A COMPUTER AIDED ENGINEERING (CAE) TOOL FOR THE ASSIMILATION OF DATA MANAGEMENT, ANALYSIS AND VISUALIZATION OF INFORMATION ASSOCIATED WITH NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM) AS AN APPLIED GEOPHYSICAL/HEALTH PHYSICS SCIENCE

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Abstract

In lieu of pending EPA and NRC regulations covering the monitoring of ground water supplies of drinking water as it relates to the public health, both private and municipal water districts, and utilities will be required to monitor for naturally occurring radioactive materials, NORM, and their constituents, ie... Radon, Radium, and Thorium. This monitoring will require the utility districts to utilize and employ "BAT", best available technology.

A more advanced set of CAE, computer aided engineering, tools are beginning to appear that combine data, graphics, and analysis capabilities within a spatial model. CAE tools are considered in this paper to fit into the BAT category. CAE can assist independent water districts as well as broad based watershed and aquifers utilized by municipal water districts in data management, engineering analysis and complex site visualization. Water companies can project regions that could create an environmental impact on public health. Data involved, ie... mechanics of ore zone hydrology in aquifers, in site assessment and analysis can now be integrated into a single model called a virtual site. The virtual site concept of data management uses an electronic version of a geotechnical engineer's conceptual site model. Please refer to Appendix A for a more detailed description.

The petroleum industry is also being impacted by a multitude of environmental issues, both past and pending legislation. Many petroleum companies are initiating a proactive environmental policy. CAE functionality can assist them by providing a vehicle for complex site data management, engineering analysis and site visualization. Concurrently, NORM is under proposed regulations (Revision 3) under the Texas Department of Health Radiation Control. Using the virtual site, engineers can directly query, edit, or manipulate data while the consequences of changes made cascade through the model. To explore the many ramifications of NORM and other potential environmental hazards, 3D graphical presentations of site specific scientific visualizations can be calculated and displayed on the fly.

Introduction

The complexity of site investigation and remediation has mandated the need for more sophisticated tools for data management, engineering analysis and site characterization and visualization. CAE tools in the environmental industry are evolving along a path similar to that followed in other branches of engineering (figure 1). Computer aided drafting and mapping systems were first developed. Soon, engineering users recognized that most of the data they dealt with were defined spatially and referenced to drawings and plans. Eventually the need for databases developed. These databases led to the second generation development of geographic information systems, GIS, which associate attributes to geographically mapped features.

The third generation of technology is model-based engineering systems. A model-based system organizes spatial information in a model of the physical world. Information structured within such a conceptual model can be manipulated in intuitive ways by the engineer. This generation of model-based tools is only now appearing for environmental users. (Consolve, 1989)

NORM Complexities and Applications

Radon and it's daughters can be considered as one of the most hazardous radionuclides to which the general public are commonly exposed. Radon as a noble gas may be present in air as a result of aeration from ground water supplies and can be considered a primary health risk associated with an estimated 5,000 to 20,000 lung cancer deaths a year in the United States. (Environmental Protection Agency, 1986). Radon gas associated with aquifers can contribute significantly to this hazard.

The concentration of radon, monitoring, and radiological surveying of ground water is of great interest and the presentation of these results is important. With the aid of the virtual site, radon tracking in aquifers and water wells can be monitored and investigated to reflect propagation, breakthrough regions, screen depth indications and maximum permissible concentrations.

As sampling continues, new data are being continuously added to the virtual site model. Results can be readily displayed, reflecting changing conditions as they occur. In past research studies, several measurements were made, and because of space limitations, the researchers would usually report a mean, standard deviation and range of values. If the data was normally distributed, this was sufficient; otherwise, it could have been considered misleading.

When the data was lognormally distributed, reporting only the mean tends to overestimate exposure of the public to radon. These values were displayed numerically, and were not easily visualized as movement of the radon propagated through the aquifer. CAE use, via the virtual site, provides a fast, accurate graphical representation of said data resulting in easier interpretation.

BACKGROUND

The EPA was required under the Safe Drinking Water Act (SDWA) (section 1412 amended in 1986) to regulate Maximum Contamination Level Goals (MCLGs) and promulgate National Primary Drinking Water Regulations (NPDWRs) for contamination in drinking water which may cause adverse effect on the health of persons and which are known or anticipated to occur in public water systems. Migration of Radon 222 in aquifers can occur through two different mechanisms. One diffusion, i.e., in this case radon gas moves in a liquid as a result of spontaneous random movement due to thermal agitation and from areas of higher concentration to areas of lower concentration. The second methodology is the fluid itself moves through the porous aquifer and carries the radon isotope along with it. Either or both mechanisms could be significant in the detection and measurement of radon.

The two mechanisms do not truly become separable except under extreme aquifer conditions which tend to enhance one over the other. An example favoring transport might be an aquifer which had extensive channeling due to solution fingering, as in the case of an aquifer with a soluble limestone core base. Diffusion might be favored in another aquifer which had such fine pore volume that good hydraulic flow was almost impossible.

Several factors influence diffusion, transport, and migration of random isotopes to points of detection and measurement in subterranean aquifers:

a. concentration of the parent Radium at the mineral-medium interface

b. the decay constant of the isotope

c. the dispersal of the isotope in the pore filling fluid

d. the porosity of the core

e. the velocity of the fluid

f. the composition the transporting fluid

g. the temperature of the transporting fluid

Observations reflect that Radon concentration in wells located in the same widespread region tend to increase with depth, to approximately 164 feet where saturation concentrations are encountered. If well depth is in excess of 320 feet, the concentration of radon commences to decrease beneath the saturation concentration. The saturation concentration event in aquifers can be related to a radon rich overburden. Typically radon producing overburden will exist no further 110 feet from the wellbore.

Further studies reflected the follow data in a thesis by Alfred E. Worden, B.S. - Presented to the University of Texas Health Science at Houston School of Public Health.

> "The permeability and porosity of the overburden around a wellbore decreases rapidly with depth. This is caused by compression due to the weight of the overburden. For this reason most of the radon will come from the overburden near the surface of the well. This overburden will have had the better opportunity for weathering and the development of micro-fractures which tend to channel the locally produced radon into the wellbore."
>
> "Even in deep wells most of the pumped water comes from the overburden near the surface because of a phenomenon called the depression cone effect. The depression cone effect is caused by the downward flow of fluid to a pumped well in the shape of an inverted cone. This flow comes from concentric overburden strata (with respect to the well bore) to the intake zone of the wellbore (liner perforations). This effect, combined with the increased residence time for water in a deep well bore, probably explains the decrease in radon concentration beyond the saturation zone. The above can be said with numbers when the mean half-life of Radon 222 (3.82 days) is compared to the mean residence time for water (5.0 days) in a wellbore approximately 160 feet deep."
>
> "One could make the conclusion from the above discussion that the mean migration distance for Radon 222 would be short to moderate for most water wells that might be tested from the standpoint of environmental health."

CASE STUDY

A study was published in June 1989 edition of WWJ by Kevin L. Dixon and Ramon G. Lee as:

> "In 1986 and 1987, a radon survey of well supplies was conducted within the American Water Works Co. system. The survey involved 377 wells in 15 states. The American Water Works system is comprised of more than 100 separate water supply systems serving five million consumers in 20 states. The operating companies that participated in the survey use varying percentages of ground water to meet their total system demand. Some operating companies use ground water to meet as little as 1 percent of their distribution demand while other companies are entirely dependent upon ground water. System

wide, ground water is drawn from approximately 500 wells and constitutes about 20 percent of the total amount of water provided to customers of the American Water Works Co. This equates to more than 50 billion gallons of ground water being pumped each year. Clearly, the forthcoming radionuclide regulations could have a significant impact on the American Water Works system and the water utility industry as a whole."

"The survey was designed to incorporate a two-phase approach. Phase one, the occurrence phase, involved the collection of replicate samples of groundwater from each well included in the survey. Sample kits supplied by the University of Maine were mailed to designated personnel experienced in the technique of collecting samples for Volatile Organic Compound (VOC) analysis. It was felt that a familiarity with a somewhat elaborate sample collection technique (such as for VOC analysis) would lead to properly collected radon samples."

"Sample collection personnel were instructed to ensure that the water samples collected were representative of fresh formation water (not stagnant casing water); the sample information sheet included in the sample kit was filled out immediately after sample collection; and, the samples were mailed to the University of Maine no later than one day after collection. This was done in order to minimize decay prior to analysis. It was also found to be particularly important for supplies with low levels of radon."

"Phase two for the survey, the treatment assessment phase, was designed to yield data to assess the effect of granular-activated carbon, packed tower aeration, and tray aeration on radon levels."

"The statistical analysis further revealed that the counting error associated with low levels of radon could be narrowed by minimizing the time between sample collection and analysis and increasing counting time to its practical limit."

Conclusions

The mere quantity of data associated with NORM and its constituents makes data management, engineering analysis and visualization a monumental task. Outdated methods of reporting; both manual and numerical representation of data are clumsy, hard to interpret and time consuming. The virtual site concept facilitates the engineer by providing a single, integrated, model-based tool that is intuitive to use, flexible, and enables them to add data quickly to see changing conditions almost immediately.

Application of the virtual site model in NORM monitoring using actual data from water wells is forthcoming. Future studies will demonstrate how automated, model-based software with sophisticated graphical and engineering capabilities can streamline an engineers work load and provide a fast, accurate means of analysis, interpretation, and visualization.

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APPENDIX A

THE VIRTUAL SITE

A virtual site, as defined by McGrath and Brown, is a conceptual model where all data are stored within a structured model of space. This computerized model can be visualized in a number of different ways; profile, plan and fence diagrams. It can be linked to analysis applications and other utility programs. Since data is stored in a spatial model, rather than static pictures, alterations to the model are promulgated to all views and to all linked analysis.

Numerous types and variety of data can be incorporated into the virtual site. The virtual site model integrates geology, stratigraphy, hydrology, topology, chemistry and contaminant data to CAD drawings, providing a means by which once isolated and dispersed data can be bought together in a meaningful analytical context. As more data becomes available, the site is immediately updated and re-evaluated. The virtual site approach to environmental data management provides a flexible framework where data management, analysis, and visualization become dynamic and interactive processes.

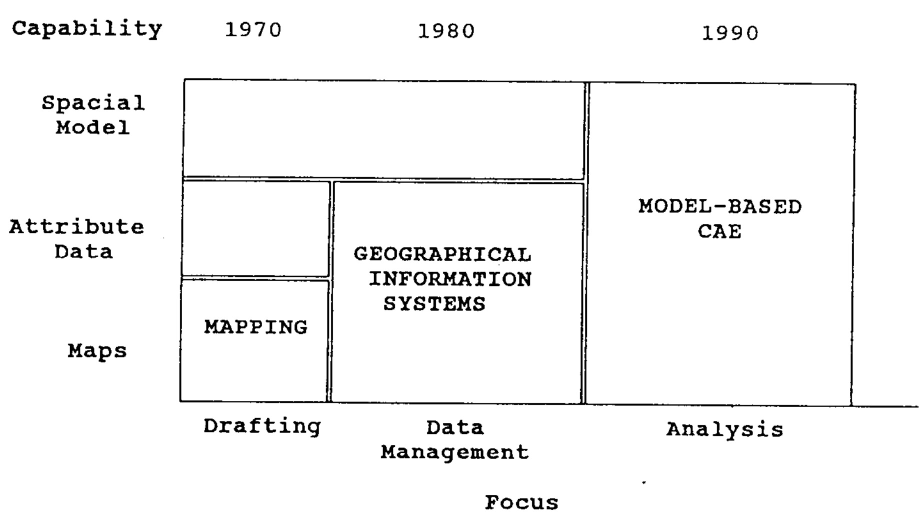

Figure 1 - Evolution of CAE tools for geo/environmental applications