POTENTIAL ENVIRONMENTAL EFFECT OF ELEVATED LEVELS OF RADIUM-226 IN PRODUCED WATER

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ABSTRACT

Produced water represents the aqueous component separated from oil. Produced water from oil showed abnormal activities of $^{226}$Ra, appreciably exceeding the admissible limit of 5 picoCuries per liter (pCi/L) for potable water, which is roughly 0.2 Becquerels/L (0.2 Bq/L). We used this as an indicator to evaluate the potential threat of contamination to underground aquatic supplies. Several samples were collected and monitored for gamma rays for a period of one year. We found that about 31% of the samples fell below 20 Bq/L; roughly 51% were in the range 20-60 Bq/L and about 18% occurred between 60-100 Bq/L. All told about 96% exceeded the stipulated limit. The potential impact of these raised levels on aquatic resources and the general environment is discussed.

Key Words: Produced water, Radioactivity, $^{226}$Ra, Decay series, Gamma ray spectroscopy.

INTRODUCTION

Produced water separated from oil is usually dumped and could infiltrate the water table. If such water is contaminated with radioactivity it could pose a serious hazard especially in arid regions where ground water and overhead streams are used as potable sources. The maximum contaminant level for radium in drinking water as specified by the U.S. Environmental Protection Agency is 5 picoCuries per litre (pCi/L), which corresponds roughly to 0.2 Becquerels per litre (Bq/L). Elevated levels of radium in produced water could, therefore, be detrimental to humans and other living organisms, and the long-term effects on the environment could be serious if remedial measures are not taken.

Objectives

Our study found elevated levels of $^{226}$Ra in produced water and our objectives were two fold: (i) to evaluate the potential impact posed to the environment by such radioactive contamination; and (ii) to suggest possible procedures for remediation.

MATERIAL AND METHODS
Instrumentation

Seventy produced-water samples were collected from different sites. The collection period extended for a period of one year from. One-litre samples were prepared for gamma ray counting in standard Marinelli beakers. The detection system (Fig. 1) consisted of a high-purity Ge detector (diameter: 59.0 mm, length: 74.2 mm) and standard electronics (EG and G Ortec, Oak Ridge, US). The detector resolution (Fig. 2) was: 1.71 keV for the $^{60}$Co 1.33 MeV gamma line³. As reflected in Fig. 2 the resolution is fairly linear up to 2000 keV. Ambient background was minimized by lead shielding. Sealed radioactive reference sources (Amersham, UK) were used to calibrate the system and validate its performance. Samples were counted overnight (12 hours) to obtain adequate statistics. The ambient background was monitored for an equivalent time. Prior to counting the samples the system was checked for linearity.

Fig. 1 : The detection system and associated electronics.
Accuracy and precision

$^{226}$Ra decays to $^{222}$Rn by $\alpha$-emission (Fig. 3). The most prolific line for our particular purposes was the 186 keV assignment that has a relative intensity of about 4%. The ‘room background count’ showed minimal levels of this radionuclide. Instrument reproducibility was established by counting a sample five times. The RSD was less than 1% indicating that the reproducibility was acceptable (Table 1). The accuracy was determined by using standard reference sources and comparing these activities with their original certified reference activities. In all cases the magnitude of the relative error did not exceed 2%, indicating that the accuracy attained was satisfactory.

RESULTS AND DISCUSSION

Biological effects of radium

$^{226}$Ra originates from $^{238}$U and decays to $^{222}$Rn$^4$. It is an alpha and gamma emitter, with a half-life of roughly 1600 years. Exposure to elevated alpha and gamma radiation creates serious biological problems, especially genetic damage, which usually arises from exposure to low doses over an extended period. Bioaccumulation of $^{226}$Ra in the food chain is a likely potential hazard and protection of the ecosystem is of prime concern. The human body treats radium in a similar way that it metabolizes calcium. Oral ingestion of minute quantities of radium results in its accumulation in the bones producing serious damage. Ultimately, the damage from continuous internal exposure to radium can potentially cause bone and sinus cancer. The study is of interest because it can be linked to sustainable living. This particular area is a developing country in an arid region, and therefore, water is vital for all forms of its development. Any form of pollution to aquatic resources will pose a threat and should be curbed.
Table 1: Measurements of reproducibility in two produced water samples, using the 186 keV gamma ray counts.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Sample #1 counts</th>
<th>Sample #2 counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>684</td>
<td>732</td>
</tr>
<tr>
<td>2</td>
<td>691</td>
<td>728</td>
</tr>
<tr>
<td>3</td>
<td>687</td>
<td>726</td>
</tr>
<tr>
<td>4</td>
<td>693</td>
<td>721</td>
</tr>
<tr>
<td>5</td>
<td>680</td>
<td>735</td>
</tr>
</tbody>
</table>

| Mean + RSD  | 687 ± 0.76%      | 728 ± 0.74%      |

Distribution of radium in produced water

The distribution of $^{226}$Ra for the one-year period showed wide scatter (Fig. 3). As can be seen from our results the levels in produced water vastly exceeded the drinking water limit (0.2 Bq/L) in several cases. Such activities could affect the biosphere when the produced water is returned to the environment. Produced water represents the aqueous component separated from oil. This aqueous phase is in contact not only with the oil but also with sludge that is associated with the oil. As a result, a chain of components could be polluted leading to far-reaching implications. Thus regular monitoring of produced water is vital to detect change and early indications of change in natural systems resulting from such pollution. The possibility exists of “fingerprinting” the different sites on the basis of these measurements. A closer inspection of Fig. 3 tells us that although there is considerable scatter of the data more than 95% of the results exceeded the permissible requirement. A breakdown of the results shows that about 31% of the samples fell below 20 Bq/L; roughly 51% were in the range 20-60 Bq/L and about 18% occurred between 60-100 Bq/L. It must be remembered that oil is pumped from thousands of feet underground. Therefore, the source of the radium originates from possible desorption of rock material and radioactive decay from minerals. Suitable protection measures should be put in place to shield the environment from such radiation. The thrust of our investigation, therefore, involved an evaluation of the potential impact posed to our environment and possible suggestions for remediation.

Potential environmental impact and remediation

Of significance is that our study could promote sustainable development in the region because radioactivity from ground waste water (at levels >0.2 Bq/L) could lead to a wide contamination of water supplies. As stated above, groundwater is used largely for human consumption and to supplement irrigation water and this water (like

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**Fig. 3**: Nuclear energy level diagram showing decay scheme of $^{226}$Ra.
rainwater), percolates the water table, and could pollute overhead streams and underground aquatic resources\(^1\). Hence, the general impact on the environment is a cause for concern, and research programmes have recently been launched to study this effect\(^6\). Essentially, the overall potential impact on the environment involves the effect on public health, livestock and crops; and the effect on wildlife such as rare birds and animals\(^7\)\(^,\)\(^8\).

A possible remediation procedure would be to deplete the levels of activity in the produced water by removing the radium by chemical means. An alternative suggestion would be to immobilize the water by storing in vitreous slabs or in underground bunkers. It would be useful to monitor water levels at different depths in oil wells to obtain some insight of the function of activity with depth. In this way we can protect the relevant ecosystem and promote sustainable living.

**CONCLUSION**

It would be useful to extend this work to consider radium levels in samples from oilfields in other countries; and also to examine the levels of other radioactive species. The foregoing remedial measures could be made more effective by chemically extracting the radium from the waste water and recycling it for use in irrigation or at construction sites. There are several ways of removing radium from waste water, for example, co-precipitation, adsorption, ion-exchange and reverse osmosis. Alternatively, mixing and diluting the waste water into sand and aggregate and converting this into concrete blocks for storage would also be a useful way of disposal. In this case, it would be in the interest of sustainable development to keep the radium levels as low as possible to protect the environment.

**REFERENCES**


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