Plasma dynamic simulations for reducing the erosion of discharge channel walls of Hall Effect Thruster (HET)

Plasma dynamic simulations for reducing the erosion of discharge channel walls of Hall Effect Thruster (HET)

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Synopsis To assess and improve the design aspects during the design and development of HETs, it is essential to perform plasma dynamic simulations on these thruster designs. A 2D-3V (two dimensional-three velocity) Particle-in-cell Monte Carlo (PIC-MC) model has been used to simulate the standard SPT-100, and the design was optimized. Later, a completely new HET geometry has been simulated with an aim to optimize the thruster design with reduced plasma wall interaction.

Of the two primary means of propulsion available today for spacecraft mobility, namely chemical and electric, electric propulsion (EP) is an area of high interest, as the key attraction of EP systems has been the requirement of lower amount of fuel and highly efficient utilization of propellant mass. HETs are electrostatic thrusters which utilize a cross-field described by the Hall Effect to generate the plasma discharge with magnetized electrons and unmagnetized ions in the axial electric and radial magnetic fields applied in an annular ceramic channel.

The shape of the magnetic field which entraps the energetic electrons inside the channel, and the erosion of the discharge channel walls are the most crucial design elements that directly impacts the thruster lifetime and performance. Hence theoretical modeling of the plasma dynamics is of great importance, and with a right emphasis on theoretical modeling, the iteration cycles required in developing an EPS can be reduced. The present work has been done with an aim of developing an erosion less HET using a theoretical design and microscopic predictions on the plasma discharge parameters and magnetic parameters, and thus to enable an optimization and characterization of the modeled design.

The discharge channel plasma and the ion beam outside the discharge channel of both SPTs have been mathematically modelled using the full PIC method of simulation [1] incorporating the Monte-Carlo Collisions (MCC). The geometry of the new HET along with the magnetic flux lines has been designed in such a way to reduce the plume interaction with the walls, and an electrostatic solver has been used for the simulation.

The Xe neutrals are treated as background gas and is predefined to give a steady state profile, with maximum density of $10^{21}/cm^3$ just at the exit of the AGD, with a linear density drop from anode to exit of the channel.

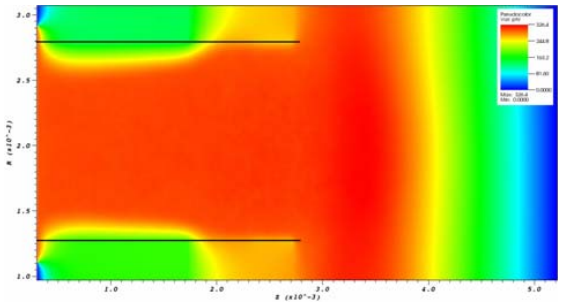

Figure 1. Plasma potential gradiant (at 0.5μs) in the discharge channel.

The electrons are assumed to have an initial electron energy of 25eV, and the cathode is modelled as electron emitter close to exit with V=0. The particle collision is handled by MCC, and both the electron-neutral collisions and ion-neutral collisions have been incorporated.

The simulation was carried out for about 0.5μs, and it was observed that the plasma potential acquires a steady state within this time. The measurements on the exhaust velocities of Xe^+ from the HET gives a value of above 20,000m/s. The simulation could also give interesting results on the plasma potential, Xe ion density and electron density.

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Optimization and analysis of process parameters of melt quenching technique for multiple performances of rare earth doped barium borate glass synthesis using Taguchi's design and grey relational approach

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ABSTRACT

Glass materials with strong physical, structural, and optical properties are in high demand in today's social and industrial sectors. Researchers have recently established the extensive uses of these widely utilized glassy materials in optoelectronic devices, aerospace, nuclear industries, etc. Optimization usually plays a significant role in the synthesis of material. Hence, this article uses the statistical optimization of multiple process parameters of the melt quenching technique for rare earth doped barium borate glass $60B_2O_3$-(40-X)BaO-XMO (MO-Er_2O_3/CeO_2 and X = 0.5,1.0,1.5 mol percentage)by Taguchi's Design of Experiment. The multiple performance characteristics were studied using Grey relational analysis. An experimental format for preparing the Barium Borate glass was utilized with a standard L9 orthogonal array designed by Taguchi. Grey relational analysis was used to analyze the effects of processing parameters, including melting temperature, the composition of rare-earth oxide, and melting time of glasses on density, refractive index, and indirect bandgap. Analysis of variance (ANOVA) showed the influence of process parameters on the multiple response parameters as directed by the S/N ratio of the response parameter. The prediction of optimal conditions for contributing process parameters to the multiple response parameters was estimated efficiently. Additionally, as compared to the initial conditions, the optimal confirmatory experiment exhibited a considerable improvement in the response parameters (refractive index, density, and indirect bandgap). Grey relational grade and analysis of variance (ANOVA) revealed that melting temperature to be sole factor significantly affecting multiple responses with a 95% confidence level. The objective of the work is to optimize the melt quenching process parameters and their influence on the physical and optical properties of glass for photonic applications. Using this optimization method, melt quenching was found to be the most influential parameter contributing about 73–74% in tuning the desired response parameters. The findings also revealed a very less deviation between the statistically predicted and experimental data of response parameter, with deviation ranging from 0.37 to 2.14%. This good agreement between experimental and predicted values of response parameters indicated the suitability of Taguchi method of optimization for melt quenching technique.

1. Introduction

Glasses have wide applications due to their excellent optical, mechanical, high resistance, thermal and optical properties. Compared to polymers and metals, the processing possibilities of glasses are highly constrained. Extreme conditions like high temperatures or chemical etching are used while shaping glass [1,2]. Hence the idea of designing robust glass materials using melt quenching technique finds increasing interest due to the expansion of glass in various technologies. Borate glass is the most stable glass with alkaline earth oxides (viz., SrO, BaO, CaO, MgO), improving glass-forming ability. In Alkaline earth borate glasses, these oxides serve as network formers when added in low quantities, and when added in high concentrations, they act as glass network modifiers [3]. Borate glass serves many scientific and industrial

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Mechanical instabilities in 2D-SiC with defects

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Excitation wavelength altered PL study of Co doped ZnO nanoparticles suitable for white LED application

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Abstract: ZnO nanoparticles doped with Co at different concentration ($Zn_{1-x}Co_xO$) were synthesized by sol–gel auto combustion method and are characterized by using various characterization tools. Structural study using X-ray diffraction technique (XRD) analysis showed the crystalline nature with hexagonal wurtzite geometry and the composition analysis using energy dispersive X-ray spectroscopy (EDX) confirmed the incorporation of Co in the ZnO lattice in the case of doped nanoparticles. Scanning electron-microscopy (SEM) and transmission electron microscopy (TEM) analysis showed the prepared nanoparticles as spherical, loosely agglomerated and having dimension of nanoscale. UV–vis DRS studies indicated a red shift in optical band gap with Co doping. PL spectra exhibits emission in the UV and visible region and the analysis revealed information about the presence of various types of defects in the ZnO lattice. An increase in the excitation wavelength gives intense emission in the high wavelength region for doped nanoparticles confirming the presence of divalent and monovalent oxygen as main defects. The $Zn_{0.93}Co_{0.07}O$ nanoparticles records CIE coordinates lying in the white region of CIE color space at 350 nm with CCT of 5561.4 K suggesting their suitability in fabrication of white light emitting diodes.

Keywords: excitation wavelength; PL; WLED; ZnO

1 Introduction

In the field of solid-state lighting (SSL) technology the demand for white light emitting diodes (LEDs) are very high which are used in the place of incandescent and fluorescent lamps [1]. To generate white light there are phosphor-converted (pc) LEDs where light from a blue or ultraviolet LEDs are converted to a long range of wavelength using phosphors. Zinc oxide is one such phosphor. Among the various semiconductors, ZnO is a potential candidate due to its wide energy gap, large free exciton binding energy of 60 mev and good thermal and chemical stability. These properties makes its use in solar cells, light emitting diodes, gas sensors, photocatalyst and many more applications [2–8]. ZnO is explored as pc LEDs due to its broad emission spectrum. But such generated white LED exhibits self-absorption in the system which makes the color rendering low and they have high cost of preparation [9]. Due to this fact pure white light emission from ZnO is in high demand. For this the method of doping is used.

ZnO can be used in optoelectronic devices by band gap modulation. By doping with various elements it is possible to tune the emission spectrum [10–14]. There are native defect states in ZnO due to presence of oxygen vacancies, zinc vacancies, oxygen interstitial and zinc at interstitials positions. The emission in ZnO mainly consists of UV emission resulting from the radiative recombination of excitons and a visible band due to defects or impurities called deep level emission (DLE) [15]. By introducing dopant, it can differ the number and nature of defects which impact the structural and optical properties. So this makes the variation in emission colour. Many studies were found in literature regarding emission characteristics of ZnO. Jayachandraiah et al. [16] reported enhanced green emission by doping Dy in ZnO, Ishan et al. [17] demonstrated red emission using Eu^{3+} ions doped in ZnO, El Mir et al. [18] studied PL spectra of Ca doped ZnO which consisted of UV, green and yellow-red bands. Khushboo et al. [19] have showed orange-red emission in Gd substituted ZnO nanocrystals due to formation of complex defects in the ZnO lattice. Shalendra et al. [20] studied various properties of ZnO nanostructures with Cu as dopant. The visible emission was in the blue-green regions and it got enhanced with the increase in Cu. Jyoti et al. [21] studied the role of defects and oxygen vacancy which effects the optical properties of Sm doped ZnO nanomaterials.

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Original Article

Assessment of heavy metal enrichment and contamination in the wetlands of Kannur district, Kerala

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Abstract The present investigation is an attempt to trace the heavy metal enrichment in the soil matrix of the wetlands Kannur district, Kerala. Wetland is an ecosystem which plays significant role in ecological balance. Characteristic vegetation of aquatic plants makes this distinct ecosystem as unique and distinguishable from other land forms and water bodies. The hydric soil prevailing in the wetlands is rich in organic matter content and also enriched with many heavy metals. In view of this, the enrichment of some major heavy metals such as Co, Fe, Mg, Cu, Zn, Cd, Hg, Ni, Pb, and As have been quantified in the soil samples collected from the wetlands of southern part of Kerala using Inductively Coupled Plasma-Mass Spectrometer. The adverse effect of this enrichment on human and environment is of serious concern and hence various pollution index parameters were calculated to assess the extent of contamination. The spatial distribution study confirms the dependence of geological factors on the enrichment of heavy metals. The study on various pollution index parameters reveals the selective enrichment of heavy metals. The continuous monitoring of wetlands is the need of the time as such areas are preserved for the cultivation of aquatic plants. The results of the investigation are presented and discussed in detail in the manuscript.

Keywords: Enrichment, heavy metal, inductively coupled plasma-mass spectrometer, pollution index, Wetland

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INTRODUCTION

In the last few decades, the air, water, and land on the earth have been contaminated by various means including human activities. Hence, risk to the public and environment has been growing day by day as a result of enhanced level of contamination. Environmental pollution is not a new phenomenon on the earth, yet it remains an issue of serious concern to all living organisms for all time. The ecological changes as a result of people intervention to lead a comfort life affect the environment adversely. Pollution is considered as one of the greatest crimes against the environment by people and occurs in the form of air, water, soil pollution. Among the various pollutants, heavy metals enrichment also plays a vital role. Hence, understanding the distribution and enrichment of heavy metals is need of the time as far as the living organisms and natural habitats are concerned. Depending upon the dose and duration, heavy metals can be poisonous to human well-being and causes extreme health issues.[1]

An ecosystem such as wetland plays a major role in the selective enrichment of heavy metals. Generally, wetlands are areas that are inundated or submerged for at least

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The green and chemical synthesis, and characterization of ZnO nanoparticles by aqueous leaf extract of aloe vera

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Abstract. The exact physical and chemical properties of nanoparticles depend on the way in which they are synthesized. The common techniques are hypothermal methods, electrochemical deposition, sol-gel method, chemical vapour deposition, co-precipitation method etc. In the present study, zinc oxide nanoparticles have been synthesized by botanical extract and chemical reducing agents with major objective to compare the nature and average particle size of the nanoparticles synthesized by these two methods. An attempt is also made to understand the influence of molarity on the chemically synthesized NPs by varying the molar concentration of precursor. The structure and morphology of synthesized NPs have been studied using X-ray diffraction (XRD) technique. For chemically synthesized NPs the major peak was observed at 36.147 for both the precursor at 0.2M and 0.3M. The average crystalline size was found to be 13.09 nm and 11.09 nm for precursor at 0.2M and 0.3M respectively. The major peak for green method was observed at 36.147 with an average crystalline size of 9.2 nm. The study clearly indicates that, green method is particularly suitable for the synthesis of smaller sized NPs.In chemical method, the molarity of the precursor influences the particle size, as the molarity decreases particle size also decreases.

1. Introduction

Nanotechnology deals with the study of particles having dimension from 1 nm to 1000 nm. Physical, chemical and biological methods are the commonly used methods for synthesizing nanoparticles [1]. The physical methods are sometimes inappropriate because they require large amount of energy, time and space. The chemical methods are considered as an unfriendly approach as they use toxic and harmful substances [2]. The green methods are generally cheap and safe for the synthesis of nanoparticles. Biodegradable raw materials such as plant parts, microbes, fruit peels and vegetables are used for green synthesis [3,4].The NPs so synthesized find their applications in various fields such as electrochemistry, catalysis, sensors, biomedicines, food packaging, health care, cosmetics, optical devices etc [5].Preparations of inorganic nanocrystalline metal oxides have wide interest due to the extremely large surface area and wide biological applications.

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Environmental Impact on Simulation of Soil to Plant Cadmium (Cd) Transfer in Amaranthus and Tomato Plants

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Abstract

In this paper, Environmental Impact on Simulation of soil to plant cadmium (Cd) transfer is analyzed in Amaranthus and Tomato Plants. The take-up of cadmium by vegetable nursery plants in sewage sludge included soil is reproduced. Plants cultivated on such fields collect heavy metals, which prompts phyto-toxicity. This manuscript depends on the reformist perceptible analytical model for substantial metal movement. The model is applied for reenacting cadmium take-up by (Amaranthus tricolor) and Tomato (Lycopersicon esculentum) utilizing estimated field information. The overseeing non-straight incomplete differential equations are settled analytically utilizing MATLAB.

Key words: Simulation, Cadmium, Amaranthus, Tomato, Phyto-toxicity, MATLAB

1 Introduction

The discharge of huge amount of sewage and other wastes from different outlets influence concentration of the heavy metals in soils. The research studies on heavy metals accumulation have great significance because of their association with environmental issues and the health of both flora and fauna. The deficiencies and excess of heavy metals concentration may result in a variety of disorders. On the other hand toxic metals are known to be very

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Light Charge Particle and Intermediate Mass Fragment Emission from Excited Compound Nuclei Formed in Heavy-ion Reaction

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Introduction

Nuclear reactions induced by heavy ions have now become a major tool in the field of nuclear physics research. A deep understanding of fusion-fission process of the compound nucleus that are formed in heavy ion reaction is essential for studying the formation of heavy nuclei. The studies in the field of heavy ion induced reactions have been targeting toward this aim. There have been extensive experimental studies on collision involving deformed nuclei that can have many orientations in the ground state. In low energy heavy ion reactions, both the light (A ~ 60) and medium mass (A ~ 110) compound systems emit Intermediate mass fragments (IMFs) with mass lighter than A ~ 20 and they arise as multiple clusters and are accompanied by the production of multiple light particles ($Z \leq 2$). Light compound nuclei (CN) with mass number $A_{CN} < 44$ that are formed in low energy (E/A < 15MeV/nuclei) heavy ion reactions are highly excited and carry large angular momenta. It was found that the decay process must depend on temperature and angular momentum dependent potential barriers. Theoretically the de-excitation of the compound systems formed in low energy nuclear reactions were studied using different models. The cluster decay studies of $^{112-122}$Ba as a ground and excited system was done within the model. In the present study the decay of excited compound nuclei like ^{48}Cr, ^{56}Ni, ^{44}Ti, and $^{26-29}$Al with and without incorporating the deformation effects has been investigated. Also, the studies were extended to the excited state decay of heavy elements. In all cases, the study has been extended and the cross sections for entrance channels and E_{CM} values other than the available experimental values have been evaluated, which can help future experimental studies in this field.

Within the Coulomb and proximity potential model (CPPM) [1] and the Coulomb and proximity potential model for deformed nuclei (CPPMDN) [2], a wide range of studies have been performed on the alpha decay of heavy and SHN, cluster decay of heavy and SHN and also on the decay of excited compound nuclei. The modified version of CPPM for excited nuclei with temperature effects included [3] was used to study the decay properties of various even-even isotopes of barium in the range $112 \leq A \leq 122$ using recent mass tables for both the ground and excited state decays.

The decay cross section

An extensive study on the decay of light nuclei in excited state has been done within the one-dimensional barrier penetration model by taking the scattering potential as the sum of the Coulomb and nuclear proximity potential. The total cross section, the intermediate mass fragment (IMF) production cross section, and the cross section for the formation of light charged particle (LP) for both the spherical as well as deformed nuclei have been calculated using the formulae of Wong for small values for E and for large values of *E*, and the Glas and Mosel formula and compared with the available experimental data.

Results and discussion

The details on the results obtained through the studies are given below.

(a) Cluster Decay of $^{112-122}$Ba Isotopes from Ground State and an Excited Compound System

Cluster radioactivity is a natural radioactivity process which is accompanied by the

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Estimation of radiation hazard indices along the coastal environment of Kavvayi, Kerala, India

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ABSTRACT

This research evaluates the level of radioactivity and the impact of radiological elements in Kavvayi's coastal areas, located within Kannur district. Radionuclide concentrations, including ^{40}K, ^{226}Ra, and ^{232}Th, were quantified in sand specimens using a highly efficient NaI (Tl) detector. Several radiological elements, such as absorbed dosage, yearly effective dosage, radium equivalent activity, lifetime excess cancer risk, and yearly gonadal dose equivalent, were computed and juxtaposed with figures reported in global regions. These radiological elements were found to be moderately above the average values proposed by the UNSCEAR 2000 report for India and the world. Our investigation demonstrates that the gamma radiation in the researched region does not present significant carcinogenic risks or likelihoods of cancer development for local residents. Nonetheless, comprehensive research is required to conclusively determine the elevated levels of natural radioactivity in the area under study. The outcomes of these rigorous examinations are presented and discussed in depth.

Selection and peer-review under responsibility of the scientific committee of the 10th National Conference on Condensed Matter Physics and Applications.

1. Introduction

Radiation stemming from cosmic sources and the radiation generated by the decay of radionuclides are both classified as types of natural radiation. The major source of these naturally occurring radionuclides is the earth's crust. Primordial radionuclides on the earth's crust and the decay products they produce are major contributors to natural radiation. With the exception of cosmogenic nuclides and the long-lived radioisotope ^{40}K, natural radioactivity is mostly obtained from the decay of radionuclides created during the nucleosynthesis phase prior to the formation of our solar system. The activity concentrations of the primordial radionuclides viz. ^{238}U, ^{232}Th, and ^{40}K are used to assess the terrestrial radioactivity in the soil. Natural radionuclides are part of the radioactive decay chains, which encompass elements such as ^{238}U, ^{235}U, and ^{232}Th. In the spontaneous process of radioactive decay, alpha particles, gamma particles or beta particles are emitted. According to UNSCEAR (1998), there are about 70 radioactive nuclides among 340 nuclides that occur naturally. Natural radionuclides are frequently distributed into diverse environmental matrices, such as soil, sand, sediment, water, and air, through the weathering of rocks and other materials. Moreover, the Earth contains a diverse range of radioactive materials, making it a source of ionizing radiation. This radiation has an impact on every ecosystem, whether it's on the surface, beneath the ground, or within the Earth's atmosphere. Monitoring the concentration of radionuclides across different ecosystems is crucial to evaluate potential risks to biota and establish effective emergency responses [1]. The inhabitants of these areas are particularly susceptible to exposure to natural radiation, which underlines the significance of this research.

The level of natural radiation in the environment can vary greatly due to numerous geographical and geological conditions. Factors such as the season, atmospheric pressure, temperature, wind patterns, the degree to which rocks have weathered, and the properties of the soil can all contribute to these fluctuations.

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A Review on the Dynamics of Natural Radionuclides Along the Coastal Environs of Kerala, South West Coast of India

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Abstract
Extensive and systematic investigations have been carried in almost all parts of the world in order to obtain a clear understanding of basic dynamics of radionuclides in the environment. In this context, this review is an attempt to probe the environment of coastal Kerala by consolidating the major studies carried out on environmental radioactivity mostly employing well-established nuclear techniques and radiochemical methods. The review indicated the need for more in depth and focused studies in this sector to confirm the sources of monazite bearing black sands and the geological factors influencing their formations. The consolidation will be scientific assessment for the future, the impact of assessment of major and minor industrial activities and other human interventions in the environment of coastal Kerala.

Keywords Radionuclide · Coastal Kerala · Monazite · Black sand

Introduction

The Major contribution of radiation exposure to human being is from natural sources of radioactivity [1]. The principal sources of natural radiation in the environment and the associated exposure vary from place to place, depending on the geographical locations, geological formations, and human activities [2]. The weathering and natural disintegration of rocks are the major processes responsible for the radioactivity level especially in soil [3]. Depending on the geographical distribution and geological formations, there are few regions where the radiation levels are substantially high; such regions are termed High Background Radiation Areas (HBRAs) [4]. The southern coastal areas of Kerala, especially Chavara, Neendakara and Karunagappally in Kollam districts, are reported as well-known HBRAs in the world [5]. Several extensive and in-depth studies specific to the coastal environs ofKerala have been carried out on the enrichment of natural radionuclides and its associated health hazards. Most of the studies indicated that the enrichment of radionuclides is mainly due to monazite-bearing black sands formed from the weathering of rocks, especially the charnockite group of rocks in the Western Ghats [6]. It is also noted that, a number researchers are actively involved in monitoring the level of radioactivity worldwide as part of the social health and hazardous awareness concern [7]. The Kerala coastal environs experiencing a High Background Radiation especially in the southern parts of the state, has been studied extensively by several investigators. In view of the above a review on the dynamics of natural radionuclides along the coastal environs of Kerala has been carried out and results are discussed in detail.

Study area

Kerala, the southernmost state of India, lies in between 8° 18′ N and 12°48′ N latitude and 74° 52′ E and 77° 22′ E longitude. The state is located in the tropical region of the Indian peninsula, and it has a geographical area of 38,863 km^2[8], which comprises of 1.18% of the total area of country. Physiographically, the land consists of three natural regions, low lands, midlands, and highlands. Kerala's common ground or coastal plain is sandwiched between the Arabian Sea and

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Original Article

Dynamics of heavy metal accumulation in an endosulfan affected area of Kasaragod district, southwest coast of India

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Abstract The heavy metal accumulation study on bed sediments of Kodangari stream situated in Enmakaje panchayath of Kasaragod district, Kerala, has been carried out. A total of 20 sediment samples along the stream were collected and analyzed for the concentration of heavy metals, namely manganese (Mn), zinc (Zn), copper (Cu), and iron (Fe), using a flame atomic absorption spectrometer. The observed concentration of Mn varies in the range of 0.14–32.80 ppm, the concentration of Zn varies in the range of 0.15–10.80 ppm, the concentration of Cu varies in the range of 1.80–12.20 ppm, and the concentration of Fe varies in the range of 19.12–378 ppm. The physicochemical parameters, namely pH, moisture content, organic matter content, and electrical conductivity, associated with the samples were also measured and correlated with the concentration of heavy metals. There exists a good correlation between the concentration of heavy metals and various physicochemical parameters. The results obtained are presented and discussed in detail in the manuscript.

Keywords: Concentration, endosulfan, heavy metal, sediments

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INTRODUCTION

The study on heavy metal content of selected samples from an environment assumes great significance because of their association with environmental issues and the health of plants, animals, and humans. These are found mainly in terrestrial rocks, sand, water, air, living matter, limestones, seawater, etc., in varying concentrations.[1] The sources of these metals in the atmosphere can be natural and/or anthropogenic. The natural sources include erosion, weathering of rocks and soils, volcanism, sea spray, thermal springs, lake and river sediments, vegetation, forest fires, biological methylation, and plant growth. Anthropogenic sources include mining operations, smelting and other industrial activities, combustion of wood, oil, coal, waste incineration, agricultural operations, and cremation.[2] The assessment of heavy metal concentration in general and toxic heavy metals in particular is important for the prediction of risk to the environment and public. The distribution of heavy metals in various environmental matrices depends on the nature of the element itself and the site of specific characteristics such as soil type and its physicochemical properties. The most important variables of soils which affect the distribution are soil pH, texture, organic matter quantity and quality, mineral composition, and electrical conductivity.[3] Increased human population,

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Original Article

Dynamics of heavy metal accumulation in an endosulfan affected area of Kasaragod district, southwest coast of India

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Abstract The heavy metal accumulation study on bed sediments of Kodangan stream situated in Enmakaje panchayath of Kasaragod district, Kerala, has been carried out. A total of 20 sediment samples along the stream were collected and analyzed for the concentration of heavy metals, namely manganese (Mn), zinc (Zn), copper (Cu), and iron (Fe), using a flame atomic absorption spectrometer. The observed concentration of Mn varies in the range of 0.14–32.80 ppm, the concentration of Zn varies in the range of 0.15–10.80 ppm, the concentration of Cu varies in the range of 1.80–12.20 ppm, and the concentration of Fe varies in the range of 19.12–378 ppm. The physicochemical parameters, namely pH, moisture content, organic matter content, and electrical conductivity, associated with the samples were also measured and correlated with the concentration of heavy metals. There exists a good correlation between the concentration of heavy metals and various physicochemical parameters. The results obtained are presented and discussed in detail in the manuscript.

Keywords: Concentration, endosulfan, heavy metal, sediments

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INTRODUCTION

The study on heavy metal content of selected samples from an environment assumes great significance because of their association with environmental issues and the health of plants, animals, and humans. These are found mainly in terrestrial rocks, sand, water, air, living matter, limestones, seawater, etc., in varying concentrations.[1] The sources of these metals in the atmosphere can be natural and/or anthropogenic. The natural sources include erosion, weathering of rocks and soils, volcanism, sea spray, thermal springs, lake and river sediments, vegetation, forest fires, biological methylation, and plant growth. Anthropogenic sources include mining operations, smelting and other industrial activities, combustion of wood, oil, coal, waste incineration, agricultural operation, and cremation.[2] The assessment of heavy metal concentration in general and toxic heavy metals in particular is important for the prediction of risk to the environment and public. The distribution of heavy metals in various environmental matrices depends on the nature of the element itself and the site of specific characteristics such as soil type and its physicochemical properties. The most important variables of soils which affect the distribution are soil pH, texture, organic matter quantity and quality, mineral composition, and electrical conductivity.[3] Increased human population,

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An analysis on geographical ascendancy and the effects of physico-chemical parameters on radionuclides concentration in the central and northern coastal regions of Kerala, India

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Abstract

The present study investigates the correlation between physico-chemical parameters and natural radionuclides, and relates its distribution with geographical factors of the study area. For the same, the activity concentration of natural radionuclides such as ^{40}K, ^{226}Ra, and ^{232}Th in sand samples collected from the central and northern parts of coastal Kerala, India has been measured using high efficiency NaI (Tl) detector and compared the concentration with 'favoring factors for distribution' that is lithology and drainage pattern. The activity concentration was also correlated with multiple physico-chemical parameters of the sand samples. The details of which are discussed in the manuscript.

Keywords Lithology · Drainage · Physico-chemical parameters · ^{40}K · ^{226}Ra · ^{232}Th · Central and northern Kerala

Introduction

The concentration of any mineral in a particular region is mostly controlled by the characteristics of the parent rock existing there [1]. The parent rock, which disintegrates throughout the weathering process, eventually becomes soil. This soil has diverse textures due to various contributing variables, and contains almost the same minerals as the parent rock has [2]. In the present study also the same technique is employed to determine the source of monazite mineral. Here, when explaining the source of the parent rock of monazite mineral, it is usually seen in high and intermediate ranked metamorphic rocks which is formed from argillaceous sediments. It is also formed due to morphometric differentiation, thorium-rich monazite which can be found in abundance in plutonic terranes [3]. The presence of plutonic metamorphic rocks containing charnockite, biotite and hornblende gneiss and schist, pegmatite etc., can be seen in Western Ghats regions of Kerala [4]. Hence lithology of the region plays an important part in the present study.

The lithology of central and northern Kerala is mainly distributed with charnockite group of rocks and Gneissic rocks. Mostly they are found in crystalline form. The Gneissic rocks include both biotite and hornblende. Remaining areas are capped with laterite rock and the coastal areas with unconsolidated sediments of Alluvium and coastal sands. This spatial distribution of lithological and geological characteristics in central and northern Kerala resembles that of southern Kerala. However, several studies reported that, the radioactivity level in the central and northern parts of Kerala shows lower values when compared with the southern parts of Kerala [5–7]. This creates contradictions in above mentioned statements.

In order to understand the concept of dispersion and transportation of radionuclides from different environmental matrices to the biota, knowledge about the distribution between different physico-chemical parameters and spatio-temporal distribution of geographical factors is essential. The natural and anthropogenic activities occur will influences the physico-chemical parameters of the different

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RADON, THORON AND THEIR PROGENY DISTRIBUTION AND ESTIMATION OF ANNUAL EFFECTIVE DOSE AND EXCESS LIFETIME CANCER RISK IN PANATHADY, KASARAGOD DISTRICT, KERALA

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Radon and thoron are natural radioactive gases that tend to accumulate in the indoor environment and one of their major health implications is the ability to cause lung cancer. Present study comprises the quantification of radon and thoron activity concentrations and measurement of gamma exposure rates in different types of dwellings from the endosulfan-affected area, Panathady, Kasaragod district, Kerala. It is observed that, residents of this area were more prone to various diseases and health problems including cancer. The LR-115 type II solid state nuclear track detectors with single entry pin-hole based dosemeters have been used for the measurement of ^{222}Radon and ^{220}Rn activity concentrations. The assessment of radiological parameters such as annual effective doses and excess lifetime cancer risk has also been done in order to understand the dose level and the associated risk. The estimated values have been compared with the limit recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and International Commission on Radiological Protection (ICRP). The average indoor radon and thoron activity concentrations observed in these dwellings were 134 ± 30 and 111 ± 28 Bq m^{-3}, respectively. The estimated activity concentrations, effective doses, etc. are found to be within the recommended level by the UNSCEAR or ICRP.

INTRODUCTION

Human beings are exposed to varying amounts of natural radiation emitted from radon, thoron and their progenies from general environment and dwellings. The ^{222}Rn and ^{220}Rn are the gaseous radioactive products by the decay of the radium isotopes ^{226}Ra and ^{224}Ra. Further ^{226}Ra and ^{224}Ra are the decay products of naturally occurring radioactive materials such as ^{238}U and ^{232}Th ever since their existence on earth[1]. Some of the atoms of these radon isotopes are released from the solid matrix of the material by recoil when the radium decays[2]. The ^{222}Rn, ^{220}Rn and their decay products are sources of dose to lung and stomach through inhalation and ingestion. However, inhalation mode gives the major contribution to dose than ingestion[3]. A certain fraction of the radon releases into the air where, in confined spaces such as homes and office buildings, radon can build up to harmful levels. Measurement of radon is interesting because of its alpha-emitting nature and its penetration power depends on the energy of the alpha particle emitted. Moreover, it decays with a half-life of 3.8 d into a short-lived series of daughter products. When these progenies attach to aerosol particles, it will be deposited in the lungs through inhalation and bombard sensitive lung tissue and cause damage due to alpha irradiation[4]. Over a period of time, irradiation of tissues leads to malignant transformation and the formation of lung cancer. Indoor radon has been considered to be the second leading cause of lung cancer after tobacco smoking[4, 5].

The main objective of this study is to assess radon, thoron and their progeny activity concentration in some dwellings and corresponding outdoor environment of Panathady Panchayath, Kasaragod district, Kerala. The study region is a well-reported endosulfan-affected area with various types of diseases and health issues including lung cancer. The study also aimed to estimate dose parameters, which are also one of the significant factors to establish the lung cancer among various other reasons behind the health issues reported in the study area and to ensure the contribution of these radionuclide activity concentrations behind the health problems. In view of the above, the radiological protection of the population residing in these areas attains great concern. The newly developed pin-hole based radon–thoron discriminating dosemeters are used for the estimation of radon and thoron in the present study. Figure 1 shows the location map of the study area. The corresponding location co-ordinates are mentioned in Table 1. The detailed description of the systematic investigation and the results obtained are presented and discussed in the manuscript.

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Environmental Impact on Simulation of Soil to Plant Cadmium (Cd) Transfer in Amaranthus and Tomato Plants

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Abstract

In this paper, Environmental Impact on simulation of soil to plant Cadmium (Cd) transfer is analyzed in Amaranthus and Tomato Plants. The take-up of cadmium by vegetable nursery plants in sewage sludge included soil is reproduced. Plants cultivated on such fields collect heavy metals, which prompts phyto-toxicity. This manuscript depends on the reformist perceptible analytical model for substantial metal movement. The model is applied for reenacting cadmium take-up by Amaranthus tricolor and Tomato (Lycopersicon esculentum) utilizing estimated field information. The overseeing non-straight incomplete differential equations are settled analytically utilizing MATLAB.

Key words: Simulation, Cadmium, Amaranthus, Tomato, Phyto-toxicity, MATLAB

1 Introduction

The discharge of huge amount of sewage and other wastes from different outlets influence concentration of the heavy metals in soils. The research studies on heavy metals accumulation have great significance because of their association with environmental issues and the health of both flora and fauna. The deficiencies and excess of heavy metals concentration may result in a variety of disorders. On the other hand toxic metals are known to be very

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Dynamics of radionuclides activity, radon exhalation rate of soil and assessment of radiological parameters in the coastal regions of Kerala, India

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Abstract
The activity concentration of natural radionuclides such as ^{40}K, ^{226}Ra and ^{232}Th and radon surface and mass exhalation rates of the soil were assessed and the related radiometric parameters have been estimated from the activities of the samples from beaches of coastal Kerala including some high background radiation areas (HBRAs). The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th were estimated using NaI (Tl) gamma ray spectrometry and the radon mass and surface exhalation rate has been estimated using the 'Can technique' with LR-115 solid state nuclear track detectors. The estimated values indicate that the radionuclide concentrations in the study area were within the recommended limit except for Kollam district when compared with world average values. Radon exhalation rate found to vary according to grain size of the soil. Dose parameters have been evaluated in order to verify the radiological protection of the general public. The results of the present systematic investigation are presented and discussed in detail in the manuscript.

Keywords Radionuclide · Soil grain size · Exhalation rate · NaI (Tl) detector · Can technique · Annual effective dose

Introduction

Human being is continuously exposed to ionizing radiations from natural sources and is an inescapable feature of life on earth. The two main contributors to natural radiation sources are high-energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides that are originated in the earth's crust, which are present everywhere in the environment with half-lives comparable to the age of earth and their decay products. External exposure to human is mainly due to the presence of terrestrial radionuclides such as ^{238}U and ^{232}Th series and singly occurring ^{40}K in rocks and soils [1]. Radon is one of the significant sources of natural radiation which is a naturally occurring radioactive isotope of uranium series with half life of 3.82 days. The decay products of radon include ^{218}Po, ^{214}Po, ^{214}Pb and ^{214}Bi, which can be attached to aerosol, may lead to greater biological effects through inhalation and lead to lung cancer on continuous exposure for a long time. Therefore, studies on activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides, radon exhalation rate and estimation of associated dose parameters in soil assumes great significance [2].

Radon is present in indoor and outdoor air since its parent nuclide ^{226}Ra occurs in trace amount throughout the earth. When ^{226}Ra decays, the fraction of the liberated ^{222}Rn in the soil grain escapes in to the air/water filled pore space and migrates through the pore space by the process known as emanation. Emanation fraction or emanation coefficient is the ratio of fraction of radon emanated to the total amount of radon generated in the soil grain [3]. The emanation happened mainly by two processes: diffusion and recoil in which diffusion do not contribute much to emanation process due to extremely short diffusion length (10^{-7} to 10^{-8}) of radon in the soil [4]. So the emanation fraction mainly comes from the recoil process, for which the range of recoil distance of radon in the common minerals is 20–70 nm, in water is 100 nm and in air is 63 mm. The emanation of radon continues until it decays or releases in to the air and this process is known as exhalation [3]. The radon exhalation rate is the rate of radon escapes from the soil surface to the atmospheric air and is measured either per unit area or per unit mass of the soil. The two mechanisms are involved in the exhalation

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Original Article

Distribution and enrichment of ^{210}Po and ^{210}Pb in the environment of Mangalore, Southwest Coast of India

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Department of Physics, Payyanur College, Kannur, Kerala, [1]Department of Physics, SJC Institute of Technology, Chickballapur, [2]Department of Physics, Mangalore University, Mangalore, Karnataka, India

Abstract The article deals with the distribution and enrichment of ^{210}Po and ^{210}Pb in soil samples of Mangalore, Southwest Coast of India. The soil samples collected from the region were analyzed for ^{210}Po and ^{210}Pb activity using radiochemical analytical technique to understand the distribution and enrichment of these radionuclides. The ^{210}Po activity in soil in the environment of Mangalore varies from 1.5 to 26.9 Bq/kg with a mean value of 12.6 Bq/kg and that of ^{210}Pb varies in the range 7.6–67.5 Bq/kg with a mean value of 38.9 Bq/kg. The mean ^{210}Po/^{210}Pb ratio observed was 0.3, and it shows that the radionuclides ^{210}Po and ^{210}Pb are not in equilibrium and the accumulation of ^{210}Pb in soil is more compared to ^{210}Po. A good correlation exists between the activities of ^{210}Po and ^{210}Pb with correlation coefficient $r = 0.7$. The absorbed gamma dose in the environment of the region varies from 39.4 to 78.8 nGyh^{-1}, with a mean value of 48.2 nGyh^{-1}. The activity of both ^{210}Po and ^{210}Pb in soil almost certainly depends on the physicochemical parameters of the soil. The results of the systematic studies on the distribution and enrichment of ^{210}Po and ^{210}Pb and the absorbed gamma dose rate in air are presented and discussed in this article.

Keywords: ^{210}Pb, ^{210}Po, enrichment, radionuclide, soil

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INTRODUCTION

Mangalore, an important region of Southwest Coast of India, is poised to become a center of major industrial activity with the operation oil refineries and petrochemical complexes, chemical and fertilizer factories, and various other industries. Most of these industrial activities are concentrated in a stretch of about 10 km. Hence, detailed studies on radiation level and distribution and enrichment of radionuclides in the environment of the region have relevance in understanding the radiation effects on the environment and human health. In view of this, detailed studies on radiation level and radionuclide distribution have been carried out in Mangalore region.[1] As part of the study, soil samples collected from the region were analyzed for ^{210}Po and ^{210}Pb activity concentration to understand the distribution and enrichment of these radionuclides in the region.

The radionuclides ^{210}Po and ^{210}Pb are among the most important natural radionuclides of Uranium series from a radioecological point of view. Both ^{210}Po and ^{210}Pb are of great concern for reasons mainly because of their large contribution to the natural radiation dose received by many species. The radionuclide ^{210}Po is one

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Original Article

Investigation on the enrichment of radionuclides in an endosulfan-affected area, Enmakaje Panchayath, Kasargod

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Abstract In the present study, systematic analysis of radionuclides concentration and radiological parameters of sediment samples collected from the banks of Kodankari stream situated in Enmakaje Panchayath, Kasargod, has been carried out. A total of twenty sediment samples were collected and analyzed for activity concentration of radionuclides, namely, ^{40}K, ^{226}Ra, and ^{232}Th using high-purity germanium detector. The activity concentration of ^{226}Ra ranges from 30.5 to 56 Bq/kg with a mean value of 41.6 Bq/kg, activity concentration of ^{232}Th ranges from 100.5 to 220 Bq/kg with a mean value of 144.4 Bq/kg, and activity concentration of ^{40}K ranges from 19.1 to 98.6 Bq/kg with a mean value of 64.7 Bq/kg. The radiological parameters such as absorbed dose, annual effective dose (indoor and outdoor), radium equivalent activity, and internal and external exposure indices were calculated and compared with the recommended safety limits prescribed by various agencies. The results of the systematic analysis are presented and discussed in detail in the manuscript.

Keywords: ^{226}Ra, ^{232}Th, ^{40}K, enrichment, radiological parameters, radionuclides

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INTRODUCTION

Radionuclides are the part of every environmental matrix and are found in varying concentration. Naturally occurring radioactive isotopes in the environment come from singly occurring ^{40}K and radionuclides of uranium and thorium series. These radioactive isotopes are present in rocks, sands, soils, sediments, and all other environmental matrices. The decay of naturally occurring radionuclides in soil/sediment produces the gamma radiation field and the sources of terrestrial gamma radiation are the decay products of thorium and uranium series and radionuclides like ^{40}K.[1] Natural radiation is the largest contributor to external dose to the world population and the radionuclides that are part of air, soil, building materials, rocks, vegetation, and food contain varying amounts of radioactivity.[2] Hence, the assessment of gamma radiation dose from natural sources has greater importance. Environmental radioactivity and external exposure due to gamma radiation occur at different levels in nature, and it varies geographically due to geological changes in each region.[3]

Between 1976 and 2000, the plantation corporation of Kerala aerially sprayed endosulfan on cashew plantation covering 11 grama panchayaths of Kasargod district, Kerala.[4] Various types of biological disorders such as neurobehavioral disorders, congenital disorders, cancers, and gynecological abnormalities can be seen at the nearby

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Preparation and Characterization of Polysulfone Based Hollow Fibre Composite Membranes for Water Purification

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ABSTRACT

Nanofiltration membranes are gaining more importance in the field of water treatment especially in desalination plants. Hollow fibre membranes have been preferred over other membrane configurations due to their high membrane surface area to module volume, mechanical property and easy handling. In the present work, we prepared new type of polysulfone (PSf) composite hollow fibre membranes by blending PSf with polyvinylpyrrolidinone-nitrobenzene (PVPD) in different compositions. New membranes were fabricated using wet-jet phase inversion technique. The resultant composite membranes were characterized by various analytical techniques such as water contact angle, SEM, DSC, TG. Pure water flux of the membranes was measured using cross-flow filtration techniques. The study revealed that increased composition of PVPD in casting solution resulted in a highly porous membrane structure and the pure water flux of the membranes increases in the same order.

Keywords: PVP, PSf, hollow fibre membrane, composite, desalination, nanofiltration

1.0 INTRODUCTION

Membrane filtration has gained enormous applications in the field of separation technology [1]. It is useful in various industrial fields such as pharmaceutical, biomedical, food, pure water production, desalination and purification of gases [2-5]. The pore size, surface roughness, mechanical strength and hydrophilicity of the membrane are the various factors influences the membrane separation process [6]. Polysulfone (PSf) is a commonly used membrane material due to its excellent mechanical, chemical and thermal properties [4, 7, 8]. It can resist extreme pH conditions of the medium and also having good film forming capacity [6]. However, the highly hydrophobic nature of the PSf membranes limits its application as a membrane material.

The membrane fouling due to the hydrophobicity of the polymeric membrane is also a major challenge for the researchers. There are several studies reported in the literature to make the PSf membranes more hydrophilic, such as coating, grafting and blending [9]. But blending with a hydrophilic polymer is the best method due to its simplicity [6]. Blending of PSf with hydrophilic polymers can change the

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Original Article

Accumulation of ^{210}Po in Medicinal Plants in the Environment of Mangalore, Southwest Coast of India

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Abstract Systematic studies on the accumulation of ^{210}Po in 12 medicinal plants and activity concentration in associated soils have been carried out. The activity of ^{210}Po was measured using a ZnS (Ag) alpha counting system. The mean ^{210}Po activity concentration was found to be 27.8 and 8.3 Bq/kg for plant and soil, respectively. The plant-to-soil mean activity ratio of ^{210}Po was found to be 3.8. A good correlation was observed between the activity concentration of ^{210}Po in plant and soil. The absorbed gamma dose rates in the study area were also measured using a portable scintillometer and found to vary in the range of 34.8–52.2 nGy/h, with a mean value of 43.5 nGy/h. The results of these systematic investigations are presented and discussed in detail.

Keywords: ^{210}Po activity, alpha counting system, dose rate, medicinal plants, soil

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INTRODUCTION

Mangalore, an important region of the southwest coast of India, is heading to become a major industrial activity center with oil refineries, petrochemical complexes, chemical and fertilizer factories, thermal power stations, and a host of other industries. Although the information on the radiation level and radionuclide distribution in different environmental matrices of the region is available in the literature, systematic studies on uptake of radionuclides by plants from soil are sparse. The uptake of radionuclides within the soil to plant is a part of the biochemical cycling. The mobility and availability of radionuclides depend on several factors such as geochemical, biological, and climatic conditions. The prediction of radionuclides uptake by plants from a given growth medium should be based on several biotic and abiotic parameters that control their behavior in soil. The risk to both the environment and human health of a given radionuclide is a function of its mobility and phytoavailability. Therefore, the studies on behavioral properties of radionuclides in soils have gained importance in environmental studies.

In view of this, about 12 Ayurvedic medicinal plants and associated soils collected from Moodabidri, near Mangalore, were analyzed for the concentration of ^{210}Po. The radionuclide ^{210}Po is one of the most toxic alpha-emitting natural radionuclides of ^{238}U series and an important contributor to the internal exposure of human population. The main sources of the ^{210}Po entering the environment are natural decay of ^{238}U series and the exhalation of radon gas from the surface layers of the earth's crust into the atmosphere as a result of the turbulent diffusion and convection processes. Plants may get radioactive nuclides

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Fully Interpenetrating Polymer Network from Natural Rubber and Guar Gum for the preparation of Nano-composites

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ABSTRACT

Fully interpenetrating polymer network (IPN) based on natural rubber (NR) and Guar Gum (GG) was prepared by using Glutaraldehyde as a common crosslinking agent. As both the polymers are naturally occurring and the resulting IPN material can be termed as a green polymeric material. The resulting material can be used as the matrix material for the preparation of nano composites. The mechanical performance of this system has been studied in detail using Universal Testing Machine. Tensile strength, elongation at break and modulus were determined. Effects of weight fraction on the physical properties of NR/GG IPN's were also studied. A remarkable improvement was observed in the mechanical strength and hardness of the blend by the formation of IPN. The effect of Glutaraldehyde concentration in the IPN was also examined.

Key words: Interpenetrating Polymer Network, Tensile Strength, Natural Rubber, Guar Gum.

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INTRODUCTION

Natural rubber and Guar gum are two well-known polymers and their biomedical, mechanical and other related properties made them an attractive choice for engineering applications [1]. Both the polymers are naturally occurring polymers. Therefore these materials can be termed as green polymers. Natural rubber has long been considered as an excellent general purpose polymer with wide ranging industrial applications [2-5]. Guar gum is a water soluble and non-toxic polymer with good film forming property. The possibility of blending the

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Assessment of natural radionuclide enrichment and radiation hazard from building materials in Kannur District, Kerala

K. Nadira Mahamood[1] · C. S. Kaliprasad[2] · Y. Narayana[3] · V. Prakash[1]

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Abstract
The activity concentrations of natural radionuclides from the ^{238}U and ^{232}Th series and singly occurring radionuclide ^{40}K have been assessed in most commonly used building materials in Kannur district, Kerala, using well established gamma ray spectrometry employing 5 cm × 5 cm scintillation NaI (Tl) detector. The results of the present work include activities of radionuclides viz. ^{40}K, ^{226}Ra and ^{232}Th and associated radiological parameters. The important and expected significant parameters estimated from the activities were radium equivalent activity (Ra_{eq}), hazard indexes and dose parameters. The study indicates that all the estimated parameters are within the recommended safety limit except for average value of excess life time cancer risk, which is slightly higher than the world average value (0.29×10^{-3}). The present investigation suggests that, the contribution to the radiation dose due to the use of these materials for the building construction is insignificant and do not contribute substantial radiation hazards to the occupants. The results of these systematic investigations are presented and discussed in the manuscript.

Keywords Radionuclide · Building material · Index parameter · Dose to organs

Introduction

Natural radioactivity is present in the environment since evolution of the earth and individuals on the earth are continuously exposed to the low levels of radiation originating from naturally occurring radionuclides. The radionuclides from the radioactive series such as uranium series originates from ^{238}U, thorium series originates from ^{232}Th and actinium series originates from ^{235}U are the major contributors of natural radiation in the environment [1–3]. In the ^{238}U series, the radionuclides in the decay chain segment which starts from ^{226}Ra are considered to be most important from the radiological point of view, since 98.5% of radiological effects of the uranium series are caused by ^{226}Ra and its daughter products. The contribution from ^{238}U and the other ^{226}Ra ancestors are normally insignificant and can be neglected [1, 4–6]. There are many singly occurring radionuclides and the most important one is ^{40}K, since it contributes significantly to the gamma radiation exposure and in turn to the natural radiation in the environment [1]. Building materials derived from natural sources such as rock, soil etc., waste products such as Phospho-gypsum, alum shale, coal, fly ash, oil shale ash, some rare minerals, certain slugs etc. and industry products such as power plants, phosphate fertilizer, the oil industry etc. often contain varying amounts of natural radionuclides [7]. Building materials exhibit long term exposure situations since individuals spend more than 80% of their time indoors [8]. Hence, it is important to assess the radioactivity level of building materials in order to estimate the radiation exposure and dose received by the population. The radionuclide concentration measurements in building materials also find relevance in setting the standards and National guidelines. Such policy making can be effectively followed while using these materials for the construction purpose. The evaluation of associated radiation hazards to human health has also to be carried out following the guidelines [1]. Building materials contribute to the environmental radioactivity in two ways, primarily by gamma radiation from ^{40}K, ^{226}Ra and ^{232}Th and their progenies as whole body

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Distribution of natural radionuclides and assessment of excess lifetime cancer risk along coastal areas of Varkala in Kerala

P. V. Divya[1] · C. S. Kaliprasad[2] · Y. Narayana[3] · V. Prakash[1]

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Abstract
Some of the coastal parts of Kerala are well reported high background radiation areas (HBRA). Hence, the radiological protection of the population in this region is of great concern. In view of this, study has been undertaken to understand the distribution and enrichment of radionuclides concentration in sand samples from Varkala region, a known HBRA. The NaI(Tl) detector was used for the measurement of radionuclides concentration in sand samples. The values obtained from the present study indicate that, the activities in sand samples were high compared with the world average values. The radiological parameters viz. absorbed dose, annual effective dose and annual gonadal dose equivalent were also calculated. Further, the excess lifetime cancer risk (ELCR) due to the exposure of radiation prevailing in the region was estimated from the activities of radionuclides. The ELCR value obtained from the present study was much higher than the world average value for all the samples. The results from the present investigation clearly indicate that, the radioactivity prevailing in the region is adversely affecting the inhabitants of the region. The results of these systematic investigations are presented and discussed in the manuscript.

Keywords Sand · Varkala · NaI(Tl) detector · ELCR

Introduction

The natural radionuclides viz. ^{238}U, ^{232}Th and ^{40}K are generally called as primordial radionuclides because they are present on the Earth since the creation of the earth. The non-uniform distribution of natural radionuclides have been observed in various environmental matrices such as soil, sand, sediment, water, air, etc. The natural radionuclides often reaches these matrices by the weathering process of the rocks and other materials.

Various regions in the world have geographical differences depending on the presence of the type of matrices such as rocks, soil, sand, sediment etc. The non-uniform distribution and enrichment of radionuclides concentration in the environment may be attributed to these geographical differences. As a result of non-uniform distribution, some of the regions are showing elevated levels of background radiation and are termed as high background radiation areas.

Major inconsistency in the enrichment of radionuclides in soil and sand are found in India and Brazil. One of the prime sources for high radiation background is radioactive minerals viz. monazite, apatite etc., and the presence of these mineral deposits in certain beaches of these two countries has been reported by several investigators [1–3].

The monazite deposit is more extensive in the coastal Kerala and it may contain 0.1–0.3% uranium and 5–7% thorium. Kulkarni et al. [3] have reported higher concentration of some important radionuclides of ^{232}Th and ^{238}U series in the high background areas of Kerala. The authors have also reported the concentration of trace elements and different types of minerals present in soil and sand. Gopal Ayengar et al. [4] have done studies on the effects of high level radiation on the residents of Kerala. Nair et al. [5] have studied background radiation and cancer incidence in Kerala, especially at Karunagapally. But the statistical power of the study might not be sufficient to make a conclusion by them

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The radiation dose and distribution coefficient of ^{210}Po and ^{210}Pb concentrations in aquatic environs of major rivers of coastal Karnataka

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Abstract
The activity of ^{210}Po and ^{210}Pb was measured in different matrices of aquatic ecosystem of the major rivers of Coastal Karnataka viz, Kali, Sharavathi and Netravathi. The environmental samples such as surface water, suspended particulate matter and sediment have been subjected to analyses. The activity of these two radionuclides were determined by radiochemical separation of ^{210}Po and counting the activity using a ZnS(Ag) alpha counter. The activity ratio of ^{210}Po and ^{210}Pb and correlation between the activity of these radionuclides were studied. From the measured concentration of ^{210}Po and ^{210}Pb, the internal Committed Effective Dose to the population for the study area was calculated. The distribution coefficient K_d between water, suspended particulate matter and sediments have been calculated to understand the distribution and accumulation of these radionuclides in different matrices of the aquatic environment.

Keywords ^{210}Po and ^{210}Pb activity · Aquatic environs · Committed effective dose Distribution coefficient

Introduction

The radionuclides ^{210}Po and ^{210}Pb in surface waters originate mainly from the radioactive decay of ^{238}U present in the earth crust [1] and atmospheric fall out due to the decay of ^{222}Rn present in the atmosphere. The chemical form and speciation of radionuclides will affect their movements and uptake by biota in the riverine environment. The way in which these radionuclide are bound to solids determine the amount of radionuclide in solution, which also influences the fraction of radionuclide that may be incorporated into organisms [2]. The radioactive materials could be transported with the flow of the river water from catchment areas consisting of different textured soil, sand and rocks. The dissolved radionuclides are adsorbed by suspended particulate matter and sediment. The distribution coefficient, K_d, is widely used to understand the eventual fate of metals and radionuclides released into aquatic environments [3]. The K_d is one of the significant parameters in predicting the fate of a radionuclide and their impacts on the environment. Partitioning of radionuclides between water and suspended matter is often described in terms of K_d, expressed as the concentration ratio between the particulate phase and the dissolved phase under equilibrium conditions [4]. Published data on natural radionuclide series for the riverine environs are sparse and there is no reference citing data for coastal Karnataka. In view of this, systematic studies were carried out to understand the distribution and accumulation of ^{210}Po and ^{210}Pb in the aquatic environs of Kali, Sharavathi and Netravathi rivers of coastal Karnatka.

Materials and method

The rivers Kali, Sharavathi and Netravathi originate from the from the western ghats. The rivers from western ghat region generally originate at an elevation ranging from 400 meters to 1600 meters above the mean sea level. The rivers generally flow westward and meet the Arabian sea after a short

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Investigation on radon concentration in drinking water to assess the whole body dose and excess lifetime cancer risk along coastal Kerala, India

P. V. Divya[1] · V. Prakash[1]

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Abstract
Some of the coastal parts of Kerala are well reported as high background radiation areas. Hence, the radiological protection of the population in this region is of great concern. In view of this, study has been undertaken to understand the distribution and enrichment of radon concentration in open well water from the region. Further, the whole body doses due to radon exposure were estimated from the radon concentration. The excess lifetime cancer risk (ELCR) was assessed from the obtained whole body dose. The Emanometry method was used for the quantification of dissolved radon in water from various open wells and the obtained concentration was found to vary in the range 0.12–4.35 Bq L^{-1}. The effective dose values from the present study were below the recommended limit of 0.1 mSv $year^{-1}$ suggested by the WHO and EU council. The ELCR value obtained from the present study was well below the world average value for most of the sampling stations except Varkala, where the value was comparable with the world average. The results from the present investigation indicate that, the dose due to radon by the consumption of water is not significant.

Keywords Radon in water · Emanometry · Coastal Kerala · ELCR

Introduction

All human beings are exposed to radiations originating from naturally occurring radioactive materials viz. air, water, soil and food. Radioactive gas radon contributes the largest fraction of radiation exposure to human beings [1]. Radon (^{222}Rn) is a noble gas having 3.8 days half-life, originates from radium (^{226}Ra) which is the daughter product of uranium (^{238}U). It originates from soils and rocks and which has the property to concentrate in houses and enclosed spaces. Radon decays to ^{218}Po and ^{214}Po are also α emitters. These radionuclides contribute 90% of the dose due to radon exposure. They contribute more than 90% of the total radiation dose received due to radon exposure [2]. The enhanced risk of cancer in human beings may be due to the exposure to radon and its progeny. In worldwide, the second leading cause of lung cancer is considered as radon inhalation.

Radon in water can enter into the human body by two different paths. Firstly, radon dissolved in water can directly enter the gastrointestinal part through the direct intake of water and deliver doses to the body. Secondly, dissolved radon can flee from household water and it concentrates in enclosed spaces after that which can enter the respiratory tract through inhalation. That is ingestion and inhalation pose potential health hazards to the inhabitants [3]. 89% of the expected cancer risk accounts through the inhalation pathway of radon and 11% accounts for ingestion pathway. 1000 Bq L^{-1} of radon concentration in tap water will increase average indoor air radon concentration by 0.1 Bq L^{-1} is suggested by UNSCEAR [4] and National Research Council.

11.1 Bq L^{-1} is the maximum contamination level for radon in drinking water suggested by the EPA [5]. However, an alternative maximum contamination level of radon is 148 Bq L^{-1} was proposed by the EPA because household usage of water contributes to indoor air radon concentration. The WHO suggested that repeated measurements are required if the radon concentration in public drinking water supplies exceeds 100 Bq L^{-1} [1].

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Original Article

Seasonal variation of radionuclides concentration in sand samples collected from Southern coastal areas of Kerala, India

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Abstract

Southern coastal parts of Kerala are well-reported high background radiation areas. Hence, the radiological protection of the population in this region may have some concern. In the present work, samples were collected during three different seasons, namely premonsoon, monsoon, and postmonsoon. The radionuclide activities obtained for various seasons have been compared in order to understand the enrichment of radionuclides during various seasons. The activities of natural radionuclides, namely ^{40}K, ^{226}Ra, and ^{232}Th in sand samples collected from Southern coastal parts of Kerala were determined using NaI (Tl) gamma-ray spectrometer. Sand samples collected during postmonsoon showed enhanced level of radionuclides concentration. The radiation dose to the population was also estimated from the activities of radionuclides in order to assess the radiation levels. The calculated values of risk assessment parameters were within the safe limits, which indicate the radiation exposure to the population due to these radionuclides is insignificant. However, seasonal variation of radionuclides concentration is significant. The results of the present systematic investigation are presented and discussed here in detail.

Keywords: Kerala, radionuclides, seasonal variation, Southern coastal area

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INTRODUCTION

There are a few regions in the world known as high background radiation areas (HBRAs) due to the local geology and geochemical effects that cause enhanced levels of terrestrial radiation. The Southern coastal areas of Kerala, especially Chavara-Neendakara at Kollam district in Kerala, are commonly referred to HBRAs in the world.[1]

Kerala coastline has a significant resident population, and it is very dynamic and fluctuates seasonally. Hence, the quantity of placer deposition of heavy minerals also changes which leads to change in the activity of primordial radionuclides. The objective is to study the radiological protection of the population and to understand the seasonal variation of radionuclides concentration in Southern parts of coastal Kerala.

MATERIALS AND METHODS

Sample collection

The regions, namely Kovalam (S_1), Varkala (S_2), Neendakara (S_3), and Panmanam (S_4) from the Southern coastal areas of Kerala, known HBRA, were selected and locations were identified on the basis of visual inspections for heavy mineral accumulation and radiation

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Original Article

Study on effects of physicochemical parameters on natural radionuclides concentration and assessment of radiological parameters in the soil samples of Mangalore, Dakshina Kannada

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Abstract

The paper deals with the distribution and enrichment of natural radionuclides ^{232}Th, ^{226}Ra, and ^{40}K in the soil samples of Mangalore. The soil samples collected from the region were analyzed for the activity of natural radionuclides using NaI (Tl) gamma-ray spectrometer. The activity of ^{232}Th varies in the range 40.5–95.2 Bq/kg with a mean value of 64.9 Bq/kg; the activity of ^{226}Ra varies in the range 54.9–77.8 Bq/kg with a mean value of 65.1 Bq/kg; and that of ^{40}K varies in the range 308.7–486.5 Bq/kg with a mean value of 368.9 Bq/kg. The calculated values of radiological parameters were found to be below the world recommended level. The results of these systematic studies are presented and discussed in this paper.

Keywords: ^{226}Ra and ^{232}Th, ^{40}K, natural radioactivity, radiological parameters

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INTRODUCTION

Mangalore, an important region of the southwest coast of India, is heading to become a major industrial activity center with oil refineries, petrochemical complexes, chemical and fertilizer factories, thermal power stations, and a host of other industries. In view of this, detailed studies on radiation level and radionuclide distribution have been carried out in the environment of the region. As part of the program, the absorbed gamma dose rate in air in the environment of the region was measured using portable scintillometer. The soil samples collected from the region were analyzed for the activities of ^{232}Th, ^{226}Ra, and ^{40}K to understand the distribution and enrichment of these radionuclides.

The radionuclide content of various components of the ecosystem depends on the interactions of a large number of different factors. These include the nature of the radionuclide itself, the site-specific characteristics, physicochemical properties of the soil, variation in plant cover, and climatic conditions. In view of this, the dependence of the activity with some of the soil physicochemical parameters has also been studied. Radiological parameters, namely, radium equivalent activity (Ra_{eq}), external exposure index (E_{ex}) and internal exposure index (E_{in}), were calculated from the activities of ^{232}Th, ^{226}Ra, and ^{40}K to evaluate the risk due to these radionuclides to the human beings in the region. The

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Original Article

Enrichment pattern and depth profile of natural radionuclides in monazite areas of coastal Karnataka

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Abstract

The activities of radionuclides ^{232}Th, ^{226}Ra, and ^{40}K have been measured in sand samples of Ullal beach area, where presence of low-level monazite has been reported. The sand samples collected from the region, at different distances from sea waterline and at different depths, were analyzed for radionuclide activity by gamma spectrometry to study the distribution, enrichment pattern, and vertical profile of the radionuclides in the region. The study on the enrichment of radionuclides in different size fractions shows highest activity confined in <125 μm and lowest activity confined in 1000–500 μm particle size fractions. The minimum ^{232}Th activity was 1.1 Bq/kg, found in Ombattu Kere beach at a depth of 10–20 cm, at waterline in 1000–500 μm particle size fraction and maximum activity of 6690.7 Bq/kg was found in Ombattu Kere beach at a depth of 10–20 cm, at 50 m away from waterline in grains of size 250–125 μm. The lowest ^{226}Ra activity was 25.1 Bq/kg, found in Ombattu Kere beach at a depth of 10–20 cm, at waterline in grains of size 1000–500 μm and highest ^{226}Ra activity was 1286.0 Bq/kg, found in Ombattu Kere beach in grains of size <125 μm for sample collected at a distance of 50 m away from waterline and at a depth of 10–20 cm. The minimum ^{40}K activity was 130.5 Bq/kg, found in Ombattu Kere beach at a depth of 20–30 cm, at 50 m away from waterline in grains of size 500–250 μm and maximum activity of ^{40}K was 5686.2 Bq/kg, found in Ombattu Kere beach for sample collected at waterline at a depth of 20–30 cm in <125 μm particle size fraction. The dose rate measured using plastic scintillometer at 1 m above the ground level at Ullal is having the range 39.4–459.9 nGy/h with a mean value of 193.2 nGy/h. The results of these investigations are presented and discussed in this article.

Keywords: ^{232}Th, enrichment, gamma spectrometry, natural radionuclides, vertical profile

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INTRODUCTION

Radiation is omnipresent in the environment of earth's surface. The greatest contribution to humankind's exposure comes from natural background radiation. However, much higher levels of exposure are usual for inhabitants of natural high background radiation areas. The major sources responsible for exposure are naturally occurring radionuclides in the earth's crust such as ^{232}Th, ^{226}Ra, and ^{40}K, which occur associated in minerals such as monazite and zircon. There are few regions in the world known as high-background-radiation areas due to local geology

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Original Article

Studies on ambient gamma dose rate and enrichment of radon, thoron, and progeny concentration in various types of dwellings and outdoor environments of Kalliasseri, Kannur district, Kerala

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Abstract The major contribution of natural background radiation exposure comes from radon, thoron, and their progeny. The activity concentration of these radionuclides depends on various factors, and the concentration level varies from place to place. The indoor concentration in dwellings depends mainly on the materials used for building construction and ventilation patterns. In the present study, an attempt is made to estimate the indoor and outdoor radon, thoron, and their progeny concentration in various types of dwellings and outdoor environments of Kalliasseri Panchayat, Kannur district, Kerala. ^{222}Rn and ^{220}Rn measurements were carried out using LR-115 type II-based pinhole cup dosimeters. Indoor and outdoor gamma exposure rate measurements were also carried out in all the dwellings using scintillation-based microradiation survey meter. The average concentrations of radon and thoron were estimated in about 40 dwellings categorized according to the construction type The seasonal variation in the enrichment of radionuclides concentration has also been studied. The respective radon and thoron progeny levels were also estimated. The average radon concentration from the present study was well within the action level (200 Bq/m^3) recommended by the International Commission of Radiological Protection (ICRP). The annual effective doses due to indoor radon and thoron were within the action level 3–10 mSv/y as suggested by the ICRP.

Keywords: Annual effective doses, gamma dose rate, pinhole cup dosimeter, radon, thoron

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INTRODUCTION

Indoor air quality is the most important issue nowadays because most individuals spend 90% of their time indoors. There are many pollutants that can deteriorate indoor air quality; however, radon and its progeny are a major pollutant for this and are an important global problem of radiation hygiene.[1] The indoor radon and thoron concentration varies with the types of construction material used in the buildings, ventilation patterns, lithology, and altitude in addition to the seasonal and diurnal variations.[2-4] The UNSCEAR (2000) estimates that 50% of the total dose received by the population is due to airborne radon

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Original Article

Seasonal variation of natural radioactivity in the environs of Kali River

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Abstract The paper discusses the results of systematic studies of activity concentrations of the ^{226}Ra, ^{232}Th, and ^{40}K in soil and sediment samples of Kali River, one of the major rivers of coastal Karnataka. The samples are collected in premonsoon, postmonsoon, and monsoon seasons; the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in soil and sediment were measured by a NaI(Tl) gamma-ray spectrometer. The activity concentration of ^{226}Ra is high in soil and sediment samples. The activity of ^{226}Ra is almost constant, except one or two sampling stations of the rivers, and the activity of ^{232}Th and ^{40}K shows nonuniform distribution in soil and sediment samples of premonsoon and postmonsoon seasons. The results of these investigations are presented and discussed in this study.

Keywords: Coastal Karnataka, gamma-ray spectrometer, natural radioactivity, river, sediment

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INTRODUCTION

Natural environmental radioactivity arises mainly from the radionuclides, such as ^{40}K, ^{232}Th, and ^{238}U series and their decay products. Gamma-radiation emitted from those naturally occurring radionuclides and from the radionuclide deposited on the ground is the main external source of irradiation of the human body. Natural environmental radioactivity and the associated external exposure due to gamma-radiation depend primarily on the geological and geographical conditions and appear at different levels of radionuclides.[1-3] For all practical field applications, only gamma radiation is of importance because alpha and beta radiation is not very penetrating and will generally not escape the matrix. In the present work, the first ever study on the distribution of natural radionuclides in the riverine environs of coastal Karnataka have been presented and discussed.

MATERIALS AND METHODS

Sample station and sample collection

At present, the sampling stations were identified along the river Kali [Figure 1].[4,5] The soil samples from the banks of the river and sediment samples from the river are collected during premonsoon, postmonsoon, and monsoon following the standard procedure.[6] The soil and sediment samples collected were brought to the laboratory, dried, grounded, and sieved to get <250 μ and filled in airtight plastic containers and stored to ensure equilibrium between radium and its short-lived daughters.

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Original Article

Assessment of radioactivity level and radiological parameters in soil samples of Akalad, Thrissur District, Kerala

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Abstract Systematic studies on radiation level and distribution of radionuclides have been carried out using NaI(Tl) detector in different locations of Akalad region, Thrissur District, Kerala. The activity of naturally occurring radionuclides viz. ^{40}K, ^{226}Ra and ^{232}Th in the samples collected from the region were measured and found to vary in the range 9.99±0.69 Bq kg^{-1} to 32.11±0.77 Bq kg^{-1} with a mean value 19.64 Bq kg^{-1}; 2.15±0.21Bq kg^{-1} to 11.28±0.39 Bq kg^{-1} with a mean value 7.73 Bq kg-1 and 20.80±0.67 Bq kg-1 to 122.40±1.16 Bq kg-1 with a mean value 79.91 Bq kg-1 respectively. The radium equivalent activity varies within the range 39.26 Bq kg^{-1} to 178.85 Bq kg^{-1} with a mean value 123.51 Bq kg^{-1}. The absorbed dose rate varies within the range 16.49 nGyh^{-1} to 79.14 nGyh^{-1} with a mean value 51.91 nGyh^{-1}. The present systematic investigation indicates that the data are comparable with the reported values elsewhere and in most of the cases observed values were well within the permissible limit.

Keywords: ^{226}Ra, ^{232}Th, ^{40}K, natural radioactivity, radiological parameters

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INTRODUCTION

Natural radionuclides are widely distributed in soil, rocks, and air. Assessment of natural radioactivity level in the environmental matrices has great importance because natural radiation is the largest contributor to the external dose to the world population [1] The distribution and enrichment of radionuclides in various environmental matrices will also be different. There are few regions in the world, the radiation levels were found to be high and termed as high background radiation areas. Coastal Kerala is one of the important parts of the south-west coast of India and a known high background radiation area. In Kerala, especially the places in Kollam district, such as Chavara, Neendakara, Karunagapally, are reported as high background radiation areas.[2] Akalad is situated in Thrissur district, part of the coastal environment of Kerala. In view of this, an attempt was made to assess the radionuclide concentration of the soil samples collected from the environment of Akalad, and the results are discussed in the paper. Radium equivalent activity and radiological parameters due to natural radiation exposure were also identified and discussed in the light of reported literature values.

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ORIGINAL PAPER

Studies on two neutrino double beta decay

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Abstract: The study aimed to develop an empirical formula for phase space factor and nuclear matrix element to analyse two neutrino double beta decay. The present work also extended to compute phase space factor using Primakoff–Rosen approximation. Using these two formulae for phase space factors we have computed two neutrino double beta decay half lives. Comparisons of the calculated half lives with the corresponding experimental values are also done. The empirical formula predictions are found to be in good agreement with the experimental data. The empirical formula is applied to various isotopes exhibiting single beta decay and our prediction on the possibility of two neutrino double beta decay will be very useful for the future experiments.

Keywords: Two neutrino double beta decay; Phase space factor; Nuclear matrix element

PACS Nos.: 23.40.-s; 21.10.Tg; 14.60.Pq

1. Introduction

Pauli's hypothesis to the existence of neutrino leads to the development of the theory of beta decay. The weak theory of nuclear beta decay by Fermi gave hint to the idea of double beta decay. The double-beta decay is the rarest nuclear weak process in which two neutrons in the nucleus are converted into two protons, and two electrons and two electron antineutrinos are emitted. The process can be thought as a sum of two beta decays. For the double beta decay to be possible, the final nucleus must have a larger binding energy than the original nucleus. It can be classified into two modes, namely two neutrino double beta decay ($2\nu\beta\beta$) and neutrino-less double beta decay ($0\nu\beta\beta$). The $2\nu\beta\beta$ conserves the lepton number and is an allowed process within the standard model of electroweak unification. More than eleven isotopes namely ^{48}Ca, ^{76}Ge, ^{82}Se, ^{96}Zr, ^{100}Mo, ^{116}Cd, ^{128,130}Te, ^{136}Xe, ^{150}Nd, ^{238}U have been experimentally observed undergoing two-neutrino double beta decay [1].

The transitions in double beta decay modes may be from $0^+ \rightarrow 0^+$ or $0^+ \rightarrow J^+$ state. $0^+ \rightarrow 0^+$ transition is most preferable as the other decay rates are suppressed due to kinematic reasons. The study of other decay modes will be of importance in distinguishing the role of different mechanisms involved in $0\nu\beta\beta$. Thus the experimental and theoretical study of nuclear double beta decay is quite wide in scope and has been excellently reviewed over the past years [2–22].

The double beta decay probability strongly depends on the transition energy, Q-value ($\sim Q^{11}$ for $2\nu\beta\beta$ and Q^5 for $0\nu\beta\beta$). The study of $2\nu\beta\beta$ decay is quite interesting from the nuclear structure point of view. There are different models for calculating nuclear matrix elements (NMEs), among which two important models are shell model [23–25] and Quasi Particle Random Phase Approximation (QRPA) [26–28]. The detection of $2\nu\beta\beta$ decay provides the experimental determination of NME involved in double beta decay process. This leads to the development of theoretical scheme for NME calculations both in $2\nu\beta\beta$ and $0\nu\beta\beta$ decays [29–32]. The study can yield a careful investigation of the time dependence of the coupling constant for weak interactions [33–37] which acts as a bridge for the running of weak interaction coupling from a high scale era to the present.

The idea of double beta decay was first proposed by Maria Goeppert-Mayer in 1935 [36]. In 1937 Ettore Majorana [38] theoretically demonstrated that all results of

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Study of cluster emissions from heavy nuclei using an empirical formula and the Coulomb and Proximity potential model for deformed nuclei

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The decay characteristics of various clusters and neutron halo nuclei from heavy elements $Z = 92-102$ are studied within the framework of the Coulomb and Proximity Potential Model for Deformed Nuclei (CPPMDN) and using a new empirical formula proposed by us. The predictive power of our formula is verified by comparing the predictions with the available experimental data and with the predictions of other models such as CPPM, Universal Decay Law of Qi *et al.* (UDL), Unified Description formula (UD) of Ni *et al.* Using the present formula and CPPMDN, decay half-lives of various light clusters from heavy elements are calculated, and the results are compared with the predictions of UDL, UD, and predictions made by Santhosh *et al.* based on the Modified Generalized Liquid Drop Model (MGLDM). The decay half-lives of halo nuclei from heavy elements are also calculated using the new formula and CPPMDN and compared with the predictions of UDL, UD, and the predictions made by Santhosh *et al.* based on the Coulomb and Proximity Potential Model (CPPM).

Keywords: Nuclear deformation; halo nuclei; cluster decay.

PACS Number(s): 23.60.+e, 23.70.+j

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Systematic Study of Alpha and Cluster Preformation Probability using New Empirical Formulae

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Cluster preformation probability in heavy nuclei is studied using the empirical formula of Ni et al., Dong et al., and four new formulae of Santhosh et al. The predictions of these formulae are then compared with the preformation probabilities extracted from the experimental decay half-lives using the Generalized Liquid Drop Model (GLDM), Density Dependent Cluster Model (DDCM), and Unified Fission Model (UFM). It has been found that except for the isospin-dependent formula of Santhosh et al., all other formulae predict much larger preformation probability than the experimentally extracted values. Further, we propose four new empirical formulae for the cluster preformation probability in heavy nuclei, and the predictions are compared with the experimentally extracted values using different theoretical models. It is found that the predictions of all the four proposed formulae are in good agreement with the predictions of various theoretical models.

Keywords: Cluster Radioactivity, Preformation
PACS Numbers: 23.60.+e; 23.70.+j; 27.90.+b

1. Introduction

The spontaneous emission of particles heavier than the alpha particle but lighter than the fission fragments from unstable nuclei is referred to as cluster radioactivity. The possibility of cluster emission was predicted by Sandulescu, Poenaru, and Greiner[1] in 1980, and the first experimental observation of the emission of ^{14}C from ^{223}Ra was made by Rose and Jones in 1984[2]. Followed by this emissions of various cluster families like ^{14}C, ^{20}O, ^{23}F, ^{24,26}Ne, ^{28,30}Mg, and ^{34}Si were experimentally observed and the corresponding decay half-lives were measured. The majority of these spontaneous decays produced the daughter element ^{208}Pb, which is doubly

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An empirical formula for the two-proton decay half-lives in the ground and excited states

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ABSTRACT

We proposed an empirical formula for the half-life of two proton emissions in the ground and excited states. The proposed empirical formula has a half-life dependence on the Q-value and the atomic number of the parent, similar to the Geiger-Nuttall law and the Viola and Seaborg formula. The half-lives of ^{6}Be, ^{12}O, ^{16}Ne, ^{19}Mg, ^{45}Fe, ^{48}Ni, ^{54}Zn, and ^{67}Kr nuclei are calculated using the present empirical formula. The empirical formula has the lowest standard deviation with experimental data ($\sigma = 1.39$) compared to previously predicted formulas, indicating that the formula can reproduce the experimental half-lives well. The predictions of the half-lives are made for another 56 nuclei whose two-proton emission is energetically feasible ($Q_{2P} > 0$). These half-life values are compared with five theoretical models and two empirical formulas. The predicted half-lives are in good agreement with other theoretical predictions. The predicted half-lives of two-proton emission in the excited states of ^{14}O*, ^{17,18}Ne*, ^{22}Mg*, ^{29}S*, and ^{94}Ag* nuclei are compared with the experimental half-lives and also with different models' and formulas' predictions. The experimentally observed half-lives of the excited states are better reproduced using the proposed formula compared with previous theoretical predictions. Only the proposed formula can reproduce the experimental half-lives of ^{94}Ag* in excited states.

1. Introduction

The nucleus spontaneously emits a pair of protons beyond the proton drip line, and this exotic two-proton radioactivity was predicted by Zel'dovich six decades ago [1]. One proton emission is the most common decay mode for odd-proton-number nuclei. However, in the case of even proton-number nuclei lying near the proton drip line, two-proton emission may occur due to proton pairing. Two protons tunnel through the potential barrier of the parent nucleus, just like in the alpha cluster or exotic cluster decay processes. Several theoretical and experimental studies are still progressing on two-proton decay. These investigations help us understand the interaction among the nucleons and provide details about the nuclear structure.

The experimental confirmation of two-proton radioactivity was delayed due to limitations in detection technology and radioactive beam facilities. After a few decades, the probability of the two proton decay widths of ^{12}O and ^{16}Ne was reported by KeKelis et al. [2]. Kryger et al. identified the two-proton emission of ^{12}O by using a ^{13}O projectile via single neutron stripping [3]. Later, true two-proton decay in the ground state was confirmed experimentally in the ^{45}Fe isotope at GSI [4] and GANIL [5] in 2002. At GANIL, two-proton emission of ^{54}Zn was discovered in 2005 [6], and then two proton decay of ^{48}Ni was identified [7]. Mukha et al. discovered the two-proton radioactivity of ^{19}Mg in 2007 by analysing the decay products [8]. An experiment with the BigRIPS separator reported the two-proton emission of ^{67}Kr [9]. The extremely short-lived two-proton emission is experimentally observed in ^{6}Be [10] and ^{16}Ne [11]. Goldanskii [12] and J. Anecke [13] first began the theoretical studies to identify the two proton-emitter nuclei. Two-proton emission was first theoretically described by Galitsky and Cheltsov [14]. There are many theoretical models to explain two-proton radioactivity, such as the screened electrostatic barrier [15], the Gamow-like model [16], the direct decay model [17], the diproton model [18], the three-body model [19], the simultaneous and sequential decay model [20], the unified fission model (UFM) [21], and the coulomb and proximity potential model (CPPM) [22]. Fengzhu Xing et al. studied the two-proton decay half-lives using the Skyrme-Hartree-Fock method [23]. B. A. Brown et al. calculated the two proton decay half-lives of ^{45}Fe using the R-matrix approach [24]. J. Rotureau et al.

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Full Length Article

Theoretical predictions on the decay modes of $^{282-310}$Og

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ABSTRACT

Possible decay modes of $^{282-310}$Og are studied within the framework of the Coulomb and Proximity Potential Model (CPPM), Universal Decay Law (UDL) and the Hatsukawa formula. A new diffusion parameter and a new preformation factor are included in the CPPM Model calculations. We have refitted the Hatsukawa formula to calculate the alpha and cluster decay half-lives in the superheavy region. The spontaneous fission (SF) half-lives are calculated using the shell correction energy-dependent formula of Santhosh et al. The predicted alpha decay half-lives are compared with the predictions of the UDL formula; and the predictions of Soumya et al. and Koyuncu et al. Possible heavy cluster decays from $^{284-297}$Og are also studied within the UDL formula and by using the empirical formula of Hatsukawa et al. with new fitting parameters, and a comparison is made with the predictions of Santhosh et al.

1. Introduction

Theoretical and experimental studies [1–6] revealed that the dominant decay modes in stable heavy and superheavy nuclei are alpha decay and spontaneous fission. The alpha decay process is considered a quantum mechanical tunneling of the alpha particle through the potential barrier imposed by the parent nucleus. The first successful explanation of alpha decay from a nucleus was provided by Gamow [7] and by Gurney and Condon [8]. The alpha decay studies are so important as they could predict the nuclear structural properties of the emitter as well as helps to identify the unknown elements through the alpha decay chains. The stability of nuclei can be predicted from the alpha decay and spontaneous fission half-lives. The stability of superheavy nuclei is strongly influenced by the shell effects and the alpha decay studies will help to identify possible new magic numbers in the superheavy region at which the shell closure occurs. Apart from spontaneous fission and alpha decay, heavy and superheavy nuclei can decay through the emission of heavier particles and the process is known as cluster radioactivity [9–12].

Many theoretical and empirical models were introduced to study the cluster and alpha emissions from heavy and superheavy elements. Theoretical models such as the Liquid Drop Model [13], Generalized Liquid Drop Model (GLDM) [14], Density Dependent Cluster Model [15], Relativistic Mean Field (RMF) Theory [16], Coulomb and Proximity Potential Model (CPPM) and the Double Folding Model [17], etc. are widely used for accurate prediction of alpha and cluster decay properties of heavy elements. The application of these theoretical models is also extended to the superheavy region in recent decades [18–20]. Empirical formulae of Poenaru et al. (UNIV) [21], Analytical formula of Royer [22], Universal Decay Law (UDL) [23], Unified Description Law (UD) [24], Viola-Seaborg semi-empirical formula (VSS) [25], the formula of Santhosh et al. [26], etc. are extensively used for describing the alpha and cluster decay half-lives of heavy and superheavy elements. The empirical formula of Xu et al. [27], the formula of A Soylu [28], and the modified formula of Santhosh et al. [29] including shell correction energies are widely used for predicting spontaneous fission half-lives.

In the past two decades, with the improvement in the experimental facilities, the synthesis of superheavy elements with Z = 107–112 was accomplished through cold fusion reactions at GSI, Darmstadt in Germany. Hot fusion processes were used to create elements with Z = 113–118 at the Joint Institute for Nuclear Research–Flerov Laboratory of Nuclear Reactions (JINR–FLNR), Dubna [4,30,31]. The alpha decay chains of the last synthesized superheavy element ^{294}Og were experimentally studied and found that ^{294}Og has an alpha decay half-life of 0.89 milliseconds [32]. Many experiments were conducted to synthesize elements with Z > 118 and have not succeeded to date. Theoretical predictions on the existence of superheavy elements with Z = 122, 124, 126, and 128 were also made by many research groups [33–37].

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Theoretical Study on Two Neutrino and Neutrinoless Double Beta Decay

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Introduction

Double beta decay is a radioactive decay process where a nucleus releases two beta rays as a single process. Here two neutrons in the nucleus are converted to two protons, and two electrons and two electron antineutrinos are emitted. In order for beta decay to be possible the final nucleus must have larger binding energy than the original nucleus. Double beta decay is difficult to study in most practically interesting cases, because both beta decay and double beta decay are possible, with probability favouring beta decay, the rarer double beta decay process is masked by these events. Thus double beta decay is usually studied only for beta stable nuclei. Like single beta decay, double beta decay does not change the mass number A. It is a second-order weak process in which two neutrons inside a nucleus spontaneously transform into two protons. More than 60 naturally occurring isotopes are capable of undergoing double beta decay. Only ten of them were observed to decay via two neutrino mode. The ββ decay can be broadly classified into four experimentally distinguishable modes. The present work is an attempt to study the Two Neutrino and Neutrinoless Double Beta Decay processes.

Studies on single beta decay process

We have made an attempt to study[1] the possibility of β^- decay from various isotopes in the heavy region with Z ranging from 80-99 using the empirical formula of Fiset and Nix. It is clear from the computed values that, beta decay half lives decreases with increase in neutron number. That is, beta decay occurs in isotopes which are neutron rich. Atoms which undergo beta decay are located below the line of stable elements on the chart of the nuclides, and are typically produced in nuclear reactors. The *Q* value for a reaction is the amount of energy released by that reaction. The value relates to the enthalpy of a chemical reaction or the energy of radioactive decay products. It is obvious that neutron number of the parent and the decay energy have a good role in the beta decay half lives. Hence we modified the empirical formula of Fiset and Nix and is given as,

$$T_\beta = \frac{540 m_e^5}{\rho(W_\beta^6 - m_e^6)} x10^5 + 0.03992\sqrt{NQ^{3/2}} - 1.21404\,\text{sec} \quad (1)$$

From experimental beta decay half-life values of 101 nuclei, the estimated standard deviation for the present formula prediction and the formula predictions of Fiset and Nix are 1.991417 and 2.333264 respectively. It is clear that the present formula prediction is better than the formula prediction of Fiset and Nix.

One of the main applications of Bethe-Weizsacker semi empirical mass formula is the prediction of the most stable isobar of a given A against beta decay. The Z value of such isobar (Z_A) is given by minimizing the atomic mass including the mass of electron from the semi empirical mass formula. We have computed the Z_A value for different isobars in the heavy region with mass number varies from 200 to 250. It is found from the plot that Z_A values show a linear relationship with the mass number. From the linear dependence of mass number and Z_A value, we have developed an empirical formula [2] for the most stable isobar of a given A against beta decay. We have also compared the present formula predictions with those obtained from Bethe-Weizsacker formula. It is found that our present formula predictions are in close agreement with the formula predictions of Bethe-Weizsacker formula. We would like to point out that the present formula is much simpler as compared to other empirical formulae. Hence the present equation is better to identify the stability of the isotopes against beta decay in the heavy region. We have also studied the mass parabolas for different nuclides with mass number ranging

Studies on the exotic decay possibilities of proton rich ^{10}C, ^{13,14}O from nuclides with Z in the range 103-118

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Introduction

Studies on exotic fragments lying on the edges of nuclear stability is one of the active current areas in nuclear Physics and many hundreds of studies have carried out since its discovery in the mid-1980s [1]. Exotic nuclei are characterized by large N/Z asymmetry and they differ remarkably from other stable and near stability elements through their short lifetime, large rms radii, low binding energy, small separation energies etc. Among different types of exotic nuclei in the nuclear landscape, our area of interest is limited to the proton rich nuclei beyond the proton drip line. The last few decades brought considerable progress in synthesizing and studying the properties of exotic nuclei [2]. The main experimental difficulty for most of the exotic nuclei is their very low production yield.

In the present work, we have studied the structure of the exotic nuclei ^{10}C, ^{13,14}O from the separation energy and driving potential calculations. Further, we have studied their decay possibilities from the superheavy parent nuclei within the range Z=103-114.

Exotic nuclei	S(1p)	S(2p)
^{10}C	4.007	3.821
^{13}O	1.512	2.112
^{14}O	4.627	6.570

Table 1. 1p and 2p separation energies of various exotic nuclei.

The model

1p and 2p separation energy for any nuclei in terms of mass excess can be calculated as

$S(p) = - \Delta M (A, Z) + \Delta M (A-1, Z-1) + \Delta M_H$

$S(2p) = - \Delta M (A, Z) + \Delta M (A-2, Z-2) + 2\Delta M_H$

$\Delta M (A, Z)$, ΔM_H, $\Delta M (A-1, Z-1)$, $\Delta M (A-2, Z-2)$ are the mass excess of the parent nuclei, mass excess of proton, mass excess of daughter nuclei produced in the 1p and 2p radioactivity respectively.

The interacting potential barrier for a parent nucleus exhibiting exotic decay is given by

$$V = Z_1 Z_2 e^2 / r + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2} \quad \text{for } Z > 0 \qquad (1)$$

Here Z_1 and Z_2 are the atomic numbers of daughter and emitted cluster; 'r' is the distance between fragment centers, l the angular momentum, μ the reduced mass and Vp is the proximity potential. The barrier penetrably P is given as:

$$P = \exp\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-Q)}dz\} \qquad (2)$$

The turning points 'a' and 'b' are given by $V(a) = V(b) = Q$, where Q is the energy released. The half life time is given by

$$T_{1/2} = \ln 2/\nu P. \qquad (3)$$

Where, $\nu = 2Ev/h$, represent the number of assaults on the barrier per second and E_v, the empirical zero point vibration energy.

Results and Discussions

In this section we present the numerical results obtained from the separation energy, potential energy and half-life calculations. Separation energies of the selected nuclei are included in the table 1. It is clear from the table that ^{13,14}O show low S (1p) than S (2p), whereas ^{10}C show S(1p)>S(2p).

Further, we have calculated the driving potential using CPPM [3], to identify the most probable cluster- core configurations. Driving potential is the difference between the interaction potential and the decay energy of the reaction (for touching configuration, z=0), for each nuclei with its all possible cluster core configurations.