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Radiological Assessment of Radionuclides in Fishes and Health Risks on the Consumer from the Ijagun River in the Ijebu Area of Ogun State

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Abstract: *Natural radionuclides have specific half lives and are capable of disintegrating with the release of ionizing radiations along with a huge amount of energy, which can be so harmful to living organisms. Activity concentrations and radiological indices of ^{40}K, ^{226}Ra and ^{228}Ra in fish species from Ijagun River in Southwest of Nigeria where mining activities are taking place, had been determined by the gamma spectrometry method using NaI (TI) detector coupled with a pre-amplifier base to a multiple channel analyzer (MCA). Twenty (20) samples of fishes were collected from the River, having four (4) species: Hemichromis fasciatus, Clarias gariepinus, Foerschichthys nigeriensis and Clarias anguillaris. The samples were collected at distances of 15 – 30 m from one another along the River with the use of a fishing net. The highest dose rates of ^{40}K, ^{226}Ra and ^{228}Ra were obtained in Clarias gariepinus of values 0.407 x 10^{-4}mGyhr^{-1}, 0.951 x 10^{-9}mGyhr^{-1} and 0.629 x 10^{-15}mGyhr^{-1}, respectively. The highest annual committed effective dose of ^{40}K to man the consumer was 0.0450mSvyr^{-1} from Clarias gariepinus, that of ^{226}Ra was 0.2286mSvyr^{-1} from Foerschichthys nigeriensis and that of ^{228}Ra was 0.5654mSvyr^{-1} from Hemichromis fasciatus.The highest excess lifetime cancer risk of ^{40}K to the consumer was 0.1574 x 10^{-3}, that of ^{226}Ra was 0.8002 x 10^{-4} and ^{228}Ra was 1.9788 x 10^{-4}. All the values obtained were within the limits recommended globally, indicating that there was no significant radiological health risk to the aquatic animals and man the consumer.*

Keywords: *Radionuclides, Fish, Gamma spectrometry, Dose rate, Health risk, Cancer*

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1.0 Introduction

Radioactivity is the sudden disintegration of an unstable nuclide resulting in the release of ionizing radiations, which can be destructive if not controlled. Natural radionuclides are elements that are found naturally in water, soil, rock and air. According to Sowole *et al*. (2019), they are capable of disintegrating with the release of ionizing radiations along with a huge amount of energy, which can be destructive. Due to geological exploration and exploitation of natural resources from the soil, these processes contribute greatly to an increase in pollution of the environment with these naturally occurring radionuclides. The presence of radionuclides in any environment is connected to natural or artificial sources. The environmental behaviour of these radionuclides depends to a large extent on the characteristics of the ecosystem, so understanding the behaviour, mobility, and potential hazard of natural radionuclides is very important for decision-making to protect the environment (Salahel Din, 2023).

Medical experts have made it known that fish consumption is very beneficial to humans as a major source of protein and one of the classes of food in the diet. Fishes in rivers are exposed to radionuclides due to their presence in river water and sediments. Ingestion of these radionuclides by fishes, get them exposed to radiological health hazards, and also to their consumers. The severity of the damage depends on the absorbing tissue or organ, the nature of the radiation and the dose (Orosun *et al.*, 2018). According to Sowole *et al.* (2019), ingestion of these contaminated aquatic organisms may result to long-term radiological health risk to the public, and may result to destruction of organs such as liver, kidney and lungs, leading to cancer. Continuous striking of body tissues and organs by ionizing radiations produced from the decay of ingested radionuclides is known to have triggered or induced cancer in living tissues such as kidney or the brain (Fasae and Isinkaye, 2018; Orosun, *et al*., 2018). According to Tawalbeh *et al.* (2012), ingested radionuclides could be concentrated in certain parts of the body. Chemical uranium toxicity primarily affects the kidney, causing damage to the proximal tubule, while this metal has also been identified as a potential reproductive toxicant (Linares *et al.*, 2006). 232Th causes effects in the lungs, liver and skeletal tissues, and 40K causes effects in muscles. Depositions of large quantities of these radionuclides in particular organs will affect the health condition of the human such as weakening the immune system, inducing various types of diseases, and finally increasing in mortality rate (Tawalbeh *et al*., 2012).

Uzorka *et al*. (2025) analyzed the concentration of selected radionuclides (226Ra, 232Th, and 40K) in the fish samples of Lake Edward, Rukungiri District, Uganda, to assess potential radiological impacts on the local population. Fish samples were collected from the lake and analyzed using gamma spectroscopy. The study measured radionuclide activity concentrations, calculated absorbed dose rates and effective doses, and evaluated hazard indices for fish. The activity concentrations in fish ranged from 12.76 to 18.73 Bq/kg for 226Ra, 2.28–4.83 Bq/kg for 232Th, and 165.33–209.06 Bq/kg for 40K. The mean absorbed dose rate (41.00 nGy/h) and effective dose (0.59 mSv/y) were below global safety limits. Hazard indices for external (0.27) and internal (0.31) exposures were well below the recommended threshold of 1mSv/y. Sowole and Adebambo (2021) determined activity concentrations and radiological indices of 40K, 226Ra and 228Ra in crab species from Igbokoda River in the coastal area of South Western Nigeria, using the gamma spectrometry method. Twenty (20) samples of three different species (Callinectes latimanus, Callinectes amnicola and Cadiosoma armatum) of crabs were collected from the River. The results obtained indicated that the highest dose rates of ^{40}K, ^{226}Ra and ^{228}Ra were obtained in *Callinectes latimanus* of values 1.12 x 10^{-2}mGyhr^{-1}, 1.26 x 10^{-6}mGyhr^{-1} and 1.10 x 10^{-12}mGyhr$^{-1,}$ respectively. The highest annual committed effective dose of ^{40}K to man was 0.0026mSvyr^{-1} from *Callinectes latimanus*, that of ^{226}Ra was 0.0068mSvyr^{-1} and that of ^{228}Ra was 0.0208mSvyr^{-1}.The highest excess lifetime cancer risk of ^{40}K to the consumer was 0.0091 x 10^{-3}, that of ^{226}Ra was 0.0237 x 10^{-3} and ^{228}Ra was 0.0728 x 10^{-3}. All the values obtained were within the limits recommended globally; indicating that there was no significant radiological health implication to the aquatic animals and the consumer. Also, Khan *et al*. (2007) assessed the ingestion dose for natural radionuclides of 25.0μSvyr^{-1} through the consumption of fish by man around the Kudankulam Nuclear Power Project site. Ingestion dose via fish had an estimate of 18.0μSvyr^{-1} from natural radionuclides for the critical population in Chitrapuzha River, near Cochin (Haridasan*et et al*., 2001), which was below the recommended limit of 1.0mSvyr^{-1} according to ICRP (2007). The study of the radionuclides: ^{40}K, ^{226}Ra and ^{228}Ra concentration levels was carried out by Sowole *et al*. (2019) along with their dose rates in species of fish from Victoria Island lagoon in Lagos State, Southwest of Nigeria. The average dose rates of ^{40}K, ^{226}Ra and ^{228}Ra in the fishes were calculated to be 0.0049 mGy hr^{-1}, 5.32 x 10^{-7} mGy hr^{-1} and 8.96 x 10^{-13} mGy hr^{-1} respectively which were below the limit of 0.4 mGyhr^{-1}recommended by NCRP (1991) as reported by Blaylock *et al*. (1993) and the annual dose rate in man consuming them was calculated to be 0.216 mSv yr^{-1} which was below the limit of 1.0 mSv yr^{-1} (ICRP, 2007), therefore did not pose radiological health problem to the aquatic animals and the consumers.

2.0 Materials and Methods

The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain concentration data of ^{40}K, ^{226}Ra and ^{228}Ra from the samples. 20 samples of fish from the Ijagun River were collected at distances of 15 – 30m from one another along the River with the use of a fishing net. Four (4) species were obtained: *Hemichromis fasciatus*, *Clarias gariepinus*, *Foerschichthys nigeriensis* and *Clarias anguillaris*. They were preserved in 40% formaldehyde in labelled containers. They were identified and grouped into their species. The groups were then oven dried at 80 ^{0}C (Akinloye *et al.*, 1999). The dried animal samples were later pulverized, weighed, packed 100.0g by mass in plastic containers and carefully sealed for 4 weeks in order to establish secular radioactive equilibrium between the natural radionuclides and their respective progenies (Sowole, 2011).

The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain the concentrations of ^{40}K, ^{226}Ra and ^{228}Ra in the samples collected. The spectrometer used was a Canberra lead shielded 7.6cm x 7.6cm NaI (Tl) detector coupled to a multichannel analyzer (MCA) through a preamplifier base. The resolution of the detector is about 10% at 0.662MeV of ^{137}Cs. For the analysis of ^{40}K, ^{226}Ra and ^{228}Ra, the photo peak regions of ^{40}K (1.46 MeV), ^{214}Bi (1.76 MeV) and ^{208}TI (2.615 MeV) were respectively used.

The cylindrical plastic containers holding the samples were put to sit on the high geometry 7.6cm x 7.6cm NaI (TI) detector. High level shielding against the environmental background radiation was achieved by counting in a Canberra 10cm thick lead castle. The counting of each sample was done for 8 hours. The areas under the photo-peaks of ^{40}K, ^{226}Ra and ^{228}Ra were computed using the Multichannel Analyzer system. The concentrations of the radionuclides were determined based on the measured efficiency of the detector and the net count rate under each photopeak over a period of 8 hours using equation 1 (Jibiri and Ajao, 2005).

$$A = \frac{N(E_\gamma)}{\varepsilon(E_\gamma) I_\gamma M t_c} \qquad (1)$$

where N(E$_\gamma$) = Net peak area of the radionuclide of interest, ε(E$_\gamma$) = Efficiency of the detector for the γ- γ-energy of interest, I$_\gamma$ = Intensity per decay for the γ- γ-energy of interest, M = Mass of the sample and t$_c$ = Total counting time in seconds (28800s).

2.1 Dose rate of natural radionuclides in Fish species

The dose rates of the radionuclides in the aquatic species were determined using the equation 2 of Blaylock *et al.* (1993):

$$D = 5.76 \times 10^{-4}\ E\ n\ \Phi C \qquad (2)$$

Where: E is the average emitted energy for gamma radiations (MeV), n is the proportion of transitions producing an emission of energy E, Φ is the fraction of the emitted energy absorbed, which are constants obtained from Blaylock *et al*. (1993), C is the concentration of the radionuclide of consideration and D is the dose rate of the radionuclide of consideration.

2.2 Annual committed effective dose to consumer

Furthermore, the annual committed effective dose (ACED) for ingestion of NORMs in fish species to man was determined using equation 3. (Tettey-Larbi *et al.*, 2013):

$$ACED = C \times DCF \times CR \quad (3)$$

where C = Concentration of each radionuclide, DCF = Dose conversion factor for ingestion obtained from UNSCEAR (2000) and CR = Consumption rate of intake of NORMs from fish species.

2.4 Excess Lifetime Cancer Risk to the consumers

Excess lifetime cancer risk (ELCR) to man the consumer was determined based on the values of the annual committed effective dose as shown in table 3.0 using equation 4 (Qureshi *et al*., 2014):

$$ELCR = ACED \times LE \times RF \quad (4)$$

Where LE is life expectancy taken to be 70 years and RF is the fatal risk factor per sievert, which was 0.05 (ICRP, 2007)

3.0 Results and Discussion

Activity concentrations of radionuclides in fish species from the study area were shown in table 1. The lowest concentration of ^{40}K was found in sample IJAFS13; *Hemichromis fasciatus* of value 31.63 ± 4.05 Bqkg^{-1} and the highest was from IJAFS14; *Clarias gariepinus* of value 50.38 ± 6.47 Bqkg^{-1}. *Hemichromis fasciatus* had the lowest concentration of ^{226}Ra in sample IJAFS20 of value 3.24 ± 0.65 Bqkg^{-1}, and the highest was from sample IJAFS8, *Foerschichthys nigeriensis* of value 5.67 ± 1.86 Bqkg^{-1}. Concerning ^{228}Ra, the lowest concentration was obtained from sample IJAFS11 in *Foerschichthys nigeriensis* of value 3.27 ± 0.42 Bqkg^{-1} and the highest was from sample IJAFS15, *Hemichromis fasciatus* of value 5.86 ± 2.02 Bqkg^{-1}. The values were lower than those obtained by Uzorka *et al*. (2025).

The highest dose rate of ^{40}K (Table 2.) was obtained from IJAFS14 in *Clarias gariepinus* of value 0.407 x 10^{-4} mGyhr^{-1} and the lowest was from IJAFS13, *Hemichromis fasciatus* of value 0.256 x 10^{-4} mGyhr^{-1}. For ^{226}Ra, *Foerschichthys nigeriensis* had the highest dose rate of value 0.951 x 10^{-9}mGyhr^{-1} (IJAFS8) and the lowest was from *Hemichromis fasciatus* (IJAFS20) of value 0.543 x 10^{-9}mGyhr^{-1}. Concerning ^{228}Ra, the highest dose rate was obtained in *Hemichromis fasciatus* (IJAFS15) of value 0.629 x 10^{-15} mGyhr^{-1} and the lowest was from *Foerschichthys nigeriensis* of value 0.351 x 10^{-15}mGyhr^{-1}. All the values were below the 0.4mGyhr^{-1} limit

Table 1: Activity concentrations of radionuclides in fish

River	Sample	Specie	Activity concentrations of radionuclides in fishes (Bqkg^{-1})		
			^{40}K	^{226}Ra	^{228}Ra
Ijagun	IJAFS1	*Clarias gariepinus*	33.27 ± 5.04	4.25 ± 0.76	3.42 ± 0.58
	IJAFS2	*Foerschichthys nigeriensis*	38.29 ± 4.73	5.12 ± 1.85	4.36 ± 0.75
	IJAFS3	*Foerschichthys nigeriensis*	43.64 ± 4.98	3.55 ± 0.47	5.24 ± 1.07
	IJAFS4	*Clarias gariepinus*	41.06 ± 6.83	5.37 ± 1.15	3.92 ± 0.67

IJAFS5	*Clarias gariepinus*	36.28 ± 5.35	4.16 ± 1.08	3.79 ± 1.36
IJAFS6	*Hemichromis fasciatus*	41.35 ± 3.28	5.14 ± 0.76	4.95 ± 2.16
IJAFS7	*Clarias anguillaris*	32.53 ± 4.92	3.74 ± 0.46	5.41 ± 1.05
IJAFS8	*Foerschichthys nigeriensis*	50.26 ± 6.83	5.67 ± 1.86	4.33 ± 1.38
IJAFS9	*Clarias anguillaris*	42.76 ± 7.25	3.43 ± 0.74	3.86 ± 0.34
IJAFS10	*Clarias anguillaris*	47.28 ± 6.19	4.08 ± 1.65	5.35 ± 1.96
IJAFS11	*Foerschichthys nigeriensis*	34.53 ± 5.58	5.13 ± 1.64	3.27 ± 0.42
IJAFS12	*Clarias gariepinus*	39.05 ± 5.31	4.63 ± 1.17	5.42 ± 0.99
IJAFS13	*Hemichromis fasciatus*	31.63 ± 4.05	4.86 ± 0.84	3.75 ± 1.10
IJAFS14	*Clarias gariepinus*	50.38 ± 6.47	5.43 ± 1.74	4.88 ± 1.62
IJAFS15	*Hemichromis fasciatus*	47.13 ± 6.55	4.85 ± 1.09	5.86 ± 2.02
IJAFS16	*Foerschichthys nigeriensis*	38.64 ± 4.94	4.36 ± 1.86	5.42 ± 1.43
IJAFS17	*Clarias gariepinus*	32.41 ± 5.37	5.38 ± 1.95	3.74 ± 0.86
IJAFS18	*Clarias gariepinus*	43.52 ± 6.54	3.94 ± 0.57	5.26 ± 1.73
IJAFS19	*Clarias anguillaris*	40.64 ± 4.82	4.88 ± 1.16	5.54 ± 1.56
IJAFS20	*Hemichromis fasciatus*	46.31 ± 5.97	3.24 ± 0.65	4.18 ± 1.29

Table 2: Determined values of dose rates of radionuclides in fish samples

Sample	**Specie**	**^{40}K x 10^{-4} (mGyhr^{-1})**	**^{226}Ra x 10^{-9} (mGyhr^{-1})**	**^{228}Ra x 10^{-15} (mGyhr^{-1})**
IJAFS1	*Clarias gariepinus*	0.269	0.713	0.367
IJAFS2	*Foerschichthys nigeriensis*	0.310	0.859	0.468
IJAFS3	*Foerschichthys nigeriensis*	0.353	0.595	0.562
IJAFS4	*Clarias gariepinus*	0.332	0.901	0.421
IJAFS5	*Clarias gariepinus*	0.293	0.698	0.407

IJAFS6	*Hemichromis fasciatus*	0.334	0.862	0.531
IJAFS7	*Clarias anguillaris*	0.263	0.627	0.581
IJAFS8	*Foerschichthys nigeriensis*	0.407	0.951	0.465
IJAFS9	*Clarias anguillaris*	0.346	0.575	0.414
IJAFS10	*Clarias anguillaris*	0.382	0.684	0.574
IJAFS11	*Foerschichthys nigeriensis*	0.279	0.860	0.351
IJAFS12	*Clarias gariepinus*	0.316	0.777	0.582
IJAFS13	*Hemichromis fasciatus*	0.256	0.815	0.402
IJAFS14	*Clarias gariepinus*	0.407	0.911	0.524
IJAFS15	*Hemichromis fasciatus*	0.381	0.813	0.629
IJAFS16	*Foerschichthys nigeriensis*	0.313	0.731	0.582
IJAFS17	*Clarias gariepinus*	0.262	0.902	0.401
IJAFS18	*Clarias gariepinus*	0.352	0.661	0.564
IJAFS19	*Clarias anguillaris*	0.329	0.818	0.595
IJAFS20	*Hemichromis fasciatus*	0.375	0.543	0.449

Table 3: Determined values of annual committed effective doses (ACED) to the consumers

Sample	**Specie**	**^{40}K ACED (mSvyr^{-1})**	**^{226}Ra ACED (mSvyr^{-1})**	**^{228}Ra ACED (mSvyr^{-1})**
IJAFS1	*Clarias gariepinus*	0.0297	0.1713	0.3300
IJAFS2	*Foerschichthys nigeriensis*	0.0342	0.2064	0.4207
IJAFS3	*Foerschichthys nigeriensis*	0.0390	0.1431	0.5056
IJAFS4	*Clarias gariepinus*	0.0367	0.2165	0.3782
IJAFS5	*Clarias gariepinus*	0.0324	0.1677	0.3657
IJAFS6	*Hemichromis fasciatus*	0.0369	0.2073	0.4776
IJAFS7	*Clarias anguillaris*	0.0290	0.1508	0.5220
IJAFS8	*Foerschichthys nigeriensis*	0.0449	0.2286	0.4178
IJAFS9	*Clarias anguillaris*	0.0382	0.1383	0.3724
IJAFS10	*Clarias anguillaris*	0.0422	0.1645	0.5162
IJAFS11	*Foerschichthys nigeriensis*	0.0308	0.2068	0.3155

IJAFS12	*Clarias gariepinus*	0.0349	0.1867	0.5229
IJAFS13	*Hemichromis fasciatus*	0.0282	0.1960	0.3618
IJAFS14	*Clarias gariepinus*	0.0450	0.2189	0.4708
IJAFS15	*Hemichromis fasciatus*	0.0421	0.1956	0.5654
IJAFS16	*Foerschichthys nigeriensis*	0.0345	0.1758	0.5229
IJAFS17	*Clarias gariepinus*	0.0289	0.2169	0.3608
IJAFS18	*Clarias gariepinus*	0.0389	0.1589	0.5075
IJAFS19	*Clarias anguillaris*	0.0363	0.1968	0.5345
IJAFS20	*Hemichromis fasciatus*	0.0414	0.1306	0.4033

Table 4: Determined values of excess lifetime cancer risk (ELCR) to the consumers

Sample	Specie	^{40}K ELCR x 10^{-3}	^{226}Ra ELCR x 10^{-4}	^{228}Ra ELCR x 10^{-4}
IJAFS1	*Clarias gariepinus*	0.1040	0.5998	1.1549
IJAFS2	*Foerschichthys nigeriensis*	0.1197	0.7225	1.4723
IJAFS3	*Foerschichthys nigeriensis*	0.1364	0.5010	1.7694
IJAFS4	*Clarias gariepinus*	0.1283	0.7578	1.3237
IJAFS5	*Clarias gariepinus*	0.1134	0.5871	1.2798
IJAFS6	*Hemichromis fasciatus*	0.1292	0.7254	1.6715
IJAFS7	*Clarias anguillaris*	0.1017	0.5278	1.8269
IJAFS8	*Foerschichthys nigeriensis*	0.1571	0.8002	1.4622
IJAFS9	*Clarias anguillaris*	0.1336	0.4840	1.3035
IJAFS10	*Clarias anguillaris*	0.1477	0.5758	1.8066
IJAFS11	*Foerschichthys nigeriensis*	0.1079	0.7240	1.1042
IJAFS12	*Clarias gariepinus*	0.1220	0.6534	1.8302
IJAFS13	*Hemichromis fasciatus*	0.0988	0.6858	1.2663
IJAFS14	*Clarias gariepinus*	0.1574	0.7663	1.6479
IJAFS15	*Hemichromis fasciatus*	0.1473	0.6844	1.9788
IJAFS16	*Foerschichthys nigeriensis*	0.1207	0.6153	1.8302
IJAFS17	*Clarias gariepinus*	0.1013	0.7592	1.2629

IJAFS18	*Clarias gariepinus*	0.1360	0.5560	1.7762
IJAFS19	*Clarias anguillaris*	0.1270	0.6887	1.8707
IJAFS20	*Hemichromis fasciatus*	0.1447	0.4572	1.4115

recommended by NCRP (1991) as reported by Blaylock *et al*. (1993). The highest annual committed effective dose of ^{40}K (Table 3.) to man the consumer was 0.0450 mSvyr^{-1} from IJAFS14 (*Clarias gariepinus*), and the lowest was from IJAFS13 (*Hemichromis fasciatus*) of value 0.0282 mSvyr^{-1}. For ^{226}Ra, the highest value was 0.2286mSvyr^{-1} from IJAFS8 (*Foerschichthys nigeriensis*) and the lowest was 0.1306 mSvyr^{-1} from IJAFS20 (*Hemichromis fasciatus*), the highest for ^{228}Ra was 0.5654mSvyr^{-1} from IJAFS15 (*Hemichromis fasciatus*) and the lowest was from IJAFS11 (*Foerschichthys nigeriensis*) of value 0.3155 mSvyr^{-1}. The values were below the recommended limit of 1.0 mSvyr^{-1} (ICRP, 2007). All the values obtained in this work were lower than those obtained by Uzorka *et al*. (2025), but higher than those obtained by Khan *et al*. (2007). The highest ELCR of ^{40}K to the consumers was 0.1574 x 10^{-3} from IJAFS14 (*Clarias gariepinus*) and lowest was 0.0988 x 10^{-3} from IJAFS13 (*Hemichromis fasciatus*) as shown in table 4, that of ^{226}Ra had the highest value to be 0.8002 x 10^{-4} from IJAFS8 (*Foerschichthys nigeriensis*) and lowest was from IJAFS20 (*Hemichromis fasciatus*) of value 0.4572 x 10^{-4}. For ^{228}Ra the highest value was 1.9788 x 10^{-4} from IJAFS15 (*Hemichromis fasciatus*), and the lowest was 1.1042 x 10^{-4} from IJAFS11 (*Foerschichthys nigeriensis*). The values were below the recommended limit of 0.29 x 10^{-3} (UNSCEAR, 2000).

4.0 Conclusion

Radiological assessment of natural radionuclides in fish species from Ijagun River in Ogun State had shown that dose rates of primordial radionuclides ^{40}K, ^{226}Ra and ^{228}Ra in the aquatic species were within the dose rate limit of 0.4 mGyhr^{-1} recommended by NCRP (1991) as reported by Blaylock *et al.* (1993). Similarly, the values of annual committed effective doses were below 1.0 mSvyr^{-1} limit recommended by ICRP (2007). Excess lifetime cancer risk values to the consumers were below the recommended limit of 0.29 x 10^{-3} (UNSCEAR, 2000). All the values of radiological parameters obtained showed that there was no significant radiological health risk to the aquatic animals and man who consumes them. In addition, all the results in this research work could serve as a baseline for further research work in the study area.

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