ELECTRET ION CHAMBERS FOR MEASUREMENT OF DISSOLVED RADON IN WATER: REVIEW OF METHODOLOGY AND LITERATURE

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ABSTRACT

The regulatory limit for dissolved radon in municipal water supplies is in the process of being introduced by US EPA. This paper is based on the documentation submitted to US EPA for considering the electret ion chamber method of measuring radon in water as an alternative method. The documentation includes three peer reviewed papers: Health Physics Journal 64:397-405, 1993; Journal Research of NIST 100:629-639, 1995; and EPA Paper presented at the 1993 AARST International Radon Conference. These papers are analyzed to draw conclusions as to the method accuracy, method precision, applicable range of radon concentration. Also discussed are advantages, disadvantages and viability as an alternative to LSS, including a cost analysis. The addition of more than 600 E-PERM labs to perform radon in water compliance measurements is expected to provide competitive prices to the advantage of municipal water supply organizations and to US EPA.

INTRODUCTION

Measurement of dissolved radon in water is useful in many applications. Radon in well water contributes to the radon in air in homes using well water. According to US EPA, 10,000 pCi L^{-1} of radon in water contributes about 1 pCi L^{-1} of radon in homes. High levels are not uncommon in some regions of the country. Home inspectors routinely measure radon in water to estimate its contribution, if any to the home with high radon concentration. If a high radon concentration is present mitigation may involve removing radon from the water.

In several mines, typically uranium, gold, and copper mines, the water runoff into the mining areas can have significant amount of dissolved radon in water. This may cause radon in the working areas in mines. Analyzing such water samples may help regulate the inhalation hazards in such mines.

US EPA is in the process of regulating radon in water for the water supplied to communities. Such regulation may become law soon. Methods of measuring radon in water are needed for making such compliance measurements as required by US EPA or States. The current paper is based on the documentation submitted to US EPA in 1997 for their review to recognize electret ion chamber method for such compliance measurements.

The purpose of this paper is to review the published literature on the measurement of radon in water using these detectors. These papers have compared the results with the results determined using the US EPA baseline technology, the liquid scintillation method (LSS) and draw some conclusions. This paper also describes the cost estimates and other useful information for regulators to consider.

ELECTRET ION CHAMBER METHOD OF MEASURING RADON IN WATER

This method is based on measuring airborne radon exhaled from water, similar to the Lucas Cell Method described in US EPA literature. Electret ion chambers (commercially known as E-PERMs) are used for measuring radon in air. Electret ion chambers are of relatively recent origin, becoming commercially available in 1990. These are considered as one of the most used and most accurate method for measuring radon in air. The fact that US EPA used these detectors for their National Ambient Radon Survey in all 50 States all round the year, adds to the credibility of the technology. The national ambient radon level of 0.4 pCi/L included in EPA Citizen's Guide to Radon was measured using electret ion chambers.

Measurement of radon in water using E-PERMs has been popular from the past five years after a detailed paper was published in Health Physics Journal in 1993. A detailed manual published by the manufacturer of the E-PERM® System gives a detailed protocol and step by step procedure for measuring radon in water. The fact that EICs are not affected by humidity renders this method as the best among those based on the exhalation method.

A small water sample is of known volume is placed in the bottom of a glass jar (Figure 1). An E-PERM is suspended in the air phase above the water. The lid of the jar is closed and sealed to make it radon leak proof. Radon exhales from the water sample and reaches an equilibrium between the air phase and water phase. At the end of desired exposure period, the jar is opened and E-PERM removed. The average radon concentration in the air phase is calculated by standard procedure applicable for radon in air measurement. A calculation using this air concentration in conjunction with the other parameters gives the radon concentration in water. The basis for the calculation is fully described in a publication in Health Physics Journal as well as in the E-PERM® System Manual.

CURRENT STATUS

Electret ion chambers are routinely used for measuring indoor radon by more than 600 users in USA, as well as in Sweden, Germany, Italy, Switzerland and in South Africa. This list includes several State and Federal agencies, including the US EPA and US Postal Service. We estimate that 10 % of E-PERM users also use instrumentation for measuring radon in water, mainly to assess its impact on radon in homes.

Review Of Document #1

"Measurement of Dissolved Radon in Water", E-PERM® System Manual Part II 8. Rev. 1 12/18/94, Pages 1-7 and two additional pages. Published by Rad Elec Inc., Revision 1, December 18, 1994.

This is a manual that gives step by step procedure for measuring radon in water. Sampling method is the same recommended by EPA.

It may be noted that radon in water is estimated from first principles. It is further recommended that the final results be multiplied by 1.15 to bring the results in par with the results obtained by LSS method. This statement is chosen rather than using LSS for calibrating the EIC System, because it is not certain whether the LSS Method is accurate with traceability to NIST.

Review Of Document #2

Peer reviewed paper: P. Kotrappa and W. A. Jester "Electret Ion Chamber Radon Monitors Measure Dissolved ^{222}Rn in Water" Health Physics 64: 397-405 (1993)

This study compared the performance of EIC method and LSS method on large number of water samples with varying radon in water concentration. The results had precision of 4 to 10%, but average bias was -15%. Considering the radon calibration revisions done in 1994 of +10%, the corrected bias is -5%.

Review Of Document #3

Peer reviewed paper: R. Colle, P. Kotrappa, and J.M.R. Hutchinson "Calibration of Electret-Based Integral Radon Monitors Using NIST Polyethylene-Encapsulated $^{226}Ra/^{222}Rn$ Emanation (PERE) Standards" Journal of Research of National Institute of Standards and Technology 100:629-639 (1995)

This is a an independent study that is traceable to NIST.

The results have precision of 4 to 10%, and bias of -9.0%. With the radon calibration revisions done in 1994 of +10%, the corrected bias is +1%.

Review Of Document #4

EPA reviewed paper: Gregory Budd, Craig Bentley: "Operational Evaluation of the EIC Method for Determining Radon In Water Concentrations" the 1993 International Radon Symposium sponsored by AARST.

The results have precision of 6 ±4 %, and bias of -27 %. With the radon calibration revisions done in 1994 of +10 %, the bias is -17%.

Please refer to Figure 2 - Bias Summary Table.

Discussion Of Summary Table

It is difficult to explain the differences in the three evaluations. There has been no intercomparison of LSS tests among different labs as such. Absolute accuracy or NIST traceability is needed.

The precision and bias appear to be reasonable for field use. In light of the documentation submitted, if US EPA recommends that we apply some bias corrections, we would be happy to suggest that to our users.

Review Of Document #5

Peer reviewed paper: S. K. Dua, P. K. Hopke and P. Kotrappa "Electret Method for Continuous Measurement of Radon in Water" Health Physics 68: 110-114(1995)

This work was done in famous Dr. Hopke's laboratory as an attempt to measure integrated average of radon in water over a period of time. This may be a solution to the problem of possible variation of radon in water over the integrating period. This instrument is ready to be manufactured and sold at a price of $4,000 to $5,000 if the need arises. The cost can be considerably less for those who use electrets and electret reader from their Radon Introductory Kit.

This methodology has distinct advantage over the LSS method, as the LSS method cannot be adopted for this type of measurement.

Review Of Cost And Comparison to LSS Method

A complete E-PERM® System Radon Introductory Kit that can do 10 simultaneous radon measurement or 10 simultaneous radon in water measurement costs under $3,000. The Kit includes detailed manual and analysis tools such as a pocket computer. The sensors coming with Kit have a potential of making at total of 100 to 150 measurements. Later 100 to 150 measurements can be done at a cost of only $125, bringing the equipment cost per measurement to under $1.

Most of 600 or so of E-PERM users already have the Kit for indoor radon measurement. Add on cost to start a radon in water measurement service is under $200.

Most of the units of the kit are reusable except for the replaceable sensors. Spent sensors are accepted back to encourage recycling of some components. The method does not use or produce any toxic liquids requiring expensive disposal procedures, such as liquid scintillation cocktails.

The LSS analysis instrument is expensive, needs skilled-trained persons to maintain and operate. Produces involve liquid radioactive/toxic waste. It is affordable only by big laboratories resulting in shortage of analytical labs or a long wait time for analysis and reporting.

CONCLUSION

If the electret ion chamber method is approved for performing compliance measurements for radon in water, each one of the E-PERM user is a potential radon in water laboratory capable of giving measurements at a price very competitive to that of LSS method. There will be no shortage of the analytical labs.

Many of the municipal water supply agency can have their own system that lets them measure not only radon in water but also do indoor radon measurements in the buildings handling water containing radon.

As manufacturer, Rad Elec is starting training and manufacturer certification program for the users of E-PERM® System very soon to ensure that the users are trained and certified by the manufacturer. This will help ensure quality measurements.

It is recommended that a US EPA proficiency program be established for labs doing radon in water, which may be integrated with those indoor radon program.

Figure 2 - Bias Summary Table

Reference	Precision	Corrected Bias
# 2 HPJ	<10 %	-5 %
# 3 NIST	<10%	+1 %
# 4 EPA	<10%	-17 %

Average bias correction -7%

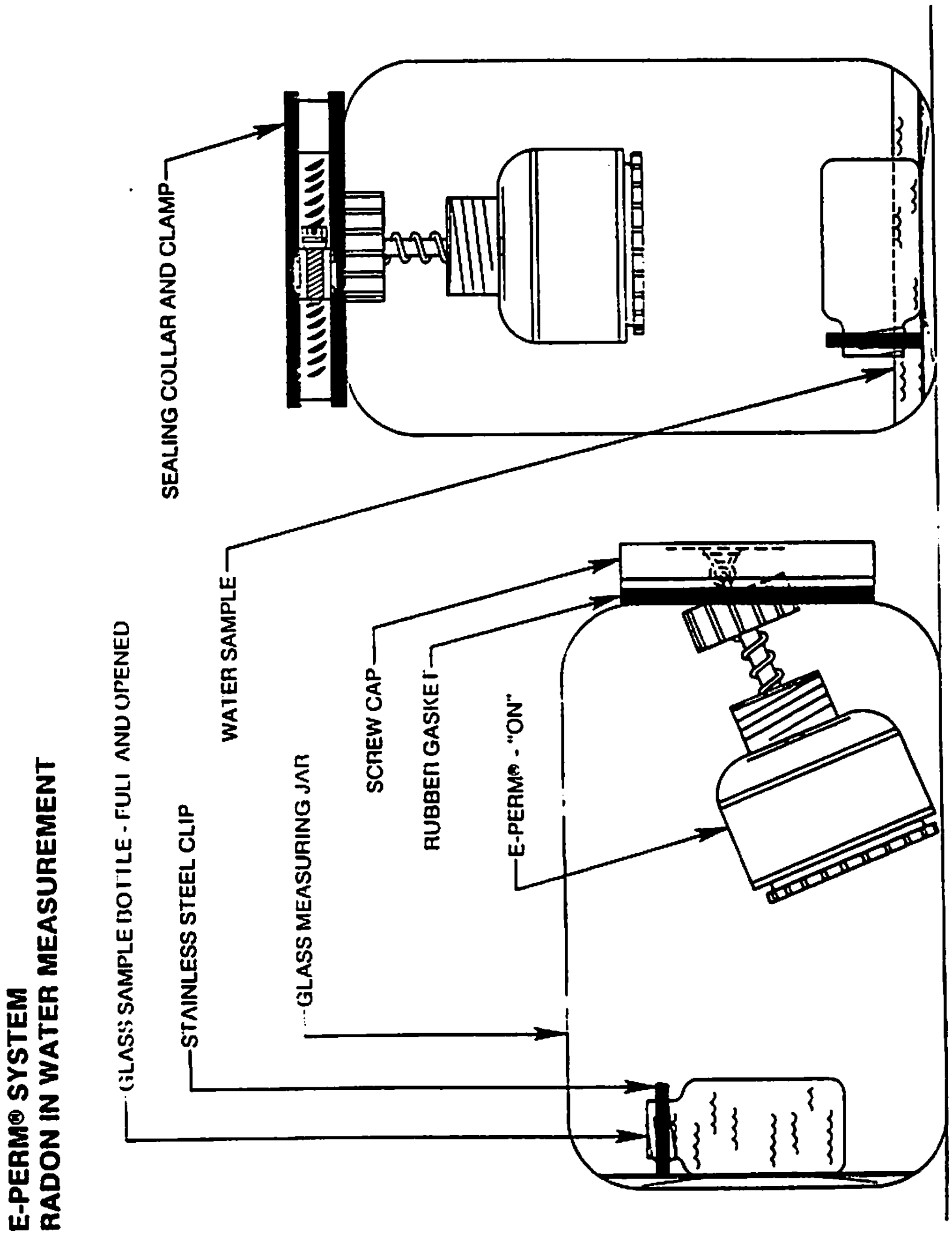
E-PERM® SYSTEM
RADON IN WATER MEASUREMENT
GLASS SAMPLE BOTTLE - FULL AND OPENED
STAINLESS STEEL CLIP
GLASS MEASURING JAR
WATER SAMPLE
SCREW CAP
RUBBER GASKET
E-PERM® - "ON"
SEALING COLLAR AND CLAMP
Position - 1
Position - 2

Figure 1