DRINKING WATER RADIOLOGICAL QUALITY DETERMINATION BASED ON GROSS ALPHA AND GROSS BETA USING LIQUID SCINTILLATION COUNTING (LSC)

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INTRODUCTION

BACKGROUND OF THE STUDY

Water is very ample and covers about two-thirds of the planet. However, most of it is saline water and only 2.5% is fresh water. In this small percentage, two thirds of it is locked in polar ice caps, 20% can be found in remote areas and only 0.08% is accessible for daily use [1].

Potable water is essential for the survival of human life. Without water, our existence is threatened. However, potable water coming directly from ground water should undergo different purifying techniques to ensure contaminant free water. The Philippine Government targets in 2010 to provide 92 to 96 percent of the people of safe drinking water [2].

One of the possible contaminants present in water is radioactive substances. Radioactive substances such as radium, uranium and thorium occur naturally in the environment [3]. This study aims to determine the radiological quality of potable water using liquid scintillation counting. This assesses the gross alpha and beta particles, known to be internal hazards, present in water.

KEYWORDS

Drinking water, Contaminants, Radioactive substances, Environment, Liquid Scintillation Counting (LSC), Groundwater.

STATEMENTS OF THE PROBLEM

The main purpose of the study is to determine the gross alpha and gross beta of the drinking water samples using Liquid Scintillation Counting (LSC) obtained from selected drinking water provider in Quezon City, and City of San Jose Del Monte and ground water sample from Nabas, Aklan.

Specifically it sought to answer the following questions:

1. What are the gross alpha and gross beta levels of the drinking water from the following locations:
   1.1 groundwater from Sitio Bacoor, Barangay Pasong Tamo, Quezon City;
   1.2 Metropolitan Waterworks and Sewarage System (MWSS) servicing Quezon City East;
   1.3 Francisco Homes II Water Management, City of San Jose Del Monte, Bulacan;
   1.4 Local Water and Utilities Administration (LWUA), City of San Jose Del Monte, Bulacan; and
   1.5 Horum-Horum Cold Spring, Nabas, Aklan?

2. Do the water samples obtained from Sitio Bacoor, and Horum-Horum meet the standard for gross alpha and gross beta based from the Philippine National Standard of Drinking Water 2007?

3. Do the water samples from MWSS, CSJDM - LWUA and Francisco Homes II Water Management meet the gross alpha and beta content based from the requirements of radiological quality set by the Philippine National Standard for Drinking Water 2007?

4. What are the implications of the study to the general radiological quality of the drinking waters?

HYPOTHESIS

The assessment must contain radioactivity level in water that is not anticipated to pose any significant risk to health.

SIGNIFICANCE OF THE STUDY

Ionizing radiation such as alpha particles and beta particles interact with matter and may cause reactions that are toxic and fatal. Ionizing radiation may also cause alterations in cells and tissues. Radiation also interacts with water forming species such as superoxides, hydroxyl radical, hydroperoxyl radical and hydrogen peroxide that oxidizes macromolecules inside the body such as DNA. A highly damaged DNA may later undergo mutagenesis and carcinogenesis. Interaction of radiation with organic substances produces carbonium ion that can alkylate nitrogen bases of the DNA [4].

Gross measurements are used as a method to screen samples for relative levels of radioactivity. Gross analysis are generally made first to determine the total amount of radioactivity, of a certain type, that is present. The more expensive specific analysis of alpha- and beta-emitting isotopes is only made if gross measurements are above background levels. When gross alpha and beta measurements are made, simply means all their activities are measured. There is no distinction between which of those isotopes are present, just how much activity is there [5].

Radionuclides that are present in water, which exceeds the minimum level requirements for safe drinking water, may result to serious health problems when absorbed by humans. The possible effects, which include cancer and genetic disorder, are stochastic. To ensure a hazard free drinking water, one should also consider analyzing the radiological quality of water based from gross alpha and gross beta content of water. The Philippine National Standards for Drinking Water 2007 and Department of Health sets 0.1 Bq/L for gross alpha and 1.0 Bq/L for gross beta content in drinking water [6].

SCOPE AND LIMITATIONS

The study focuses on the determination of the gross alpha and gross beta level of radionuclide present in the water samples collected from Sitio Bacoor ground water pump, Francisco Homes II water supply, City of San Jose del Monte – Local Water and Utilities Administration, and Horum-Horum Cold Spring in Nabas, Aklan. Water samples from Sitio Bacoor and Horum-Horum, Aklan did not undergo any form of water treatment.

The study made used of purposive sampling technique in selecting locations for water samples. The areas are within the vicinity of the researchers, which is the primary criterion of the selection. Sample from Hurom-Hurom is included to have an additional ground water sample.

The experimentation is conducted in the Analytical Measurements Research Unit, Philippine Nuclear Research Institute (PNRI). The gross alpha and gross beta in the water samples are determined via liquid scintillation counting (LSC).

It is not the aim of the study to identify possible radionuclide contaminants present in water and trace their sources. Other parameters to test the safety of drinking water which are not included in the present study are microbiological quality and physico-chemical quality.

REVIEW OF RELATED LITERATURE AND STUDIES

OCCURRENCE OF NATURAL RADIOACTIVITY IN WATER

Natural radionuclides are commonly present in the sources of drinking water like the groundwater. Some of the alpha emitters present in the water include Uranium-238, Polonium-210, Radium-226, and Thorium-230 [7]. Beta emitters found in water are from natural decay series of uranium, thorium and actinium, from the naturally occurring isotope potassium-40 and from the artificially produced isotopes strontium-90 and Cesium-137. Radionuclides found in groundwater are associated with the presence of uranium, thorium, and radium in rock and soil [8]. See Figure 1.

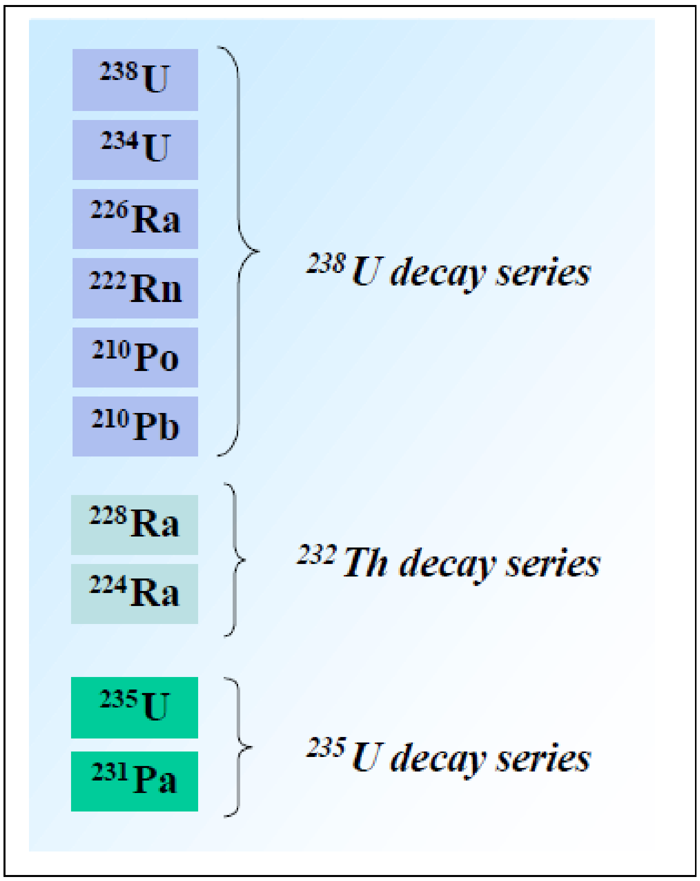


Figure 1. Naturally Occurring Radioisotopes
Source: http://www.idswater.comCommonPaperPaper_217wisserab.pdf

RADIOACTIVITY STANDARDS FOR DRINKING WATER

Natural radioactive substances coming from rocks and soil of the earth and due to man-made by-products from reactors may contaminate the water supply. Due to these possibilities, the Department of Health (DOH) included radiological quality, which is based from the standard set by the World Health Organization (WHO), in the Philippine National Standards for Drinking Water 2007 [6].

Table 1: Standard Values for Radiological Constituents

Constituents	Activity Level (Bq/Liter)
Gross alpha activity	**0.1**
Gross beta	**1.0**
Radon	**11**

TYPES OF RADIOLOGICAL ANALYSIS

The most common analyses for assessing the radiological quality of water are shown in the table [9]:

Table: Summary of Radiological Analysis for Water

Gross Alpha	Measurement of all alpha particles activity simultaneously
Gross Beta	Measurement of all beta particles activity
Tritium	Low energy beta radiation
Strontium-90	Beta emitter resulting from nuclear testing
Gamma Spectroscopy	Identification of radionuclides using their unique gamma radiation emissions

DETECTORS USED IN DETERMINING ALPHA AND BETA PARTICLES

There are standard parameters used for determining the quality/drinkability of potable waters. Methods, such as physico-chemical, and microbiological analyses were widely used. Another important type of analysis, which is the test for radioactivity levels, determines the radioactivity of a water sample.

GAS IONIZATION DETECTORS

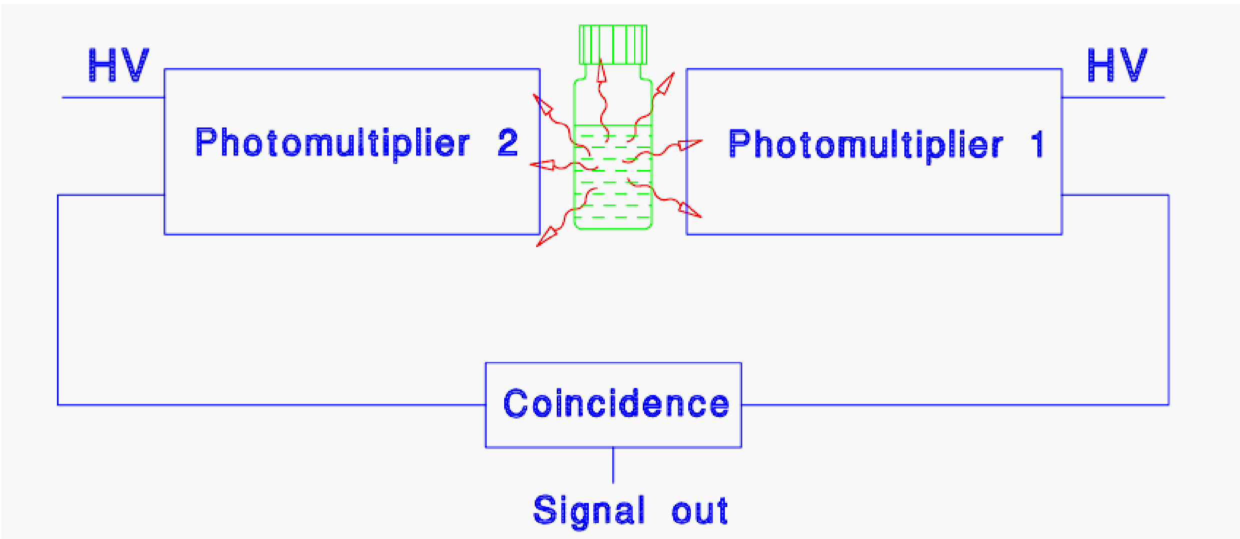
When a moving energetic particle (such as alpha, beta and gamma particles) interacts with a gaseous atom, an electron in an orbital may be freed from the atom. This interaction forms an ion pair of the ejected electron and a positively charged ion. The minimum energy required to form an ion pair in a gas is called ionization potential.

The ion pairs can be separated by applying a potential gradient in the electrodes. When the positive ions move to the cathode and the negative ions move to the anode, pulses are formed. These pulses are detected via individual events or integrated currents.

There are three types of gas ionization detectors: (1) ion chamber; (2) proportional counter; and (3) Geiger-Muller counter [10].

LIQUID SCINTILLATION COUNTING (LSC)

CONCEPT AND METHOD



The main concept of scintillation detection is due to the absorbance of energy (from decay energy) that will eventually lead to the excitation of electrons. When an electron absorbed energy, it is promoted to a higher energy level and is said to be in excited state. The excited electron, which is unstable, will emit energy in the form of photons.

In liquid scintillation, the scintillation occurs in the solution. The solution or the cocktail is composed of the solvent and the phosphor. The solvent absorbs the energy from radiation from radioisotope. The phosphors dissolved convert the energy absorbed by the solvent into light energy [11]. Refer to Figure 2.

Figure 2. Block diagram of scintillation counter
Source: http://www.ehs.psu.edu/radprot/LSC_Theory2.pdf

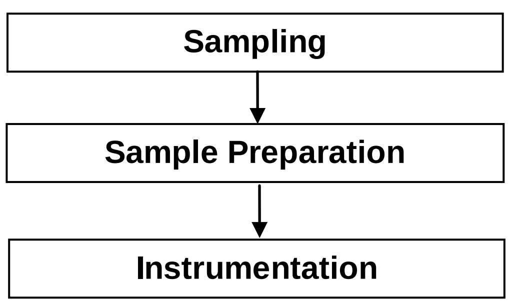
STUDIES INVOLVING RADIOLOGICAL QUALITY OF WATER

The availability of low background liquid scintillation counter provides an alternative for gross alpha and beta determinations and offers several advantages over the traditional procedure. The liquid scintillation (LSC) technique requires a minimal sample preparation time. A methodology based on LSC technique for the determination of gross alpha and gross beta activities in drinking waters was developed. Counting parameters have been optimized for the best possible separation of alpha and beta emitters and validation tests have also been performed in order to assure the accuracy of the method.

Lopes et.al. in their study, entitled “Monitoring of Gross Alpha and Gross Beta and Tritium Activities in Portuguese Drinking Waters” determined the gross beta and tritium activities in the forty Portuguese drinking waters analyzed using the ISO standard methods (Portuguese Guidelines). The study revealed that beta and tritium activities are below the guidance levels proposed in the Portuguese Drinking Water Quality Guidelines. However, the concern is for the gross alpha activity, which exceeded the recommended level. In general, it can be concluded that the ingestion of these drinking waters does not create a radiological hazard to the human consumption, however, more detailed analyses will be necessary mainly the determinations of the individual alpha emitters radionuclide concentrations [7].

A study made by Tavcar, et.al. (2005) used a sensitive and reliable method for the simultaneous determination of 241 Am, 237 Np, plutonium radioisotopes and 90 Sr in soil and sediment samples. Analysis involves leaching of the samples in conc.HNO3, followed by radiochemical separation and purification. The radiochemical procedure begins with separation of 241 Am/90 Sr, plutonium radioisotopes and 237 Np by anion exchange chromatography. 241 Am and 90 Sr from the combined effluent are separated using TRU resin and Sr resin. Counting sources for alpha spectrometric measurements were prepared by the microcoprecipitation technique. Radiochemical yields were determined using 243 Am, 239 Np and 242 Pu tracers. Strontium recovery was determined gravimetrically and Sr counting sources were analyzed by liquid scintillation counting. The method was successfully tested by analysis of six reference materials and on two sediment samples with high activities of the selected radionuclides. The results were compared with reference and literature values [12].

METHODOLOGY



SAMPLING

Five samples were collected in different sites namely: Sitio Bacoor, Metropolitan Waterworks and Sewarage System (MWSS) East Quezon City, Francisco Homes II, City of San Jose Del

Monte - Local Water Utilities and Adminitration (CSJDM - LWUA), and Hurom- Hurom cold spring in Nabas, Aklan. A liter of each sample were collected and stored in plastic bottles.

WATER SOURCE PROFILE

SITIO BACOOR

Groundwater in Metro Manila comes from the Guadalupe and Antipolo Plateau. The main aquifer can be found in the Guadalupe Plateau. The area of the Guadalupe plateau covers 472

square kilometers that extends beneath the bed of Laguna. The Antipolo Plateau has an area of 30 square kilometers [13].

The groundwater in Sitio Bacoor located in Tandang Sora, Quezon City is open to the public. The depth is about 91.44 m (300 feet). Refer to figure 3.

MWSS EAST QUEZON CITY

Most water supply distributed in various parts of Metro Manila comes from the Angat river. The water coming from the Angat reservoir is treated in the two treatment facilities: La Mesa and Balara treatment plant. The treatment of water involves six major steps: (1) screening; (2) mixing; (3) flocculation; (4) sedimentation; (5) Filtration; and (6) Chlorination. Water distributed in east Quezon City comes from the treated water of the Balara treatment plant. [14]

FRANCISCO HOMES II WATER MANAGEMENT

Francisco Homes II is located in Barangay Graceville, City of San Jose del Monte, Bulacan. It is one of the few subdivisions in the city which have its own water system. Its water system is operated by V and V Francisco Water Management. Water is extracted from deep well and is classified as chlorinated water.

CSJDM-LWUA

Bulk of water requirement of the city is being served by the San Jose del Monte Water District. Water originated from the Angat Dam and treated by the LWUA treatment facility. In subdivisions within San Jose del Monte West District, most of it had changed its water source from owned water supply to water district.

Figure 5. San Jose del Monte West *(Upper right: Water from treatment facility in Francisco Homes I, Lower right: FH II water tank)*
(Courtesy of Google Earth, May 20, 2010, 4:42 am)

1. *HUROM-HUROM COLD SPRING*

It originated from the ground water of Laserna, Nabas, Aklan and travels through a network of cracks and fissures of Hurom-Hurom caves.

Figure 6. Hurom-Hurom Cold Spring, Laserna, Nabas, Aklan
(Courtesy of Google Earth and http://ferdil.multiply.com/video/item/93/Hurom-Hurom_cold_spring, May 20, 2010, 5:04 am)

SAMPLE PREPARATION

From each 1 L sample collected, 100 mL of each sample was measured and transferred to a 250 mL beaker. The water samples were evaporated and concentrated up to 1 mL. Each samples were acidified by 1 mL 0.5 N hydrochloric (HCl) acid. The concentrated water samples were transferred to scintillation vials and 19 ml of scintillant (OptiPhase HiSafe 3) was added to each vial. OptoPhase HiSafe 3 is capable of handling a broad range of solutes, thus making it ideal for a variety of scintillation applications. The sample-scintillant mixture (or cocktail) was shaken to mix the substances completely. The samples were set aside for an hour to allow chemiluminiscence.

Figure 6. Vials, OptiPhase HiSafe 3 and 0.5 N HCl

Figure 7. Water Sample

INSTRUMENTATION

The water samples were analyzed using Wallac Guardian 1414 Liquid Scintillation Counter. The protocol in the said instrumentation is as follows: (1) Counting Time – twice for every thirty minutes; (2) Unit – Counts per minute; (3) Pulse Shape Analyze (PSA) – 45; and (4) Precision – 0.01.

The alpha and beta efficiency are based from the efficiency of Americium-241, an alpha emitter and chlorine-36, a beta emitter. An efficiency of 91.32% was obtained for the alpha and an efficiency of 92.16% for the beta.

FIGURE 8. LIQUID SCINTILLATION COUNTER

DATA AND RESULTS

Table: Gross Alpha and Gross Beta Activity of Water Samples

Water Samples	LLD of Beta (Bq/L)	Beta Activity (Bq/L)	LLD of Alpha (Bq/L)	Alpha Activity (Bq/L)
Sitio Bacoor	0.3	Less than LLD	0.05	Less than LLD
Horum-Horum	0.3	Less than LLD	0.05	Less than LLD
FH II	0.3	Less than LLD	0.05	Less than LLD
LWUA	0.3	Less than LLD	0.05	Less than LLD
MWSS	0.3	Less than LLD	0.05	Less than LLD

Based from the table, the low level of detection for beta is 0.3 Bq/L and for alpha is 0.05 Bq/L for all the water sample tested. Both the detected gross beta and gross alpha activities of all the water samples are less than the low level detection. Hence, the detected alpha and beta activity does not exceed the standard set by the Philippine National Standards for Drinking Water 2007 (PNSDW 2007) and the Department of Health (DOH).

The water samples passed the radiological quality set by the said standard and do not exhibit possible radiological hazard.

CONCLUSIONS AND RECOMMENDATIONS

All the water samples are radiologically safe for drinking based on the limits prescribed by the Philippine National Standards for Drinking Water 2007 and the Department of Health.

The following recommendations are suggested to be conducted for the same ground water and for the Francisco Homes 2 water tested in this study to assure its safety:

- microbiological test
- physico-chemical tests.

APPENDIX

Computation for Activity of Beta

$$\mathrm{Activity_{beta}} = \frac{\mathrm{Netcpm_{beta}} \ \mathrm{x}\ 1000}{60\ \mathrm{x}\ \mathrm{Eff_{beta}}\ \mathrm{x\ Sample\ Vol.}}$$

$$\mathrm{Activity_{beta}Error} = \mathrm{Activity_{beta}}\ \mathrm{x} \sqrt{\frac{\mathrm{Net\ CPM\ Error\ x\ Net\ CPM\ Error}}{\mathrm{Net\ CPM_{beta}\ x\ Net\ CPM_{beta}}} + \frac{\mathrm{Eff_{Cl36}\ Error\ x\ Eff_{Cl36}\ Error}}{\mathrm{Eff_{beta}\ x\ Eff_{beta}}} + \frac{\mathrm{Volume_{error}\ x\ Volume_{error}}}{\mathrm{Sample_{volume}\ x\ Sample_{volume}}}}$$

$$\mathrm{LLD_{beta}} = 4.66\ \mathrm{x} \sqrt{\frac{\dfrac{\mathrm{Background_{beta}}}{\mathrm{BackgroundCountingTime + SampleCountingTime\ x\ 1000}}}{60\ \mathrm{x\ Eff_{beta}\ x\ Sample_{volume}}}}$$

Computation for Activity of Alpha

$$\mathrm{Activity_{alpha}} = \frac{\mathrm{Netcpm_{alpha}}\ \mathrm{x}\ 1000}{60\ \mathrm{x\ Eff_{alpha}\ x\ Sample\ Vol.}}$$

$$\text{Activity}_{\text{alpha}}\ \text{Error} = \text{Activity}_{\text{alpha}} \times \sqrt{\frac{\text{Net CPM Error} \times \text{Net CPM Error}}{\text{Net CPM}_{\text{alpha}} \times \text{Net CPM}_{\text{betaalpha}}} + \frac{\text{Eff}_{\text{Am241}}\ \text{Error} \times \text{Eff}_{\text{Am241}}\ \text{Error}}{\text{Eff}_{\text{alpha}} \times \text{Eff}_{\text{alpha}}} + \frac{\text{Volume}_{\text{error}} \times \text{Volume}_{\text{error}}}{\text{Volume}_{\text{error}} \times \text{Volume}_{\text{error}}}}$$

$$\text{LLD}_{\text{alpha}} = 4.66 \times \sqrt{\frac{\dfrac{\text{Background}_{\text{alpha}}}{\text{BackgroundCountingTime} + \text{SampleCountingTime} \times 1000}}{60 \times \text{Eff}_{\text{alpha}} \times \text{Sample}_{\text{volume}}}}$$

REFERENCES

1. http://mccloudwatershedcouncil.org/articles/6-2-08%20BBC.pdf

2. http://dirp3.pids.gov.phrisdpspidsdps0938.pdf

3. http://www.nj.govdeprppdownloadradwater.pdf

4. Manahan, Stanley (2003) Toxicological Chemistry and Biochemistry. Lewis Publishers

5. http://www.stoller-eser.com/FactSheet/htm

6.http://webcache.googleusercontent.com/search?q=cache:DIFwvZMb5cMJ:www.lwua.gov.ph/tech_mattrs_08/Philippine%2520National%2520Standards%2520for%2520Drinking%2520Water%25202007.doc+Philippine+National+Standard+for+Safe+Drinking+Water&cd=2&hl=tl&ct=clnk&gl=ph

7. http://www.colloquium.fr06IRPACDROMdocsP-172.pdf

8. http://www.idswater.comCommonPaperPaper_217wisserab.pdf

9. http://www.bnl.govewmsser99serappc.pdf

10.Seaborg, Glenn, et.al. (2006). Modern Nuclear Chemistry. John Wiley and Sons, Inc.

11. http://www2.fpm.wisc.edusafetyRadiationdocslsc_guide.pdf

12.http://acta.chem-soc.si5252-1-60.pdf

13.http://www3.pids.gov.phrispdfpidsdps0105.PDF

14.http://www.mwss.gov.ph/water_supply.php