics of soil, soil temperature and humidity, and so on [8]. The bio-availability of metals in soil is a variable process which is based on specific combinations of chemical, biological, and environmental parameters [9]. Metals distribution in plants is very heterogeneous and is governed by genetic, environmental and toxic factors. The variation of heavy metals in plant-soil association is based mainly on the levels of soil contamination and plant species [10]. Plants traps heavy metals from the soil through the root and from the atmosphere through over ground vegetative organs [11]. Some plants species have lower tolerance to toxic metals absorption in polluted mine soil as they accumulate high concentrations of Ni, Cr, As, Cd, and Pb [12]. More so, different plant species grown in the same soil may have different concentrations of the same element [13]. Some authors have reported the existence of differences in accumulation of heavy metals in plant cultivars, age of plants, plant organs and tissues [14-17]. The same heavy metals can be transferred to water through erosion, where heavy metals are flushed to our rivers and streams and we consume them. Transmission of metals from soil to plant tissues and from soil to water is studied using an index called Transfer Factor (TF). Soil to plant transfer factor is calculated as a ratio of concentration of a specific metal in plant tissue to the concentration of same metal in soil, also soil to water transfer factor is calculated as a ratio of concentration of a specific metal in water to the concentration of same metal in soil, both represented in same units [18]. Higher TF values (≥1) indicate higher absorption of metal from soil by the plant and also indicate higher transfer of metal from soil to the water. On the contrary, lower values indicate poor response of plants towards metal absorption and the plant can be used for human consumption and also lower values indicate poor response of water towards metal transfer and the water can be used for human consumption [19].

The present study will unveil the extent of transfer factor of heavy metals due to mining activities in some selected part Plateau State, Nigeria and the health implications on the inhabitants.

2. Materials and Method

2.1 Materials

The materials that will be used in carrying out this research are:

i. Hand trowel
ii. Plastic containers
iii. Hand gloves
iv. polyethylene sampling bottles
v. Geo-positioning System meter (GPS meter)
vi. Masking tape
vii. Permanent marker and Joter
viii. X-Ray Fluorescence Spectrometry System (XRF)

2.2 Method

2.2.1 Study Area

Plateau is the twelfth-largest state in Nigeria. Approximately in the centre of the country, it is geographically unique in Nigeria due to its boundaries of elevated hills surrounding the Jos Plateau which is its capital, and the entire plateau itself (Hodder, 2000).

Plateau State is celebrated as "The Home of Peace and Tourism". With natural formations of rocks, hills and waterfalls, it derives its name from the Jos Plateau and has a population of around 3.5 million people. Plateau State is located at North Central Zone out of the six geopolitical zones of Nigeria. With an area of 26,899 square kilometers, the State has an estimated population of about three million people. It is located between latitude 08°24'N and longitude 008°32' and 010°38' east. The state is named after the picturesque Jos Plateau, a mountainous area in the north of the state with captivating rock formations. Bare rocks are scattered across the grasslands, which cover the plateau. The altitude ranges from around 1,200 metres (3,900 ft) to a peak of 1,829 metres (6,001 ft) above sea level in the Shere Hills range near Jos. Years of tin and columbite mining have also left the area strewn with deep gorges and lakes [20].

Though situated in the tropical zone, a higher altitude means that Plateau State has a near temperate climate with an average temperature of between 13 and 22 °C. Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies between 131.75 cm (52 in) in

the southern part to 146 cm (57 in) on the Plateau. The highest rainfall is recorded during the wet season months of July and August. The average lower temperatures in Plateau State have led to a reduced incidence of some tropical diseases such as malaria. The Jos Plateau makes it the source of many rivers in northern Nigeria including the Kaduna, Gongola, Hadeja and Damaturu rivers. The Jos Plateau is thought to be an area of younger granite which was intruded through an area of older granite rock, making up the surrounding states. These "younger" granites are thought to be about 160 million years old. This creates the unusual scenery of the Jos Plateau. There are numerous hillocks with gentle slopes emerging from the ground like mushrooms scattered with huge boulders. Also, volcanic activity 50 million years ago created numerous volcanoes and vast basaltic plateaus formed from lava flows. This also produces regions of mainly narrow and deep valleys and pediments (surfaces made smooth by erosion) from the middle of rounded hills with sheer rock faces. The phases of volcanic activities involved in the formation of Plateau State have made it one of the mineral rich states in the country. Tin is still mined and processed on the plateau [20].

Plateau State is known as The Home of Peace and Tourism in Nigeria. Although the tourism sector isn't thriving as much as it should due to meagre allocations to it by the State Government, its natural endowments are still attractions to tourists mostly within Nigeria [20].

The geographical coordinates of the data points are tabulated in Table 1 and the map of Nigeria showing Plateau state, the map of Plateau state showing the mining Local Governments and map of mining Local Government showing the sample points are shown respectively in Figures 1, 2 and 3.

Table 1. Geographical Coordinates of the Data Points

Village	Sample Points	Geographical Coordinates	
		East	North
Bassa	PT01	8°44'34.8"	10°09'39.6"
	PT02	8°40'58.8"	10°06'50.4"
	PT03	8°41'49.5"	10°06'00.00"
	PT04	8° 46' 4.8"	10° 4' 30"
	PT05	8° 51' 7.2"	10° 6' 57.6"
	PT06	8° 54' 3.6"	10° 7' 55.2"
	PT07	8° 50' 56.4"	10° 3' 57.6"
	PT08	8° 48' 3.6"	10° 0' 32.4"
	PT09	8° 41' 52.8"	9° 57' 21.6"
	PT10	8° 46' 37.2"	9° 56' 2.4"
	PT11	8° 43' 4.8"	9° 51' 46.8"
	PT12	8° 39' 3.6"	9° 44' 42"

Table 1 continued

Village	Sample Points	Geographical Coordinates	
		East	North
Jos South	PT01	8° 49' 48"	9° 50' 42"
	PT02	8° 52' 33.6"	9° 49' 37.2"
	PT03	8° 49' 4.8"	9° 47' 34.8"
	PT04	8° 55' 55.2"	9° 46' 51.6"
	PT05	8° 48' 21.6"	9° 45' 10.8"
	PT06	8° 52' 48"	9° 44' 24"
	PT07	8° 53' 34.8"	9° 43' 22.8"
	PT08	8° 51'	9° 43' 1.2"
	PT09	8° 44' 2.4"	9° 42' 54"
	PT10	8° 43' 8.4"	9° 40' 19.2"
	PT11	8° 45' 46.8"	9° 40' 1.2"
	PT12	8° 49' 51.6"	9° 39' 32.4"
Barkin Ladi	PT01	9° 4' 55.2"	9° 40' 33.6"
	PT02	9° 1' 30"	9° 37' 55.2"
	PT03	8° 58' 1.2"	9° 36' 39.6"
	PT04	8° 55' 26.4"	9° 34' 19.2"
	PT05	9° 0' 25.2"	9° 30' 36"
	PT06	8° 59' 31.2"	9° 27' 25.2"
	PT07	8° 55' 8.4"	9° 28' 33.6"
	PT08	8° 48' 25.2"	9° 29' 20.4"
	PT09	8° 53' 13.2"	9° 23' 13.2"
	PT10	8° 43' 55.2"	9° 22' 55.2"
	PT11	8° 42' 57.6"	9° 21' 10.8"
	PT12	8° 44' 13.2"	9° 20' 34.8"
Mangu	PT01	9° 9' 57.6"	9° 42' 21.6"
	PT02	9° 6' 21.6"	9° 34' 19.2"
	PT03	9° 13' 8.4"	9° 33'
	PT04	9° 11' 52.8"	9° 31' 30"
	PT05	9° 12' 36"	9° 29' 34.8"
	PT06	9° 17' 20.4"	9° 28' 22.8"
	PT07	9° 15' 21.6"	9° 25' 40.8"
	PT08	9° 11' 20.4"	9° 25' 58.8"
	PT09	9° 4' 1.2"	9° 25' 12"
	PT10	9° 8' 6"	9° 7' 55.2"
	PT11	9° 16' 30"	9° 6' 57.6"
	PT12	9° 12' 18"	9° 4' 1.2"
Jos East	PT01	9° 13' 22.8"	10° 0' 57.6"
	PT02	9° 7' 37.2"	10° 0' 7.2"
	PT03	9° 4' 8.4"	9° 59' 24"
	PT04	9° 0' 46.8"	9° 57' 50.4"
	PT05	9° 3'00.00"	9° 57' 3.6"
	PT06	9° 0' 46.8"	9° 55' 51.6"
	PT07	9° 0' 28.8"	9° 53' 45.6"
	PT08	9° 8' 2.4"	9° 55' 8.4"
	PT09	9° 13' 8.4"	9° 53' 20.4"
	PT10	9° 8' 24"	9° 51' 57.6"
	PT11	9° 13' 1.2"	9° 49' 4.8"
	PT12	9° 6' 21.6"	9° 46' 12"

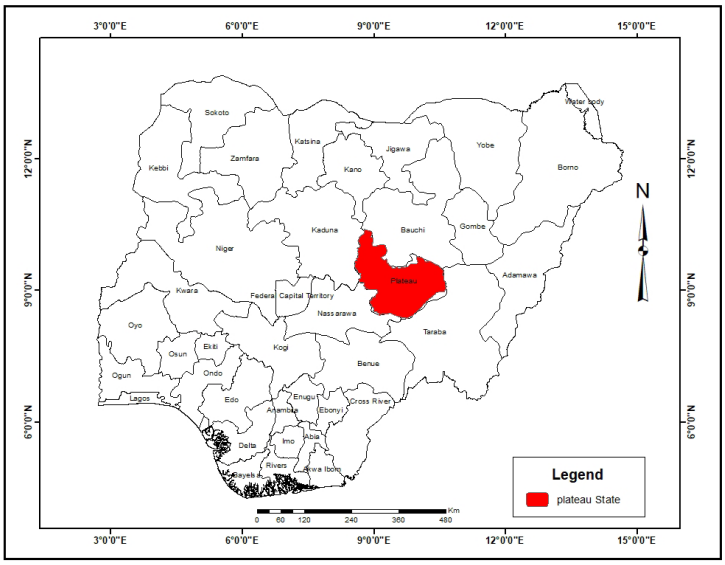


Figure 1. Map of Nigeria Showing Plateau State

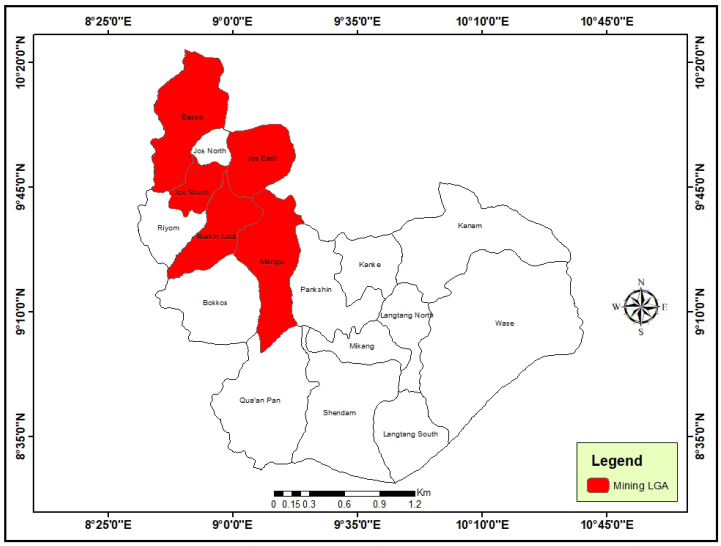


Figure 2. Map of Plateau State Showing Mining Local Government Areas

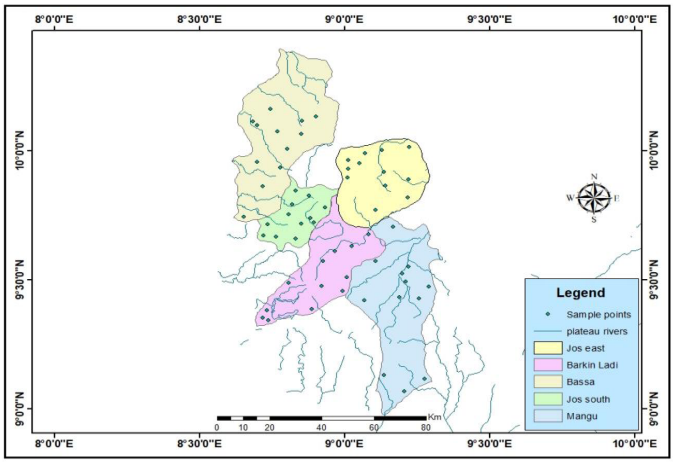


Figure 3. Map of Mining Local Government Areas Showing Sample Points

2.2.2 Population Sample

The population of the study includes all the notable towns where mining activities take place within Plateau State which include 5local governments (Mangu, Barkin Ladi, Jos South, Jos East and Bassa) with 95 villages.

2.2.3 Sample Collection

Soil, water and vegetable samples were pair collected. A simple systematic random sampling technique was used to select twenty (20) soil sample, twenty (20) edible plant sample, and twenty (20) water samples from the mining local government of Plateau State. Sixty (60) samples in all were analyzed in this study. Vegetables' rooted soil samples were taken at 0-20 cm depth. A composite sample is composed of three (3) subsamples at each sampling site for water, vegetables and soils.

2.2.4 Soil Sample Collection

Twenty samples of soil from the mining local government of Plateau State was collected. The sample was collected by coring tool to a depth of 5 cm or to the depth of the plough line. The collected samples each of approximately 4 kg in wet weight was immediately transferred into a high density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability and its position coordinates were recorded for reference purposes using GPS meter.

2.2.5 Edible Plant Sample Collection

Twenty edible plant samples were collected from the mining local government of Plateau State. The collected samples were immediately transferred into a high density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

2.2.6 Water Sample Collection

Twenty water samples were collected from streams from the mining local government of Plateau State. The collected samples were immediately transferred into plastic containers and were well covered to avoid cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

2.2.7 Edible Plant Sample Preparation

Only the edible part of each plant sample was used for analysis. The plant samples were washed with ultrapure water three times. After the water had evaporated, the plant samples were weighed, oven-dried at 65 °C for 48 h, weighed again and then crushed into powder. The heavy metal concentration in edible portions of plant was determined on a wet weight basis. The edible plant sample was taken for XRF analysis.

2.2.8 Soil Sample Preparation

All soil samples were naturally air-dried until constant weight is reached. The dried soil samples were homogenized with pestle in a mortar, and then passed through standard sieves 0.9 mm, 0.3 mm, and 0.15 mm for analysis of pH, organic matter (OM) and heavy metal contents, respectively. Soil pH were measured using a pH electrode and the ratio of solid: water was 1:2.5. OM contents of soil samples were determined using the loss on ignition method. The soil sample was taken for XRF analysis.

2.2.9 Water Sample Preparation

Water samples for heavy metals determination was acidified with two (2) drops of concentrated HNO_3; Samples for Dissolved oxygen determination was fixed with 2ml each of Manganese(II) sulphate solution (winkler A) and Alkali-iodide Azide reagent (Winkler B) per sample. These operations were carried out on the field. All samples were then placed in an ice-chest and taken to the laboratory on the same day. The digested water sample was taken XRF analysis.

2.2.10 Method of Data Analysis

Concentrations of elements were analyzed by the X-Ray Florescence Spectrometric Analysis available at Centre for Dryland Agriculture Bayero University, Kano. The results obtained was used to evaluate the soil-plant and soil-water transfer factor.

Transfers factor

Transfers factor (TF) was calculated to understand the extent of risk and associated hazard due to waste water irrigation and consequent heavy metals accumulation in edible portion of test plant and water. According to Rilwan et al. [21], the Transfers factor from soil to plant and from soil to water is given by the relation;

$$TF_{soil\text{-}plant} = \frac{C_{plant}}{C_{soil}} \text{ and } TF_{soil\text{-}water} = \frac{C_{water}}{C_{soil}} \quad (1)$$

The ratio "> 1" means higher accumulation of metals in plant or water parts than soil (Sajjad et al., 2009). If the transfer coefficient of a metal is greater than 0.50, the plant will have a greater chance of the metal contamination by anthropogenic activities [22].

3. Results and Discussion

3.1 Results

The results for the concentration levels of five heavy metals (Ni, Cr, As, Cd and Pb) were determined using XRF Cu-Zn method. A total of twenty samples each of water, soil and edible were randomly collected from some mining sites of Plateau State, Nigeria. The coordinates (Latitudes and Longitudes) of the sample points were also measured and recorded with the aid of a Global Positioning System (GPS). The results which include heavy metals in water, heavy metals in soil and heavy metals in edible plants are presented in Tables 2-4 respectively.

Table 2. Concentration of Water Samples in mg/L.

H/M / S/P	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
			Bassa						**Jos South**			
P01	0.003	0.050	0.005	0.003	0.001	**0.062**	0.001	0.05	0.003	0.001	0.005	**0.060**
P02	0.001	0.050	0.006	0.001	0.005	**0.063**	0.002	0.03	0.002	0.003	0.002	**0.039**
P03	0.005	0.050	0.020	0.002	0.006	**0.082**	0.005	0.04	0.060	0.005	0.004	**0.114**
P04	0.002	0.020	0.010	0.005	0.005	**0.042**	0.003	0.07	0.020	0.002	0.001	**0.096**
P05	0.005	0.060	0.005	0.001	0.010	**0.081**	0.004	0.01	0.004	0.004	0.030	**0.052**
P06	0.003	0.020	0.002	0.002	0.002	**0.029**	0.004	0.02	0.007	0.005	0.004	**0.040**
P07	0.012	0.040	0.001	0.003	0.003	**0.060**	0.014	0.04	0.002	0.001	0.006	**0.063**
P08	0.006	0.010	0.010	0.005	0.006	**0.037**	0.005	0.04	0.040	0.003	0.002	**0.090**
P09	0.003	0.050	0.005	0.003	0.001	**0.062**	0.001	0.05	0.001	0.006	0.004	**0.062**
P10	0.005	0.050	0.020	0.002	0.006	**0.082**	0.006	0.02	0.060	0.003	0.006	**0.095**
P11	0.003	0.020	0.002	0.002	0.002	**0.029**	0.001	0.01	0.003	0.001	0.001	**0.016**
P12	0.001	0.050	0.006	0.001	0.005	**0.063**	0.005	0.06	0.004	0.005	0.004	**0.078**
	0.004	**0.040**	**0.007**	**0.003**	**0.005**	0.059	**0.004**	**0.04**	**0.017**	**0.003**	**0.006**	0.067
			Barlin Ladi						**Mangu**			
P01	0.004	0.040	0.004	0.002	0.006	**0.056**	0.005	0.06	0.002	0.001	0.007	**0.075**
P02	0.004	0.020	0.003	0.002	0.003	**0.032**	0.005	0.04	0.001	0.003	0.004	**0.053**
P03	0.007	0.030	0.070	0.004	0.005	**0.116**	0.006	0.05	0.050	0.003	0.006	**0.115**
P04	0.005	0.060	0.030	0.001	0.002	**0.098**	0.004	0.08	0.010	0.002	0.003	**0.099**
P05	0.006	0.020	0.005	0.003	0.040	**0.074**	0.007	0.04	0.003	0.002	0.050	**0.102**
P06	0.006	0.010	0.008	0.004	0.003	**0.031**	0.004	0.03	0.006	0.003	0.004	**0.047**
P07	0.016	0.030	0.003	0.002	0.007	**0.058**	0.015	0.05	0.001	0.001	0.006	**0.073**
P08	0.007	0.030	0.050	0.002	0.003	**0.092**	0.002	0.05	0.030	0.001	0.004	**0.087**
P09	0.003	0.040	0.002	0.005	0.005	**0.055**	0.004	0.06	0.001	0.004	0.006	**0.075**
P10	0.008	0.010	0.070	0.002	0.007	**0.097**	0.003	0.03	0.050	0.001	0.008	**0.092**
P11	0.003	0.020	0.004	0.002	0.002	**0.031**	0.005	0.04	0.002	0.001	0.003	**0.051**
P12	0.007	0.050	0.005	0.004	0.005	**0.071**	0.008	0.07	0.003	0.003	0.006	**0.090**
	0.006	**0.030**	**0.021**	**0.003**	**0.007**	0.068	**0.006**	**0.05**	**0.013**	**0.002**	**0.009**	0.080
			Jos East									
P01	0.008	0.03	0.001	0.002	0.005	**0.046**						
P02	0.002	0.01	0.002	0.002	0.003	**0.019**						
P03	0.009	0.02	0.01	0.004	0.004	**0.047**						
P04	0.001	0.03	0.05	0.001	0.001	**0.083**						
P05	0.004	0.01	0.006	0.003	0.02	**0.043**						
P06	0.007	0.04	0.003	0.002	0.001	**0.053**						
P07	0.018	0.02	0.003	0.002	0.004	**0.047**						
P08	0.005	0.01	0.01	0.001	0.005	**0.031**						
P09	0.001	0.07	0.005	0.003	0.002	**0.081**						
P10	0.006	0.03	0.01	0.002	0.004	**0.052**						
P11	0.002	0.04	0.003	0.001	0.002	**0.048**						
P12	0.005	0.03	0.002	0.002	0.005	**0.044**						
	0.006	**0.03**	**0.009**	**0.002**	**0.005**	0.050						

Table 3. Concentration of Soil Samples in mg/kg.

H/M S/P	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
			Bassa						**Jos South**			
P01	49.8	67.9	22.8	3.21	57.9	**201.61**	59.8	66.2	22.1	2.21	52.9	**203.21**
P02	33.3	82.8	10.5	2.97	92.8	**222.37**	35.3	82.1	12.5	3.97	72.8	**206.67**
P03	47.4	98.8	17.7	2.09	88.8	**254.79**	47.5	98.5	18.7	4.09	92.8	**261.59**
P04	28.5	71.0	11.5	2.69	81.0	**194.69**	38.5	69.0	12.5	1.69	61.0	**182.69**
P05	45.3	93.9	16.9	3.00	83.9	**243.00**	44.3	93.0	16.2	5.00	87.9	**246.40**
P06	46.3	86.9	13.4	1.82	96.9	**245.32**	45.3	86.1	11.4	2.82	66.6	**212.22**
P07	54.6	78.4	35.1	2.69	68.4	**239.19**	54.7	74.4	25.1	4.69	58.4	**217.29**
P08	51.2	98.9	19.6	2.00	78.9	**250.60**	31.2	88.9	29.6	3.00	88.9	**241.60**
P09	33.3	82.8	10.5	2.97	92.8	**222.37**	37.3	83.8	14.5	2.37	52.8	**190.77**
P10	28.5	71.0	11.5	2.69	81.0	**194.69**	22.5	71.0	11.1	2.61	86.0	**193.21**
P11	54.6	78.4	35.1	2.69	68.4	**239.19**	54.1	74.4	45.1	2.59	68.9	**245.09**
P12	47.4	98.8	17.7	2.09	88.8	**254.79**	47.1	92.8	19.1	2.49	84.8	**246.29**
	43.4	**84.1**	**18.5**	**2.58**	**81.6**	230.22	**43.1**	**81.7**	**19.8**	**3.13**	**72.8**	220.59
			Barkin Ladi						**Mangu**			
P01	49.3	56.3	33.2	3.32	63.8	**205.92**	38.4	60.0	22.2	3.72	75.2	**199.52**
P02	46.2	71.0	23.6	4.98	61.7	**207.48**	42.5	75.0	22.5	3.93	77.7	**221.63**
P03	37.2	87.4	29.8	5.18	81.7	**241.28**	37.2	87.4	29.8	5.18	81.7	**241.28**
P04	28.4	58.0	23.6	2.72	72.5	**185.22**	51.4	63.3	26.2	5.71	69.5	**216.11**
P05	47.3	82.0	27.2	6.10	77.8	**240.40**	47.3	82.0	27.2	6.10	77.8	**240.40**
P06	42.5	75.0	22.5	3.93	77.7	**221.63**	54.1	81.7	30.2	3.54	73.3	**242.84**
P07	51.4	63.3	26.2	5.71	69.5	**216.11**	49.2	72.7	28.6	3.48	63.9	**217.88**
P08	39.4	77.8	30.7	4.23	77.8	**229.93**	34.4	67.8	37.7	4.23	71.8	**215.93**
P09	49.2	72.7	28.6	3.48	63.9	**217.88**	39.4	77.8	30.7	4.23	77.8	**229.93**
P10	38.4	60.0	22.2	3.72	75.2	**199.52**	46.2	71.0	23.6	4.98	61.7	**207.48**
P11	63.5	63.6	56.2	3.62	79.2	**266.12**	63.5	63.6	56.2	3.62	79.2	**266.12**
P12	54.1	81.7	30.2	3.54	73.3	**242.84**	28.4	58.0	23.6	2.72	72.5	**185.22**
	45.6	**70.7**	**29.5**	**4.21**	**72.8**	222.86	**44.3**	**71.7**	**29.9**	**4.29**	**73.5**	223.70
			Jos East									
P01	38.0	65.4	23.4	4.72	75.2	**206.72**						
P02	40.5	71.6	22.1	3.13	77.7	**215.03**						
P03	27.2	81.4	21.8	3.18	81.7	**215.28**						
P04	55.4	53.3	21.2	5.11	69.5	**204.51**						
P05	42.3	62.3	23.2	4.21	77.8	**209.81**						
P06	51.1	86.7	20.2	3.14	73.3	**234.44**						
P07	41.2	61.3	21.6	3.78	63.9	**191.78**						
P08	37.4	60.8	17.7	3.23	71.8	**190.93**						
P09	31.4	71.8	20.3	4.26	77.8	**205.56**						
P10	42.2	71.9	26.6	4.18	61.7	**206.58**						
P11	69.5	69.6	46.2	3.32	79.2	**267.82**						
P12	21.4	58.3	29.6	2.12	72.5	**183.92**						
	41.5	**67.9**	**24.5**	**3.70**	**73.5**	211.03						

Table 4. Concentration of Edible Plants Samples in mg/kg.

H/M / Edible Plants	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
	Bassa						**Jos South**					
Zogale	4.9	0.9	0.02	0.02	1.9	**7.70**	5.2	0.8	0.03	0.03	1.95	**7.99**
Kuka	5.4	0.8	0.01	0.01	2.0	**8.20**	4.4	0.5	0.02	0.02	1.78	**6.67**
Rama	9.5	0.8	0.02	0.02	1.6	**11.9**	6.3	0.6	0.03	0.03	1.43	**8.38**
Yateya	7.5	1.1	0.01	0.03	2.2	**10.8**	4.1	0.9	0.02	0.04	1.73	**6.81**
Alayyahu	4.4	1.0	0.02	0.01	2.1	**7.52**	6.6	0.9	0.03	0.02	2.11	**9.63**
Shuwaka	8.3	0.6	0.01	0.02	1.4	**10.4**	8.3	0.7	0.02	0.03	1.56	**10.7**
Yakuwa	6.6	0.8	0.04	0.02	1.9	**9.39**	3.6	0.7	0.05	0.03	1.87	**6.19**
Karkashi	5.3	1.0	0.02	0.02	1.8	**8.10**	7.0	1.0	0.03	0.03	1.67	**9.72**
Ugu	4.6	0.7	0.03	0.02	1.8	**7.16**	6.7	0.7	0.04	0.03	1.94	**9.32**
Rogo	6.3	0.9	0.02	0.01	1.5	**8.72**	4.9	0.9	0.03	0.03	1.45	**7.35**
Water Leaf	5.2	0.8	0.03	0.02	1.3	**7.36**	3.0	0.7	0.04	0.03	1.31	**5.15**
Kabeji	4.1	0.7	0.04	0.03	1.9	**6.78**	5.1	0.7	0.05	0.04	1.81	**7.69**
Mean	**6.0**	**0.8**	**0.02**	**0.02**	**1.8**	**8.67**	**5.4**	**0.8**	**0.03**	**0.03**	**1.72**	**7.96**
	Barkin Ladi						**Mangu**					
Zogale	4.8	0.9	0.02	0.02	2.0	7.72	3.7	0.7	0.02	0.03	1.93	6.38
Kuka	5.3	0.8	0.02	0.02	2.5	8.69	4.2	0.8	0.02	0.03	2.47	7.53
Rama	8.5	0.8	0.04	0.05	1.5	10.9	7.4	0.6	0.04	0.04	1.35	9.40
Yateya	7.0	1.1	0.02	0.01	2.2	10.4	6.0	1.0	0.02	0.04	2.13	9.21
Alayyahu	4.3	1.0	0.02	0.02	2.1	7.47	5.1	0.7	0.02	0.02	2.14	8.00
Shuwaka	5.3	0.5	0.01	0.02	1.4	7.29	4.2	0.3	0.01	0.02	1.24	5.84
Yakuwa	6.0	0.7	0.03	0.03	2.0	8.84	5.1	0.7	0.02	0.03	1.63	7.49
Karkashi	5.2	1.0	0.03	0.03	1.8	8.08	4.3	0.9	0.03	0.03	1.38	6.66
Ugu	4.6	0.5	0.02	0.02	1.9	7.05	4.2	0.4	0.04	0.03	1.35	5.99
Rogo	8.5	0.9	0.02	0.02	1.7	11.2	7.3	0.6	0.03	0.03	1.42	9.32
Water Leaf	5.7	0.9	0.02	0.04	1.3	7.97	4.8	0.5	0.02	0.03	1.45	6.78
Kabeji	4.2	0.7	0.05	0.03	1.9	6.86	3.7	0.6	0.03	0.02	1.03	5.37
Mean	**5.8**	**0.8**	**0.03**	**0.03**	**1.9**	**8.54**	**5.0**	**0.6**	**0.03**	**0.03**	**1.63**	**7.33**
	Jos East											
Zogale	7.3	0.6	0.03	0.03	1.4	9.30						
Kuka	4.2	0.4	0.04	0.03	1.4	6.00						
Rama	4.8	0.5	0.02	0.03	1.5	6.80						
Yateya	6.0	1.0	0.01	0.06	2.2	9.30						
Alayyahu	4.2	0.8	0.02	0.03	2.5	7.50						
Shuwaka	4.2	0.3	0.01	0.02	1.2	5.80						
Yakuwa	3.7	0.7	0.02	0.03	1.9	6.40						
Karkashi	4.3	0.9	0.03	0.03	1.4	6.70						
Ugu	4.2	0.4	0.04	0.03	1.4	6.00						
Rogo	7.3	0.6	0.03	0.03	1.4	9.30						
Water Leaf	3.7	0.6	0.03	0.02	1.0	5.40						
Kabeji	3.3	0.2	0.05	0.02	1.5	5.10						
Mean	**4.8**	**0.6**	**0.03**	**0.03**	**1.6**	**7.00**						

3.2 Results Analysis

The results for the concentration of heavy metals in water, soil and edible plants are presented in Tables 2-4 respectively, and are further used to calculate the soil-plant and soil-water transfer factors as presented in Tables 5-9.

Table 5. Soil-Edible Plants and Soil-Water Transfer Factor for Bassa

	Soil-Edible Plants						Soil-Water					
H/M / S/P	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0006	0.056	0.25	0.15	0.0005	**0.46**	0.00006	0.0007	0.00022	0.0009	0.00002	**0.002**
P02	0.0002	0.060	0.60	0.10	0.0025	**0.76**	0.00003	0.0006	0.00057	0.0003	0.00005	**0.002**
P03	0.0005	0.060	1.00	0.10	0.0038	**1.16**	0.00011	0.0005	0.00113	0.0010	0.00007	**0.003**
P04	0.0003	0.019	1.00	0.17	0.0023	**1.19**	0.00007	0.0003	0.00087	0.0019	0.00006	**0.003**
P05	0.0011	0.061	0.31	0.08	0.0047	**0.46**	0.00011	0.0006	0.00030	0.0003	0.00012	**0.002**
P06	0.0004	0.034	0.15	0.09	0.0014	**0.28**	0.00006	0.0002	0.00015	0.0011	0.00002	**0.002**
P07	0.0018	0.051	0.03	0.17	0.0016	**0.25**	0.00022	0.0005	0.00003	0.0011	0.00004	**0.002**
P08	0.0011	0.010	0.53	0.23	0.0033	**0.77**	0.00012	0.0001	0.00051	0.0025	0.00008	**0.003**
P09	0.0007	0.069	0.19	0.13	0.0005	**0.39**	0.00009	0.0006	0.00048	0.0010	0.00001	**0.002**
P10	0.0008	0.054	0.87	0.14	0.0040	**1.07**	0.00018	0.0007	0.00174	0.0007	0.00007	**0.003**
P11	0.0006	0.024	0.06	0.11	0.0015	**0.20**	0.00005	0.0003	0.00006	0.0007	0.00003	**0.001**
P12	0.0002	0.072	0.14	0.03	0.0026	**0.25**	0.00001	0.0005	0.00034	0.0005	0.00006	**0.001**
	0.0007	**0.048**	**0.43**	**0.13**	**0.0024**	**0.60**	**0.00009**	**0.0005**	**0.00053**	**0.0010**	**0.00005**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 6. Soil-Edible Plants and Soil-Water Transfer Factor for Jos South

	Soil-Edible Plants						Soil-Water					
H/M / S/P	Ni	Cr	As	Cd	Pb	**Total**	Ni	Cr	As	Cd	Pb	**Total**
P01	0.0002	0.060	0.10	0.03	0.0026	**0.197**	0.00002	0.0008	0.00014	0.0005	0.00009	**0.0014**
P02	0.0005	0.065	0.10	0.15	0.0011	**0.317**	0.00006	0.0004	0.00016	0.0008	0.00003	**0.0050**
P03	0.0008	0.064	2.00	0.17	0.0028	**2.234**	0.00011	0.0004	0.00322	0.0012	0.00004	**0.0039**
P04	0.0007	0.077	1.00	0.05	0.0006	**1.128**	0.00008	0.0010	0.00160	0.0012	0.00002	**0.0016**
P05	0.0006	0.011	0.15	0.17	0.0142	**0.348**	0.00009	0.0001	0.00025	0.0008	0.00034	**0.0028**
P06	0.0005	0.028	0.29	0.15	0.0026	**0.474**	0.00009	0.0002	0.00061	0.0018	0.00006	**0.0012**
P07	0.0039	0.059	0.04	0.03	0.0032	**0.144**	0.00026	0.0005	0.00008	0.0002	0.00010	**0.0030**
P08	0.0007	0.041	1.33	0.09	0.0012	**1.467**	0.00016	0.0005	0.00135	0.0010	0.00002	**0.0033**
P09	0.0002	0.076	0.03	0.18	0.0021	**0.282**	0.00003	0.0006	0.00007	0.0025	0.00008	**0.0072**
P10	0.0012	0.022	1.76	0.12	0.0041	**1.912**	0.00027	0.0003	0.00541	0.0011	0.00007	**0.0006**
P11	0.0003	0.013	0.07	0.03	0.0008	**0.119**	0.00002	0.0001	0.00007	0.0004	0.00001	**0.0030**
P12	0.0010	0.089	0.08	0.12	0.0022	**0.286**	0.00011	0.0006	0.00021	0.0020	0.00005	**0.0029**
	0.0009	**0.050**	**0.59**	**0.11**	**0.0031**	**0.742**	**0.00011**	**0.0005**	**0.00120**	**0.0011**	**0.00008**	**0.0030**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 7. Soil-Edible Plants and Soil-Water Transfer Factor for Barkin Ladi

	Soil-Edible Plants						Soil-Water					
H/M / **S/P**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0008	0.04	0.20	0.10	0.0030	0.348	0.00008	0.0007	0.00015	0.0006	0.00009	0.0009
P02	0.0008	0.02	0.15	0.10	0.0012	0.276	0.00009	0.0003	0.00013	0.0004	0.00005	0.0037
P03	0.0008	0.04	1.75	0.08	0.0032	1.870	0.00019	0.0003	0.00235	0.0008	0.00006	0.0029
P04	0.0007	0.06	1.50	0.10	0.0009	1.658	0.00018	0.0010	0.00127	0.0004	0.00003	0.0016
P05	0.0014	0.02	0.33	0.20	0.0186	0.574	0.00013	0.0002	0.00018	0.0005	0.00051	0.0017
P06	0.0011	0.02	0.67	0.17	0.0021	0.864	0.00014	0.0001	0.00036	0.0010	0.00004	0.0014
P07	0.0026	0.04	0.12	0.07	0.0035	0.238	0.00031	0.0005	0.00011	0.0004	0.00010	0.0027
P08	0.0013	0.03	1.72	0.08	0.0017	1.835	0.00018	0.0004	0.00163	0.0005	0.00004	0.0022
P09	0.0007	0.08	0.08	0.24	0.0026	0.401	0.00006	0.0006	0.00007	0.0014	0.00008	0.0042
P10	0.0009	0.01	3.33	0.08	0.0041	3.433	0.00021	0.0002	0.00315	0.0005	0.00009	0.0010
P11	0.0005	0.02	0.18	0.05	0.0015	0.259	0.00005	0.0003	0.00007	0.0006	0.00003	0.0021
P12	0.0017	0.07	0.10	0.13	0.0026	0.297	0.00013	0.0006	0.00017	0.0011	0.00007	0.0022
	0.0011	**0.04**	**0.84**	**0.12**	**0.0038**	**1.004**	**0.00014**	**0.0004**	**0.00080**	**0.0007**	**0.00010**	**0.0022**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 8. Soil-Edible Plants and Soil-Water Transfer Factor for Mangu

	Soil-Edible Plants						Soil-Water					
H/M / **S/P**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0014	0.089	0.09	0.03	0.004	0.21	0.00013	0.0010	0.00009	0.0003	0.00009	0.002
P02	0.0012	0.052	0.04	0.09	0.002	0.18	0.00012	0.0005	0.00004	0.0008	0.00005	0.003
P03	0.0008	0.083	1.19	0.07	0.004	1.35	0.00016	0.0006	0.00168	0.0006	0.00007	0.002
P04	0.0007	0.080	0.48	0.06	0.001	0.62	0.00008	0.0013	0.00038	0.0004	0.00004	0.002
P05	0.0014	0.055	0.20	0.13	0.023	0.41	0.00015	0.0005	0.00011	0.0003	0.00064	0.002
P06	0.0009	0.087	0.50	0.13	0.003	0.72	0.00007	0.0004	0.00020	0.0008	0.00005	0.001
P07	0.0029	0.074	0.04	0.04	0.004	0.16	0.00030	0.0007	0.00003	0.0003	0.00009	0.002
P08	0.0005	0.056	0.94	0.04	0.003	1.04	0.00006	0.0007	0.00080	0.0002	0.00006	0.002
P09	0.0009	0.169	0.03	0.15	0.004	0.35	0.00010	0.0008	0.00003	0.0009	0.00008	0.003
P10	0.0004	0.053	2.00	0.03	0.006	2.09	0.00006	0.0004	0.00214	0.0002	0.00013	0.001
P11	0.0010	0.087	0.10	0.03	0.002	0.22	0.00008	0.0006	0.00004	0.0003	0.00004	0.003
P12	0.0022	0.124	0.09	0.13	0.006	0.36	0.00028	0.0012	0.00013	0.0011	0.00008	0.002
	0.0012	**0.084**	**0.47**	**0.08**	**0.005**	**0.64**	**0.00013**	**0.0007**	**0.00047**	**0.0005**	**0.00012**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 9. Soil-Edible Plants and Soil-Water Transfer Factor for Jos East

	Soil-Edible Plants						Soil-Water					
H/M / **S/P**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
P01	0.0011	0.05	0.04	0.06	0.0035	0.2	0.00021	0.0005	0.00004	0.0004	0.00007	0.001
P02	0.0005	0.03	0.06	0.07	0.0022	0.2	0.00005	0.0001	0.00009	0.0006	0.00004	0.002
P03	0.0019	0.04	0.48	0.13	0.0028	0.7	0.00033	0.0002	0.00046	0.0013	0.00005	0.003
P04	0.0002	0.03	4.55	0.02	0.0004	4.6	0.00002	0.0006	0.00236	0.0002	0.00001	0.002
P05	0.0009	0.01	0.25	0.09	0.0081	0.4	0.00009	0.0002	0.00026	0.0007	0.00026	0.001
P06	0.0017	0.12	0.25	0.08	0.0008	0.5	0.00014	0.0005	0.00015	0.0006	0.00001	0.002
P07	0.0048	0.03	0.13	0.06	0.0021	0.2	0.00044	0.0003	0.00014	0.0005	0.00006	0.001
P08	0.0012	0.01	0.31	0.04	0.0036	0.4	0.00013	0.0002	0.00056	0.0003	0.00007	0.002
P09	0.0002	0.20	0.14	0.11	0.0015	0.4	0.00003	0.0010	0.00025	0.0007	0.00003	0.002
P10	0.0008	0.05	0.40	0.06	0.0028	0.5	0.00014	0.0004	0.00038	0.0005	0.00006	0.002
P11	0.0005	0.07	0.09	0.04	0.0019	0.2	0.00003	0.0006	0.00006	0.0003	0.00003	0.002
P12	0.0015	0.18	0.04	0.10	0.0033	0.3	0.00023	0.0005	0.00007	0.0009	0.00007	0.002
	0.0013	**0.07**	**0.56**	**0.07**	**0.0028**	**0.7**	**0.00015**	**0.0004**	**0.00040**	**0.0006**	**0.00006**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

Table 10. Summary of the Results presented in Tables 5-9 for the Soil-Edible Plants and Soil-Water Transfer Factor in Bassa, Jos South, Barkin Ladi, Mangu and Jos East

	Soil-Edible Plants						**Soil-Water**					
H/M / **Villages**	Ni	Cr	As	Cd	Pb	Total	Ni	Cr	As	Cd	Pb	Total
Bassa	0.001	0.05	0.4	0.1	0.002	**0.6**	0.0001	0.0005	0.0005	0.001	0.0001	**0.002**
Jos South	0.001	0.05	0.6	0.1	0.003	**0.7**	0.0001	0.0005	0.0012	0.001	0.0001	**0.003**
Barkin Ladi	0.001	0.04	0.8	0.1	0.004	**1.0**	0.0001	0.0004	0.0008	0.001	0.0001	**0.002**
Mangu	0.001	0.08	0.5	0.1	0.005	**0.6**	0.0001	0.0007	0.0005	0.001	0.0001	**0.002**
Jos East	0.001	0.07	0.6	0.1	0.003	**0.7**	0.0002	0.0004	0.0004	0.001	0.0001	**0.002**
Mean	**0.001**	**0.06**	**0.6**	**0.1**	**0.003**	**0.7**	**0.0001**	**0.0005**	**0.0007**	**0.001**	**0.0001**	**0.002**

P = Points; = Mean; Cr = Chromium; Cd = Cadmium; As = Arsenic; Pb = Lead; Ni = Nickel.

It was also observed from Table 10 that the soil-edible plant and soil-water transfer factors has the mean values of 0.7 mg/kg and 0.002 mg/L respectively.

On soil-edible plant transfer factor, the total transfer factor has its trend is in descending order with Barkin Ladi (1.0) mg/kg > Jos South and Jos East (0.7) mg/kg > Bassa and Mangu (0.6) mg/kg.

On soil-water transfer factor, the total transfer factor has its trend is in descending order with Jos South (0.003) mg/kg > Barkin Ladi, Bassa, Jos East and Mangu (0.002) mg/kg.

Comparison of Results with World Health Organization (WHO)

The results presented in Table 10 were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as seen in Figures 4 and 5.

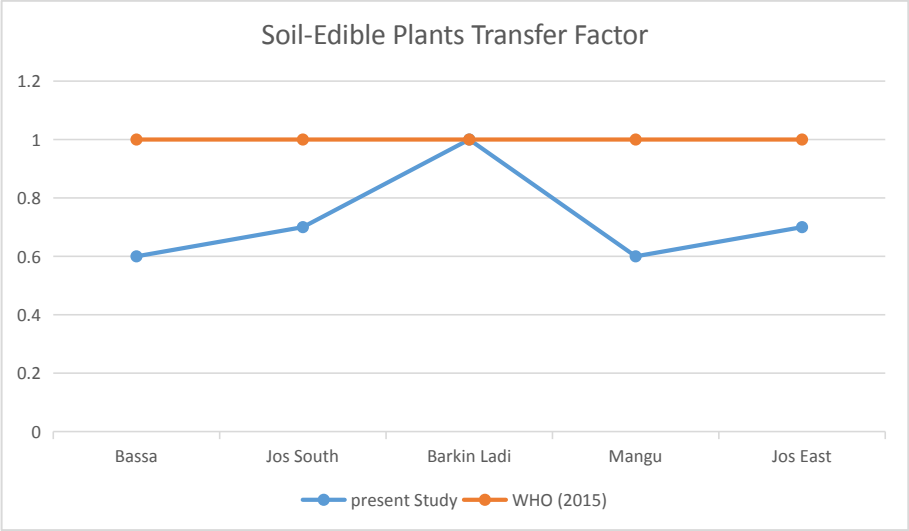


Figure 4. Chart of Soil-Edible Plants Transfer Factor with World Health Organization

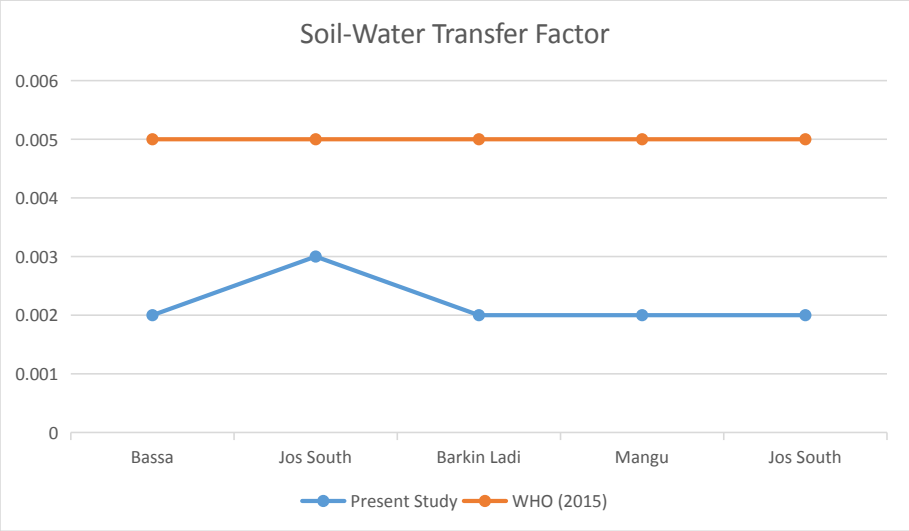


Figure 5. Chart of Soil-Water Transfer Factor with World Health Organization

Based on the results presented in Figure 4, the soil-edible plants transfer factor for Barkin Ladi seem to be closely equal to that recommended by the World Health Organization, on the other hand, the results presented in Figure 5 showed that the soil-water transfer factor for all villages are less than the World Health Organization recommended limit.

3.3 Discussion

Concentration of different elements in plants depends upon the relative level of exposure of plants to the contaminated soil as well as the deposition of toxic elements in the polluted air by sedimentation. In this study, the soil-edible plant and soil-water Transfer Factor (TF) for various metals showed that the TF values differed slightly between the locations.

On soil-edible plant transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: As (0.6) mg/kg > Cd (0.1) mg/kg > Cr (0.06) mg/kg > Pb (0.003) mg/kg > Ni (0.001) mg/kg. The total TF for different locations decreases in the following order: Barkin Ladi (1.0) mg/kg > Jos South and Jos East (0.7) mg/kg > Bassa and Mangu (0.6) mg/kg.

On soil-water transfer, the mean TF for different heavy metals in soil-edible plants decreased in the following order: Cd (0.001) mg/L > As (0.0007) mg/L > Cr (0.0005) mg/L > Pb (0.0001) mg/L and Ni (0.0001) mg/L. The total TF for different location decreases in the following order:

Jos South (0.003) mg/kg > Barkin Ladi, Bassa, Jos East and Mangu (0.002) mg/kg.

4. Conclusions

Based on the findings of this study, it can be concluded that the water and edible plants in the study area are good for public consumption, even though, regular checking of heavy metals in the study area is recommended.

Conflict of Interest

There is no conflict of interest.

References

[1] Balabanova, B., Stafilov, T., Šajn, R., et al., 2014. Comparison of response of moss, lichens and attic dust to geology and atmospheric pollution from copper mine. International Journal of Environmental Science and Technology. 11, 517-528.

[2] Moore, F., Kargar, S., Rastmanesh, F., 2013. Heavy metal concentration of soils affected by Zn-smelter activities in the Qeshm Island, Iran. Journal of Sciences, Islamic Republic of Iran. 24, 339-346.

[3] Ogunkunle, C.O., Fatoba, P.O., Awotoye, O.O., et al., 2013. Root-shoot partitioning of copper, chromium and zinc in Lycopersicon esculentum and Amaranthus hybridus grown in cement-polluted soil. Environmental and Experimental Biology. 11, 131-136.

[4] Yan, X., Zhang, F., Zeng, C., et al., 2012. Relationship between heavy metal concentrations in soils and grasses of roadside farmland in Nepal. International Journal of Environmental Research and Public Health. 9, 3209-3226.

[5] Kouamé, I.K., Kouassi, L.K., Dibi, B., et al., 2013. Potential groundwater pollution risks by heavy metals from agricultural soil in Songon area (Abidjan, Côte d'Ivoire). The Journal of Environmental Protection. 4, 1441-1448.

[6] Shamuyarira, K.K., Gumbo, J.R., 2014. Assessment of heavy metals in municipal sewage sludge: A case study of Limpopo Province, South Africa. International Journal of Environmental Research and Public Health. 11, 2569-2579.

[7] Bi, X., Feng, X., Yang, Y., et al., 2006. Environmental contamination of heavy metals from zinc smelting areas in Hezhang County, western Guizhou, China. Environment International. 32, 883-890.

[8] Tarradellas, J., Bitton, G., Russel, D., 1996. Soil Ecotoxicology. (ed) CRC Lewis Publisher, New York.

[9] Panuccio, M.R., Sorgonà, A., Rizzo, M., et al., 2009. Cadmium adsorption on vermiculite, zeolite and pumice: batch experimental studies. Journal of Environmental Manage. 90, 364-374.

[10] Guala, S.D., Vegaa, F.A., Covelo, E.F., 2001. The dynamics of heavy metals in plant-soil interactions. Ecological Modelling. 221, 1148-1152.

[11] Mmolawa, K.B., Likuku, A.S., Gaboutloeloe, G.K., 2011. Assessment of heavy metal pollution in soils major roadside areas in Botswana. African Journal of Environmental Science and Technology. 5, 186-196.

[12] Freitas, H., Prasad, M.N.V., Pratas, J., 2004. Plant community tolerant to trace elements growing on the degraded soils of São Domingos mine in the south east of Portugal: environmental implications. Environment International. 30, 65-72.

[13] Ibrahim, A.K., Yakubu, H., Askira, M.S., 2014. Assessment of heavy metals accumulated in wastewater irrigated soils and lettuce (Lactuca sativa) in Kwadon, Gombe State Nigeria. American-Eurasian Journal of Agricultural & Environmental Sciences. 14, 502-508.

[14] Krstic, B., Stankovic, D., Igic, R., et al., 2007. The potential of different plant species for nickel accumulation. Biotechnology & Biotechnological Equipment. 21, 431-436.

[15] Naser, H.M., Sultana, S., Mahmud, N.U., et al., 2011. Heavy metal levels in vegetables with growth stage and plant species variations. Bangladesh Journal of Agricultural Research. 36, 563-574.

[16] Jolly, Y.N., Islam, A., Akbar, S., 2013. Transfer of metals from soil to vegetables and possible health risk assessment. Springer Plus. 2, 385.

[17] Filipović-Trajković, R., Ilić, S.Z., Šunić, L., 2012. The potential of different plant species for heavy metals accumulation and distribution. The Journal of Food, Agriculture and Environment. 10, 959-964.

[18] Rangnekar, S.S., Sahu, S.K., Pandit, G.G., et al., 2013. Study of uptake of Pb and Cd by three nutritionally important Indian vegetables grown in artificially contaminated soils of Mumbai, India. International Research Journal of Environmental Sciences. 2, 1-5.

[19] Usman, R., Kamal, A.M., Ugwu, E.I., et al., 2020. Assessment and Analysis of the Presence of Heavy Metals in Water in Ara and Laminga of Nasarawa State, Nigeria: Health Implication on the Populace. The Pacific Journal of Science and Technology. 21, 240-246.

[20] Rilwan Usman, A.M., Kamal, A., Mamman, M.M., et al., 2021. Health Implication of the Accumulation of Heavy Metals Concentration in Ara and Laminga Water Sources of Nasarawa Local Government Area in Nasarawa State, Nigeria. NAUB Journal of Science and Technology (NAUBJOST). 1(June Issue), 101-106.

[21] Rilwan, U., Abbas, A.A., Abdulrahman, H., 2020. Heavy Metal Contamination in Swampy Agricultural Soils of Kokona, Nasarawa, Nigeria. Asian Journal of Applied Chemistry Research. 5, 28-33.

[22] Rilwan, U., Abbas, A.A., Muhammad, S., 2020. Heavy Metal Contamination and Its Risk for Swampy Agricultural Soils of Keffi, Nasarawa West, Nigeria. Asian Journal of Applied Chemistry Research. 5, 1-11.

BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Oncology Research
https://ojs.bilpublishing.com/index.php/jor

ARTICLE

Health Effects of Radiation Exposure to Human Sensitive Organs across Some Selected Mining Sites of Plateau State, Nigeria

J. Waida[1] U. Ibrahim[2] N.G. Goki[3] S.D. Yusuf[2] U. Rilwan[4*]

1. Department of Physics, Borno State University, Maiduguri, Borno State, Nigeria
2. Department of Physics, Nasarawa State University, Keffi, Nasarawa State, Nigeria
3. Department of Geology and Mining, Nasarawa State University, Keffi, Nasarawa State, Nigeria
4. Department of Physics, Nigerian Army University, P.M.B 1500 Biu, Borno State, Nigeria

ARTICLE INFO

Article history
Received: 22 February 2022
Revised: 18 July 2022
Accepted: 28 July 2022
Published Online: 10 August 2022

Keywords:
Radionuclides
Mining
D_{organ}
Radiation
Effective dose
Excess lifetime cancer risk

ABSTRACT

The association of radiation with matter, being it from external means (i.e. external sources) or from internal pollution of the body by toxic substances, can pose biological hazard which may show the clinical symptoms later. The nature and extent of these symptoms and the time they take to appear are a function of the amount of radiation absorbed and the rate at which it is received. This study aimed at assessing the health effects of radiation exposure to human sensitive organs across some selected mining sites of Plateau State Nigeria. Finding of this study have revealed that the mean D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body for different mining points of Plateau State are 0.29 mSv/y, 0.26 mSv/y, 0.31 mSv/y, 0.36 mSv/y, 0.28 mSv/y, 0.21 mSv/y and 0.30 mSv/y respectively. From the findings presented, it can be concluded that the background radiation in Plateau State is not an issue of health concern in regards to sensitive organs and may not course immediate health effect except when accumulated over long period of time which may cause cancer to the indoor members on approximately seventy years of exposure.

1. Introduction

The association of radiation with matter, being it from external means (i.e. external sources) or from internal pollution of the body by toxic substances, can pose biological hazard which may show the clinical symptoms later. The nature and extent of these symptoms and the time they take to appear is a function of the amount of radiation absorbed and the rate at which it is received. Radiation Safety is bothered about cellular effects, which may damage the chromosomes and their components (e.g., genes, DNA, etc.). Radiation association with the body produces micro sub-cellular-level effects that may cause cellular responses and, in the accumulation, may produce macro observable health effects on some organs or tissues. Irradiation of tissue sets a series of intracellular biochemical

*Corresponding Author:
U. Rilwan,
Department of Physics, Nigerian Army University, P.M.B 1500 Biu, Borno State, Nigeria;
Email: rilwan.usman@naub.edu.ng; waidajasini@gmail.com

DOI: https://doi.org/10.30564/jor.v4i2.4469

events into motion that start with ionization of a molecule, and may lead to cellular injury. This may, in turn, lead to further injury to the organ and to the organism. Some factors can modify the response of a living organism to a given radiation dose. Factors associated with the dose include the dose rate, the energy and type of radiation (Depending on the quantity of ionization deposited along a unit length of track of radiation, LET), and the temporal pattern of the exposure. The DNA is considered to be the main target molecule for radiation toxicity. Molecular effects, which includes effect to the DNA, can occur in any of two ways from an exposure to radiation. Firstly, radiation can associate directly with the DNA, causing a single or double-strand DNA breaks or bonding base pairs. Secondly, radiations can associate directly with other neighboring molecules within or outside of the cell, such as water, to produce free radicals and active oxygen species. These reactive molecules, in turn, associates with the DNA and/or other molecules within the cell (membranes, mitochondria, lipids, proteins, etc.) to produce a wide range of health implication at the cellular and tissue levels of the organism [1-5]. Cellular/Organ Radio sensitivity [6-8]. The health consequences of radiation exposure depend on also some biological factors which include species, age, sex, the portion of the body tissues exposed, different radio sensitivity, and repair mechanisms. According to the Law of Bergonie and Tribondeau, the sensitivity of cell lines is directly proportional to their mitotic rate and inversely proportional to the degree of differentiation [9-14]. Cellular changes in susceptible cell types may result in cell death; extensive cell death may produce irreversible damage to an organ or tissue, or may result in the death of the individual. If the cells are adequately repaired and relatively normal function is restored, the subtler DNA alterations may also be expressed at a later time as mutations and/or tumors [12-15].

This study will find solution to question like; the various factors that leads to the variation in radiation effects in Plateau State, the hazards of man's continual exposure to radiation through different radiation emitting source and possible protection and control measures to its exposure.

This study aimed at assessing the health effects of radiation exposure to human sensitive organs across some selected mining sites of Plateau State Nigeria.

2. Materials and Method

2.1 Materials

The materials used to execute this research work are the inspector Alert Nuclear Radiation Monitor with the serial number 35440, made in USA by ion spectra (International Med. Com. Inc) using alkaline battery 0f 9.0 volts, a scientific calculator, personal computer (laptop), pen and exercise book.

2.2 Method

The methods of radiation measurement used in this research work were by using radiation monitor with in-build Geiger Muller tube operating in the Dose Rate mode to determine the background ionizing radiation level from the selected mining sites of Plateau State. The Geiger Muller tube generates a pulse of electrical current each time radiation passes through the tube which cause ionization. Each pulse is electrically detected and registered as a count , but CPM, been the most direct and appropriate method of measuring alpha and beta activity was chosen as the correct mode. The inspector Alert was held above the ground level (1 m above). The device was turn on and measurements were taken after a deep sound that indicates the statistical validity of the readings on the liquid crystal display (LCD) of the monitor.

2.2.1 Study Area

Plateau is the twelfth-largest state in Nigeria. Approximately in the centre of the country, it is geographically unique in Nigeria due to its boundaries of elevated hills surrounding the Jos Plateau which is its capital, and the entire plateau itself [16].

Plateau State is celebrated as "The Home of Peace and Tourism". With natural formations of rocks, hills and waterfalls, it derives its name from the Jos Plateau and has a population of around 3.5 million people. Plateau State is located at North Central Zone out of the six geopolitical zones of Nigeria. With an area of 26,899 square kilometers, the State has an estimated population of about three million people. It is located between latitude 08°24'N and longitude 008°32' and 010°38' east [17-19].

The map of Nigeria showing Plateau State, the map of Plateau State showing the mining Local Governments and map of mining Local Government showing the sample points are shown respectively in Figures 1, 2 and 3. The geographical coordinates of the data points are tabulated in Table 1.

2.2.2 Method Data Collection and Measurement

The instrument used was Inspector Alert Meter. This detector is a relatively economical meter frequently used to perform surveys of very low radiation fields. It can measure variations in background dose rate. The measuring range is 0 to 5000 μR/hr. (For μSv/h, use Model 19 Series 8, P/N: 48-2582.) The cast aluminum instrument housing with a separate battery compartment and accom-

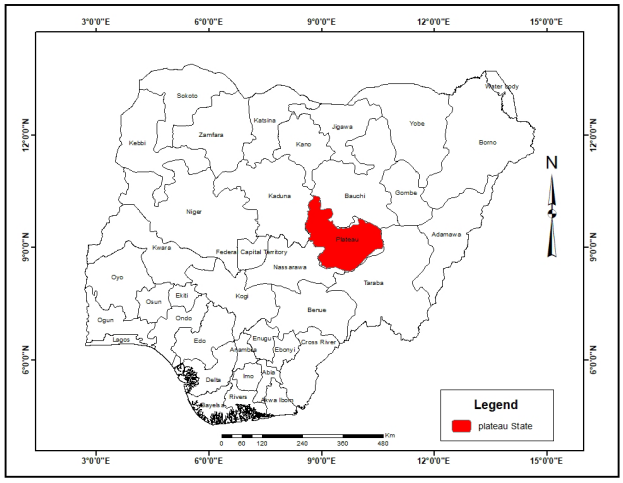


Figure 1. Map of Nigeria Showing Plateau State

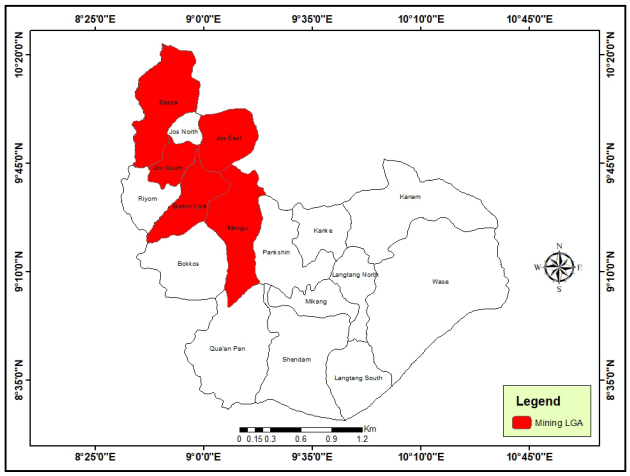


Figure 2. Map of Plateau State Showing Mining Local Government Areas

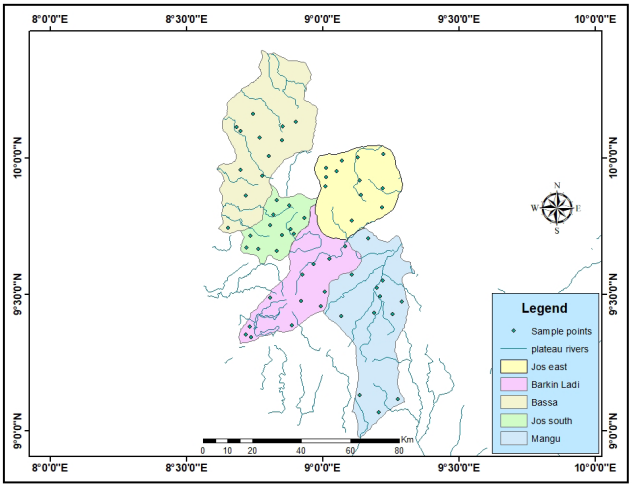


Figure 3. Map of Mining Local Government Areas Showing Data Points

Table 1. Geographical Coordinates of the Data Points

Village	Sample Points	Geographical Coordinates	
		East	North
Bassa	PT01	8°44'34.8"	10°09'39.6"
	PT02	8°40'58.8"	10°06'50.4"
	PT03	8°41'49.5"	10°06'00.00"
	PT04	8° 46' 4.8"	10° 4' 30"
	PT05	8° 51' 7.2"	10° 6' 57.6"
	PT06	8° 54' 3.6"	10° 7' 55.2"
	PT07	8° 50' 56.4"	10° 3' 57.6"
	PT08	8° 48' 3.6"	10° 0' 32.4"
	PT09	8° 41' 52.8"	9° 57' 21.6"
	PT10	8° 46' 37.2"	9° 56' 2.4"
	PT11	8° 43' 4.8"	9° 51' 46.8"
	PT12	8° 39' 3.6"	9° 44' 42"
Jos South	PT01	8° 49' 48"	9° 50' 42"
	PT02	8° 52' 33.6"	9° 49' 37.2"
	PT03	8° 49' 4.8"	9° 47' 34.8"
	PT04	8° 55' 55.2"	9° 46' 51.6"
	PT05	8° 48' 21.6"	9° 45' 10.8"
	PT06	8° 52' 48"	9° 44' 24"
	PT07	8° 53' 34.8"	9° 43' 22.8"
	PT08	8° 51'	9° 43' 1.2"
	PT09	8° 44' 2.4"	9° 42' 54"
	PT10	8° 43' 8.4"	9° 40' 19.2"
	PT11	8° 45' 46.8"	9° 40' 1.2"
	PT12	8° 49' 51.6"	9° 39' 32.4"
Barkin Ladi	PT01	9° 4' 55.2"	9° 40' 33.6"
	PT02	9° 1' 30"	9° 37' 55.2"
	PT03	8° 58' 1.2"	9° 36' 39.6"
	PT04	8° 55' 26.4"	9° 34' 19.2"
	PT05	9° 0' 25.2"	9° 30' 36"
	PT06	8° 59' 31.2"	9° 27' 25.2"
	PT07	8° 55' 8.4"	9° 28' 33.6"
	PT08	8° 48' 25.2"	9° 29' 20.4"
	PT09	8° 53' 13.2"	9° 23' 13.2"
	PT10	8° 43' 55.2"	9° 22' 55.2"
	PT11	8° 42' 57.6"	9° 21' 10.8"
	PT12	8° 44' 13.2"	9° 20' 34.8"
Mangu	PT01	9° 9' 57.6"	9° 42' 21.6"
	PT02	9° 6' 21.6"	9° 34' 19.2"
	PT03	9° 13' 8.4"	9° 33'
	PT04	9° 11' 52.8"	9° 31' 30"
	PT05	9° 12' 36"	9° 29' 34.8"
	PT06	9° 17' 20.4"	9° 28' 22.8"
	PT07	9° 15' 21.6"	9° 25' 40.8"
	PT08	9° 11' 20.4"	9° 25' 58.8"
	PT09	9° 4' 1.2"	9° 25' 12"
	PT10	9° 8' 6"	9° 7' 55.2"
	PT11	9° 16' 30"	9° 6' 57.6"
	PT12	9° 12' 18"	9° 4' 1.2"
Jos East	PT01	9° 13' 22.8"	10° 0' 57.6"
	PT02	9° 7' 37.2"	10° 0' 7.2"
	PT03	9° 4' 8.4"	9° 59' 24"
	PT04	9° 0' 46.8"	9° 57' 50.4"
	PT05	9° 3'00.00"	9° 57' 3.6"
	PT06	9° 0' 46.8"	9° 55' 51.6"
	PT07	9° 0' 28.8"	9° 53' 45.6"
	PT08	9° 8' 2.4"	9° 55' 8.4"
	PT09	9° 13' 8.4"	9° 53' 20.4"
	PT10	9° 8' 24"	9° 51' 57.6"
	PT11	9° 13' 1.2"	9° 49' 4.8"
	PT12	9° 6' 21.6"	9° 46' 12"

panying metal handle offer an industrial robustness and quality that promote long lasting protection.

The meter was held one meter above the ground to reflect abdominal level of human readings in count per minute. Readings were taken three times in μR/hr after which the average reading was calculated for each of the camp work visited. The analytical procedure was conducted for five days, in Plateau State.

2.2.3 Method of Data Analysis

UNCEAR [20] recommended indoor occupancy factors of 0.8. This occupancy factor is the proportion of the total time during which an individual is exposed to a radiation field. Eight thousand seven hundred and sixty hours per year (8760 hr/yr) were used. Equation (1) converts from Gamma Activity in milli Röentgen per hour to Exposure Dose Rate in micro – Sievert per hour, Equation (2) converts the Exposure Dose Rate in micro – Sievert per hour to Annual Effective Dose Rate in milli Sievert per year, Equation (3) evaluates the Excess Lifetime Cancer Risk, while Equation (4) evaluates the Annual Effective Dose Rate to organs.

$$10mR/hr(GA) = 1\mu Sv/hr(EDR) \quad (1)$$

$$AEDRmSv/yr = [(EDR)\mu Sv/hr \times 8760hr/yr \times 0.8] \div 1000 \quad (2)$$

$$ELCR = AEDR \times DL \times RF \quad (3)$$

$$D_{organ} = AEDR \times F \quad (4)$$

3. Results and Discussion

3.1 Results

Gamma activity level was obtained from the field, after which Equations (1) – (4) were used to evaluate the Exposure Dose Rate (EDR), Annual Effective Dose Rate (AEDR), Excess Lifetime Cancer Risk (ELCR) and Effective Dose to different organs of the body (D_{organ}) and are presented in Tables 2, 3, 4 and 5.

Table 2 presented the raw data obtained for gamma activity level at different mining points of Plateau State, which was later summarized in Table 3 for further interpretation and analysis.

Table 3 presented the summary of the raw data obtained for gamma activity level at different mining points of Plateau State and the calculated values for exposure dose rate, effective dose rate and excess lifetime cancer risk.

Based on the data presented, exposure levels and related radiological health indices appear to be similar for all villages except that of Barkin Ladi and Jos East which appear slightly different.

Table 2. Exposure Levels and Related Radiological Health Indices in Plateau State

Village	Sample Points	Gamma Activity (mR/hr)	Exposure Dose Rate (μSv/hr)	Effective Dose Rate (mSv/yr)	Excess Lifetime Cancer Risk
Bassa	PT01	0.64	0.064	0.45	1.6
	PT02	0.60	0.060	0.42	1.5
	PT03	0.61	0.061	0.43	1.5
	PT04	0.65	0.065	0.46	1.6
	PT05	0.62	0.062	0.43	1.5
	PT06	0.60	0.060	0.42	1.5
	PT07	0.63	0.063	0.44	1.5
	PT08	0.68	0.068	0.48	1.7
	PT09	0.64	0.064	0.45	1.6
	PT10	0.67	0.067	0.47	1.6
	PT11	0.62	0.062	0.43	1.5
	PT12	0.66	0.066	0.46	1.6
Mean		**0.64**	**0.064**	**0.45**	**1.6**
Jos South	PT01	0.66	0.066	0.46	1.6
	PT02	0.67	0.067	0.47	1.6
	PT03	0.67	0.067	0.47	1.6
	PT04	0.64	0.064	0.45	1.6
	PT05	0.68	0.068	0.48	1.7
	PT06	0.63	0.063	0.44	1.5
	PT07	0.60	0.060	0.42	1.5
	PT08	0.62	0.062	0.43	1.5
	PT09	0.65	0.065	0.46	1.6
	PT10	0.61	0.061	0.43	1.5
	PT11	0.60	0.060	0.42	1.5
	PT12	0.64	0.064	0.45	1.6
Mean		**0.64**	**0.064**	**0.45**	**1.6**
Barkin Ladi	PT01	0.63	0.063	0.44	1.5
	PT02	0.68	0.068	0.48	1.7
	PT03	0.64	0.064	0.45	1.6
	PT04	0.67	0.067	0.47	1.6
	PT05	0.62	0.062	0.43	1.5
	PT06	0.66	0.066	0.46	1.6
	PT07	0.64	0.064	0.45	1.6
	PT08	0.60	0.060	0.42	1.5
	PT09	0.61	0.061	0.43	1.5
	PT10	0.65	0.065	0.46	1.6
	PT11	0.62	0.062	0.43	1.5
	PT12	0.60	0.060	0.42	1.5

Table 2 continued

Village	Sample Points	Gamma Activity (mR/hr)	Exposure Dose Rate (μSv/hr)	Effective Dose Rate (mSv/yr)	Excess Lifetime Cancer Risk
Mean		**0.63**	**0.063**	**0.44**	**1.5**
Mangu	PT01	0.64	0.064	0.45	1.6
	PT02	0.68	0.068	0.48	1.7
	PT03	0.63	0.063	0.44	1.5
	PT04	0.60	0.060	0.42	1.5
	PT05	0.62	0.062	0.43	1.5
	PT06	0.65	0.065	0.46	1.6
	PT07	0.61	0.061	0.43	1.5
	PT08	0.60	0.060	0.42	1.5
	PT09	0.64	0.064	0.45	1.6
	PT10	0.66	0.066	0.46	1.6
	PT11	0.67	0.067	0.47	1.6
	PT12	0.67	0.067	0.47	1.6
Mean		**0.64**	**0.064**	**0.45**	**1.6**
Jos East	PT01	0.64	0.064	0.45	1.6
	PT02	0.60	0.060	0.42	1.5
	PT03	0.61	0.061	0.43	1.5
	PT04	0.65	0.065	0.46	1.6
	PT05	0.62	0.062	0.43	1.5
	PT06	0.60	0.060	0.42	1.5
	PT07	0.64	0.064	0.45	1.6
	PT08	0.68	0.068	0.48	1.7
	PT09	0.63	0.063	0.44	1.5
	PT10	0.60	0.060	0.42	1.5
	PT11	0.62	0.062	0.43	1.5
	PT12	0.65	0.065	0.46	1.6
Mean		**0.63**	**0.063**	**0.44**	**1.5**

Table 3. Summary of Exposure Levels and Related Radiological Health Indices in Plateau State

Village	Gamma Activity (mR/hr)	Exposure Dose Rate (μSv/hr)	Effective Dose Rate (mSv/yr)	Excess Lifetime Cancer Risk
Bassa	0.64	0.064	0.45	1.6
Jos South	0.64	0.064	0.45	1.6
BarkinLadi	0.63	0.063	0.44	1.5
Mangu	0.64	0.064	0.45	1.6
Jos East	0.63	0.063	0.44	1.5
Mean	**0.64**	**0.064**	**0.45**	**1.6**

Table 4 shows that the estimated mean D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body due to radiation exposure and inhalation in different mining points of Plateau State, which was later summarized in Table 5 for further interpretation and analysis.

Table 5 presented the summary of the evaluated results for D_{organ} values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body due to radiation exposure and inhalation in different mining points of Plateau State.

Based on the data presented, the effective dose to different organs of the body in Plateau State appears to be similar for all villages except that of Liver in Jos East which appear slightly different.

3.2 Result Analysis

In this section, the results presented in Table 3 and Table 5 are used to plot charts in order to compare the results of the present study with UNSCEAR.

Table 4. Dose to different organs of the body in Plateau State

Village	Sample Points	Effective Dose Rate to Sensitive Organs						
		Lungs	Ovaries	Bone Marrow	Testes	Kidney	Liver	Whole Body
Bassa	PT01	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT02	0.27	0.24	0.29	0.34	0.26	0.19	0.29
	PT03	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT04	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT05	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT06	0.29	0.24	0.29	0.34	0.26	0.19	0.29
	PT07	0.28	0.26	0.30	0.36	0.27	0.20	0.30
	PT08	0.31	0.29	0.33	0.39	0.30	0.22	0.33
	PT09	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT10	0.30	0.27	0.32	0.39	0.29	0.22	0.32
	PT11	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT12	0.29	0.27	0.32	0.38	0.29	0.21	0.31
Mean		**0.29**	**0.26**	**0.31**	**0.36**	**0.28**	**0.21**	**0.30**
Jos South	PT01	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT02	0.28	0.25	0.30	0.35	0.27	0.20	0.29

Table 4 continued

Village	Sample Points	Effective Dose Rate to Sensitive Organs						
		Lungs	Ovaries	Bone Marrow	Testes	Kidney	Liver	Whole Body
	PT03	0.30	0.27	0.32	0.39	0.29	0.22	0.32
	PT04	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT05	0.31	0.29	0.33	0.39	0.30	0.22	0.33
	PT06	0.28	0.26	0.30	0.36	0.27	0.20	0.30
	PT07	0.29	0.24	0.29	0.34	0.26	0.19	0.29
	PT08	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT09	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT10	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT11	0.27	0.24	0.29	0.34	0.26	0.19	0.29
	PT12	0.29	0.26	0.31	0.37	0.28	0.21	0.31
Mean		**0.29**	**0.26**	**0.31**	**0.36**	**0.28**	**0.21**	**0.30**
Barkin Ladi	PT01	0.28	0.26	0.30	0.36	0.27	0.20	0.30
	PT02	0.31	0.29	0.33	0.39	0.30	0.22	0.33
	PT03	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT04	0.30	0.27	0.32	0.39	0.29	0.22	0.32
	PT05	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT06	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT07	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT08	0.27	0.24	0.29	0.34	0.26	0.19	0.29
	PT09	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT10	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT11	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT12	0.29	0.24	0.29	0.34	0.26	0.19	0.29
Mean		**0.29**	**0.26**	**0.31**	**0.36**	**0.28**	**0.21**	**0.30**
Mangu	PT01	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT02	0.31	0.29	0.33	0.39	0.30	0.22	0.33
	PT03	0.28	0.26	0.30	0.36	0.27	0.20	0.30
	PT04	0.29	0.24	0.29	0.34	0.26	0.19	0.29
	PT05	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT06	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT07	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT08	0.27	0.24	0.29	0.34	0.26	0.19	0.29
	PT09	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT10	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT11	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT12	0.30	0.27	0.32	0.39	0.29	0.22	0.32
Mean		**0.29**	**0.26**	**0.31**	**0.36**	**0.28**	**0.21**	**0.30**
Jos East	PT01	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT02	0.27	0.24	0.29	0.34	0.26	0.19	0.29
	PT03	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT04	0.29	0.27	0.32	0.38	0.29	0.21	0.31
	PT05	0.28	0.25	0.30	0.35	0.27	0.20	0.29
	PT06	0.29	0.24	0.29	0.34	0.26	0.19	0.29
	PT07	0.29	0.26	0.31	0.37	0.28	0.21	0.31
	PT08	0.31	0.29	0.33	0.39	0.30	0.22	0.33
	PT09	0.28	0.26	0.30	0.36	0.27	0.20	0.30
	PT10	0.29	0.24	0.29	0.34	0.26	0.19	0.29
	PT11	0.28	0.25	0.30	0.35	0.27	0.20	0.29
Mean		**0.29**	**0.26**	**0.31**	**0.36**	**0.28**	**0.20**	**0.30**
	PT12	0.29	0.27	0.32	0.38	0.29	0.21	0.31

Table 5. Summary of Dose to different organs of the body in Plateau State

Village	Effective Dose Rate to Sensitive Organs						
	Lungs	Ovaries	Bone Marrow	Testes	Kidney	Liver	Whole Body
Bassa	0.29	0.26	0.31	0.36	0.28	0.21	0.30
Jos South	0.29	0.26	0.31	0.36	0.28	0.21	0.30
Barkin Ladi	0.29	0.26	0.31	0.36	0.28	0.21	0.30
Mangu	0.29	0.26	0.31	0.36	0.28	0.21	0.30
Jos East	0.29	0.26	0.31	0.36	0.28	0.20	0.30
Mean	**0.29**	**0.26**	**0.31**	**0.36**	**0.28**	**0.21**	**0.30**

3.2.1 Comparison of Annual Effective Dose Rate with United Nation Scientific Committee on Effect of Atomic Radiation

The data presented in Table 3 were used to plot a chart in order to compare the result of annual effective dose rate with UNSCEAR. This chart is presented in Figure 4.

On comparison of annual effective dose rate with UNSCEAR, it is observed that the effective dose for all the areas is found to be low.

3.2.2 Comparison of Excess Lifetime Cancer Risk with United Nation Scientific Committee on Effect of Atomic Radiation

The data presented in Table 3 were used to plot a chart in order to compare the result of excess lifetime cancer risk with UNSCEAR. This chart is presented in Figure 5.

On comparison of excess lifetime cancer risk with UNSCEAR, it is observed that the excess lifetime cancer risk was found to be high.

3.2.3 Comparison of Dose to Different Organs of the Body with United Nation Scientific Committee on Effect of Atomic Radiation

The data presented in Table 5 was used to plot a chart in order to compare the result of effective dose to different organs of the body with UNSCEAR. This charts are presented in Figures 6 to 10.

On comparison of Effective Dose Rate to Organs (D_{organ}) with UNSCEAR, it is observed that the D_{organ} was found to be lower compare to UNSCEAR for all villages presented in Figures 6 to 10.

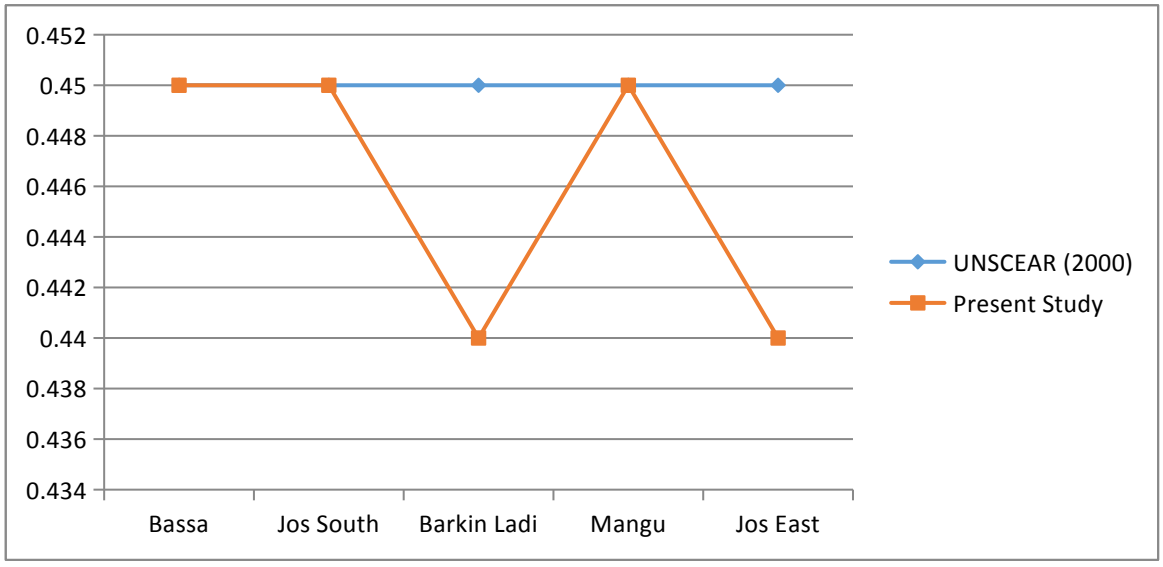


Figure 4. Comparison of Annual Effective Dose Rate with UNSCEAR

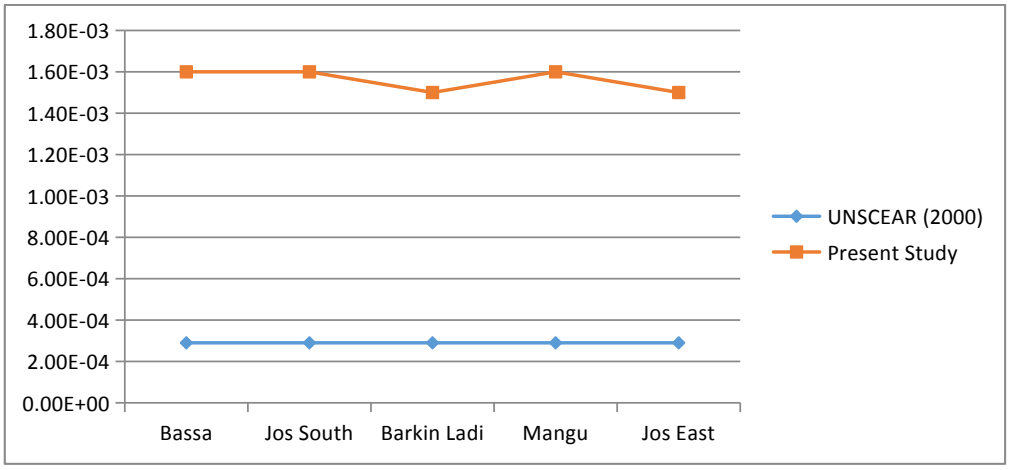


Figure 5. Comparison of Excess Lifetime Cancer Risk with UNSCEAR

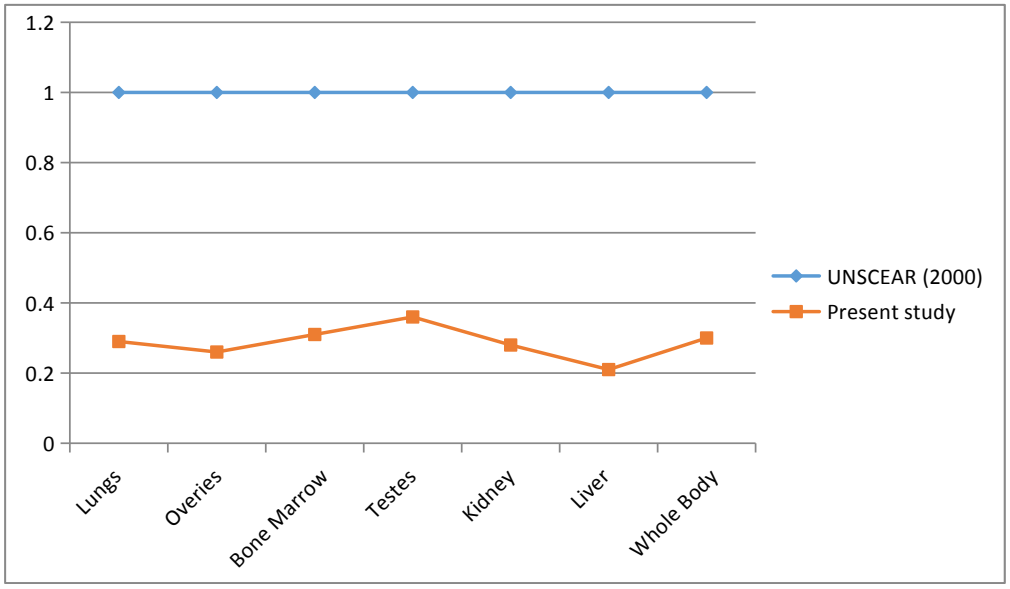


Figure 6. Comparison of Effective Dose Rate to Organs (D_{organ}) for Bassa with UNSCEAR

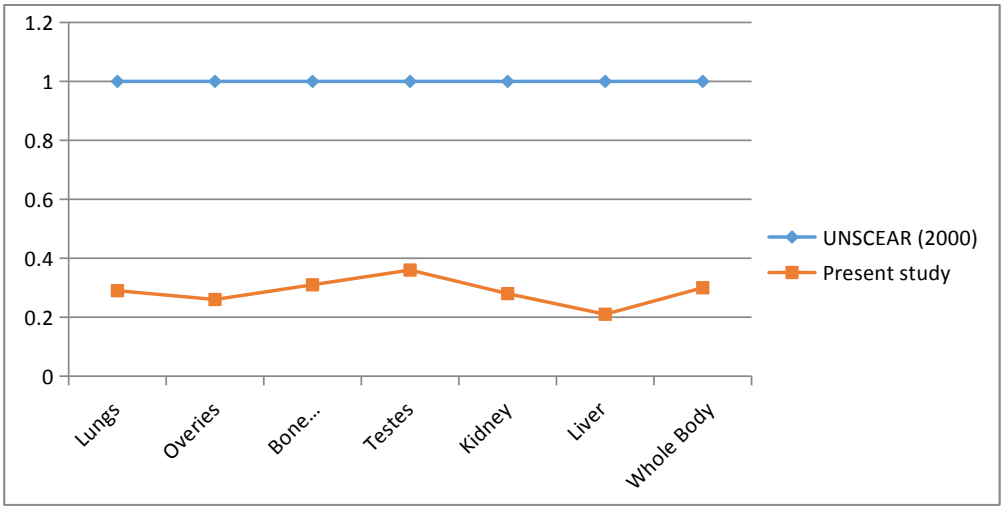


Figure 7. Comparison of Effective Dose Rate to Organs (D_{organ}) for Jos South with UNSCEAR

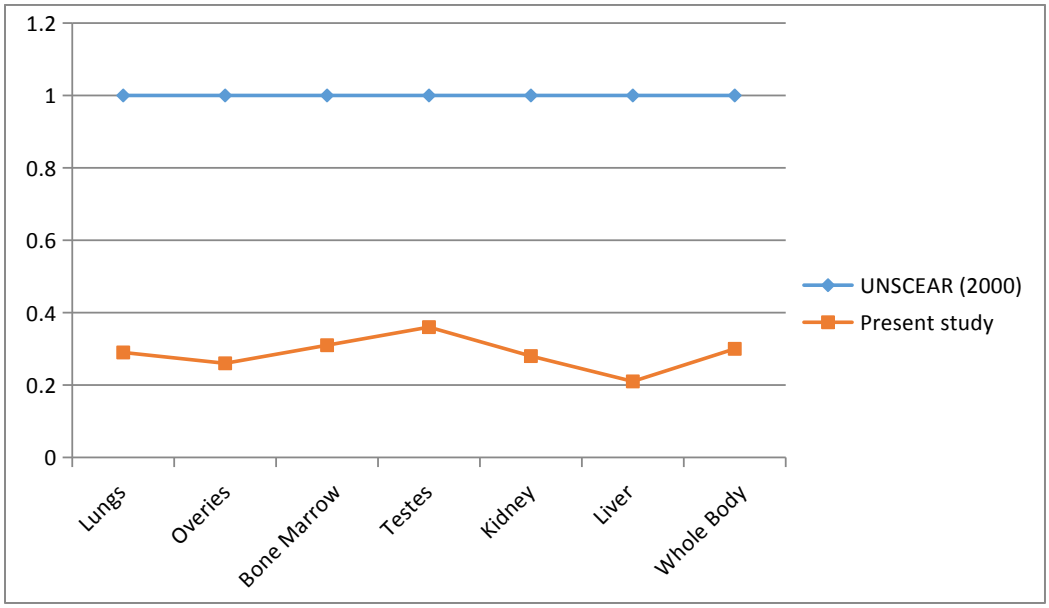


Figure 8. Comparison of Effective Dose Rate to Organs (D_{organ}) for Barkin Ladi with UNSCEAR

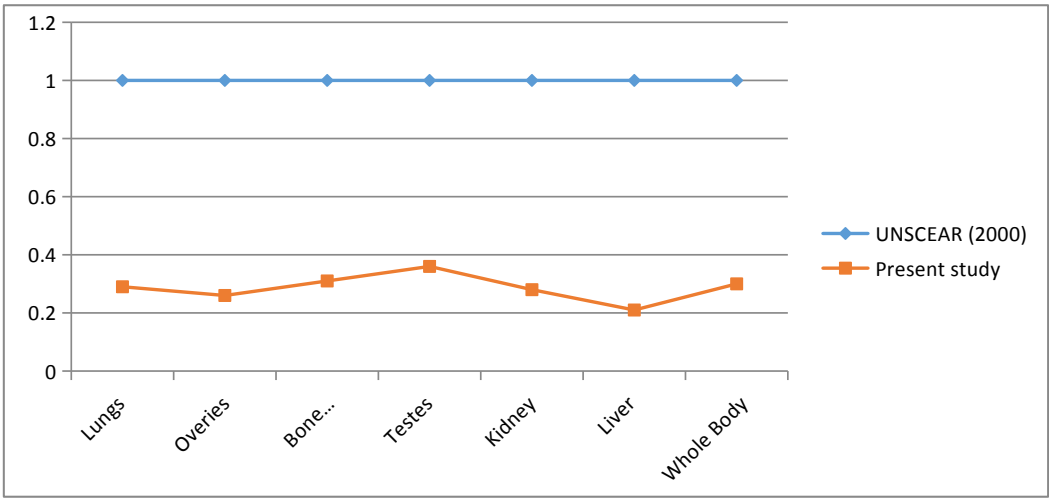


Figure 9. Comparison of Effective Dose Rate to Organs (D_{organ}) for Mangu with UNSCEAR

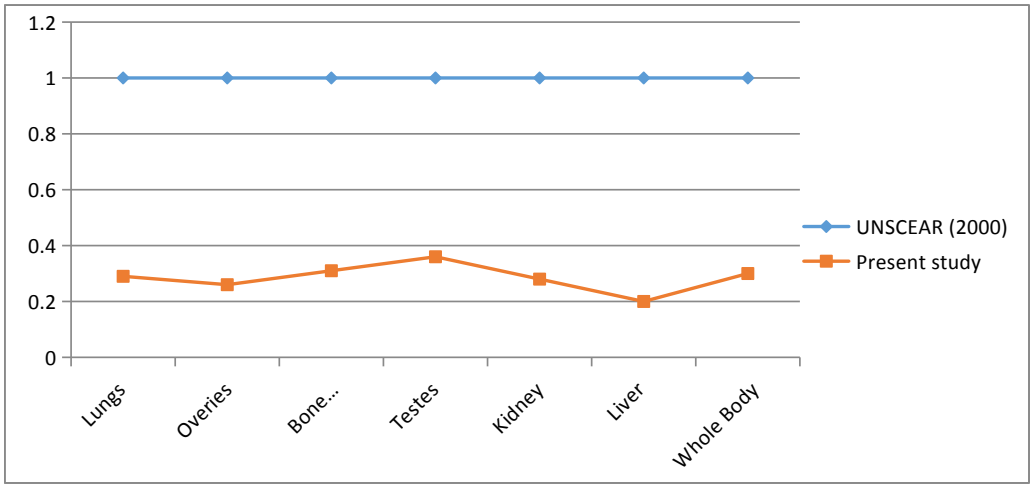


Figure 10. Comparison of Effective Dose Rate to Organs (D_{organ}) for Jos East with UNSCEAR

4. Discussion

On annual effective dose rate, finding of this study have revealed that the mean annual effective dose rate for different mining points of Plateau State are 0.45 mSv/y which is equal to the value of effective dose recommended by UNSCEAR and may cause radiological hazard to the public and workers on excessive exposure. This finding on comparison of Annual Effective Dose Rate (AEDR) is in line with the finding [13,14]. But not in line with the findings [15] who investigated the indoor and outdoor ionizing radiation level at Kwali General Hospital, Abuja Nigeria using a well calibrated Geiger Muller counter and found the average annual effective dose rate as 0.750± 0.020 mSv/yr and 0.189±0.005 mSv/yr for indoor and outdoor measurements respectively. Also not in line with the findings [16] who assessed the background ionizing radiations at Biochemistry, Chemistry, Microbiology and physics laboratories of Plateau State University Bokkos using Gamma-scout Radiometer and found the mean annual effective dose rate of the laboratories for indoor and outdoor to be 1.54 mSv/yr and 0.44 mSv/yr respectively.

On comparison of excess lifetime cancer risk, finding of this study have revealed that the mean excess lifetime cancer risk (ELCR) for different mining points of Plateau State are 1.6×10^{-3} which is higher than the value of excess lifetime cancer risk (ELCR) recommended by UNSCEAR and may cause radiological hazard to the public and workers. This finding is in line with the finding [13,14]. But not in line with the findings [15] who investigated the indoor and outdoor ionizing radiation level at Kwali General Hospital, Abuja Nigeria using a well calibrated Geiger Muller counter and found the average excess lifetime cancer risk as $2.63 \times 10^{-3}$and 0.66×10^{-3} for indoor and outdoor measurements respectively. Also not in line with the findings of [16] who assessed the background ionizing radiations at Biochemistry, Chemistry, Microbiology and physics laboratories of Plateau State University Bokkos using Gamma-scout Radiometer and found the mean excess lifetime cancer risk of the laboratories for indoor and outdoor background radiation level to be 1.54 mSv/yr and 0.44 mSv/yr respectively.

On comparison of Effective Dose Rate to Organs (D_{organ}) values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body, finding of this study have revealed that the mean Dorgan values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body for different mining points of Plateau State are 0.29 mSv/y, 0.26 mSv/y, 0.31 mSv/y, 0.36 mSv/y, 0.28 mSv/y, 0.21 mSv/y and 0.30 mSv/y respectively, which is higher than the value of effective dose to organs recommended by the international tolerable limits of 1.0 mSv annually which further stress that the radiation levels do not constitute any immediate health effect on residents of the area. This finding is in line with the finding [12-16].

5. Conclusions

This tends to unveil the effect of exposure to radiation on human organs as a result of illegal mining taking place in some part of Plateau State. Data in milli Roentgen per hour (mR/hr) were converted to exposure dose rate in micro Sivert per hour (μSv/hr), from exposure dose rate in micro Sivert per hour (μSv/hr) to Annual Effective Dose Rate in milli Sivert per year (mSv/yr), from Annual Effective Dose Rate in milli Sivert per year (mSv/yr) to Excess Lifetime Cancer Risk and also lastly, from Annual Effective Dose Rate in milli Sivert per year (mSv/yr) to Annual Effective Dose Rate to Organs in milli Sivert per year (mSv/yr). From the findings presented, it can be concluded that the background radiation in different mining sites of Plateau State is not an issue of health concern except when accumulated by the public over a long period of time which may cause cancer to the members of public on getting themselves approximately seventy years of exposure. It is therefore, advised or recommended that the government stop all the illegal miners from mining and introduce mechanize mining for easy control of the health effects.

Conflict of Interest

There is no conflict of interest.

References

[1] Rilwan, U., Rufai, A.M., Yahaya, I., 2021. Assessment of Radiation Level and Radiological Health Hazards in Keffi Dumpsite, Nasarawa State, Nigeria using Inspector Alert Nuclear Radiation Monitor (Dose to Organs (D_{organ}) Approach). Journal of Chemical Research Advances. 2(2), 13-19.

[2] Chad-Umoren, Y.E., Adekanmbi, M., Harry, S.O., 2007. Evaluation of Indoor Background Ionizing Radiation Profile of a Physics Laboratory. Facta Universitis series: Working and living. Environmental Protection. 3(1), 1-7.

[3] Dawdall, M.,Vicat, K., Frearso, I., et al., 2004. Assessment of the RadiologicalImpacts of Historical Coal Mining Operations in the Environment of Ny-Alesund, Svalbard. Journal of Environmental Radioactivity. 71(1), 101-114.

[4] Farai, I.P., Vincent, U.E., 2006. Outdoor Radiation Level Measurement in Abeokuta, Nigeria, by Ther-

moluminescent Dosimetry. Nigerian Journal of Physics. 18(1), 121-126.

[5] Felix, B.M., Robert, R.D., Emmanuel, W.M., 2015. Assessment of Indoor and Outdoor Background Radiation Levels in Plateau State University Bokkos, Jos, Nigeria. Journal Environmental and Earth Sciences. 5(8), 67-99.

[6] United Nation Scientific Committee on the Effects of Atomic Radiations (UNCSEAR), 1988. "Report to the General Assembly Scientific Annexes", New York; United Nations.

[7] Huyumbu, P., Zaman, M.B., Lababa, N.H.C., et al., 1995. Natural Radioactivity in Zambian Building Materials Collected from Lusaka. Journal of Radioactivity Nuclear Chemistry. 11(1), 299.

[8] James, I.U., Moses, I.F., Vandi, J.N., et al., 2015. Measurement of Indoor and Outdoor Background Ionizing Radiation Levels of Kwali General Hospital, Abuja. Journal of Applied Sciences and Environmental Management. 19(1), 89-93.

[9] Maria, S., Gael, P.H., Michael, K., et al., 2010. Accounting for Smoking in the Radon Related Lung Cancer Risk among German Uranium Miners. Result of Nested Case Control Study. Health Physics. 98(1), 20-28.

[10] Nisar, A., Mohamad, S.J., Muhammad, B., et al., 2015. An overview on measurements of natural radioactivity in Malaysia. Journal of Radiation Research and Applied Sciences. 1(8), 136-141.

[11] Norma, E.B., 2008. Review of Common Occupational Hazards and Safety Concerns for Nuclear Medicine Technologist. Journal of nuclear Medicine and Technology. 36(2), 11-17.

[12] Sadiq, A.A., Agba, E.H., 2012. Indoor and Outdoor Ambient Radiation Levels in Keffi, Nigeria. University Series. Working and Living. Environmental Protection. 9(1), 19-26.

[13] Tikyaa, E.V., Atsue, T., Adegboyega, J., 2017. Assessment of the Ambient Background Radiation Levels at the Take-Off Campus of Federal University Dutsin-Ma, Katsina State- Nigeria. FUDMA Journal of Sciences (FJS). 1(1), 58-68.

[14] Ghoshal, S.N., 2007. Nuclear Physics. S. Chand and Company LTD. India. 51(1),956-1002.

[15] Rilwan, U., Hudu, A., Ubaidullah, A., et al., 2021. Fertility Cancer and Hereditary Risks in Soil Sample of Nasarawa, Nasarawa State, Nigeria. Journal of Oncology Research. 3(2), 22-27.

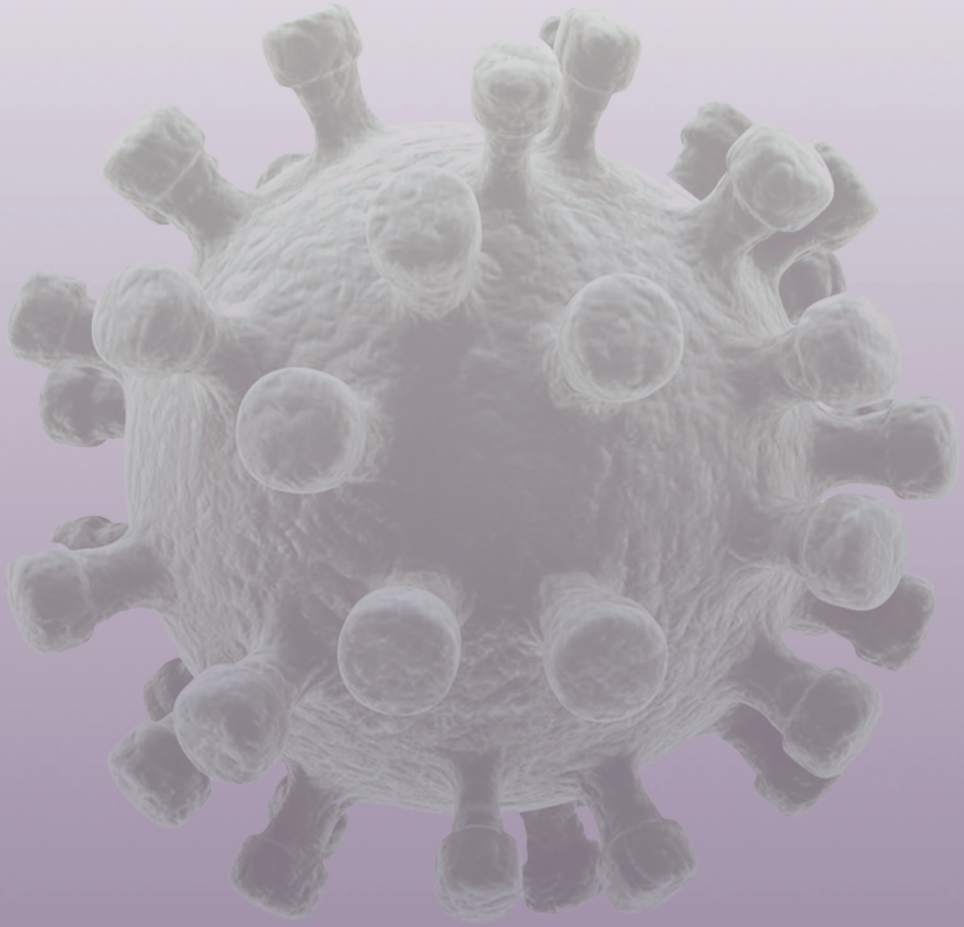
[16] Rilwan, U., Maisalatee, A.U., Jafar, M., 2021. Assessment of Indoor and Outdoor Radiation Exposure in Nasarawa General Hospital, Nasarawa State, Nigeria. Journal of Radiation and Nuclear Applications. An International Journal. 6(3), 245-249.

[17] Rilwan, U., Umar, I., Ngari, A.Z., et al., 2019. Assessment of Gamma Radiation from ^{232}Th, ^{226}Ra and ^{40}K in Nassarawa, Nigeria. Asian Journal of Research and Reviews in Physics. 2(4), 1-10.

[18] Rilwan, U., Umar, I., Onuchukwu, G.C., et al., 2020. Evaluation of Radiation Hazard Indices in Mining Sites of Nasarawa State, Nigeria. Asian Journal of Research and Reviews in Physics. 3(1), 8-16.

[19] Agba, E.H., Onjefu, S.A., Ugwenyi, J., 2000. Preliminary investigation of Ambient Radiation Level of mining sites in Benue State. Nigeria Nuclear Physics. 219(1), 222.

[20] UNCEAR, 2000. Radiological Protection Bulletin. United Nations Scientific Committee on the effect of Atomic Radiation No. 224, New York.



BILINGUAL
PUBLISHING CO.
Pioneer of Global Academics Since 1984

Tel:+65 65881289
E-mail: contact@bilpublishing.com
Website:ojs.bilpublishing.com

2630-5267
02
9 772630 526229