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ENVIRONMENTAL RADIOACTIVITY, RADIOLOGICAL HAZARD ASSESSMENT, AND MONITORING STRATEGIES IN HILLA CITY AND BABIL GOVERNORATE, IRAQ: REVIEW

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ABSTRACT

This review synthesizes and critically evaluates published clinical investigations on herbal and anthropogenic radioactivity in Hilla City and the wider Babil Governorate, critical Iraq. Reviewed research embody more than one environmental compartments, consisting of surface soil, drinking water, groundwater, locally cultivated food plants, and airborne particulate be counted amassed during dust storms. Reported pastime concentrations of primordial radionuclides (238U/226Ra, 232Th, and 40K) and radon (222Rn) are tested along derived radiological risk parameters, which includes absorbed gamma dose costs (D), radium equal activity (Raeq), external threat indices (Hex), and annual effective doses (AED). While most measured values in Hilla City fall inside the world over advocated reference degrees hooked up by UNSCEAR, ICRP, and WHO, vast methodological heterogeneity exists throughout sampling depths, detector systems (NaI(Tl) vs. HPGe), and dose-conversion assumptions. Furthermore, regional measurements from surrounding districts which include Al-Kifl have to be handled as comparative baselines rather than direct proxies for city Hilla. To deal with existing spatial, temporal, and epidemiological gaps, this paper proposes an integrated, GIS-supported environmental radiation monitoring framework for Hilla City.

Keywords: Environmental Radioactivity; Natural Radionuclides; Radon; Radiological Hazard Indices; Hilla City; Babil Governorate; Iraq.

1 INTRODUCTION

Across the reviewed literature for Hilla City and Babil Governorate, radiological hazard checks rely upon standardized dosimetric formulations recommended through worldwide radiation-protection bodies [1]. Specifically, the outside terrestrial absorbed gamma dose fee D (nGy h^{-1}) at 1 m above ground is calculated from unique sports of 226Ra (AU), 232Th (ATh), and 40K (AK) in Bq kg^{-1} as: D = 0.462 AU + 0.604 ATh + 0.0417 AK [2]. The corresponding out of doors and indoor annual effective doses (AED, mSv y^{-1}) are derived the usage of a conversion coefficient of 0.7 Sv Gy^{-1} alongside standard occupancy factors of 0.2 for out of doors publicity and zero.Eight for indoor publicity [3].

Table 1: Summary of consultant environmental radioactivity research in Hilla City and Babil Governorate, Iraq.

Study & Year	Location	Medium	Analytical Technique	Key Radionuclides / Parameters	Main Findings & Compliance
Alghazaly (2024) [4]	Hilla City (various regions)	Soil	Gamma-ray spectrometry	238U, 232Th, 40K, Raeq, Hex, AED	Activity concentrations & chance indices largely within UNSCEAR permissible limits.
Mekhalif et al. (2019) [5]	Hilla City (industrial sites)	Soil	Gamma-ray spectrometry	238U, 232Th, 40K, D, AED	Baseline herbal radioactivity set up for business zones; no acute contamination.
Ali et al. (2020) [6]	Hilla City	Soil	Gamma spectrometry	Natural radionuclides & hazard indices	Evaluated spatial distribution of terrestrial radionuclides throughout urban Hilla.
Salman et al. (2019) [7]	Babil Governorate (regional)	Soil	Gamma-ray spectrometry	226Ra, 232Th, 40K, radiological hazards	Evaluated spatial distribution of terrestrial radionuclides throughout urban Hilla.
Al-Jnaby (2018) [8]	Hilla City	Drinking water	Alpha/Radon detection (RAD7/CR-39)	222Rn concentration, annual ingestion/inhalation dose	Measured dissolved radon in municipal water; within WHO/EPA reference thresholds.
Jassim et al. (2018) [9]	Hilla City (different districts)	Drinking water	Radon measurement	222Rn activity & effective dose	Spatial variation cited throughout districts; low radiological hazard to customers.
Obaid & Kadhim (2025) [10]	Hilla City	Atmospheric dust (dust storm)	Gamma-ray spectrometry	238U, 232Th, 40K in airborne dust	Demonstrated significance of dust storms as an episodic inhalation pathway.
Alghazaly (2024) [11]	Hilla City (local markets)	Food items	Gamma-ray spectrometry	238U, 232Th, 40K, ingestion AED	Market foodstuffs within worldwide radiological protection limits.
Al-Hamzawi & Kareem (2022) [12]	Babil Governorate	Food crops	SSNTD (CR-39)	238U, 226Ra, radon exhalation rates	Quantified uranium/radium uptake in nearby vegetation; beneficial for switch modeling.

The collective findings of those investigations indicate that environmental radioactivity research in Hilla City has improved from remoted measurements of character environmental cubicles in the direction of a broader multi-media evaluation encompassing soil, water, meals products, and atmospheric dust [13]. However, the present literature does now not but provide a whole spatial and temporal database covering all environmental media, in particular regarding groundwater, indoor radon, size-fractionated airborne particulate count, and soil-to-plant transfer elements in neighborhood agricultural vegetation [14].

Furthermore, it is methodologically vital to distinguish among investigations done directly within urban and peri-city Hilla City and those conducted some other place in Babil Governorate [7]. Measurements obtained from Al-Kifl or other governorate districts must be utilized strictly as local comparative baselines as opposed to interpreted as direct representations of radiological conditions inside Hilla City [12].

2 ENVIRONMENTAL RADIATION MONITORING AND PROTECTION STRATEGIES

An effective, sustained environmental radiation-monitoring programme is essential to hit upon temporal modifications in radionuclide concentrations, compare cumulative population publicity, and set up reliable radiological baseline information [15]. For Hilla City, a complete tracking framework must comprise the subsequent five core components:

2.1 Soil Monitoring

Soil samples should be systematically amassed across residential, agricultural, commercial, and potentially affected zones inside Hilla City, incorporating stratified geographical coordinates and multiple soil intensity profiles [4]. The deployment of high-purity germanium (HPGe) gamma-ray spectrometry is suggested over low-resolution scintillation detectors to as it should be solve person photopeaks and distinguish primordial decay collection (238U and 232Th) from anthropogenic radionuclides including 137Cs [16].

2.2 Water Monitoring

Municipal drinking water networks and private groundwater wells ought to be robotically analyzed for dissolved radon (222Rn), uranium (238U), and radium (226Ra) hobby concentrations [8]. Radon measurements should adhere to verified analytical protocols, with strict interest to hermetic sample collection, upkeep, and minimization of degassing losses all through subject delivery and laboratory analysis [17].

2.3 Atmospheric Monitoring

Airborne particulate remember should be gathered continuously all through each regular meteorological situations and episodic dust storms [10]. Quantifying radionuclide pastime concentrations throughout aerodynamic particle-length fractions (e.G., PM10 and PM2.5) is important for accurately characterizing internal inhalation exposure pathways and lung dose deposition [3].

2.4 Food and Agricultural Monitoring

Locally cultivated and advertised vegetables, fruits, cereals, and animal products must be systematically evaluated the usage of gamma-ray spectrometry [18]. Concurrent analysis of paired soil and crop samples is needed to determine website online-unique soil-to-plant transfer elements (TF) beneath nearby irrigation and fertilization practices [19].

2.5 Indoor Radon Monitoring

Long-term passive indoor radon measurements (e.G., using CR-39 strong-state nuclear tune detectors) should be carried out throughout residential dwellings, faculties, hospitals, and public workplaces, as air flow quotes, air-conditioning usage, constructing materials, and air-change prices strongly govern indoor radon accumulation [20]. In alignment with World Health Organization (WHO) guidelines, neighborhood government ought to establish dependent radon survey protocols aimed at identifying high-radon homes and implementing cost-effective mitigation measures [17].

3 RESEARCH GAPS AND FUTURE PERSPECTIVES

Despite the growing body of published studies on environmental radioactivity in Hilla City and Babil Governorate, seven critical scientific and methodological gaps remain to be addressed:

3.1 Limited geographical insurance

Existing investigations have targeted on selected districts or point locations [6]; excessive-decision spatial mapping encompassing all city, suburban, and rural sectors of Hilla remains vital.

3.2 Insufficient seasonal and temporal tracking

Most available datasets constitute single-season snapshots, while multi-year seasonal campaigns are required to seize fluctuations pushed by way of soil moisture dynamics, dirt hurricane frequency, hydrological modifications, and indoor air flow styles [9].

Three. Limited quantification of anthropogenic radionuclides: Future investigations ought to include systematic high-resolution HPGe analysis of artificial radionuclides—mainly 137Cs and fallout isotopes—to set up clear baselines against capability transboundary or commercial releases [21].

3.3 Incomplete cross-media environmental integration:

Soil, water, atmospheric dirt, and nutrients measurements are typically conducted in isolation, while integrating those cubicles inside a unified radioecological switch model is crucial for holistic general-dose assessment [22].

Five. Absence of connected epidemiological facts: Environmental hobby measurements by myself can not set up causal hyperlinks to radiation-triggered fitness results, requiring destiny integration of environmental dosimetry with fastidiously designed epidemiological studies that manage for confounding risk elements [23].

3.4 Methodological uncertainty in dose assessment:

Variations in assumed occupancy factors, dose-conversion coefficients, water/food ingestion costs, and analytical calibration requirements introduce discrepancies throughout posted annual effective dose estimates, necessitating standardized countrywide dose-assessment protocols [24].

3.5 Lack of centralized long-time period spatial databases:

Developing a dedicated Geographical Information System (GIS) repository integrating radionuclide hobby concentrations, terrestrial gamma dose charges, and geolocated metadata—combined with geostatistical interpolation and machine-mastering algorithms—would permit strong trend analysis and hotspot prediction [25].

4 CONCLUSIONS

This review severely examined the to be had scientific literature regarding environmental radioactivity in Hilla City and the surrounding Babil Governorate, Iraq, demonstrating that primordial natural radionuclides (238U/226Ra, 232Th, and 40K and 222Rn have been quantified across floor soil, ingesting water, foodstuffs, and hurricane-derived atmospheric dirt .

Collectively, earlier research offer valuable baseline measurements of particular activity concentrations, absorbed gamma dose prices, annual powerful doses, and radiological risk indices, with most stated values falling inside the world over regular reference limits. However, these findings must be interpreted carefully in light of sampling places, detector decision, and dosimetric assumptions, whilst preserving a clean difference between city Hilla datasets and broader Babil Governorate surveys.

Current medical evidence does no longer imply considerable radioactive infection or a validated elevation in radiation-associated morbidity amongst citizens of Hilla City. Nevertheless, implementing an incorporated, GIS-enabled environmental radiation tracking programme combining soil, water, atmospheric particulate, meals-chain, and indoor radon measurements with standardized dose-assessment methodologies will provide a rigorous clinical foundation for long-time period environmental control and public health protection in Hilla City.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors, Fatima O. Nasser and Amer S. Al-Khafagi, declare no conflicts of interest regarding this manuscript.

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