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Estimation of Radon Concentrations in Groundwater along the Coast of Chennai A City and Estimation of Ingestion Dose

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Abstract--Radon (Rn) is a carcinogenic gas and therefore it is hazardous to inhale since it emits alpha particles. It is radioactive, odourless, colourless, water soluble and the heaviest noble gas. The occurrence and the distribution of radioactivity in water depend on the local geological characteristics of the source, soil, rock and other factors. The underground water often moves through rock and soil containing radon and radon gets soluble in the water. In this study, the result of systematic measurement of activity concentration of 222Rn in drinking water from sources of public water supply along the coastal regions of Chennai City is discussed. The method used in the present study is Radon Emanometry method using alpha counter. From these measurements, the corresponding annual effective ingestion dose is determined. Quantification of 222Rn dose in drinking water of Chennai city will help to understand how safe it is to drink. The results obtained in this study indicate that the 222Rn concentration was in the range of 1.2 to 5.3Bq l−1 with the mean value of 4.3 Bq l−1 for closed well and 2.1 Bq l−1 for open well from the 98 samples collected from different areas of Chennai City. While the average values are within the maximum concentration limit of 11.1 Bq l−1 set by USEPA and world average value of 10 Bq l−1 set by WHO. The effective dose receive by the population of coastal Chennai was found to be varied from 0.004 to 0.019Sv y−1 with a mean value of 0.044 Sv y−1 for closed well and 0.022 Sv y-1 for open well.

I. INTRODUCTION

A. General

Water is one of the most abundant substances on earth and is a principal constituent of all living things. It is used in various aspects of daily lives that include power generation, agriculture and domestic activities. It is therefore important for the water to be free from chemical, microbiological and radiological contamination. Naturally occurring ^{222}Rn, belonging to Uranium-238 (^{238}U) decay series. It was the fifth radioactive element to be discovered, in 1900 by Friedrich Ernst Dorn after Uranium, Thorium, Radium and Polonium and named Radium Emanation. Its atomic number is 86 and the atomic weight is 222. It is produced by the radioactive decay of radium-226, which is found in Uranium ores, phosphate rock, shale, igneous and metamorphic rocks such as granite, gneiss and schist and to a lesser degree, in common rocks such as limestone (Godish T.2001). Every square mile of surface soil, to a depth of 6 inches (2.6 km^2 to a depth of 15 cm), contains approximately 1 gram of radium, which releases radon in small amounts to the atmosphere (United States Environmental Protection Agency, Dec 1990).

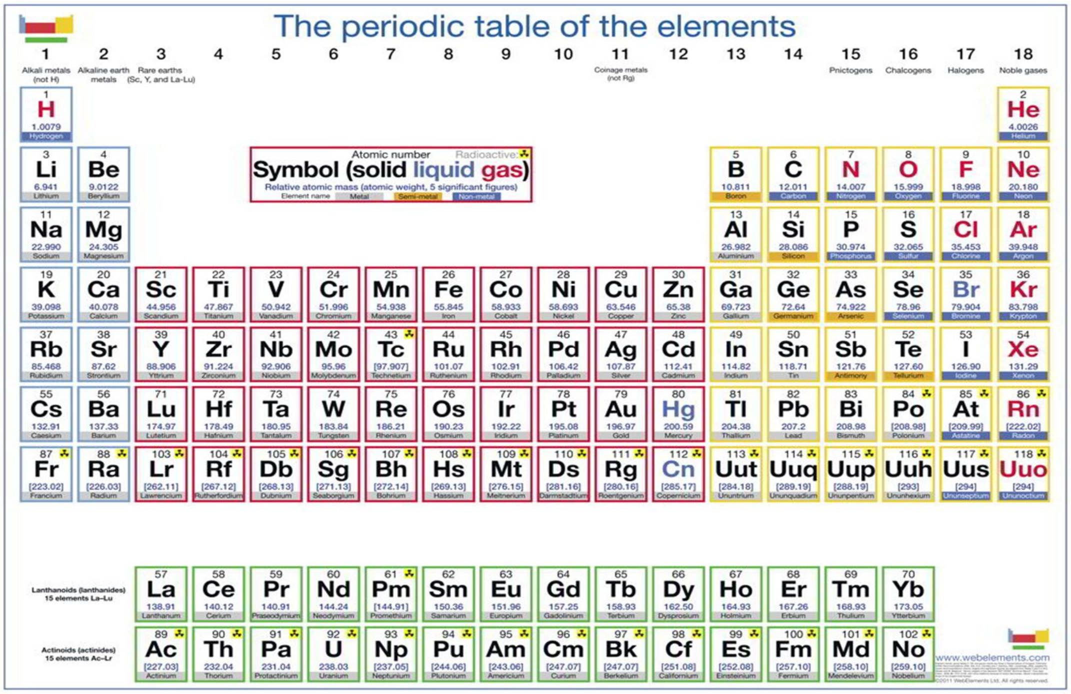

Fig 1 the periodic table of the elements.

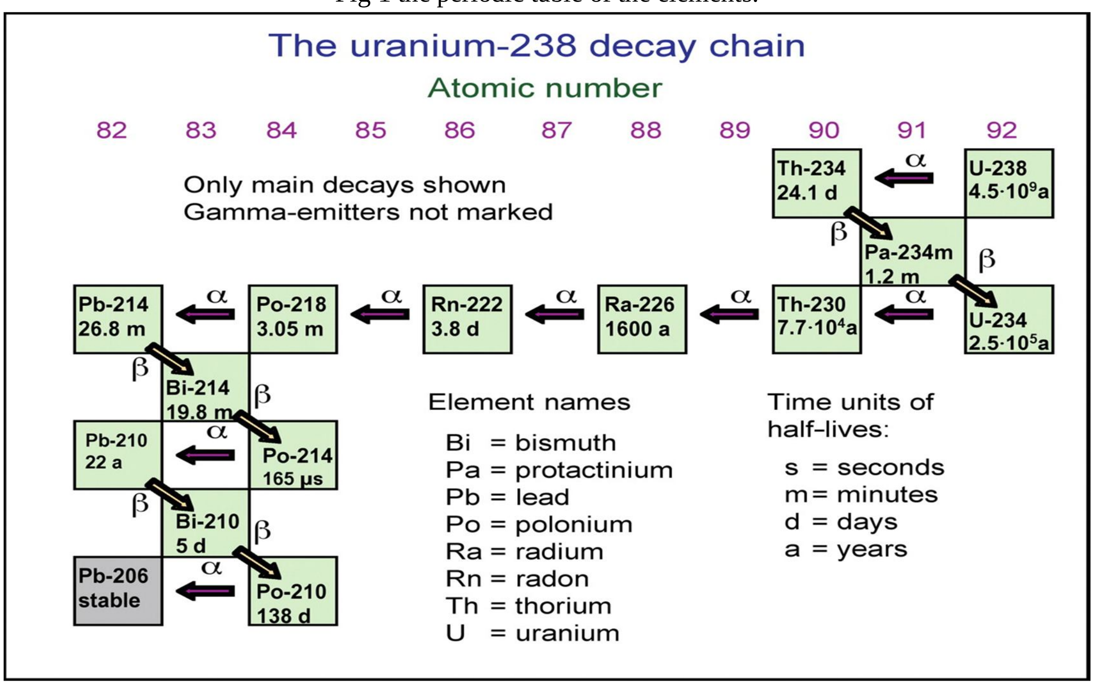

Fig 2 The uranium-238 decay chain

B. Need For The Study

Radon is a carcinogenic gas and therefore it is hazardous to inhale since it emits alpha particles. Radon has the highest solubility in water of the noble gas, with a mole fraction value of 0.00125 at 37°C and a half life of 3.82 days, which is 15 times higher than that of helium or neon. Because of this property, radon can accumulate in high concentrations in ground water and poses a greater health risk for people who ingest or inhale it. Radon in water may therefore present dual pathways of exposure for individuals -- through drinking water and inhalation of air containing radon released from groundwater. The aerosols tend to trap into the lungs where they release radiation and they break down further, these particles release small bursts of energy. This can damage lung tissue and

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increase your chances of developing lung cancer over the course of your lifetime. Radon can also reach other body tissues through ingestion resulting in radiation exposure to the internal organs. Ingestion of radon is believed to increase the risk of stomach cancer.

C. Objectives Of The Study

To investigate natural radiation pollution in groundwater of coastal areas in Chennai city.

To determine the levels of radon in various well water samples in Chennai city.

Quantification of Radon gas in selected open and closed wells in the coastal areas of Chennai.

The ingestion dose should be evaluated using the measured ^{222}Rn concentration.

This work also aims to compare the results with the World Health Organization (WHO) standards so as to have an idea of the risk level with respect to cancer.

II. REVIEW OF LITERATURE

Kannan et. al. (2001) conducted a study on ^{222}Rn concentration in different sources of water at Kalpakkam environment. ^{222}Rn activity in different sources of water using emanometry method and it was found to vary in the range of 153-3836 mBq l^{-1}. Total annual effective dose due to ingestion and inhalation of ^{222}Rn is found to vary in the range of 1.7- 21.4 µSv.

Selvasekara pandian S. (2001) focused on the radon concentration in water in Coonoor, India. The gas collection measurement method was employed to determine radon activity concentrations in the water of Coonoor. Open well water, dam water and stream water have been investigated for their radon concentrations. It is observed from the table that the ^{222}Rn concentration varies from 0.03 Bq l^{-1} to 5.72 Bq l^{-1} with a mean value of 1.20 Bq l^{-1}. The calculated annual average effective dose for the stomach is 6.9 µSv y^{-1} and for lung it is 3.3 µSv y^{-1}. The total dose varies from below detection limit to 49 µSv y^{-1} with a mean value of 10.2 µSv y^{-1}.

Ningappa C. (2008) published a report on concentrations of radon and its daughter Products in and around Bangalore city. This test is conducted by using Solid State Nuclear Track Detector (SSNTD) based twin cup dosimeters, and the activity of radium present in soils and rocks was measured by using HPGe detector. The value of radon concentration in the indoor air near granite quarries varies from 55 to 300 Bqm^{-3} with a median of 155 Bqm^{-3} and its progeny varies from 0.24 to 19.6 mWL with a median of 8.4 mWL. In Bangalore city, the concentration of radon varies from 18.4 to 110 Bqm^{-3} with a median of 45 Bqm^{-3} and its progeny varies from 1.62 to 11.24 mWL with a median of 4.15 mWL. The activity of radium varies in granitic regions of the Bangalore rural district from 42.0 to 163.6 $Bqkg^{-1}$ with a median of 112.8 $Bqkg^{-1}$.

Candrashekara M. S. (2010) conducted an experiment on radiation dose due to radioactive elements present in ground water and soil samples around the Mysore city, India. The ^{222}Rn in ground water varies from 4.25 to 435 Bq l^{-1} with a median of 25.9 Bq l^{-1} and ^{226}Ra concentration varies from 0.28 to 189 mBq l^{-1} with median of 4.75 mBq l^{-1}. The median of inhalation and ingestion doses due to ^{222}Rn in water is 65.2 and 5.43 µSv y^{-1} respectively.

Sathish L. A. (2010) focused on a study of effective radiation dose due to indoor Radon and Thoron concentrations in Bangalore city, India. It has been measured in houses at 10 locations in different parts of Bangalore, India. The average value of radon and thoron concentrations in the studied area is found to be 33.4 ± 6.1 and 21.6 ± 2.5 Bq m^{-3}, respectively. The dose rate due to Radon, Thoron, and their progenies ranged between 0.1 – 0.5 µSv y^{-1}.

III. METHODOLOGY

A. Introduction

The methodology employed to fulfil the various objectives of this project was derived from reviewing several literature. Active and Passive techniques are used for the measurement of radon. Instruments like Alphaguard, Doseman, DosemanPro, and Lucas Cells are widely used. Alpha spectrometry and Gamma spectrometry are used for spectroscopic analysis of various materials. For the measurement of integrated radon exposures, Solid State Nuclear Track Detectors (CR-39 and LR-115 films) are being used. Radon in air can also be detected using charcoal canisters with a detection limit 20 Bq l^{-1} (US EPA, 1986). Several well-established methods exist for the collection and measurement of radon in water.

B. Techniques for Measuring Radon in Water

The techniques for measuring radon in water include

Direct gamma counting (Galli et al. 1999),

Electret ion chambers (Kotrappa and Jester 1993), and

Gas transfer by membranes (Surbeck 1996, Freyer et al. 2003).

The most prevalent methods for measuring radon concentrations in water are,
Liquid scintillation counting and
The de-emanation radon measurement techniques (Prichard et al. 1991, Prichard and Gesell 1977,Lucas 1957, 1964)

C. Working Principle of Alpha Counter

A scintillation counter is an instrument for detecting and measuring ionizing radiation. It consists of scintillator which generates photons of light, a sensitive photomultiplier tube which converts that light into electrical signals.

1) Operation: A charged particle strikes the scintillator, its atom excited & photons are emitted and directed at the photomultiplier tubes. They strike the first dynode and releases single electron. That single electron on the dynode releases number of secondary electrons when they strike second dynode. Each subsequent dynode releases further electrons and so there is a current amplifying effect at each dynode stage. Each stage has higher potential than the previous to provide accelerating field. The resultant o/p signal is in the form of measurable pulse and the pulse carries into about the energy of the original incident radiation on the scintillator, thus both intensity and energy of the radiation can be measured. Extra High Tension (EHT) should be always 900 volts.

α energy → light → electron → multiplication of electrons →electric pulse.

D. Methods of Measurements

1) ^{222}Rn Concentration In Water: Radon in water is measured by bubbling the radon into evacuated Zns(Ag) scintillation cells (lucas cell) in a controlled way using specially built devices. From the Radon Emanometry method, the concentration of Rn-222 in water was calculated using the equation given by Raghavayya et al.(1980).

$$^{222}Rn\ (Bq\ l^{-1}) = \frac{69.671*0.001*c}{D1*D2*D3*E*V}$$

Where,

C→Counts above background (Counts/s)

D1→ Decay of radon from the time of sample collection upto the time radon transfer from the radon bubbler to scintillation cell

- $D1 = e^{-\lambda t1}$

λ→Radon decay constant

- λ=0.0001259 per minute

t_1→Duration between sample collection and radon collection in the scintillation cell

D2→ Decay of radon from the time radon transfer from the radon bubbler to scintillation cell upto the time of counting

- $D2=e^{-\lambda t2}$

t_2→Duration between radon collection in scintillation cell and radon counting

D3→Radon buildup factor

- $D3=1-e^{-\lambda t3}$

t_3→Counting duration

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E. Work Has Been Done

1) Calculations:

Table 3.5.1.1: Sample no. VK-1

Sample No.		VK-1	
Sample		Water	
Type of sample		Borewell (closed)	
Place of collection		Besant nagar, murugan temple	
Date of sample collection		11.9.14	
Time of sample collection		11:00:00	
Time of transfer the sample to radon bubbler		12:14:00	
Volume of sample in the radon bubbler	V	0.06	Litre
Time of radon collection (from the radon bubbler to scintillation cell)		12:21:00	
Time of starting counting radon in the scintillation cell		15:41:00	
Radon decay constant	λ	1.26E-04	Per minute
Duration between sample collection and radon collection in the scintillation cell	t1	81	minutes
Decay of radon from the time of sample collection upto the time radon transfer from the radon bubbler to scintillation cell	D1	0.9898	$D1 = e^{-\lambda t1}$
Duration between radon collection in scintillation cell and radon counting	t2	200	minutes
Decay of radon from the time radon transfer from the radon bubbler to scintillation cell upto the time of counting	D2	0.975	$D2 = e^{-\lambda t2}$
Radon buildup factor(during counting)		15	Minutes
	λt3	0.001888	
	D3	1.89E-03	$D3 = 1 - e^{-\lambda t3}$
S+B sample+bkg counts		265+81=346	
S+B duration(minutes)		15	Minutes

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B Bkg counts		10+32=42	
B duration(minutes)		15	Minutes
S sample counts	C	304	
Efficiency %		74%	
Rn 222 in water= (69.67*0.001*C)/(D1*D2*D3*E*V)		2615	mBq/l
		2.6	Bq/l

Table-3.5.1.2 Sample no. VK-2

Sample No.		VK-2	
Sample		Water	
Type of sample		Borewell (closed)	
Place of collection		Besant nagar vk house	
Date of sample collection		09-09-14	
Time of sample collection		10:45:00	
Time of transfer the sample to radon bubbler		12:15:00	
Volume of sample in the radon bubbler	V	0.06	Litre
Time of radon collection (from the radon bubbler to scintillation cell)		12:20:00	
Time of starting counting radon in the scintillation cell		16:20:00	
Radon decay constant	λ	1.26E-04	Per minute
Duration between sample collection and radon collection in the scintillation cell	t1	95	minutes
Decay of radon from the time of sample collection upto the time radon transfer from the radon bubbler to scintillation cell	D1	0.9881	$D1 = e^{-\lambda t1}$
Duration between radon collection in scintillation cell and radon counting	t2	240	minutes
Decay of radon from the time radon transfer from the radon bubbler to scintillation cell upto the time of counting	D2	0.9702	$D2 = e^{-\lambda t2}$

Radon buildup factor(during counting)		15	Minutes
	$\lambda t3$	0.001888	
	D3	1.89E-03	$D3=1-e^{-\lambda t3}$
S+B sample+bkg counts		246+133=379	
S+B duration(minutes)		15	Minutes
B Bkg counts		4+16=20	
B duration(minutes)		15	Minutes
S sample counts	C	359	
Efficiency %		74%	
Rn 222 in water= (69.67*0.001*C)/(D1*D2*D3*E*V)		3115	mBq/l
		3.1	Bq/l

Table 3.5.1.3 Sample no. VK-3

Sample No.		Vk-3	
Sample		Water	
Type of sample		Borewell (closed)	
Place of collection		Anna university, near estate office	
Date of sample collection		10.9.14	
Time of sample collection		13:14:00	
Time of transfer the sample to radon bubbler		13:20:00	
Volume of sample in the radon bubbler	V	0.06	Litre
Time of radon collection (from the radon bubbler to scintillation cell)		13:25:00	
Time of starting counting radon in the scintillation cell		16:25:00	
Radon decay constant	λ	1.26E-04	Per minute
Duration between sample collection and radon collection in the scintillation cell	t1	11	minutes
Decay of radon from the time of sample collection upto the time radon transfer from the radon bubbler to scintillation cell	D1	0.9986	$D1 = e^{-\lambda t1}$

Duration between radon collection in scintillation cell and radon counting	t2	180	minutes
Decay of radon from the time radon transfer from the radon bubbler to scintillation cell upto the time of counting	D2	0.9776	$D2=e^{-\lambda t2}$
Radon buildup factor(during counting)		15	Minutes
	λt3	0.001888	
	D3	1.89E-03	$D3=1-e^{-\lambda t3}$
S+B sample+bkg counts		25+198=223	
S+B duration(minutes)		15	Minutes
B Bkg counts		25+7=32	
B duration(minutes)		15	Minutes
S sample counts	C	191	
Efficiency %		74%	
Rn 222 in water= (69.67*0.001*C)/(D1*D2*D3*E*V)		1624	mBq/l
		1.6	Bq/l

Table 3.5.1.4 Sample No. VK-5

Sample No.		VK-5	
Sample		Water	
Type of sample		Borewell (closed)	
Place of collection		Parameshwari nagar, 4th street, iskon homes, adayar	
Gps of place of collection		13°00’9”n 18°15’27”e	
Date of sample collection		16-09-14	
Time of sample collection		8.00.00	
Time of transfer the sample to radon bubbler		11.35.00	
Volume of sample in the radon bubbler	V	0.06	Litre
Time of radon collection (from the radon bubbler to scintillation cell)		11.40.00	

Time of starting counting radon in the scintillation cell		15.00.00	
Radon decay constant	λ	1.26E-04	Per minute
Duration between sample collection and radon collection in the scintillation cell	t1	220	minutes
Decay of radon from the time of sample collection upto the time radon transfer from the radon bubbler to scintillation cell	D1	0.973	D1 $=e^{-\lambda t1}$
Duration between radon collection in scintillation cell and radon counting	t2	200	minutes
Decay of radon from the time radon transfer from the radon bubbler to scintillation cell upto the time of counting	D2	0.975	D2$=e^{-\lambda t2}$
Radon buildup factor(during counting)		15	Minutes
	λt3	0.001888	
	D3	1.89E-03	D3$=1-e^{-\lambda t3}$
S+B sample+bkg counts		203+20=223	
S+B duration(minutes)		15	Minutes
B Bkg counts		8+13=21	
B duration(minutes)		15	Minutes
S sample counts	C	202	
Efficiency %		74%	
Rn 222 in water= (69.67*0.001*C)/(D1*D2*D3*E*V)		1780	mBq/l
		1.8	Bq/l

Table 3.5.1.5 Sample No. VK-6

Sample No.		VK-6	
Sample		Water	
Type of sample		Borewell(closed)	
Place of collection		Venkatesh house, sasthri nagar, adayar.	
Date of sample collection		26-09-14	
Time of sample collection		11.05.00	

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Time of transfer the sample to radon bubbler		12.07.00	
Volume of sample in the radon bubbler	V	0.06	Litre
Time of radon collection (from the radon bubbler to scintillation cell)		12.17.00	
Time of starting counting radon in the scintillation cell		15.40.00	
Radon decay constant	λ	1.26E-04	Per minute
Duration between sample collection and radon collection in the scintillation cell	t1	72	minutes
Decay of radon from the time of sample collection upto the time radon transfer from the radon bubbler to scintillation cell	D1	0.991	$D1 = e^{-\lambda t1}$
Duration between radon collection in scintillation cell and radon counting	t2	203	minutes
Decay of radon from the time radon transfer from the radon bubbler to scintillation cell upto the time of counting	D2	0.9748	$D2=e^{-\lambda t2}$
Radon buildup factor(during counting)		15	Minutes
	λt3	0.001888	
	D3	1.89E-03	$D3=1-e^{-\lambda t3}$
S+B sample+Bkg counts		179+170=349	
S+B duration(minutes)		15	Minutes
B Bkg counts		16+9=25	
B duration(minutes)		15	Minutes
S sample counts	C	324	
Efficiency %		74%	
Rn 222 in water= (69.67*0.001*C)/(D1*D2*D3*E*V)		2789.5	mBq/l
		2.8	Bq/l

F. ^{222}Rn Concentration in Different Sources of Water-Literature Review

Sources	Location	^{222}Rn concentration range	References
All sources of water	Chennai coastal area	2.98 Bq l^{-1}	Present study

All sources of water	Kalpakkam	0.15-3.84 Bq l^{-1}	Kannan et al.(2001)
Indoor air	Bangalore city	55 to 300 Bq.m^{-3}	Ningappa C. (2008)
Ground water	Mysore city	4.25 to 435 Bq l^{-1}	Candrashekara M. S. (2010)
Indoor radon in houses	Bangalore city, India	33.4 ± 6.1 and 21.6 ± 2.5 Bq m^{-3}	Sathish L. A. (2010)
Ground water	NITJ, Punjab	2560 to 7750 Bqm^{-3}	Badhan K. (2010)
Open well	Coastal Kerala	0.03 - 1.31 Bq l^{-1}	Cunha D P.(2011)
Bore wells, open wells, lakes and running water	Moradabad of Western Uttar Pradesh	28.34- 40.98 Bq l^{-1}	Mishra P. (2012)
Lakes, open wells, drilled wells, taps and rivers	Mysore city	643.9 Bq l^{-1}	Rajesh B.M. (2012)
Bore wells, open wells, lakes and river water	Guwahati	21.31 Bq l^{-1}	Dey G. K. (2012)
Selected wells and boreholes	Zaria, Nigeria	7.18 ± 1.11 Bq l^{-1} for wells and 7.41 ± 2.04 Bq l^{-1} for borehole waters	Garba N. N. (2012)
Bore well	Mandya region, Karnataka State	6.44 ± 0.20 to 44.83 ± 0.54 Bq l^{-1}	Shivakumara B.C. (2012)
Ground water	Ramanagara and Tumkur districts, Karnataka,	2.96 ± 0.89 to 299.06 ± 6.98 Bq l^{-1}	Srilatha M. C. (2014)

Table-3.9: ^{222}Rn CONCENTRATION IN DIFFERENT SOURCES OF WATER-LITERATURE REVIEW

G. Phase II: Work In Progress

Maximum number of samples yet to be collected in and around Chennai city

The comparison of ^{222}Rn concentration in coastal areas and inland areas of Chennai city is on progress.

Ingestion dose calculation using the measured ^{222}Rn concentration.

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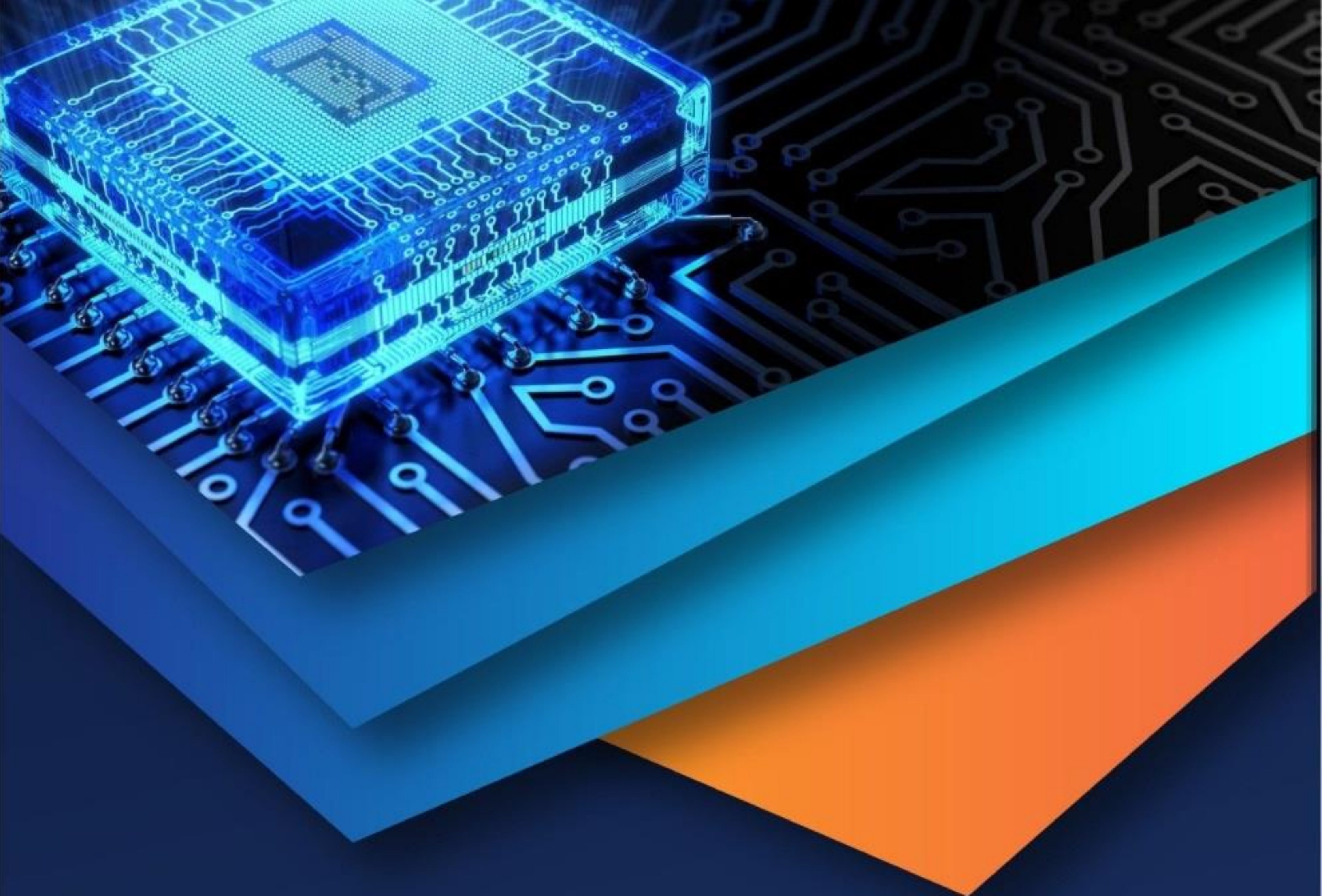

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