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Physicochemical Activities of Blood Biomarkers Due to Ingestible Radon-222 in Drinking Water and Its Associated Health Consequences

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Abstract**—**Generally, water contamination is a serious health concern, affecting millions of people worldwide every year. Among the water contaminants, radon is a radioactive contaminant understudied and under-regulated. It produces many adverse health effects, including cancer. It is a natural gas that cannot be seen, tasted, or smelled. It develops from the radioactive decay of radium found in the rock of soil and has been considered a health hazard due to its radioactivity in nature. To examine its effects and physicochemical characteristics on the blood biomarkers due to its ingestion in drinking water, its concentrations were monitored and measured in treated and untreated water using Electronic Radon Active Detector (RAD7), while human blood samples were collected using the required laboratory tools. The blood samples were collected and examined physicochemically using semi-automated chemistry analyzer to evaluate the chemistry parameters of the blood. Statistically, results obtained were analyzed using *T*-test of variables at 95% confidence interval. The outcome of results revealed 112.03 Bq/m^3, 561.67 Bq/m^3 and 2,753.00 Bq/m^3 of radon-222 concentrations in the three water samples used respectively. Demographically, chemistry parameters biomarkers of the blood determined displayed some levels of variations due to radon-222 contaminants ingested from untreated water. Also, analyzed results of blood revealed the associations between the physicochemical parameters of the blood biomarkers and volunteers' health consequences. The consequences observed were more severed with group B volunteers than group A, due to high level of radon contaminants in borehole water consumed by group B than in well water consumed by group A. The percentages of elevated and depressed biomarkers observed differ from initial reference values and, were the dysfunction indicators. They are directly or indirectly associated to human's state of health. Most significant biomarkers affected were; HCO_3, Cl, K, Cr and Na, they are relevant biomarkers in medicine to determine human's state of health at any point in time.

Keywords**—**Radioactive, radon, biomarker, ingestion, dysfunction.

I. Introduction

GENERALLY in health sciences, water contamination is a serious health concern that needs scientific approaches. Research revealed that contaminated water affects millions of people worldwide every year [2] and, according to Centre for Disease Control and Prevention (CDC), 7.2 million Americans get sick yearly due to unsafe water consumption [2]. Among radioactive contaminants in water, radon is understudied and under-regulated [2]. It is a radioactive gas that cannot be seen, tasted or smelled; developed from radioactive decay of radium, found in the rock of soil [15]. Health authorities consider radon as a health hazard due to its radioactivity in nature [2]. Consuming or inhaling radon contaminated water leads to cell damage which eventually results in cancer. Radon emanates from the soil beneath the earth crust. Most underground water is contaminated and polluted with dissolved radon, drinking such water is risky and can lead to stomach cancer [4]. In 1989, National Academy of Science reported that, EPA estimated radon in drinking water causes about 168 cancer death per year [4]; 89% of estimated population were affected with lung cancer caused by breathing radon released to indoor air emanated from water and 11% of stomach cancer was associated to ingestion of radon through consumption of radon contaminated water.

However, not all drinking water contains high level of radon [4]. Surface drinking water sources, e.g. river, lake, or reservoir, contain very low level of radon as most radon in such water will be released into the air before reaching the supplier destination. Most concerned water are those originated from underground, such as well or borehole water that sourced from an aquifer. Though, not all underground water contains high level of radon, their concentrations in water depends on nature of the rock of the soil [15]. Currently, there is no federally-enforced law on drinking water standard on radon, only EPA proposed and not supported private well and borehole water regulations [4]. EPA proposed that, radon concentration level must not more than 4,000 pCiL^{-1}; it contributes approximately 0.4 pCiL^{-1} radon in air within the home.

Research activities have also provided means of reducing radon levels in water before consumption. The first fundamental step is to test the water supply systems. If the water contains high level of radon, it is advisable to treat the water before getting to home by applying any of the two main types of radon removal methods for well water: either *activated carbon filtration* to deactivate radon from water or by *aeration method* to push the concentrated radon vapor away from home by blowing the air [4].

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According to [8], a proportion of inhaled or ingested radon is chemically inert and, could enter the blood circulation, affect the blood contents and act on the human body to affect human health status [6]. Latest research on increased in radon exposure discovered some potential biomarkers in peripheral blood that reflects the corresponding damage changes due to radiation exposed to, especially radon. Quiescent lymphocytes are one of the human immune cells that are highly differentiated non-proliferating cells due to their sensitivity to radiation; mature lymphocytes are vulnerable to radiation damage [8].

Biomarkers first appeared in the field of geology, refer to the bioorganic compounds that originated from bio-organism in the geological materials [14]. It is significant for the early diagnosis, treatment and prognosis monitoring of many diseases in health-related systems [7]. A biomarker is a biological indicator that can be measured to assess various biological states, both in health and certain medical conditions. These markers are often utilized for diagnostic purposes or to evaluate normal physiological processes, pathological changes, or the responses of the body to medical treatments. They are crucial in the healthcare sector and have applications across various scientific fields [3]. In the field of medicine, biomarkers can take the form of traceable substances introduced into the body to assess organ function or other aspects of health. For example, rubidium chloride is employed as a radioisotope to assess the perfusion of heart muscle [3].

One well-known biomarker in medicine is Prostate-Specific Antigen (PSA), which serves as an indicator of prostate size and can exhibit rapid changes, potentially signaling the presence of cancer. In some cases, highly specific mutant proteins are used as biomarkers for cancer detection, as these proteins are typically only produced by existing tumors, offering unparalleled specificity for medical purposes [13]. Biomarkers used in personalized medicine are typically categorized as either prognostic or predictive. Prognostic biomarkers provide information about the likelihood of a patient's outcome, regardless of the specific treatment received, while predictive biomarkers help optimize treatment strategies and indicate the likelihood of benefiting from a particular therapy. These biomarkers play a crucial role in molecular diagnostics for conditions like chronic myeloid leukemia, colon, breast, lung cancer, and melanoma, contributing to improved prevention and treatment [11]. Hematologically, most common blood biomarkers available are [9]: Complete Blood Count (CBC) biomarkers, Lipids Panel (LP) biomarkers, Basic Metabolic Panel (BMP) biomarkers, Comprehensive Metabolic Panel (CMP) biomarkers.

Research has also demonstrated that biomarkers of exposure to radon and its progeny can be identified or quantified in various human tissues and fluids, including teeth, bone, blood, hair, and whiskers. These radon progenies can be measured using specific and reliable methods [10]. The biomarkers of radon in the body tissues and fluids are an indication of inhaling or ingestion of radon contaminated food or water containing.

Studies have emphasized that the small intestine serves as the primary site for the absorption of nutrients and various contaminants into the bloodstream. However, there is also evidence to suggest that the absorption of certain elements and their radioisotopes can occur in other regions of the alimentary tract, including the mouth, stomach, and colon [10]. Absorption from the stomach typically takes place for highly lipid-soluble substances such as alcohol and certain weak acids. In addition, the large intestine has the capacity to absorb water and electrolytes, such as sodium and chloride.

In physicochemical activities, blood and urinary indices are mostly used samples to examine a transient and reversible decline in health-related functions like kidney or liver functions. They survey the persistent in structural kidney impairment and are mostly attributed to Acute Tubular Necrosis (ATN), a blood biomarker of kidney functions [1]. In the field of hematology, various blood biomarkers can be assessed in a medical laboratory through the utilization of diverse analytical techniques [9]. In physicochemical analysis, CMP biomarkers are required tests for kidney function, liver function, diabetic and parathyroid status, and electrolyte and fluid balance [9]. Commonly, CMP biomarkers in medical diagnosis include a panel of 14 blood tests and are an expanded version of the BMP, which includes liver tests. PMB tests for electrolyte levels, kidney function, and blood sugar levels are the most common tests used by health care providers and consist of seven or eight biochemical tests [9]. It is also used to assess and monitor overall health status, response to medication and medical therapies, and indicators of metabolic functioning. Thus, this research was embarked on to evaluate the physicochemical activities of blood biomarkers due to radon-222 concentrations ingested in drinking water to affirm its associated health consequences using CMP of Chemistry Parameter (CP) biomarkers.

II. Research Methodology

A. Sampling Techniques

For this research, twelve human volunteers were allowed to be taken specific treated water that contained insignificant level of radon contaminants. They were restricted within the two experimental locations to obey some rules for period of a week. On experiment day, all volunteers were divided into two groups and set at two different locations for the experiment. 5 ml of blood samples were collected and dispensed into EDTA bottle for further examination and analysis using required laboratory reagents. Twelve blood samples were collected (six from each group) at 0 hour (before taken of untreated water).

Experimentation continued with some volunteers in group A and B allowed to drink 450 ml of untreated *well* water and *borehole* water that contained high level of radon-222 respectively, leaving four volunteers behind as control sample. The collection of blood samples continued at 1-5 h with the above procedure after drinking of untreated water at different hours of study. The volume and quantity of untreated water took (Table I) varied between the studied volunteers. Physicochemical activities of blood samples collected determined were the dysfunctional CP biomarkers after consuming untreated well and borehole water.

TABLE I
GROUP A AND B STUDIED VOLUNTEERS AND RATE OF CONSUMPTION OF WELL AND BOREHOLE WATER

SN	Volunteers	Rate of Consumptions (Hours)	Time of Consumption
1	CV11	Control	No
2	TV12	0 – 1	1 time
3	TV13	0 – 4	4 times
4	TV14	0 – 2	2 times
5	TV15	0 – 3	3 times
6	CV16	Control	No
7	TV21	0 – 1	1 time
8	TV22	0 – 2	2 times
9	CV23	Control	No
10	TV24	0 – 4	4 times
11	TV25	0 – 3	3 times
12	CV26	Control	No

TV: Tested Volunteer; CV: Control Volunteer.

B. Measurement of Radon-222 Concentrations in Water

As required, radon-222 (^{222}Rn) concentrations were measured from all water samples using Electronic Radon Active Detector (RAD7) detector, manufactured by Durridge Company USA. Its concentrations in water samples were measured by connecting the water probe through a desiccant ($CaSO_4$) to the inlet of the RAD7. The experimental setup of the radon equipment used is as shown (Fig. 1).

Fig. 1 Measurement of Radon-222 concentrations in Water

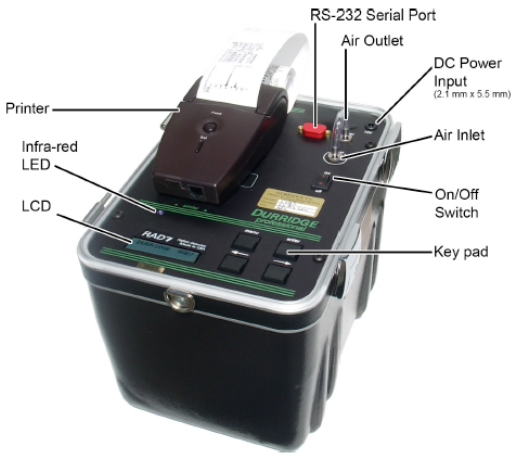

Fig. 2 RAD7 functional parts labeled

Measurements of radon in water samples were carried out with three different water samples collected in 1 liter bottle as recommended [12]. For every measurement of radon-222 level in water, the RAD7 water probe was inserted into the bottle contained the water sample to be analyzed and through a tube to a Desiccant ($CaSO_4$) filter tube, and then to the Air-inlet probe (pore size 1 μm) that blocks fine dust particles from entering the RAD7. To calibrate the RAD7, it is required to be purged to ensure that the relative humidity in the measurement chamber is equal to or less than 8% as recommended [12]. Each measurement was run for four times and took 5 minutes. The three water samples used are; bottle and sachet water as treated water, direct borehole and well water as untreated water, all within FUTA campus.

C. CP Biomarkers

Using Semi-automated Chemistry Analyzer, CMP biomarkers as CP of the blood were determined from each blood sample collected at 0 hour and other studied hours in both two groups of populations. Specifically for this research, seven CP biomarkers determined from volunteers' blood are: Urea (Ur), Creatinine (Cr), Potassium (K), Chloride (Cl), Hydrogen Carbonate (HCO_3), Calcium (Ca) and Sodium (Na). The variations in their characteristics at 0 hour and other studied hours are dysfunction of blood biomarkers which were compared with reference values at 0 hours. They are directly or indirectly related in determining human's state of health at any time.

D. Analysis of CP Biomarkers

Demographically, the results of CP biomarkers obtained at different hours of studies are presented (Figs. 3-16). Inferentially, *T*-test of variables at 95% confidential and probability level were used to examine the degree and level of significant using SPSS version 22.0 set at 0.05 Alpha level of significance. Hence, characteristics and dysfunction of CP biomarkers due to radon-222 contaminants ingested in drinking water were determined. Furthermore, estimating the percentages of significant biomarkers for Tested Volunteers (TV) and Control Volunteers requires (1) and (2). The percentage estimated for TVs provides the degree of altered and dysfunction biomarkers due to variations in quantity and quality of untreated water consumed by the two groups.

$$\%E_{TV} = \frac{T_{SVT}}{T_{TOT}} \, x \, 100\% \quad (1)$$

$$\%E_{CV} = \frac{T_{SVC}}{T_{TOC}} \, x \, 100\% \quad (2)$$

E_{TV}: Expected Tested Value, E_{CV}: Expected Control Value, T_{SVT}: Total Significant Value for Tested Volunteer, T_{SVC}: Total Significant Value for Control Volunteer, T_{TOT}: Total Outcome for Tested Volunteer and T_{TOC}: Total Outcome for Control Volunteer.

III. RESULTS AND DISCUSSION

A. Radon Concentrations in Water

Table II presents the names, Global Positioning System

(GPS) locations, sources and concentrations of radon-222 measured from the three water samples required.

TABLE II
RADON-222 CONCENTRATIONS MEASURED IN DIFFERENT WATER SAMPLES

Name of Water Samples	GPS Locations	Sources and Locations	Radon-222 Concentrations (Bq/m^3)
FUTA Treated Water	$7^0$18′16′′N $5^0$7′51′′E	Within FUTA Campus	112.03 ± 208.00
FUTA Well Water	$7^0$17′45′′N $5^0$8′54′′E	Within FUTA Campus	561.67 ± 350.33
FUTA Borehole Water	$7^0$18′16′′N $5^0$7′45′′E	Within FUTA Campus	2753.00 ± 664.67

Table II presents the concentrations of radon-222 measured from the three water samples used. From the results, highest concentrations of radon were recorded in FUTA *borehole* water (2,753.00 Bq/m^3), followed by FUTA *well* water (561.67 Bq/m^3), and the least was recorded in FUTA treated (bottle and sachets) water (112.03 Bq/m^3). Records showed that both results of radon consumed were far below the limit of consumption [4], [5] and could not pose any serious dangers to volunteers but, could affect their health status through its absorptions to bloodstream and alter the blood biomarkers. This could be detriment if the concentration is higher than limit of consumption [4].

B. Physicochemical/CP Activities of Blood Biomarkers

The chemistry biomarkers determined from the blood samples of group A & B volunteers at different studied hours are presented (Figs. 3-16). From the laboratory experiment, out of 72 expected blood samples from all the volunteers in the two groups, to further laboratory analysis, only 48 (i.e. 24 from each groups) blood samples were able to be obtained completely throughout the experimental period. This was due to difficulties such as; unable to identified blood vein, fear of the needle and syringe puncture and many others encountered with some volunteers during the experiment. The completed blood samples obtained were analyzed physicochemically to obtain CP of the blood as blood biomarkers. From the graphs, volunteers TV12, TV14 and TV15 were tested volunteers under examinations in Group A while CV11 is a control. Also, volunteers TV21, V22 and V25 were tested volunteers in Group B while CV26 is a control.

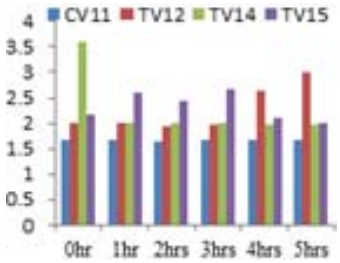

Fig. 3 Variation of Urea at different Hours for Group A

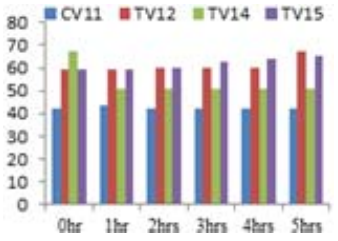

Fig. 4 Variation of Creatinine at different Hours for Group A

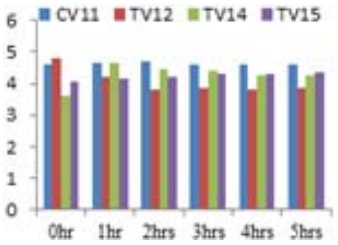

Fig. 5 Variation of Potassium at different Hours for Group A

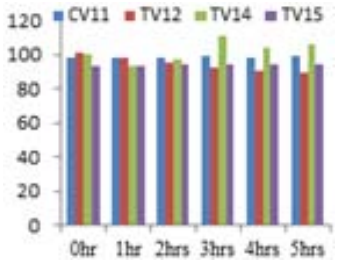

Fig. 6 Variation of Chloride at different Hours for Group A

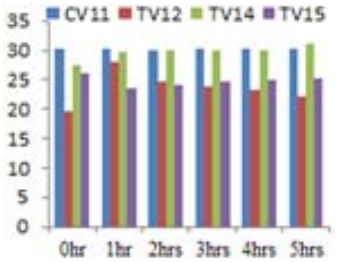

Fig. 7 Variation of Hydrogen Carbonate at different Hours for Group A

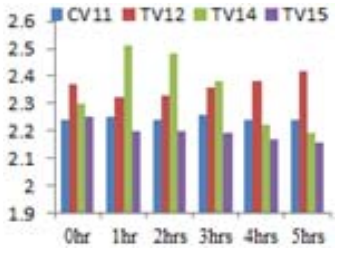

Fig. 8 Variation of Calcium at different Hours for Group A

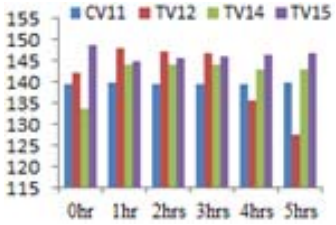

Fig. 9 Variation of Sodium at different Hours for Group A

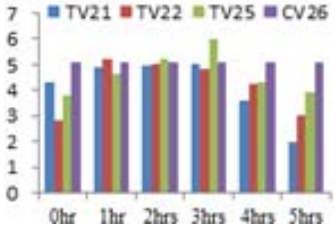

Fig. 10 Variation of Urea at different Hours for Group B

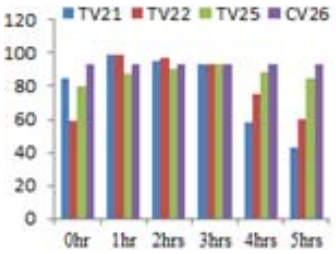

Fig. 11 Variation of Creatinine at different Hours for Group B

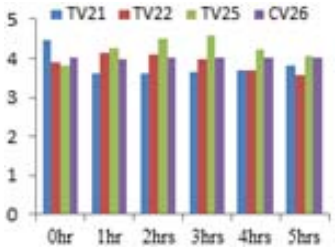

Fig. 12 Variation of Potassium at different Hours for Group B

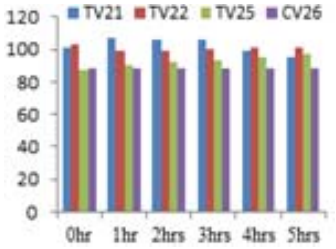

Fig. 13 Variation of Chloride at different Hours for Group B

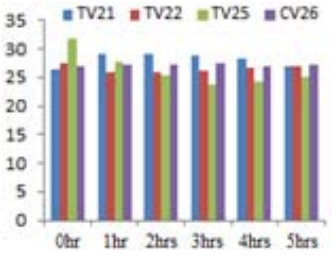

Fig. 14 Variation of Hydrogen Carbonate at different Hours for Group B

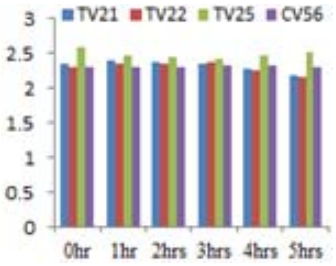

Fig. 15 Variation of Calcium at different Hours for Group B

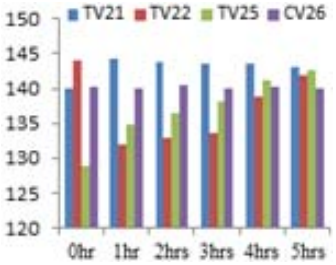

Fig. 16 Variation of Sodium at different Hours for Group B

From Figs. 3-16, observations showed that, there exist large variations in altered biomarkers between 0 and 1 hour, where some biomarkers increased and decreased with large variations for all tested volunteers. However, other results at 1-5 hours followed the suits and continuously increased or decreased. The variations observed on the blood biomarkers simply illustrate the effects of contaminants present in the borehole and well water consumed and, volunteers that consumed borehole water produced more severe effects than well water.

C. Physicochemical Activities of Blood Biomarkers

With physicochemical activities of the blood data obtained, the results of T-test analysis (Tables III A and B) from CP biomarkers for both group A and B volunteer's blood samples are presented. This determines the activities of blood biomarkers due to radon contaminants ingested in drinking water at 0 hour and other hours of studied. Using (1) and (2), both E_{TV} and E_{CV} were estimated to provide the degree of dysfunction biomarkers based on the significance of their T-*test* of variables.

TABLE III A
T-*TEST* RESULTS OF CP BIOMARKERS FOR GROUP A TESTED VOLUNTEERS

TV	Ur (mmol/L)	Cr (mmol/L)	K (mmol/L)	Cl (mmol/L)	HCO_3 (mmol/L)	Ca (mmol/L)	Na (mmol/L)	% per Vol.
TV12	0.219	0.219	0.006	0.019	0.017	0.670	0.807	42.86
TV14	0.004	0.004	0.006	0.477	0.006	0.429	0.004	71.43
TV15	0.232	0.064	0.017	0.022	0.017	0.008	0.007	85.71
% per Bio.	33.33	33.33	100	66.67	100	33.33	66.67	

TABLE III B
T-*TEST* RESULTS OF CP BIOMARKERS FOR GROUP A CONTROL VOLUNTEERS

CV	Ur (mmol/L)	Cr (mmol/L)	K (mmol/L)	Cl (mmol/L)	HCO_3 (mmol/L)	Ca (mmol/L)	Na (mmol/L)	% per Vol.
CV11	0.084	0.348	0.310	0.538	0.203	0.203	0.199	0.00

TABLE IV A
T-*TEST* RESULTS OF CP BIOMARKERS FOR GROUP B TESTED VOLUNTEERS

TV	Ur (mmol/L)	Cr (mmol/L)	K (mmol/L)	Cl (mmol/L)	HCO_3 (mmol/L)	Ca (mmol/L)	Na (mmol/L)	% per Vol.
TV21	0.736	0.566	0.005	0.496	0.014	0.311	0.005	42.86
TV22	0.024	0.035	0.987	0.007	0.014	0.889	0.022	71.43
TV25	0.055	0.010	0.014	0.015	0.007	0.007	0.010	85.71
% per Bio.	33.33	66.67	66.67	66.67	100	33.33	100	

TABLE IV B
T-*TEST* RESULTS OF CP BIOMARKERS FOR GROUP B CNTROL VOLUNTEERS

CV	Ur (mmol/L)	Cr (mmol/L)	K (mmol/L)	Cl (mmol/L)	HCO_3 (mmol/L)	Ca (mmol/L)	Na (mmol/L)	% per Vol.
CV26	0.611	0.788	0.058	0.024	0.076	1.000	0.842	0.00

TABLE V
COMPARISONS OF *T*-TEST ANALYZED CP BIOMARKERS FOR BOTH GROUP A AND B VOLUNTEERS

Vol.	Ur (mmol/L)	Cr (mmol/L)	K (mmol/L)	Cl (mmol/L)	HCO_3 (mmol/L)	Ca (mmol/L)	Na (mmol/L)
Group A	33.33	33.33	100	66.67	100	33.33	66.67
Group A	33.33	66.67	66.67	66.67	100	33.33	100
Ave. (%)	33.33	50.00	83.34	66.67	100	33.33	83.34
% Diff.	0.00	+ 33.34	- 33.33	0.00	0.00	0.00	+ 33.33

Tables III A and IV A present T-test analyzed results of CP biomarkers for all tested volunteers under examinations while Tables III B and IV B are for control volunteers. Also presented in the tables, the percentages of significance CP biomarkers per volunteers and per biomarkers were calculated. The percentages calculated revealed the degree of altered and dysfunction biomarkers due to quantity and quality of untreated water consumed. Analytically, the expected effective percentage of significance for tested volunteers should be positive while that of control volunteer should be 0% if actually the dysfunction in CP biomarkers was due to ingested contaminants (i.e. Radon-222) from untreated water and other factors remain constant. Among the results of tested volunteers in group A, both HCO_3 and K have the highest significance ($P < 0.05$) with 100% in percentage per biomarkers and followed by Na and Cl with 66.67% while others recorded low significance of 33.33%. However, in percentage per volunteers, TV15 has the highest of 85.71%, followed by TV14 with 71.43% and the least recorded was from TV12 with 42.86%. Also in group B, both HCO_3 and Na have the highest significance in percentages per biomarkers with 100%, followed by K, Cl and Cr with 66.67% while others recorded low significance of 33.33%. However, TV25 has 85.71%, followed by TV22 with 71.43% and lastly TV21 with 42.86% in percentages per volunteers respectively. The variations in percentages of significance per biomarkers ascertained the degree of altered and dysfunction biomarkers due to quality of untreated water consumed (i.e. *well* and *borehole* water) while, variations in percentages per volunteers ascertained degree of altered and dysfunction biomarkers due to variations in quantity of untreated water consumed. Thus, non-significance results of control volunteers signified no effects since they did not take untreated water with high level of Radon-222. Only Cl in group B has 0.024 significance value, its effect could be due to measurement error or other environmental impact. Table V presents the results comparison of analyzed group A and B volunteers based on qualities of water consumed.

From the results in Table V, the difference in percentage T-test analyzed results for both group A and B blood samples were due to different levels of Radon-222 contaminants ingested from *well* (i.e. 561.67 Bqm^{-3}) and *borehole* (i.e. 2,753.00 Bqm^{-3}) water. The differences in positive and negative signs indicate elevation and depression level of CP biomarkers as affected by the qualities of untreated water consumed. The most active CP biomarker due to Radon-222 contaminant ingested is HCO_3 with highest percentage average of 100%, followed by K and Na with 83.34% while Cl and Cr with 66.67% and 50% respectively. The difference of +33.33% in Na and Cr meant, the more Radon-222 contaminated water consumed, the higher will be in the elevation of Na and Cr blood biomarkers while the difference in –33.33% in K meant the more Radon-222 contaminated water consumed, the lower will be the

depressions of K blood biomarker. The average percentages estimated account for the physicochemical activities of blood biomarkers while, elevation and depression levels account for the degree of dysfunctions of affected biomarkers due to Radon-222 contaminants ingested from untreated water. The affected CP biomarkers affirmed by this research are;

- HCO_3 also known as bicarbonate, is a byproduct of body's metabolism and responsible for maintaining the balance of acids and bases in body, i.e. the pH value. It is an important "opponent" of acids, works as an acid buffer and ranges between 20.00 to 30.00 mmol/L. Its low levels in the blood are a sign of metabolic acidosis.
- K is a type of electrolytes that helps in control muscle and nerve activities, maintains fluid levels, and performs other important functions. Body needs K to help heart and muscles work properly and its levels that are too high or too low may indicate a medical problem [10]. Its normal ranges are between 3.6 and 5.2 millimoles per liter (mmol/L) of blood (3.00-5.00 in some countries). Greater than 5.5 mmol/L is critically high, and over 6 mmol/L can be life-threatening [10]. Too much K in body leads to heart beat irregularly, which in the worst cases, can cause heart attack.
- Na blood test evaluates an essential mineral in the body particularly important for nerve and muscle function [9]. Too much Na can raise blood pressure. Its normal level is between 135 and 145 milliequivalents per liter (mEq/L) or 137 to 147 in some countries [9]. Hyponatremia occurs when the sodium in blood falls below normal range in which, many possible conditions and lifestyle factors can lead to it.
- Cl is one of the most important electrolytes in the blood that helps keep the amount of fluid inside and outside of body cells in balance [9]. It also helps maintain proper blood volume, blood pressure, and pH of body fluids. Its normal range is between 96 and 106 milliequivalents per liter of blood (mEq/L) (95.00-110.00 mmol/L in some countries) [9]. Its level above normal causes hyperchloremia.
- Cr test measures how well kidneys perform their job of filtering waste from body blood. It is a chemical compound left over from energy-producing processes in muscles. Healthy kidneys filter Cr out of the blood. Its range for adult men, 0.74 to 1.35 mg/dL (65.4 to 119.3 micromoles/L), for adult women, 0.59 to 1.04 mg/dL (52.2 to 91.9 micromoles/L) or 50.00 t0 110.00 in some countries [9]. High Cr levels causes kidney damage or dehydration.

Thus, through this research work, elevation and depression level of aforementioned identified biomarkers from their baselines is an indication of health challenges and consequences upon the ingestible radon-222.

IV. Conclusion

The laboratory analysis conducted on human volunteer's blood samples revealed the activities of CP biomarkers due to ^{222}Rn contaminants ingested in drinking water and its associated health consequences. Using Semi-automated Chemistry Analyzer, CP biomarkers were analyzed and, the concentrations of ^{222}Rn in water were monitored and measured using RAD7. The results revealed the concentrations of ^{222}Rn in *borehole* water with 2,753.00 Bq/m^3 and *well* water with 561.67 Bq/m^3. The biomarker results data obtained were analyzed statistically using *T*-Test of variables of SPSS package. The analyzed results showed correlations between ^{222}Rn concentrations ingested from drinking water and dysfunction biomarkers. According to [4] and [5], the radon levels in both water samples used were far below the limitation for radon risk in drinking water. Observations showed that the larger variations of altered and dysfunction CP biomarkers between 0 hour and 1 hour was due to first doses of radon contaminants absorbed to the blood stream, diluting and altered the blood biomarkers while others were due to continuation in absorptivity of radon contaminants in the blood stream. The associated health consequences of Radon-222 were estimated in percentages from the two studied groups. Results showed that, group B volunteers produce more severe damages than those in group A and were due to high concentration of radon-222 contaminants in *borehole* than *well* water. The percentage differences of CP observed (i.e. elevation and depression) differ from the initial CP reference values and, were the dysfunctions indicators of blood biomarkers. Most affected CP biomarkers, such as HCO_3, K, Na, Cl, Cr, are directly or indirectly required in determining general health status in clinical diagnosis. Hence, this research work recommends that both *well*, *borehole* or any underground sourced water should be properly disinfected before consumption to ensure it is free from radioactive contaminants. This will alleviate the associated health consequences of ^{222}Rn contaminants when ingested in drinking water.

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