TEACHING ABOUT NUCLEAR SCIENCE AND TECHNOLOGY: WASTE MANAGEMENT AND DISPOSAL AN IMPORTANT SUBJECT

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ABSTRACT

Penn State University has a long and continuous history of nuclear science and technology. From its development of the first and oldest research reactor in the United States to its nationally ranked nuclear engineering program, Penn State continues to support and encourage nuclear science and technology development through research and resident, continuing, distance and outreach education.

This paper will cover the development, scope, and sequence of these programs. It will also discuss why waste management and disposal are important issues to the future of our society.

INTRODUCTION

When it comes to nuclear science and technology, education and research are not new to Penn State. Penn State’s Breazeale Reactor will celebrate its 50th anniversary on July 8, 2005.

For the past 35 years, Penn State's Nuclear Engineering has offered numerous types of educational programs about nuclear science and technology including public outreach and continuing education specializing in teacher and youth programs. In each of these programs, the subject of waste management and disposal has surfaced in either the curriculum or during question and discussion periods with participants. Invariably, people want to know how and why waste is generated as well as about the management and disposal of such waste.

In recent years, Penn State has developed several broad based outreach programs covering nuclear science and technology specifically designed for management of radioactive isotopes and waste. Other programs include a summer curriculum workshops for teachers and youth. Early in this decade, Penn State through a consortia of Big 10 universities started a Mini-Grant Program which provides grants to enable high schools, industry, national labs, medical research, colleges, and other universities to interact with Research and Training Reactors (URTR) at Big 10 schools that include Illinois, Michigan, Ohio State, Penn State, Purdue, and Wisconsin.

Today, Penn State’s Mechanical and Nuclear Engineering Department in the College of Engineering is the headquarters for education and outreach, including its new dual degree program in Mechanical and Nuclear Engineering. This new program is proving to be a magnet for students who want the broadest potential in the future jobs and technology.

Penn State’s Research Science and Engineering Center housed in the Breazeale Nuclear Reactor facility provide the labs and reactor science experience for resident and outreach education. Other significant programs have been administer by Penn State including an association solely responsible for low-level radioactive waste management and disposal matters from a state, compact and national level.

From the Beginning

The American Association for the Advancement of Science recognized nuclear technology as one of the top 20 discoveries of the 20th century. In the Association’s journal article entitled, “Discoveries That Shaped Our Lives,” the first discovery took place in 1905 when Albert Einstein transformed science with his six important papers. “Two of them created a new branch of physics--relativity. A third helped create quantum physics. The other three altered the course of atomic theory and statistical mechanics.” The second had to do with the scientists who learned how “to cleave an atom.” When science finally unleashed the atom through fission chain reactions it would apply the technology from a warfare application into peaceful uses that have astounded and improved the quality of life. [a]

Atoms for Peace and the Penn State Reactor

Penn State’s entry into nuclear science is credited to Dr. Eric Walker, Dean of the College of Engineering from 1951through1956.

In 1954, Milton Eisenhower was President of Penn State, but he was also the senior advisor and older brother of then President of the United States, Dwight D. Eisenhower. Dr. Walker, then head of the School of Engineering, thought it would be a good idea to develop a research reactor on campus to promote President Eisenhower’s “Atoms for Peace” program. Before both Eisenhower brothers started their respective presidential administrations, Dr. Walker required “every undergraduate to take an elementary course in nuclear energy as part of the general sequence in physics.”[b]

U.S. President Eisenhower’s Atoms for Peace program’s sole purpose was to utilize nuclear technology for peaceful purposes. It gave nuclear science and technology a tremendous boost in civilian applications. Eisenhower’s theme can still be felt today in programs throughout the United States on developing new and better ways to utilize radiation science and technology to improve the quality of life in examples found in industry, medicine, research, space travel, and electric power production.

Dr. Walker encouraged the creation of a nuclear engineering curriculum, but also the possibility of developing Penn State’s own research reactor. Eric Walker went on to be President of Penn State from 1956 through 1970, and was the “prime mover” in the growth of the research reactor facility as well as the startup of the Department of Nuclear Engineering. [c]

Penn State continues to be one of the oldest and leading nuclear engineering education/retraining and research reactor programs in the United States.

Building and Licensing the First University Reactor

Dr. Walker contacted a personal friend, William A. Breazeale, a physicist at the Oak Ridge National Laboratory and former Professor of Electrical Engineering at the University of Virginia. [d]

"Bill (William) Breazeale who was in charge of developing and operating Penn State's first research reactor was a physicist by training, but also had a strong engineering background," said Warren F. Witzig, Professor Emeritus and former Head of the Nuclear Engineering Department at Penn State. Penn State began to build its research reactor in 1955. During the licensing process, the Penn State reactor received an R2 License from the United States Atomic Energy Commission (AEC), precursor to today's United States Nuclear Regulatory Commission (NRC).

The distinction of having the R1 License designation was to have gone to the North Carolina State College," said Witzig. "North Carolina State College (today's NC State) had many ties to Oak Ridge, Tennessee, where much of America's early nuclear technology was developed during the 1940's.

However, the distinction of being the first university reactor goes to Penn State. The North Carolina State College reactor was called a "Pickle Barrel Reactor." It name came from its size—that of pickle barrel. The North Carolina State College reactor started operation in 1953. However, after operating for nearly two years, the reactor had corrosion problems and was shut down. Technically, it was not operational when the "License R-1" was issued by the AEC. The North Carolina State College reactor was later dismantled and replaced by a larger reactor, but not under the same license number. [e]

"Breazeale found himself in a unique situation. Being the first meant you were faced with few rules, meets or bounds. This included no examinations for reactor operators at that time," said Witzig. "Bill wrote the operator's examination, took the examination himself and graded it. This, of course, is something which would not be allowed today, but in 1955, with the start of a new program, such activities had to happen. Keep in mind that America did not build or operate its first commercial power plant until 1957 at Shippingport, Pennsylvania."

The Penn State Breazeale Reactor (PSBR) was licensed by the AEC on July 8, 1955. It was the first operating research reactor with an R2 license. PSBR has run continuously since its startup and therefore is America's longest operating university reactor. In 1992, the American Nuclear Society (ANS) designated Penn State's reactor a national nuclear historical landmark.

Penn State's first reactor was a MTR (Materials Testing Reactor), developed in Idaho Falls, Idaho. The reactor core was a uranium aluminum alloy clad fuel. The MTR ran successfully from 1955 through 1965. William M. Breazeale was Penn State nuclear research reactor's first director from 1955-1958.

The development of Penn State's research reactor facility has its own interesting story regarding funding. According to Dr. Witzig, the funds for building the research reactor facility came from profits the University received from vending machine sales on campus. "The money amounted to

$250,000,” said Witzig. “In 1954, that was a lot of money!” Penn State Board of Trustees approved the use of the funds and the project began.

Nuclear Engineering Gets it Start

In 1959, Nunzio Geisippe (Joe) Palladino was hired by Penn State as the first department head of the Nuclear Engineering Department in the College of Engineering. The first degree bestowed by the Nuclear Engineering Department was a master’s degree. In 1959, the research reactor joined the department. Early in the department’s history, it had an enrollment between 15 and 20 students in the master’s degree program. The doctoral program was added in the early 1960’s.

The greatest growth in Penn State’s Nuclear Engineering Department came during the 1960s. During this period, America’s startup of nuclear power plants and impending orders for new reactors. This gave Penn State an important role—to prepare students for jobs the growing nuclear power industry. In 1968, the Nuclear Engineering Department began an undergraduate program. Courses in reactor management later included waste management techniques.

Continuing, Distance and Outreach Education

Outreach programs began to develop and expand during Witzig administration from 1967-1996. Witzig valued and promoted continuing education and outreach in addition to research and resident instruction.

Dr. Witzig hired staff to work with faculty on a variety of innovative programs for a broad cross section of people of all ages. Many of these programs were industry-funded grants, other funds came from federal and state government agencies. Some programs were funded internally as part of the Department's strategic plan. According Witzig, the peak of the department's continuing and distance outreach programs came during the late 1970's and early 1980's. He noted that the budget for programming was in excess of a million dollars per year during that period.

Teacher Education in Nuclear Science

In 1969, Penn State and the Commonwealth of Pennsylvania’s Education Department piloted a six-week nuclear concepts summer course for teachers. The course included classroom instruction and experiments at the Breazeale reactor. The course ran continuously through 1994. In 1999, the course was rejuvenated as a one-week workshop with an optional three credit science education graduate course. Penn State’s College of Education sanctioned the three graduate credits and the Mechanical and Nuclear Engineering Department staff and faculty designed and ran the workshop/course. The week-long event was initially designed as a general adult education program, with an emphasis on curriculum ideas and sharing. By 2001, it was evident that chemistry and physics teachers who were attending the event were not getting valuable time at the research reactor for experiments. The workshop/course was revamped and is open exclusively to chemistry and physics teachers. One-third of the workshop/course is now centered on hands-on activities at the research reactor. The response to the change has nearly doubled the interest and application to attend the workshop or optional graduate course.

In 2004, another aspect was added to the workshop. One of the selected participants indicated that he had rising seniors who were interested in nuclear technology and had an introduction course. He suggested that the program offer a youth component to the week-long program. The project director reviewed the request and allowed five students to attend the workshop/course. The director, with staff, designed a Young Engineers and Scientists program that enabled them to interact with the teachers on some days, but also work on projects which were at their level of understanding.

This activity proved to be quite successful. In 2005, the Young Engineers and Scientists program will partner with the Westinghouse High School Honors Institute in Pittsburgh, Pennsylvania and bring ten students to the University Park Campus during the week of July 11-15.

Over the past six years, the benefits of offering such programs have confirmed increased learning borne out by the pre and post test scores. Since 1999, the pre-test score mean average was 59.5 percent and post-test score mean average was 89 percent or almost a 30 percent increase in cognitive learning about nuclear science and technology.

In each workshop, both high-level and low-level radioactive waste management and disposal were among the major topics of interest.

Other Outreach Programs

“Energy for Tomorrow,” a spin-off of “This Atomic World,” was instituted in 1974. Energy for Tomorrow was primarily an auditorium program about the many facets of energy and electricity.

Boy Scouts of America’s Atomic Energy merit badge was rewritten by Penn State staff in 1985. Penn State was also responsible for running Boy Scout Science and Energy Camps for nearly a decade in Pennsylvania, Maryland, and Virginia.

Girl Scouts of America’s Electric Adventure was a camp for scouts which included adult education programs about energy forms such as nuclear power.

“Energy for the 80s” and “ENTER 2000” were two workshops and graduate summer courses that focused on nuclear power development and later the accident at Three Mile Island. Mayor Robert Reid of Middletown was one of the most impressive speakers. The Mayor debunked many of the myths surrounding the accident and events during the post-accident work at Three Mile Island.

“SEE the Future” was a workshop for middle school children that focused on science, energy and engineering, and included a radiation awareness segment. This program encouraged minority youth to participate through Penn State centers in Pittsburgh, Harrisburg, and Philadelphia.

CASEE (Community Access to Science and Energy Education) and Limerick Continuing Education Program were two Penn State programs that were run within the Emergency Planning Zones (EPZ) of the Peach Bottom Atomic Power station and Limerick Nuclear Power station. The EPZ area covered six Pennsylvania counties and two Maryland counties. Both programs included citizen advisory committees and centered on programs involving radiation, risk/benefit, nuclear power operations, including waste management, treatment, storage, and disposal. Each program was underwritten by unrestricted grants from the Philadelphia Electric Company to Penn State.

A TMI community education program was created through the Nuclear Engineering Department at Penn State after the Unit II accident in 1979. This program involved citizens monitoring of the controlled venting of noble gas Krypton.

In 1980 and again 1985, the federal government passed legislation pertaining to low-level radioactive waste (LLRW) siting. Pennsylvania formed the Appalachian States Compact and designed itself as a host state to site the first LLRW facility. The Pennsylvania LLRW original timetable began in 1988 through late 1994. The timetable tasks were as follows: develop regulations, 16 months; select operator, 18 months; identify site 12 months; select one site, 12 months; license application, 6 months; licensing review, 18 months; and construction of facility, 12 months. In 1988, Penn State was provided unrestricted grants to develop a public outreach program. It was later called the PIER (Public Involvement and Education on Radiation) Program. Later that year, another group approached Penn State to develop a trade association linking users from all sector of generation and form the ACURI (Appalachian Compact Users of Radioactive Isotopes) Association. In 2000, the Association was renamed as (American Council of Users of Radioactive Isotopes) to develop a national organization. Each program focused on LLRW subjects and issues. Both had either a citizen advisory committee or a Board of Directors.

ACURI was a user/generator advocate organization that involved itself in public meetings, hearings, proving testimony, studying public issues and attitudes, interacting with federal and state agencies such as DOE, NRC, EPA and the Office of Management and Budget (OMB). OMB and the EPA requested ACURI member services in several studies performed by those agencies.

One important contribution ACURI in regard to management of waste was to develop a complete list of LLRW forms. This list provided generators and regulators a better way of communicating to not only themselves, but the public. The listed forms were: Biological and medical pathological; contaminated soil; dewatered filter media; dry active waste; evaporator bottoms, concentrates, sump sludge; gaseous waste; incinerator ash or residues; ion exchange resins, beads, or powder; irradiated reactor components; liquid scintillation fluids or vials; mineral extraction/Uranium sludge; process aqueous liquids; processed organic liquids including oil; sealed source, devices, gauges; and surface contaminated objects.

The ACURI website (now decommissioned) at one point during its five year existence received nearly one-quarter of a million hits per month. The website included general and specific information that could informed any age level or expertise. [f]

New Millennium Program

In October 2002, The US Department of Energy awarded Penn State as the prime institution in a grant entitled, "Innovations and Enhancements for a Consortium of Big 10 University Research and Training Reactors (URTR)." This multi-million dollar, multi-year grant includes the Mini-

Grant Program under one of its many task statements. The Program consists of an opportunity for high schools, industry, national labs and other colleges or universities—worldwide. Applicants are required to develop a proposal that will link with a Big 10 URTR facility. Each proposal is individually reviewed by independent at least three reviewers. The Mini-Grant Governance Committee then make a recommendation of what grants should be funded to the US DOE for final approval. Big 10 Consortia members include the universities of Illinois, Michigan, Ohio State, Penn State, Purdue, and Wisconsin. [g]

The Big 10 Consortia Mini-Grant Program has a website which includes news and information, plus an on-line application and review system. The address is: <http://www.mne.psu.edu/minigrant/>

Jack S. Brenizer, Jr., is Professor and Chair of Nuclear Engineering Program at Penn State is also the Principal Investigator of the Big 10 Consortia and Chairman of the Mini-Grant Program. According to Brenizer, the Mini-Grant Program received 27 applications for 2004-2005. This was an increase of 14 applications or over 100 percent from the first year. The 2004-2005 applicants included 12 high schools, 12 colleges and universities, 1 industry, 1 national lab, and 1 medical center. URTR distribution included: Illinois (4); Ohio State (4); Penn State (9); Purdue (4) and Wisconsin (6). The University of Michigan was not added to the URTR list until May 2004. A breakdown of applicant locations is as follows: California (1); Colorado (1); Idaho (1); Illinois (5); Indiana (3); Pennsylvania (7); South Africa-Johannesburg (1); Virginia (2); Washington DC (1); and Wisconsin (2). The 27 applications submitted represented a total of $505,896. Mini-Grant funds available amounted to $171,663.

The grants for fiscal year 2005-2006 will receive a fourteen percent increase in grant funding. In addition, another Big 10 school has been added to the list of Big 10 Consortia members. Brenizer says, "The Mini-Grant Program has been very successful in providing funds for many sectors of our society to become more involved with research reactors in many interesting ways."

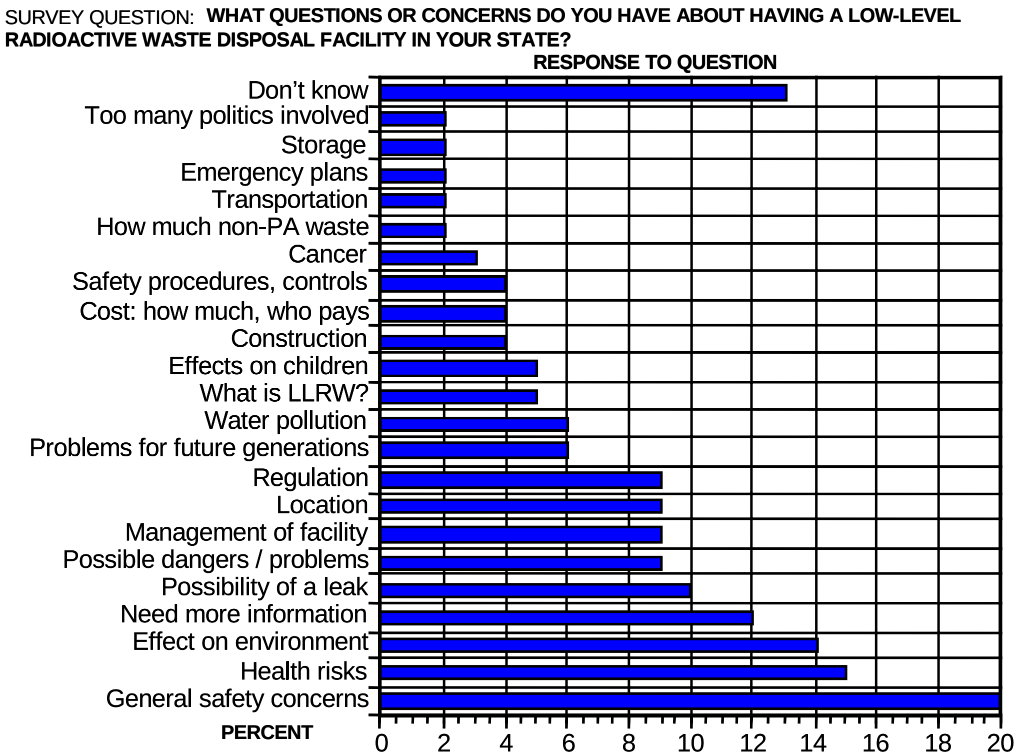
Why Inform and Educate

To many people, waste management and disposal is still considered the Achilles heel of the nuclear science and technology industry. "Without an informed public," says Professor Witzig, "the cycle of use, management, and disposal of radionuclides can be changed or disrupted by public interest groups and government. The disruption can cause unnecessary costs or even stop the final storage or disposal process of high-or low-level radioactive waste."

Penn State has learned over many years of programming that waste management and waste disposal issues have been a concern of the general public. Participants in workshops, meetings or courses have many questions that are not answered by the popular press. Through a variety of surveys and pre-program development planning, waste management, but more specifically subjects such as the risks associated with waste disposal techniques, safety in shipping, long term risks to ground water and the environment protection were reported.

One classic survey published by the ACURI Association in 1993, continues to address similar issues today regarding a waste disposal facility, especially one being developed in one's backyard. Matters such as general safety concerns, health risks, effect on the environment and the need for information were most frequently given, as found in Figure 1. These issues have not changed much over the past decade, but remain dormant until some action is taken regarding waste disposal or management in the news.

Fig. 1.



[h]

Fig. 2.

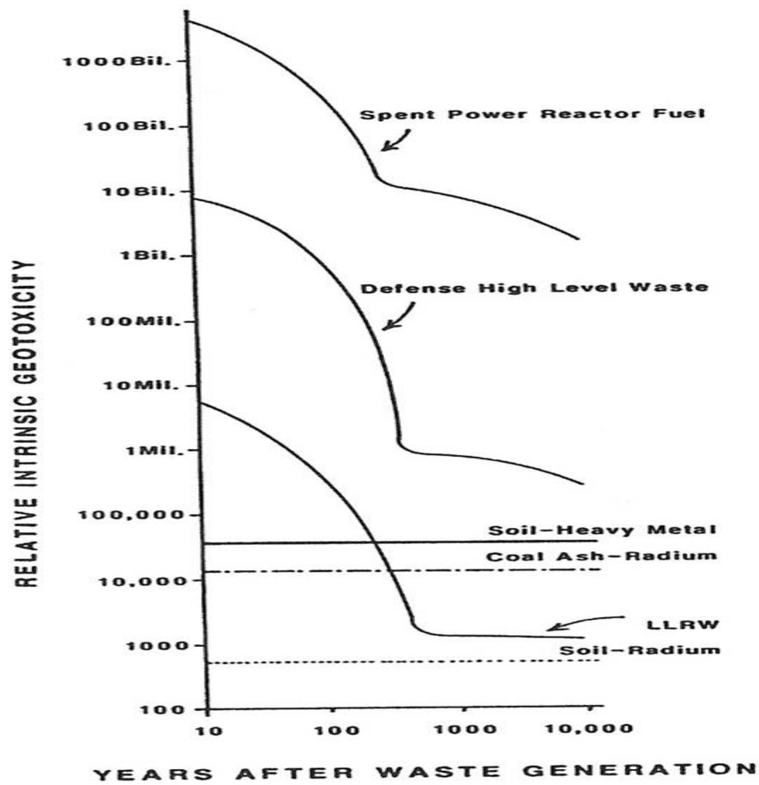
Risk in Perspective—Powerful Information

Risk is a relative value that a person or society defines in terms of fear or danger in respect to health, safety, and the environment. Risk is relative because it may be different to people in the same situation in what they feel that they can control, reduce or eliminate the so-called risk situation. [i]

In the field of nuclear science and technology, risk seems to range in two forms from tolerable to intolerable and acceptable to unacceptable.

Radioactive materials and the use of radioactive isotopes are commonly used in our society. Some of the uses can be found in electricity generation, agriculture research, beverage gauges, smoke detectors, food irradiation, well logging, cancer research diagnosis and therapy, FDA drug approval process, crime investigation, jet engine flaw checks, medical imaging, laboratory tests, non-stick pans, airport luggage checks, sterilization of consumer products, and pipe weld checks. [j]

There are five types of radioactive waste which are commonly mentioned: High-Level Waste (HLW), Spent Fuel, Mill Tailings, Transuranics, and LLRW. To assess risk from any of these types to the public regarding storage or disposal, there needs to be a common denominator to help a person see relationships and differences, therefore improving one's understanding of the subject and the risk. In Figure 2, soil with a radium consistency is used as the common denominator. The compares various radioactive waste types including those from coal ash with radium. [k]



[l]

Fig. 2.

Without risk-based communication, almost everything and anything could be deemed unacceptable. Risk-based communication helps put common poisons found in the home, which we generally disregard, in perspective to other hazards found in the popular press.

Radioactive Waste has not Disappeared

Since 1999, host states responsible for hosting a LLRW facility in the United States have quit, delayed, or suspended their siting process and development in their respective state or compact. The rationale for the action has come to several reasons:

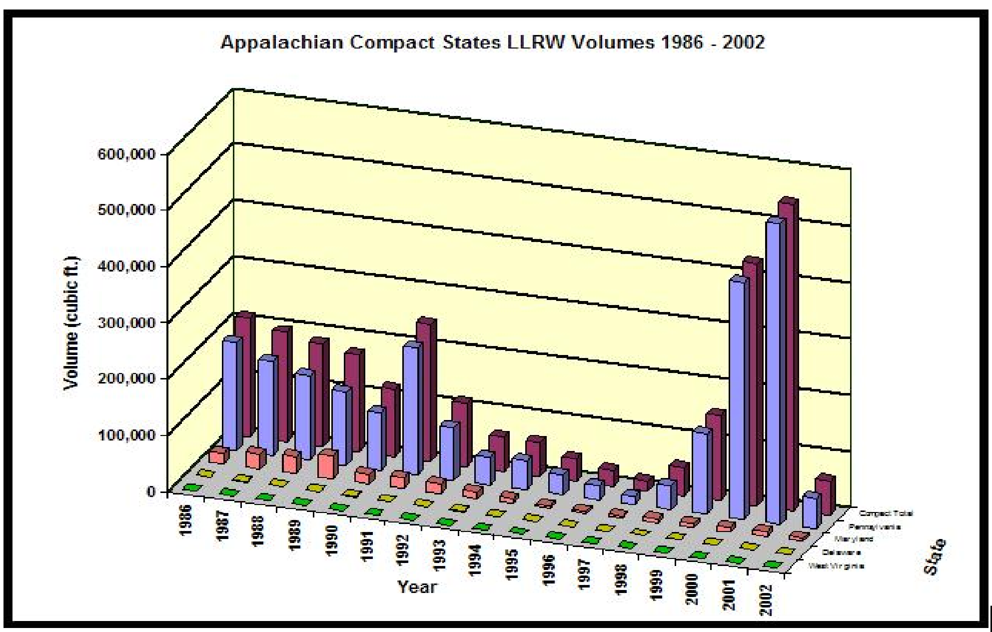
1) Access to other waste sites

2) Significant decline of waste volumes
3) Funding matters
4) Resignation that mandated responsibilities have been met
5) Providing for restart options

Over $600 million have been spent by states/compacts throughout the United States since the mid 1980s, but no state or compact has opened a new facility licensed under the Low-Level Policy Act or its Amendment.

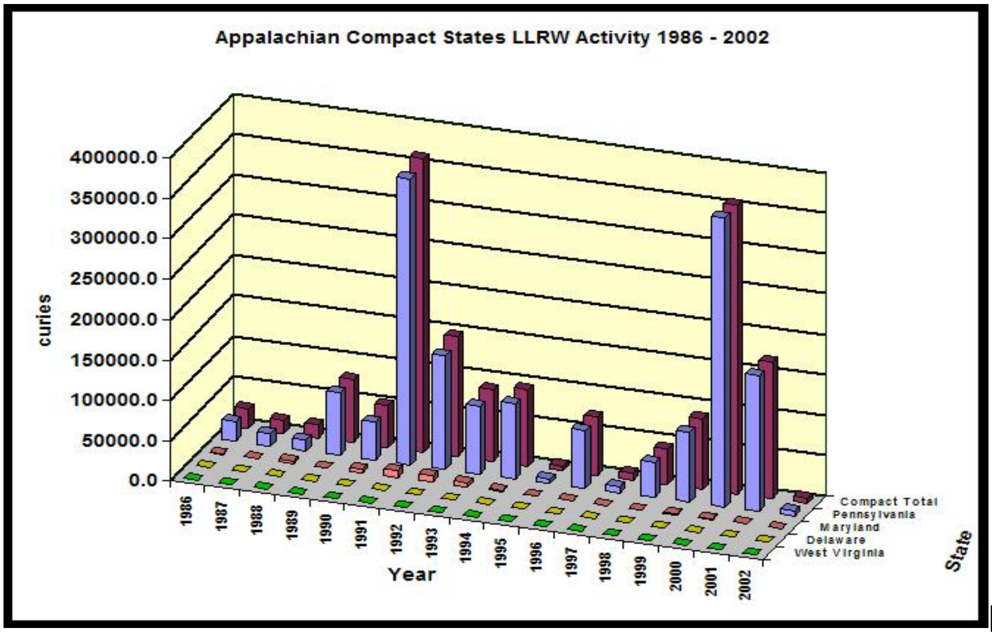
Currently there are several LLRW facilities that provide disposal services in the United States. The Barnwell facility in South Carolina will accept waste from states outside its Atlantic Compact through 2008 under special contracts and waste allocations. Envirocare in Utah currently accepts Class A waste, but has struggled with attempting to acquire Class B and Class C license to dispose. Also Envirocare recently announced business changes through an advertised sale in December 2004. In Texas, Waste Control Specialists, who operate a RCRA licensed facility, are currently attempting to license a Class A facility through the state of Texas. The Northwest compact’s facility, though limited to its member compact state users, does provide disposal to certain discrete radioactive materials. Several other companies throughout the United States also provide treatment and other waste management services. Without these facilities, America would face a crisis in managing radioactive waste.

Waste numbers have not really diminished or disappeared. With at over 100 operating nuclear power plants in the United and thousands of other licensed users of radioactive materials, it is not practical or sensible to believe that radioactive waste or the need for disposal will disappear in the near or extended future. The following illustrations in Figure 3 and Figure 4 show the variations of waste volumes and activities for the Appalachian Compact states of Delaware, Maryland, Pennsylvania and West Virginia from 1996 through 2002. It is understood that radiation volumes and activity has not disappeared.



[m]

Fig. 3.



[n]

Fig. 4.

Education and Information, a Future Must
As the 21st century moves through its first decade, a number issues seem to be facing nuclear science and technology development and future growth. Some of them are:

a) Deregulation and consolidation of power plants and business
b) License extensions of nuclear power plants
c) Yucca Mountain’s licensing and approval process developments
d) California energy crisis
e) State of U.S. and world economy
f) Pebble bed reactor initiative
g) DOE’s Generation IV Roadmap
h) Post September 11th security issues
i) Hires by utilities, vendors, and government
j) Funding initiative changes [o]

Like it or not, each one of the above issues has a link to waste management, treatment, storage or disposal. America’s ability to make sound decisions in the future must come from an informed electorate.

CONCLUSION

The peak of research reactors came in 1979 in the United States. There were 63 university research reactors throughout the United States. Today the number is down to 26 university research reactors. This number is thought by many as one that has not yet seen bottom. This then begs a more important question, where will future nuclear scientists come from?

The so-called "brain drain" could become a serious issue in the field of nuclear science and technology if America's youth do not learn about nuclear science and it applications in our schools. Conversely, if the public is not aware of many applications of nuclear science and technology, politicians may hear only the more vocal naysayer and inhibit or stop legitimate waste management, treatment, storage or disposal.

We should all encourage and support nuclear science and technology educational programs at all levels, to ensure that America will "SEE the Future," as a leader in Science, Engineering and Education—some people call that "intellectual capital!"

FOOTNOTES

[a] Ferris, Timothy, et al, SCIENCE 84, p.61

[b] Bezilla, Michael, p. 144-145

[c] ibid

[d] Penn State Breazeale Reactor reports

[e] Interview with Dr. Jester

[f] ACURI Board Minutes

[g] Mini-Grant Report to Governance Committee, November 2004

[h] ACURI Newsletter, May 1993, pp. 8-10

[i] Johnson, Branden B., et al, Part I and Part II, pp. 3-27

[j] ACURI Association Factsheet

[k] Dornsife, William P., Table I, page 4

[l] Ibid, p. 8

[m] PA DER BRP Annual Report, p. 36

[n] PA DER BRP Annual Report, p. 37

[o] DODRAD LLW Annual Meeting, 2004, consensus of speakers

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