SUMMARY

SERC Workshop on NORM and TENORM
Ohio State University, May 12, 2014

In response to citizens' concerns and a number of recent articles in leading newspapers, Ohio State University's Subsurface Energy Resource Center (SERC) organized a workshop to address the possibility that the extraction of gas and oil from deep shale formations might increase the public's exposure to radiation. Counting the speakers, 101 individuals participated; there were professors and students from various colleges and universities as well as representatives of public agencies, the private sector, and non-governmental organizations.

In his opening remarks, SERC Director **Jeffrey Daniels** highlighted several months of preparatory work by a committee comprising Ohio State faculty along with colleagues from Battelle, the Environmental Defense Fund, Marietta College, and West Virginia University. In view of the committee's efforts and the qualifications and advanced expertise of the speakers, Daniels expressed confidence that the workshop's overall objective – that attendees would be better informed about the current state of knowledge about naturally occurring radioactive materials (NORM) and technologically enhanced NORM (TENORM) and about needs for additional investigation – would be accomplished.

After this welcome, **John Frazier**, a certified health physicist (CHP) and independent consultant, laid the groundwork for the day's discussions by explaining the basic concepts of NORM and TENORM. He began by highlighting the distinction between radiation (i.e., energy in transit, either as particles or electromagnetic waves) and radioactivity (i.e., the characteristic of some materials to emit radiation). He also drew the audience's attention to key features of radionuclides, such as their respective half-lives and modes of decay. Frazier focused on a pair of elements, radium-226 (Ra-226) and radium-228 (Ra-228), which are naturally present throughout the earth (almost always in trace amounts by mass) as part of the uranium and thorium decay series. He noted that Ra-226 and Ra-228 are two of the principal radionuclides of interest in NORM and TENORM. He also described potential exposure pathways, both the external (from sources outside the body) and internal (from radioactive materials that are inhaled or ingested) and emphasized the importance of proximity to sources and realistic exposure durations when assessing potential radiation doses. Frazier then presented a summary of natural background radiation sources and the associated annual doses everyone receives, due in part to the presence of Ra-226, Ra-228 and their radioactive progeny. He also described other radiation doses everyone receives annually, especially from diagnostic medical procedures. After pointing out that TENORM is generated from a wide variety of human activities, such as water purification and the production of phosphate and potash fertilizer, Frazier closed with observations that potential radiation doses from TENORM in oil and gas production are very low and are within the range of natural background radiation doses. Throughout his presentation, he referenced published sources of more in-depth information about each of the topics he covered.

Another CHP and consultant, **Bill Thomas**, was the next speaker. Complementing Frazier's remarks, Thomas's presentation dealt with natural background radiation, the assessment of exposure and its pathways, and TENORM. Half the radiation that people are exposed to is related to medical treatments (X-rays, etc.), and radon and thoron are the source of another 37 percent; thus, all other sources account for 13 percent of total exposure. As a rule, concentrations of radioactive material in the byproducts of oil and gas production are quite modest. For example, radium concentrations in 86

percent of all solid wastes classified as NORM-contaminated are below 100 picocuries/gram (pCi/g); of the remaining 14 percent of solid wastes, less than 1 percent of those wastes have concentrations greater than 1,000 pCi/g. Likewise, analysis of oil and gas liquids extracted from the Marcellus formation average 1,000 pCi/liter (pCi/l) and rarely exceed ten times that concentration. Thomas provided a comprehensive view of exposure pathways along with the TENORM regulations that currently exist in Ohio. These regulations, which are more stringent than regulations pertaining to NORM, apply to TENORM, such as flow-back and produced water and sludge from wastewater treatment, but not to NORM, such as drill cuttings or drilling mud.

The technical presentations of Frazier and Thomas were complemented by an overview of regulations and standards provided by **Holly Pearen**, an attorney with the Environmental Defense Fund. Pearen began by pointing out that regulatory authority is shared at the national level by the Department of Energy, the Nuclear Regulatory Commission, and the U.S. Environmental Protection Agency (USEPA), depending on how radioactive waste is categorized, although her primary focus was on the USEPA. The agency's recommendations for the handling of low-level radioactive wastes (LLRWs) are guided by the "as-low-as-reasonably-achievable" (ALARA) principle, and serve as a baseline for specific environmental standards and compliant state regulation. She then highlighted that threshold concentration limits vary considerably from state to state. Pearen closed her presentation with an overview of ongoing studies of NORM and TENORM in oil and gas wastes, including USEPA's investigation of the impact of hydraulic fracturing on drinking water sources, USGS's efforts to characterize produced water, and studies contracted by Pennsylvania's Department of the Environment and North Dakota's Department of Health. In light of nationwide regulatory variation and ongoing research, Pearen expects further rule-making to address NORM and TENORM management and disposal in states where oil and gas are produced.

CHP **Andrew Lombardo** – senior vice president of Perma-Fix, a nuclear services and waste management firm – continued the discussion, focusing in particular on NORM and unconventional oil and gas production. He began by describing the radioactive progeny of three naturally-occurring elements: uranium, actinium, and thorium. He then explained that TENORM can result if the decay series of any of those three elements is disturbed – for example, when produced water that contains dissolved solids flows out of an unconventional gas or oil well. As Frazier had noted in his presentation, Ra-226 and Ra-228 present in these solids in small concentrations is mobile in the environment (see above) and decays into radon gas – the only non-particulate member of natural decay series. Additionally, Lombardo noted that horizontal drill cuttings are rich in uranium and all its progeny and that the methane produced at unconventional wells contains radon. Reiterating Pearen's observations right before his presentation, Lombardo indicated that USEPA is primarily responsible at the federal level for setting NORM and TENORM standards for the oil and gas industry and that regulation is left to state authorities. He also described federal regulation of workers' exposure to radioactive material by the Occupational Health and Safety Administration (OHSA). Lombardo closed with a detailed review of the current and likely evolution of NORM and TENORM standards and regulations.

Paul Ziemkiewicz, director of the Water Research Institute at West Virginia University (WVU), spoke next. In 2011, the West Virginia Legislature authorized the institute to carry out three studies of the environmental consequences of shale energy development. Ziemkiewicz was the prime investigator of one of the studies, which encompassed: (1) characterization of hydrologic and other wastes, (2) identification of pathways of exposure to hazardous materials, and (3) identification of ways to reduce this exposure. Along with measurements of organic and inorganic contaminants contained both in produced and flow-back water and in drill cuttings and drilling muds, data on radioactivity were

presented. In general, radioactivity in drill cuttings, drilling muds, and slurries containing flow-back water were slightly above background NORM levels and in no instance more than twice those levels. Among several recommendations for further study, Ziemkiewicz emphasized the importance of examining how to handle wastes for the sake of reducing human exposure to NORM and TENORM.

The next presentation was made by **Loren Babcock**, a professor in Ohio State's School of Earth Sciences. Babcock offered a primer on the geology of shale: "laminated, indurated, fissile, sedimentary rock composed mostly of clay-sized grains." Gray shale, which tends to contain more calcium carbonate, was distinguished from black shale, which contains more organic carbon and iron sulfides, although the two often co-occur. Black shale also contains more uranium (which tend to bond to organic matter) – with average concentrations slightly exceeding 10 parts per million, which is comparable to the uranium content of the fly ash that remains after coal is burned. Babcock focused on intra-continental shale formations, such as the Marcellus and Utica, which consist of marine deposits over intra-continental basins.

Jeff Schubert, of Paul C. Rizzo Associates, began his presentation about NORM, TENORM, and the oil and gas industry by describing radiation at the atomic level and tracing out the decay series for uranium-238 (U-238) and thorium-232 (Th-232). He also identified a number of geological formations with elevated contents of these and other radioactive elements – including coal seams, marine deposits rich in phosphates, and (as Babcock had noted) black shale. Radiation measurements of various sorts for Marcellus samples extracted in New York and Pennsylvania were presented. Measurements for drill cuttings, filtration wastes, etc. were shared as well.

Two representatives of Pittsburgh-based AMEC Environment and Infrastructure, **Mark Gannon** and **Alex Lopez**, made the first presentation after lunch. AMEC advises its clients on the management of all byproducts of oil and gas production, including the handling and treatment of produced and flow-back water. This management depends on technical and financial factors. There are regulatory controls as well and the AMEC representatives described the rules and guidelines about NORM and TENORM that currently apply in Ohio and Pennsylvania.

The first speaker after the break was **Mark Moody**, who is currently employed by Battelle but who has many years' experience in the oil and gas industry. Moody provided the audience with the basics of drilling and coring, including relevant vocabulary, and summarized existing regulations and proposed legislation in this state related to NORM and TENORM. He pointed out that the Ohio Environmental Protection Agency (OEPA) and Ohio Department of Health have primary responsibility for NORM regulation. However, the state's Division of Oil and Gas Resources Management (DOGRM) regulates drill cuttings, which are a source of NORM. Testing for TENORM is required of wastes prior to disposal in a state-permitted landfill, although no such testing is required for material reused on a drill pad, disposed of in a Class-II injection well, used in enhanced recovery, or transported out of state. No treatment is required of material found to be within 5 pCi of background regulation.

Pace Analytical's **Dennis Leeke** explained the techniques his firm employs to assess the Ra-226 and Ra-228 contained in liquids (e.g., produced water and flow-back water) as well as radioactivity of various sorts. He indicated the turn-around time for various tests and reported that his firm is working on an alternative method for determining Ra-226 content that takes less time than the current "in-growth" technique, which requires 21 days to yield results.

Since **Bill Dornsife**, of Waste Control Specialists, was unable to participate in the workshop, **Mike Hall** spoke next. Hall's company, Clean Harbors, has a pair of large-scale, Subtitle C landfills, one located in Deer Trail, Colorado and the other in Buttonwillow, California. His firm is expecting volumes to increase substantially as unconventional hydrocarbon development expands and as rule-making for NORM and TENORM continues in a number of states. Proper disposal of wastes hinges on careful characterization of all wastes, including wastes that are exempt from Subtitle C regulations. Hall closed by describing the two landfills operated by Clean Harbors, which has more than three decades' experience in this business.

The last three speakers of the day were university professors who shared research findings relevant to this workshop. To begin, **Prabir Dutta**, of Ohio State's Department of Chemistry, described research he is carrying out with students and colleagues aimed at finding ways to minimize the problems associated with flow-back and produced water. He proposed two strategies. One strategy is to alter fracking sand so it has a higher level of ion-exchange, thereby ensuring that fewer dissolved solids are brought out of the ground. The other is an alternative to the current process for removing barium and other elements from produced water. The current process, which involves oxidation and lime treatment, is expensive (since it only recovers 50 percent of all water) and leaves a residual with elevated levels of NORM and dissolved solids. The alternative strategy is to combine the adsorption of barium (and simultaneously radium) with new ion-exchanging and adsorptive materials. Dutta reported that experiments with these strategies are promising, although commercial viability will depend on costs of the new materials as well as their effectiveness.

Elisabeth Widom, from the Department of Geology and Environmental Earth Science at Miami University, explained the various ways that she has measured the presence of TENORM in the environment. Her research has focused on radiation from the Fernald Feed Materials Production Center in Ross, Ohio, which was the largest producer of uranium metal during the Cold War. Widom described the collection and analysis of tree bark, lichen, and sediment core samples. The findings she presented indicate that TENORM is substantially elevated within a few miles of the Fernald plant, though not above background levels a little farther away. Widom also pointed out that lichen provides a cumulative record of airborne TENORM and that analysis of sediment cores is particularly useful in determining the timing of TENORM contamination.

Tarunjit S. Butalia, of Ohio State's Department of Civil, Environmental, and Geodetic Engineering, made a presentation coauthored by his colleague, Jason Cheng, about the use of drill cuttings as road aggregate, construction material, and engineered fill as well as in mine reclamation. He noted that the USEPA does not classify these cuttings as hazardous waste. Neither does the state of Ohio, unless NORM levels are elevated or the cuttings contain refined oil-based substances. Butalia pointed out that cuttings that include, for example, oil-based drilling muds can be stabilized, either through bioremediation or thermal treatment. Engineering properties can also be improved by mixing in fly ash, cement, and other solidifying agents.

The workshop concluded with a wrap-up discussion, led by **Rich Haut** of Environmentally Friendly Drilling (EFD) Systems and involving the moderators of the morning and afternoon sessions. There was general agreement that regulations ought to be tightly focused and that standards and definitions should be consistent and realistic. All stakeholders should be engaged as regulations are developed, both to ensure a common understanding of issues and problems and to address all concerns appropriately. Additionally, considerable support was expressed for the accurate measurement of background levels of radiation and the identification of exposure pathways, as is needed to determine

exposure parameters. Some good studies related to these topics are underway and the International Atomic Energy Agency published a useful reference book in March 2014, titled *Environmental Behavior of Radium*.