General Safety Considerations

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Attitudes and Practices Regarding Disposal of Liquid Nuclear Waste at Clinton Laboratories in the Very Early Years: A Historical Analysis

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Abstract: *This article is a condensation of a report of the same title, which is an extensive review of early waste disposal practices during the War years and immediately after. The original report was based largely on unpublished documents in the Oak Ridge National Laboratory's Central Files area of Laboratory Records, and these references can be found in the initial report. This summary contains only selected examples of extensive quotations upon which the report is based. The full report gives much more detail on the biographical history of the important people discussed.*

Disposal of wastes and other contaminated materials from the three plants on the Oak Ridge Reservation in Tennessee is a highly visible, dominant issue today. Billions of dollars are being spent to correct what many perceive to be the mistakes of the past, referring to the decades from the mid-1940s through recent times. Many—indeed, perhaps most—people perceive that wastes have been carelessly handled and have been disposed of in a haphazard fashion with little regard for safety, human health, and the environment. In many instances, care was not taken as it should have been, and uncontrolled releases to the environment have occurred. This fact is recognized, but documentation of those instances is not the objective of this article.

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When people are queried about their perceptions of disposal practices during the very early days of operation of Oak Ridge National Laboratory (ORNL), which was called Clinton Laboratories until 1948, the response is generally either that they know nothing about it but presume little professional attention was given to the issue or they state outright that the wastes were probably "dumped in the woods, or in the river," or words to that effect. Few individuals hold the view that wastes were disposed of in a (semi) professional manner; however, such a position is generally unsupported by facts.

Recent research at ORNL[1] has revealed that very conscious decisions and efforts were made, even as construction began at Clinton Laboratories, to handle liquid waste in a safe manner on the basis of scientific and medical knowledge at the time. This awareness continued through the War years and afterward. A group of insightful and influential individuals consistently sought safe methods of handling the highly radioactive and dangerous wastes and of disposing of them properly. Documentation of this position is the subject of this article.

This article deals almost exclusively with liquid radioactive wastes with passing reference to gaseous wastes. Solid wastes did not receive the attention that the liquids did for many years; where appropriate, discussion of solid wastes is included. This study does not deal with worker exposure and contamination incidents.

The objective of this article is to present information that demonstrates the awareness and surprisingly high level of conscientiousness in handling liquid wastes during the very early years of construction and operation of Clinton Laboratories, the years 1943 until after World War II. Less complete information will also be presented to substantiate attitudes and actions through the balance of the 1940s.

OAK RIDGE AND THE MANHATTAN PROJECT

It is important that the reader have rudimentary knowledge of the Manhattan Project to more fully appreciate how decisions were made during the War years; details are provided in the many excellent books that have been written about the efforts to design and construct the nuclear weapons used to end the War.

In 1938, German scientists proved that the uranium isotope, ^{235}U, was fissile. It was then well known throughout the world that a nuclear weapon was possible, although it would be necessary to enrich this isotope greatly because it was diluted naturally by the nonfissile ^{238}U. Within a few years, the United States mounted an aggressive effort to enrich ^{235}U and to produce plutonium, which is also fissile and can be produced from ^{238}U. The Metallurgical Laboratory (Met Lab), under the direction of Nobel Prize winner Arthur Compton, was set up at the University of Chicago to address these challenges; in December 1942, the first self-sustaining nuclear reaction was demonstrated at Met Lab with a small and crude graphite reactor (called the “pile”) under the direction of Enrico Fermi.

It was evident that a more isolated site was required for continued enrichment, production, and testing of these fissile radionuclides, so a large expanse of land was purchased in East Tennessee in late 1942 with the displacement of several thousand local residents. Literally overnight, construction started on three major super-secret facilities. Two of these (K-25 and Y-12) were built for enrichment of the ^{235}U by gaseous diffusion and electromagnetic processes. The third facility, Clinton Laboratories, was for production and separation of plutonium. It was quickly realized that full-scale plutonium production was unwise in a populated region like East Tennessee, so the production reactors were sited in the desolate desert of Washington State, a site known as Hanford. The Clinton site was used as a pilot-scale facility for development of plutonium production in the Graphite Reactor and chemical separation techniques in the adjacent building (Building 205). By November 1943, the reactor had gone critical, and plutonium was produced at year’s end. From early 1943 to the end of the year, 150 buildings, costing $13 M, were constructed at Clinton Laboratories (see Figs. 1 to 6 for the locations of buildings and the construction history through 1947). Plans were for the laboratory to be temporary and to exist for only about 1 year. Developments at Hanford closely followed what was learned at Clinton.

In parallel, Los Alamos was constructed for the actual design, production, and testing of the nuclear weapons. The first one was tested in New Mexico in July 1945; in August of that year, weapons were dropped on Japan to end World War II.

The Manhattan Project stands as one of the most remarkable feats in modern times. The top nuclear scientists in the free world totally dedicated their careers to deciphering the physics and chemistry of unknown elements (plutonium did not exist before 1941) and to designing revolutionary weapons. Decisions were made on the basis of the best available information, which in many cases was scant at best. The behavior of radionuclides in the environment and in living matter was largely unknown, although the dangers associated with them were well recognized.

LIQUID WASTE DISPOSAL AT CLINTON LABORATORIES

Space does not permit a detailed review of the disposal processes for liquid wastes, but the fundamentals can be briefly reviewed to understand the material that follows. Liquid wastes were generated primarily from the separations building (Building 205) where neutron-irradiated slugs of uranium were dissolved to recover plutonium; resulting from this were liquid wastes rich in fission products, organics, uranium, some plutonium, and nitrate. In addition, similar wastes were produced at the research buildings (e.g., Building 706) and elsewhere. Amounts on the order of 30,000 gal/day were generated. The acidic wastes were neutralized, and most activity was precipitated out. Lower activity wastes were then sent directly to a 1.6-million-gal settling basin; higher activity wastes went to storage in a series of underground (gunite) tanks where radionuclides decayed and further precipitation occurred (see Figs. 7 and 8). When the activity was low enough, the

Fig. 1 Construction started on February 1, 1943. This photograph was taken March 1 and shows the western end of the facility where the administrative offices were located. Today this area is just inside the fence. Note that only a rough access road was graded, which became a sea of mud during rain.

Fig. 2 Progress as of April 15, 1943. This is a view looking northwest from above where the two holding ponds would be built; the road in the center goes up the ridge where the graphite reactor (the pile, Building 105) would later be built out of the field of view to the right. Left of the road were the administrative and service buildings; right of it were production and research facilities.

wastes were sent to retention ponds, held for an average of 3 days, and then sent to the settling basin. Outflow from the basin was mixed (ratio 1:35) with clean process water and released to White Oak Creek, which flowed into White Oak Lake, an artificial lake specifically created to retain the drainage before controlled release to the Clinch River, where further dilution (about 500 000:1) occurred. This method for disposal was used until the turn of the decade when an evaporator was built to reduce total volume. Then wastes were disposed of directly into seepage pits in shale; in the mid-1960s, these liquids were mixed with cement and injected deep into the ground, a process known as "hydrofracture."

Solid low-level wastes were disposed of in burial trenches well into the 1980s. Considerably less attention

Fig. 3 Progress as of June 27, 1943. This is the same view as in Fig. 2. The steam plant, in the center, is one of only three buildings not constructed from wood. The other buildings are the separations building (205) and the reactor building (105); the foundation for the separations building can be partially seen right of the road on the ridge. Behind the steam plant is a two-story structure, the Health Division.

was given to their disposal than to the disposal of liquids, and we shall explore reasons for this. Gaseous wastes during the War were exhausted through high stacks to the atmosphere; the discussion that follows deals briefly with some of the decisions related to gases.

THE CENTRAL FILES: SURVIVING RECORDS

The bulk of material comprising this study came from unpublished documents that survived in the Central Files at ORNL where about 100 000 documents are filed. About half of these were generated in the 1940s. They are listed in a data base, so key words and authors' names can be used to search for relevant materials. Approximately 8 000 potentially relevant items were identified, and of these, some 1 000 were individually examined; about 150 were of use. Without doubt, there are many more documents to be uncovered.

In the following text, we have retained the Central Files reference number, where appropriate, because it provides the reader with a chronologic benchmark against which activity can be established. The number consists of three parts: the first two-digit part marks the year the document was filed, the second part indicates the month, and the third part indicates the sequence in which the document was filed that month. Therefore the number 44-5-139 represents the 139th item filed in May 1944.

THE YEAR OF CONSTRUCTION

. . . Approaching Pure Water

The issue of waste disposal was not noted in the earliest documents dealing with construction of Clinton Laboratories, although an early flow sheet for a chemical separations process noted that wastes would be generated (43-1-19); however, notes taken on Nov. 16, 1942, by Glenn Seaborg at the Met Lab when different separation processes were being considered included the question, "can process wastes be handled safely," as one of the factors for

Fig. 4 Progress as of August 31, 1943. The partially completed pile (Building 105) is seen in the center with the separations building under construction to the right. On the other side of the pile is the machine shop where the graphite was prepared. In the background are the six large gunite tanks, and on the north side of the road are the two smaller tanks; all are yet to be covered. Farther away are the two retention ponds. The large building to the left (706A) is the Chemistry Division. The Physics Division building is on the hill to the right of the pile behind the steam plant.

consideration.[2] Figure 9, a time line that traces important events related to the following discussion, can be used for reference purposes.

Shortly after construction began in 1943, there was communication to Martin Whitaker, the Laboratory Director, on how much water should be "kept moving through the basins without excessive contamination of the river" along with discussion of rates of water intake for drinking and hazards associated with immersion in the river water (43-3-85 and 43-3-124). Whitaker had been an assistant to Fermi at Met Lab after serving as Physics Department Chairman at New York University.

The issue of testing waters before release was important, and the lack of available and sensitive instruments was a problem (43-3-240, 43-3-246, 43-3-273, 43-3-277, and 43-4-115). Because continuous radiation detectors were not available, batch testing of samples in the laboratory "before discharging to the river" was suggested, and the "degree of sensitivity" (i.e., contamination) of wastes "that can be discharged from the ponds to the river" was highlighted. A discharge limit of 10^{-4} Ci/ft^3 was specified for releases to White Oak Creek.

A dominant figure in health and safety was Robert Stone, hired by Compton to oversee all health aspects

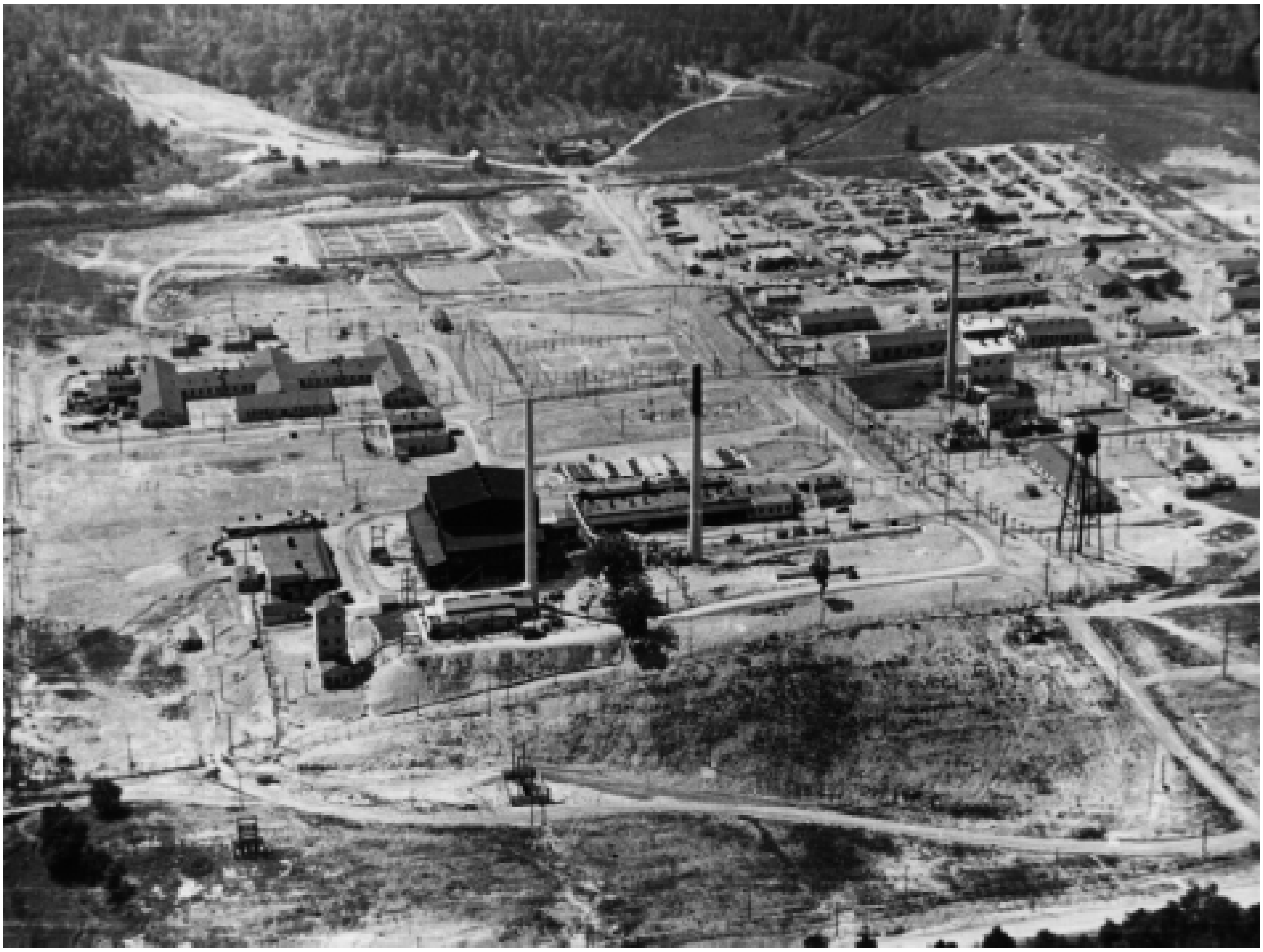

Fig. 5 Clinton Laboratories in the summer of 1944. The graphite reactor is the dark building just left of center, and the separations plant (Building 205) with its emission stack is to its right. The chemistry building (706A) is the large structure beyond the reactor, and the underground gunite tanks are to the right of the chemistry building in the large open area; other smaller tanks were associated with individual buildings. To the right of the separations building is the long one-story physics building beyond the water tower, with administrative and nonresearch facilities in the background. Behind and to the right of the chemistry building can be seen the two retention ponds, and behind them is the large settling basin, which was constructed in the summer of 1944. White Oak Creek flows behind the basin and out of the field of view at the base of the slope with trees.

of the Manhattan Project; Stone was uniquely qualified on the basis of his previous experience of applying nuclear physics to medicine, and he came to Oak Ridge at an early point. In April, during a meeting of the Radiation Instrument Coordinating Committee (probably at Met Lab), he requested "detailed plans for waste disposal at Site X" (the secret designation for Clinton) and said that "wastes going into the river must be kept at a very low level of radiation, approaching pure water" (43-4-156). The sampling protocol for ponds and tanks was established.

Others were also cognizant of protection of public health. Lyle Borst, a chemist who came from Met Lab to Clinton, raised the issue of problems associated with waste disposal from Building 706A (Chemistry) by pointing out that certain constituents "would be considered dangerous" (43-6-112). The "health group at the University of Chicago" asked about discharges to the creek to make certain they "will be consistent with the public health in that area," and advice was sought to ensure that disposal was consistent with "normal industrial practice in the general area."

Fig. 6 Clinton Laboratories in 1947. The graphite reactor building had been painted white after the War, and the "Hot Laboratory" was expanded. The Physics Division building now had three wings. Just below the separations building was a new training school facility, and Quonset huts, which became the central machine shop, were under construction. There were no paved roads at this time.

Setting Release Limits

A series of "process manuals" was issued in 1943 with detailed descriptions of various processes for operation of Clinton Labs. One of these, the "Waste Disposal Wet D Process" by William Kirst (a chemical engineer with du Pont since 1926), is most revealing with regard to safe disposal. Whitaker, Director of the Labs, officially received this manual in September, but it was prepared much earlier, perhaps in February. In it is detailed information on ways for handling liquid and gaseous wastes, the process lines, waste chemistry, disposal stacks for Building 205, the underground gunite tanks, and leak detection for the tanks. The "maximum allowable radioactivity . . . discharged to the river" was defined as 0.1 R/day for exposure, a figure established in 1934 by the U.S. National Committee on Radiation Protection and Measurements. Emphasis was on the need to hold the liquids in retention ponds until activity was low enough to ensure safe discharge to the creek.

During this time attention was also focused on gaseous emissions. Whitaker had previously questioned dangers associated with gases accumulating at the top of the Building 205 stack (43-1-26), and in communication to Compton, he asked for estimates of the amount of gas to be released (43-1-12). Sophisticated calculations were performed to set "tolerable" (safe) levels for atmospheric emissions (43-4-196). R. B. Smith, Secretary of the Central Safety Committee, notified

Fig. 7 The gunite tanks under construction in the spring of 1943. These are the six large tanks located south of the main road and adjacent to the chemistry complex (706 area). The beveled lip on the pad below the tanks can be seen; this was to help prevent releases of any spill or leak that occurred. The construction behind the tanks is the form for the graphite reactor.

Fig. 8 Construction of the gunite tanks nears completion in July of 1943. Workers are applying a final protective outer layer to one of the tanks.

Whitaker in April that gases "leaving the Pile will be continually monitored and if abnormally high activity is found, the Pile should be immediately shut down" (43-4-193). Miles Leverett proposed research on the stack gases "to make certain that the plant creates no personal hazard through atmospheric pollution" (43-11-27). Many more documents reflect concern over the gaseous wastes.

The Sacrificial Lambs

The gunite tanks were, without question, the centerpiece for waste handling, and without their proper function, activities could not proceed; their construction and operation were carefully planned and undertaken. Not only were they highlighted in Kirst's Process Manual but also they appeared on a January drawing list (43-1-159). In late 1943, Whitaker wrote Compton to update their construction status (43-11-118); he verified that they were watertight, that a special lining was added, and that the tanks "are as safe for their purpose as it is possible to make them." He discussed their stability with regard to vibrations resulting from rock quarrying along Bethel Valley Road and dismissed any detrimental effects on the tanks.

At the same time, Howard Curtis, Head of the Biology Section, first proposed biological monitoring of the wastewaters in White Oak Lake (43-11-44), noting that river water, into which the lake drains, "will be used as the water supply for several towns below the plant." He urged that rabbits and mice be used to establish acceptable "tolerance concentrations," noting that such data were not available for radionuclides and heavy metals; it would be necessary to sacrifice "from time to time" the animals so they could be examined. Curtis, an eminent biophysicist, left his professorship at Columbia University to join the Project; he returned to teaching after the War.

For Safe Disposal into the River

Numerous examples occurred to demonstrate that there was conscious adherence to established release limits [for example, Leverett, Chief of the Engineering Development Section of the Technical Division, wrote to Richard Doan, Associate Laboratory Director for Research, regarding disposal of waste from the smaller underground tanks and pointing out that discharges to the river could be done over a 16-day period "without exceeding either the tolerance activity of the river water . . . or the tolerance concentration of uranium in drinking water" (43-11-79)]. Leverett had previously worked with Compton and Eugene Wigner on reactor (pile) design, had headed the Engineering Group at Met Lab, and had participated in selection of the Oak Ridge site. Doan had been Chief Administrative Officer at Met Lab and a member of Compton's "Planning Board" along with other notables, including Samuel Allison, Enrico Fermi, Norman Hilberry, Frank Spedding, Leo Szilard, John Wheeler, and Eugene Wigner.

Another example involved Oswald Greager, Head of the Separations Development Division. In the weekly report for his division (43-11-152), he discussed analyses under way on supernatant liquid in a tank to "determine if it can be pumped out and discarded into the nearby creek." This and other communications from Greager indicated that wastes were disposed of into the creek in late 1943, much earlier than generally accepted for the first such disposal.

Finally, in December, Marshall Acken, a Section Head in Greager's division, provided a very detailed account of the assignment of different liquid wastes to different tanks and the sequence in which each tank was to be filled and emptied (43-12-55). The stated objective was to allow maximum decay time prior to dilution to acceptable levels "for safe disposal into the river." Acken, a physical chemist, returned to du Pont and to Hanford after the War.

Rising to the Occasion

The year drew to closure with added emphasis on human health. On December 30, a proposal surfaced again to conduct "biological studies" with application to waste issues at Hanford (43-12-496). It appears that this was Howard Curtis's biological monitoring idea from November; the records do not reflect if and when this work actually started.

Simeon Cantril was Director of the Medical Division at Clinton Labs; he wrote Whitaker to establish his organization as the responsible one for regulating discharges from the "waste-storage ponds and a lake backed up by a dam on White Oak Creek." He indicated that they would control releases to the river "after activity had been determined and inspection of the dam;" he planned for locks on the dam structure, a fence around the ponds, and regular record keeping of all discharges. A tolerance level of "100 mrem/24 h" was insisted on; no release would be authorized if this level were exceeded. Cantril, specially recruited by Compton, had a long career in medicine, having worked at the Swedish Hospital in Seattle, the Radium Institute in Paris, and the Tumor Institute in Chicago before joining the Met Lab.

Obviously, considerable attention had been directed by the end of 1943 to proper management of liquid waste and protection of public health. As the year ended, not only was the major phase of construction completed but also the graphite reactor had gone critical almost 2 months earlier, the separations plant had begun operation in December, and plutonium was being supplied to the Met Lab for studies there. With regard to liquid waste management, sophisticated process steps had been defined, release limits established, the importance of monitoring before (and after) release was understood, lines of authority had been drawn, and responsibilities for protection of the public health had been demarcated. The individuals who had stepped forward to establish the waste management procedures were prominent scientists, engineers, and medical professionals in positions of authority. On the basis of most accounts, this point was still months before waste materials were to be released to the ponds.

THE YEAR OF PRODUCTION

Background Values

At the Met Lab, Glenn Seaborg's journal notes for January 1, 1944, revealed his anticipation and excitement as the new year unfolded:

> The beginning of 1944 finds our Project deep in the problems of plutonium production, extraction, and purification. This vast involvement with a secret, synthetic element unheard of not much longer than two years ago and unseen until sixteen months ago in August 1942, would seem incredible to the outside world. Moreover, the means of producing plutonium in copious quantities—the chain-reacting pile—became operational just one year ago. I thought about these matters today when we received our first shipment of plutonium from Clinton Laboratories—1,500 micrograms! It equals almost the total amount of plutonium produced by all previous cyclotron bombardments. It is hard for me to remain nonchalant when I realize that before the end of February, production of plutonium will increase a thousandfold and gram quantities will then become available.[2]

The first burial ground for solid waste was established at Clinton (44-1-16). A brief memorandum from Cantril to R. B. Smith named a site on the south side of the creek for "disposal of actively contaminated broken glassware or materials not sufficiently clean to be used in other work." Responsibility for oversight of this is unclear (as opposed to the proactive position taken by Cantril for liquid wastes), and no reference to health and safety appears related to this disposal operation. Later correspondence from Greager (44-4-82) referred to "heavily contaminated materials" and the need to "make sure these [disposal] operations are carried out safely," but concern was with worker exposure rather than prevention of releases. Indeed, it was evident that little attention was devoted to solid wastes; it was several years before they began to receive much attention.

Fig. 9 (See page 192 for legend.)

Fig. 9 (Continued) (See page 192 for legend.)

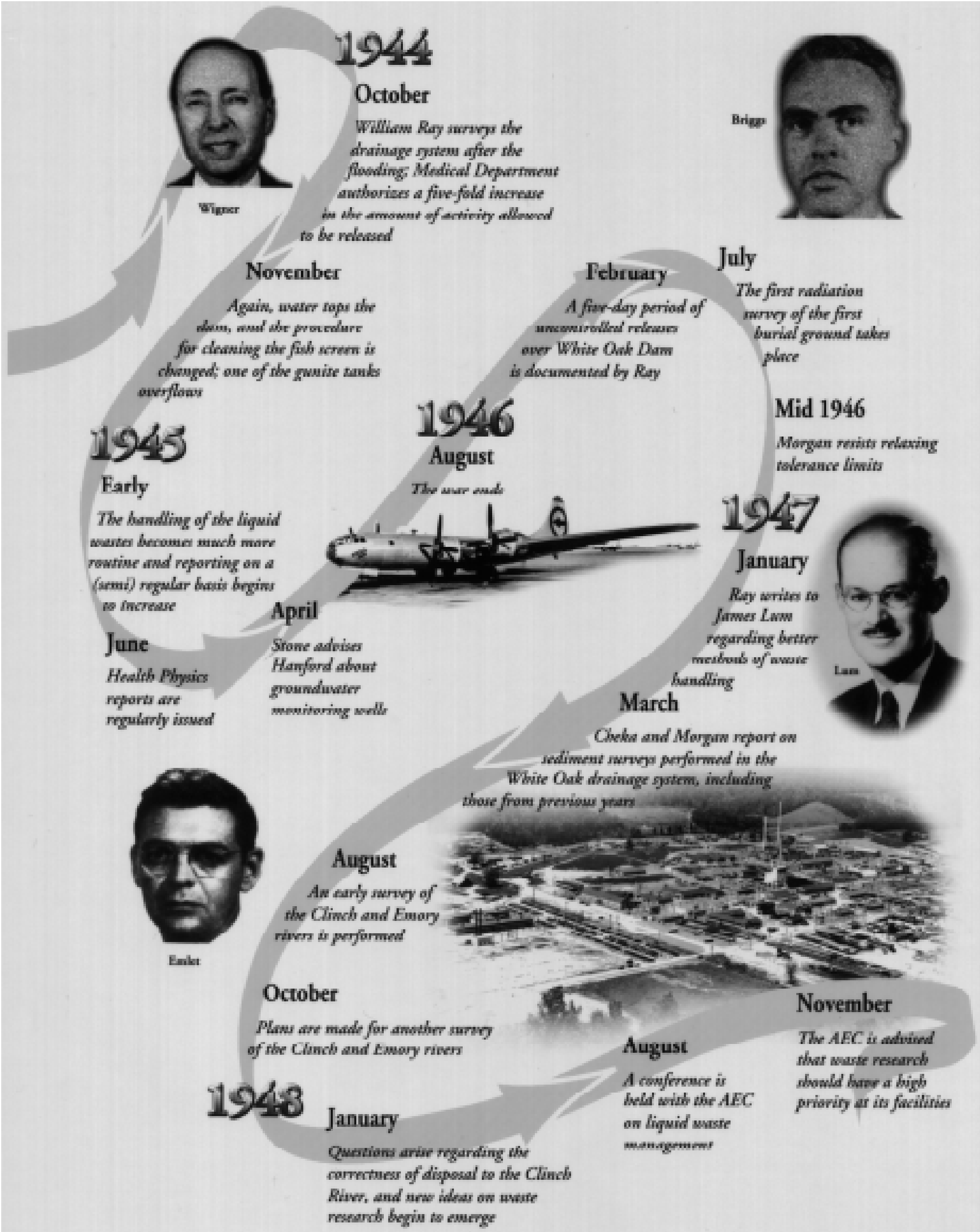

Fig. 9 Timeline depicting important dates related to the handling of liquid wastes at Clinton Laboratories.

Cantril, concerned about disposal of hot materials from the Chemistry Division (Building 706A), chastised Frank Vaughan, Assistant Superintendent for the 200 Area (gunite tanks), telling him that it was his (Vaughan's) responsibility to monitor disposals into the tanks and that he [and (Warren) Johnson] should have "some formal understanding of the waste problem from 706A" (44-1-22). A few months later, Cantril again expressed concern, this time to Doan, about 706A wastes, saying "the waste disposal . . . is inadequate and is eventually going to run us into trouble" (44-5-3).

Health physics by now had emerged as a recognized, yet infantile, profession. Clinton Labs had hired Karl Morgan as a health physicist and was hosting Herbert Parker, who was learning the profession before going to Hanford. In February, Morgan reported to Parker results of background studies in White Oak Lake (44-2-221), noting that "contamination of the water is extremely low and too low to detect with a counter which can determine contamination as low as 3% of tolerance." Parker and 15 others were being trained here as part of Hanford's health protection and instrumentation team. At Hanford, he headed all health physics activities and eventually was Manager of Hanford Laboratories; he was a colleague of Cantril's at the Swedish Hospital and was enticed by Cantril to join the Project in 1942. Morgan had worked on cosmic radiation in graduate school, joined the Met Lab, then came to Clinton Labs in 1943 and spent his career there. Both individuals are renowned for work in health physics.

Fission Products and Fish

Reducing the volume of waste, as well as lowering the activity, were objectives that occupied staff. George Boyd, a physical chemist, proposed research to reduce volume and to recover by-products, presumably for reuse (44-3-254). Boyd submitted his proposal to Warren Johnson, Chemistry Division Director. Both had left professorships at Chicago to join the Project. Johnson forwarded the proposal to Doan, asking for support, noting "the greater part of the [proposed] program has been completed" (44-3-222). Doan responded with a hand-written note criticizing Johnson for allowing work to be done prior to authorization. Johnson left when the War was over to return to Chicago, where he later became Emeritus Vice-President; he also served in many capacities for the AEC and was named as ORNL Director in 1947 but never assumed the position.

During this period, research on the uptake of fission products by fish began to emerge. Kenneth Cole, previously a biophysicist at Columbia University who had headed the Health Division at the Met Lab, wrote Stone regarding the "distribution of radio-active materials in fish." Stone answered, pointing out that most fission-product activity was in parts of the fish not consumed by humans and noting experiments under way in Washington State using salmon. Indeed, it was at this time that long-term research on uptake began at the Applied Fisheries Laboratory at the University of Washington and at Hanford.[3] Cole, often called the "father of biophysics," took a professorship at Chicago after the War.

Technology Transfer to Hanford

One reason for the existence of Clinton Labs was to serve as a pilot plant for Hanford, and there are many examples of this with regard to waste management. One involved a request from John Tilley of du Pont to Whitaker, in which he asked that Greager's group look into the use of caustic soda for neutralization of waste liquids to reduce waste volumes at Hanford (44-4-202). Richard Apple, a Group Leader in chemistry, also looked into the addition of NaOH and Na_2CO_3 for neutralization and volume reduction (through precipitation) of Hanford wastes (44-4-152). Previously, Marshall Acken had undertaken work on neutralization of Hanford's waste (43-12-457) and had made a recommendation termed by Lombard Squires (44-6-531 and 44-5-690) to "materially reduce the hazard of discharging the wastes into the ground" from Building 224 at Hanford. Squires indicated the effluent should be "tenaciously absorbed in the ground and would not migrate," and tests to confirm this were under way at Clinton. He further discussed radioactive precipitates in the stream at Clinton, speculating the same would occur at Hanford; these precipitates, once dried under arid Hanford conditions, would represent a "serious dust hazard" and "necessary design changes to overcome it should be made." Acken, Apple, and Squires, all chemists with du Pont, left Clinton Labs for Hanford late in 1944.

Precipitated Activity Precipitates Action

The precipitates Squires referred to had created quite a stir. Waverly Smith, a Section Head in the Technical Division who left after the War, described a series of events that are testimony to the attention to waste handling (44-4-47, 44-4-54, 44-5-101, and 44-9-54). Initial storage capacity for the underground tanks of 1 year was based on a lanthanum fluoride separations process; however, when the process was changed in June 1943 to the bismuth phosphate process, creating more waste, storage capacity was halved. Solids precipitation could reduce waste volume and restore capacity; research on this was initiated in early 1944. Discharge of the supernatant liquid without exceeding tolerance limits to the ponds at 25 000 gal/day and then to the creek started on March 6. Within days "it was observed that a precipitate was collecting in the ponds and that a large fraction of it washed into White Oak Creek." On March 16 and 17, creek sediment samples were quite hot; starting on March 18, additional lab tests with the use of calcium chloride were undertaken to precipitate additional activity in the tanks; starting on April 17, the precipitation steps were implemented and continued until April 27. This ceased on the 27th because a new creek survey on the 26th by Overstreet and Jacobson[4] showed "measurable activity at the mouth of the creek where it empties into the Clinch River," however, it was not known what the nuclides were or what the specific hazard might be. Immediately, discharges ceased, and plans were made for construction of the 1.6-million-gal settling basin. Later (June), after some knowledge of the specific nuclides was obtained, medical guidance established discharge limits of 1 to 5 Ci/day.

Work started at once on the basin; a group under the direction of Leverett was assigned responsibility to "be sure that no unusual conditions will arise which will result in unsatisfactory removal in the new settling basin of precipitated solids" (44-5-335). The basin was put into operation on July 3, but by the 8th, Leverett had written Doan indicating that the basin "is falling short by a factor of 3 to 5 of the desired and predicated decontamination" (44-7-167). Obviously agitated, he offered a number of suggestions, many of which had been offered earlier (for example, one related to dilution ratios because too much water flowed through the basin and settling did not occur; another dealt with weirs and baffling in the basin to improve mixing). Later in the month, William Kay documented responses to Leverett's suggestions (44-7-20), pointing out what could and could not be done; in a telling comment, he said "we proceeded with the basin in a manner that was certainly a compromise between ideal design and the necessity for getting the job done as quickly as necessary." Such words certainly applied to most everything done during those hectic months!

Monitoring on the Increase

In the spring of 1944, emphasis on monitoring and tracking effluents increased. A group under Apple was charged to determine the fate of certain radioactive elements "on the further dilution which will occur in White Oak Creek and Clinch River" and to "decide first if there really is any hazard in discharging the fraction of a curie per day and second what specific elements need to be removed" (44-5-335). Another example demonstrating high-level awareness was a letter from Whitaker to Joseph Hamilton at Berkeley advising him about progress on the settling basin, assuring him that there was "no reason for concern about the possibility that activity will seep through the wells of the basin," and reporting that they were "awaiting . . . results of fission assay . . . of materials found in the water discharged from our plant." Hamilton, with a distinguished career, was the medical advisor for the entire project, having been hired by Compton. In June, Cantril summarized data on mud samples taken from the holding ponds to the Clinch River (44-6-311), and a report by Eisenacher was issued (44-7-158) on samples from throughout the creek system. Curtis reported results of biological monitoring, noting contamination in fish from the lake as well as from the confluence of White Oak Creek and the river (44-6-271). More examples can be cited.

Use of a Noxious Agent

Attention on removal of as much activity as possible before release of the wastes continued, as did debate about the maximum number of curies to be released daily. Apple and Hamilton (44-7-68) addressed continued treatment of wastes with calcium chloride, the fact that much of the activity is "fixed on the clay, which should significantly reduce their [Sr, Te, Cs, and Ba] adsorption from the digestive tract," and a release rate of up to 1 Ci/day. Richard Apple left Clinton about this time to work at Hanford.

Parker, who also moved to Hanford at this time, issued a rambling report[5] presenting sophisticated discussion on beta–gamma counting, aspects of discharge, and exposure scenarios associated with wastes in the settling basin and the creek system and recommending a release rate of up to 5 Ci/day. He said that releasing activity to the river was better than trying to fence off a large area, and "the maximum waste discharge is therefore governed largely by security since an elaborate fence and patrol system outside the plant site might excite interest." Finally, he suggested a "noxious agent" be added to the water "to discourage drinking by pastured animals and swimming," but dilution in the Clinch would have to render the water "palatable." This report presents an interesting blend of sophisticated science with other less familiar (at least to Parker) aspects of environmental protection and waste management.

Oversight from the Health Division dominated the next several months with regard to disposal practices. Stone, in a letter to Walter Simon, Manager at Hanford, suggested that Overstreet and Jacobson (who did the creek survey at Clinton) be hired to conduct studies at Hanford because they "have been working with Dr. Hamilton on the metabolism of fission products" (44-7-319); Simon responded positively. Stone also alerted Hanford that gases from the separations plant at Clinton were not being adequately monitored, a fact that "carelessly escaped my attention," to make certain a similar situation did not arise there (44-5-439). He advised Argonne on a "special lined disposal pit" and said "burial in the ground is sufficient, provided the area will be marked off for a long time to come and fenced in" (44-7-336). At Clinton, the Health Division acquired responsibility for monitoring the 205 stack gases in September, 9 months after stepping forth to take the responsibility at White Oak dam (44-9-170).

Dam Releases

By September, Simeon Cantril had left Clinton to join his colleague, Herbert Parker, at Hanford; John Wirth took over the Medical Division. Wirth had to deal with unwanted overflow at White Oak dam because of very high rainfall and the fact that fish screens at the dam continued to clog up and thus cause the lake water to rise (44-9-893). In communication to Whitaker, he proposed changing some procedures set up the previous December for responsibility in controlling flow at the dam as well as more frequent cleaning of the screens. He carefully noted that, in spite of the overflow, "repeated water samples have never given a reading much above . . . drinking water" and that effluent from the plant area was monitored several times a day. Wirth continued to monitor the situation (44-10-320 and 44-11-375), eventually going to daily cleaning of the screens. After the flooding, William Ray issued a report (44-10-100) with detailed data on sediments and waters from the settling basin and creek system taken before, during, and after the flood. He stated, "no downstream health hazard resulted;" the report described the near loss of one side of the settling basin because of the rainfall and the fact that wastes had to be held in Building 205 because there was no place for them to go.

On the basis of medical guidance from Hamilton and Stone, the amount of activity allowed to be released from the settling basin to the creek increased in October (44-10-335 and 44-10-362); "the effluent water will not show an activity of more than 200 cts/cc/min" (previously the limit was 100), and if the "activity should rise to 400 cts/cc/min or above the waste discharge will be stopped immediately and the Health Department notified."

Later in the year, a gunite tank overflowed, described by Harrison Brown, Assistant Division Director in Chemistry (44-11-342). Brown, who assumed responsibility for the incident, estimated 90 gal was lost and cited "negligence on our part" and "poor instrumentation" as reasons for the incident. After the War, Brown left Clinton to work at the Institute for Nuclear Studies in Chicago.

By the end of 1944, great strides had been taken to manage safe disposal of the liquid waste at Clinton Labs. Full-scale production was achieved in the graphite reactor and the separations building, and considerable activity was occurring in the 706 area; therefore wastes were being generated rapidly. The attentiveness and responsiveness of individuals charged with managing "safe" disposal were reflected in actions throughout the year, and waste disposal was still under authority of the highest levels of management. Of course, by now the initial mission for Clinton Labs had been fulfilled, and uncertainty about the future emerged.

THE YEAR OF DESTRUCTION

If Hanford, Why not Clinton?

During the last months of 1944, and certainly in 1945, there was a marked change in communications related to liquid waste disposal at Clinton Labs. The learning curve had been steep for the first 8 or 9 months of 1944, but the frequency of problems and their associated documentation sharply decreased during the last months of 1944. A search of the Central Files data base affirmed this change. Handling of wastes had become somewhat routine, and more regular reporting on discharges at all points in the system became the norm in 1945. Staff began to look toward the future, speculating on what it held, and later in the year, memos reflect knowledge that the War was nearing an end.

Laboratory management made changes in off-site air monitoring. Wirth informed Whitaker (45-4-150) that "all the off area and the on area X-22 chambers for monitoring atmospheric radiation were discontinued [in March]," there were sufficient data for establishment of background, and the "expense of their upkeep" was such that use would be discontinued.

In April, Stone sent an interesting letter to Hamilton (45-4-293) after a visit to Hanford. He discussed disposal of Hanford wastes to tanks and noted "inactive" water was sufficient to dilute wastes that get into the ground to well within tolerance limits. He cited use of groundwater wells for monitoring and said information from these wells was "not likely to be put into practical use unless some unforeseen accident occurs." He called for a final report, saying these [monitoring well] studies need not be continued. The irony of this is obvious today, and it is curious that wells were installed at the arid Hanford site this early and not at Oak Ridge until 1950. Disposal of massive amounts of liquids to the ground at Hanford,[3] a practice not used at Oak Ridge until the 1950s, must have led them to see a need for monitoring. In contrast, solid waste burial grounds were not established at Hanford until 1945 (45-4-538).

Looking Toward the Future

Records indicate that Health Physics Section monthly reports, under Morgan, began to be published in mid-1945 (45-6-2), but their regularity at this early stage was sporadic. The majority of reports dealt with radiation exposure, clean-up of contaminated areas, etc., rather than with waste disposal. The June report, cited previously, stated, "a new burial ground has been opened east of the plant site. Initial observation indicates that it may become as messy and offer the same radiation problems as did the old one [burial ground 1] unless more careful planning is carried out." This referred to burial ground 2, on the hill across from what is today the 4500 complex. In the August monthly report (45-8-292), activity of water discharged from the settling basin was reviewed, noting "it had varied considerably during the past four months. It is seen, therefore, that the total radioactive discharge ranged between zero and ~14 Ci/day during this period. This activity was diluted before it left the settling basin with ~900,000 gal of water/day."

During 1944 and early 1945, amounts of radioactive wastes from the separations plant were very large. The production of plutonium slowed at Clinton Labs, however, and some disposal issues associated with Building 205 changed as the barium separations process was adopted early in 1945. Beecher Briggs, a Section Chief, wrote Leverett (45-6-70) offering suggestions on new procedures to more effectively handle wastes, especially those from Building 706-D, where the new process was put in place; he asked for a daily forecast of the amount of activity to be discharged. At about the same point, Wirth wrote Leverett (45-6-184) to explain differences in waste streams from the 200 area and the 706 buildings, explaining the need for procedural changes. Miles Leverett, a leader in waste activities, left Clinton Labs as the War ended and worked on nuclear energy for aircraft propulsion.

When it became clear that the War would end, staff began to look forward; for instance, Morgan wrote Stone on "problems confronting health physics if fission research and development continues" (45-6-105). He discussed 12 issues of concern to the health physics community, some of them related to waste management. He highlighted the need for work on airborne radioactive dusts and gases as well as the need for study of the topography, geology, soil surface, and weather history of disposal sites. This last suggestion was primarily in reference to solid waste, and it was about this time that records reflect the initial thinking for improved solid waste disposal.

Nevertheless, hazards associated with liquid waste were not ignored. Again Morgan wrote Stone on the "past and future health physics programs" (45-8-263). One activity he described is off-site monitoring "of discharged water and mud below the plant." He concluded, "In no case has the radioactivity level . . . reached a level that could be expected to cause any damage to man, animal, or plant," an early reference to environmental concerns.

Harrison Brown wrote Doan just before the War's end on the future of Clinton Labs, speculating that the Labs may continue "on a permanent basis" (45-7-305). He discussed issues related to retention of staff, research conditions, enhanced salaries, improved living conditions, etc. Issues related to waste disposal were not mentioned, and it was evident that thoughts were beginning to shift toward other directions now. Later in the decade, however, the need for enhanced research on waste surfaced again. Richard Doan joined the exodus of administrators and scientists leaving Clinton as the War ended; he became involved with reactor development at Idaho Falls and continued a very distinguished career.

AFTER THE END: ENHANCED AWARENESS

The Taking of Chances is Unwarranted!

Attention continued to be given to monitoring and regulating wastes at the War's end, but the absolute number of related documents diminished greatly. One report by Ray, Section Chief in Health Physics, dealt with "dumping of wastes of unusual activity" in January 1946 (46-2-277). Many factors (delayed analytical reports, inexperienced operators, and heavy rainfall) caused uncontrolled discharge of wastes into the lake for a 5-day period, overflow of the dam, and release to the river. Ray stated emphatically, "That this event was experienced without serious consequences should not lull us into complacency but should spur us to maintain increased vigilance toward preventing *any* such accident." He concluded that "the protection of the drinking water systems of the Tennessee and Mississippi river valleys can not be over emphasized for those responsible for their control. The taking of chances is unwarranted!"

Intolerance for Tolerance Changes

A series of requests was made to reestablish or alter tolerance levels for discharges to the creek and river [for instance, Morgan denied a request (46-5-446) to raise the tolerance level of water in the settling basin, made because the isotopes dominating the waste stream had shorter half-lives; he noted that, although this was true, they also had greater (biological) absorption]. In July, Wirth responded to Merlin Peterson (Leverett's replacement) regarding plutonium releases; the levels Peterson had proposed were within accepted limits, Wirth says, but he cautioned Peterson to look carefully at gross beta–gamma activity to make certain it did not exceed tolerance. Peterson proposed changing the point of measurement for tolerance limits from the exit of the settling basin to the "exit of the creek enclosure" (dam) (46-7-272), but this was not done.

Attention to the burial ground began to emerge. The first radiological survey of the original burial ground was conducted in July 1946 (46-8-78); seven samples of soil were taken for alpha determination, and very low levels were found in some. It was recommended that the site be seeded and marked "with permanent monuments to guard against excavation or defacing which would promote erosion."

It Has Served Its Purpose Well

Early in 1947, Ray wrote the new Laboratory Director, James Lum, about future waste disposal at the Lab. Martin Whitaker, a leading advocate for proper disposal since the inception of the facility, had left to assume the presidency of Lehigh University, and Lum and Wigner served as codirectors. Ray said that, because the "pressure of war . . . has relaxed," wastes should be handled "in a more ideal fashion" (47-1-163). He proposed either continuation of discharges with proper dilution, counting on the fact that nuclides would not be reconcentrated by some "natural phenomenon," or removal of all radioactivity from effluents and storage "forever."

During 1947 and 1948, a number of studies were directed at assessing the effectiveness of the White Oak Creek system for retention of nuclides and releases into the river, including review of all earlier such studies; these were done by Joseph Cheka, Karl Morgan, Thomas Burnett, and Lloyd Setter. Space does not permit individual reviews of these, but the attention directed at comparison of analytical techniques, quantitative analysis of the distribution of activity within the drainage system, the ability of the system to retain nuclides, engineering recommendations to enhance retention, cognizance of the importance of continued surveys, etc., demonstrated a keen awareness of the need for proper disposal and monitoring. Cheka and Morgan concluded that the White Oak Creek basin "has served its purpose well," but Setter later pointed out the significant loss of activity during flood stages.

The Atomic Energy Commission Arrives

In January 1947, the Atomic Energy Commission (AEC), which had universal authority over all aspects of nuclear materials production, regulation, etc., was formed. There was increasing interaction with the AEC on waste disposal issues. At Clinton, routine periodic reports were issued for the first time in 1947 on discharges from the settling basin and lake, although this information had been documented in less regular fashion previously. A series of (semi) regular reports on air monitoring were written, in which monitoring results, meteorological data, instrumentation needs, etc., were discussed. Monthly Health Physics Department reports, requested by the AEC, were more detailed, up to 10 pages long, and contained information on many issues beyond wastes. An increasing trend in allowable discharge limits can be seen. Recall the earlier discussion of the increase from 200 to 400 cts/cc/min; the October Health Physics report said that "discharge[s] . . . exceeding 500 c/m/ml are permitted only with the permission of the Health Physics Department." By then, the limit had increased to 500, but the record of this decision process is yet incomplete.

Further review of the monthly reports reveals an evolution of activities leading to increased characterization of waste-related contamination. Another survey of Clinch and Emory Rivers was planned for October (following such a recommendation in August) in collaboration with K-25; for November, construction work "to prevent further contamination of the environment" (early use of the word), sampling of rivers, and burial ground surveys were discussed. The 1948 reports have regular sections on Clinch River studies, nuclide sorption research, discharge studies at the dam, planned ecological work in the creek system, and development of field instrumentation. More references to burial grounds appeared, and core drilling for subsurface characterization was presented; hiring a geology professor from The University of Tennessee to "throw light on the underground flow of water" around burial grounds was noted.

Laboratory management was conscientiously attempting to dispose of certain wastes (barrels of dissolved uranium, uranium slugs, plutonium, etc.), as shown by a series of internal letters as well as letters to the AEC. Since October 1946, the Lab had sought approval for disposal, but such had not been obtained, even as late as November 1947, well after the AEC had been formed. Obvious frustration appears in these communications; for instance, one letter from Logan Emlet, who had supervised construction of the graphite reactor, questioned the efficacy of the AEC using the laboratory for waste disposal from other facilities, saying "if it is decided that we take care of all projects garbage, I should like to make a thorough study of the problems involved and forward the comments to you on what additional facilities would be necessary." AEC responses have not yet been found.

Unless We Get Your Support and Interest . . .

The earliest reference to organized research directed at waste issues surfaces in 1948; before then, there had been "research," as we have seen, but no formal or organized program existed. As the Health Physics Division grew, enhanced research was evident on nuclide behavior in biota, mineral surface reactions with nuclides, etc. The scientific thinking that underlay some activities was reflected in a memo by Burnett describing a dead wildfowl found near the dam. The bird was highly contaminated and, as Burnett noted, represented a concentration—rather than dispersal—of radionuclides, leading to a potentially dangerous situation if carried up the food chain. He proposed examination of alternate waste management practices and said that they "will begin pilot experimental studies at once of possible improvement" (48-1-368). In another document (48-1-369), Burnett proposed a series of "waste disposal research problems" for liquid and gaseous wastes directed at removal of nuclides, appropriate dilution of them, and new measurement technologies.

In June 1948, the AEC formed a committee on liquid process waste disposal and charged it with making recommendations for improvement of disposal practices across the AEC complex and with determining relevant research needs (48-10-343).[6,7] Upon visiting ORNL, the committee heard presentations from technical staff and managers. Morgan told them that in 1947 a group of scientists from the Tennessee Valley Authority (TVA), the Public Health Service, the U.S. Weather Bureau, Vanderbilt University, and the University of Tennessee met to begin study of disposal problems; he noted the need for geologic studies of the burial grounds and the presence of geologic faults nearby. He almost apologized for the waste disposal system, noting that it was inadequate because it had been constructed during the War, and he offered a prophetic statement: "It will be some time before we have all the answers to our problems of waste disposal." Forrest Western, questioning the wisdom of "continued dumping of significant quantities of waste into the river" acknowledged "inadequate information [for] a good evaluation of the hazards." He then made a strong pitch for "extensive, systematic study of the behavior of radioactive materials" in the environment and pointed out benefits of using Oak Ridge "in obtaining answers to many of our questions." The minutes indicated a plaintive comment, obviously directed at the AEC committee: "unless we get your support and interest we cannot make further investigations along the lines outlined above." Obviously, ORNL was seeking research funding.

The committee report, issued in 1949, acknowledged the need to keep radioactive discharges low so that they do “no harm to the community of plants, animals and men;” discharge standards “are believed satisfactory from the public health standpoint.” Air emissions at ORNL from the separations plant and the reactor were only a tiny fraction of the natural radioactivity in the air, which was 10 to 100 times that added, the report said. Likewise, the level of radioactivity added to the Clinch River, “about 1/1000 microcurie per gallon,” was much lower than that in popular mineral waters consumed throughout the country. The report concluded with recommendations, the most sweeping of which was: “A long range R&D program in liquid waste disposal should be established and given a higher priority since waste disposal is a limiting factor in the full development of the atomic energy program.” Interestingly, an interim version of this report (48-11-310) contained perhaps more insightful observations and recommendations, such as the fact that research on waste issues was generally less attractive than “fundamental research;” contractors often did the minimum necessary, and their solutions to problems were often temporary, local, and potentially hazardous; waste disposal had been of very low priority; and “management has failed to recognize the problem of waste disposal.” These and other comments never made it into the final report and do not necessarily reflect conditions at Oak Ridge.

In November 1948, the Health Physics Division report reflected new initiatives in waste-related research “preparatory to a Commission-wide research program on Liquid Waste Disposal” (48-11-297). The summary outline of the program (48-11-193) included identification of projects, descriptions, applicability, time for completion, facilities required, available personnel, and budgets for fiscal years 1948 and 1949; most projects dealt with chemical studies of wastes.

Thus, toward the end of the decade there was still awareness on the part of the AEC and its contractors of the need for waste-related research. What remains to be done is a further examination of what actually was implemented across the AEC complex as the Cold War heated up and attentions were directed at accelerated weapons development.

ISSUES OF RELATIVITY

The history described in this article is much more than an anecdote of ephemeral interest—it has relevance as much more than a simple footnote to the Manhattan Project. The documents discussed reveal a remarkable degree of integrity displayed by those who were leaders in Clinton Laboratories and waste management at the time operating under extreme conditions. Placing those early disposal practices in perspective should help us understand the care and dedication those early leaders exhibited. This level of care may not come as a surprise to some, but to most it will. Long overdue and generally posthumous acknowledgment and recognition are deserved, not only for obvious personal interest and reward but also for scientific and medical documentation of what occurred.

In no way does the revelation that commendable disposal practices were exercised over five decades ago diminish the fact that large amounts of contaminants were released to the environment. These observations neither remove 1 Ci of activity from the list of those generated and released nor diminish in any way the technical and fiscal challenges we face today in the world of environmental restoration as we apply standards of the 1990s to practices of the 1940s. One social challenge faced today, however, deals with public perception, fostering understanding, and acceptance of historical ways in which wastes were handled. Without doubt, the prevailing opinion is that wastes of all kinds—and perhaps especially the liquids—were handled carelessly. The present U.S. Department of Energy, a successor to the AEC (which, of course, did not even exist during the War), is continually facing criticism and scrutiny for real—as well as perceived—historical mistakes. Perhaps information of the type contained in this study can help frame a slightly mollified and more receptive reaction on the part of those who are critical.

The fact that conscientious decisions were made in the disposal of wastes in the 1940s, as documented herein, should not lead one to believe that the *entirety* of activities directed toward disposal was commendable. Without doubt, conscious—and perhaps deliberate—steps were taken to dispose of materials in an unauthorized fashion, and there certainly were accidents, totally undocumented, when materials were inadvertently released. Because of the lack of documentation, the records fail to reveal much of this; documented incidents that were found have been presented. Additional records deal with laboratory contamination and issues of personnel exposure, but such have not been the focus of this study.

Actions from 50 years ago must be evaluated in light of what was known then and in relationship to what the practices of the time were. It is in this perspective, perhaps, that the greatest admiration is deserved. Although probably not fully recognized then, the waste materials generated at Clinton Labs can be said to have represented the greatest disposal challenges within the entire Manhattan Project. True, much greater amounts were generated at Hanford, but the toxic mixture of fission products, uranium, plutonium, transplutonium elements, nitrate, and hazardous metals in mobile liquid form at a location with rainfall and surface water for drinking—coupled with nearby population centers—certainly elevated the risk at Clinton. Facets of this are woven throughout the historical documents. Remember, also, that Clinton Labs was originally expected to operate for about 1 year, and the tanks were so designed. When separation processes changed and when the facility operated for extended times, these factors obviously stressed waste management plans accordingly. During the 1940s, little was known about the health effects of nuclides—especially their environmental behavior—and inhalation and ingestion were deemed to be the exposure scenarios; hazards from chronic exposure to radiation were not well recognized. Finally, instrumentation was primitive; gross beta and gamma (and alpha) counts could be obtained, but specific knowledge of the pertinent nuclide was either impossible to get or occurred weeks after a sampling. To blindly apply present standards to past practices is not only improper but it also is misleading and reflects ignorance of the facts.

Today, the thought of releasing 1 or 2 Ci of activity—much less 5!—per day into the creek and river system is an unpardonable sin. Yet the release limit was carefully calculated, monitored, and accepted 50 years ago. Medical knowledge deemed this to be an acceptable release scenario based on the dilution that would occur in the river and on scant information related to biological uptake of radionuclides. It was readily acknowledged that adequate information was unavailable to completely assess dangers, but conservative thinking was applied to arrive at this release limit; those who set this limit cannot be faulted for lack of knowledge or for misdirected intent. It almost goes without saying that the other contaminants with which we concern ourselves today (metals, nitrates, and organic compounds) were largely not even recognized as dangerous then. Really, the only one that was monitored at all was lead, a known toxicant. Interwoven throughout this story is the fact that concern was strictly for human health and not for environmental impact at first, although environmental systems (fish) were used to measure the extent of contamination.

Throughout this article passing reference has been made to attention given to the disposal of contaminated solid waste, with recognition that its treatment was much less insightful than that for liquid wastes. In light of the facts that liquid wastes were obviously much more contaminated, were in a mobile form, and that burial of solid wastes of all sorts below ground surface was standard practice everywhere, it is not surprising that this distinction occurred. During the 1940s, little was known about groundwater and its potential for transporting contaminants; indeed, in technical literature for groundwater hydrology, scant reference occurs to groundwater systems at this time, much less to contamination thereof. Even though knowledge of groundwater systems was also important for proper management of liquid waste, recognized at ORNL in the 1950s, note that groundwater is not mentioned at all in health and safety considerations for Clinton liquid wastes during the 1940s; its importance to the burial grounds was noted before its relevance to liquid wastes was realized. Indeed, knowledge of subsurface hydrologic systems and their importance simply did not exist then. It is incorrect to criticize this "oversight" today.

One might legitimately raise the question, however, that if things were done so conscientiously then and done by individuals of high professional caliber, such as we have discussed, then why are we today faced with such great costs to rectify their actions, and why do we automatically presume things were done carelessly 50 years ago? The answer to the first part is simple. Our knowledge base today is orders of magnitude greater than it was then, and we much more fully understand parameters controlling contaminant movement in the environment as well as potential dangers associated with contaminants of all kinds, not just the radionuclides. Add to this the directly relevant fact that standards have changed drastically over the years, and clearly the situation we face today is a result of our own genius and creativity, the product of the natural evolution of scientific endeavors. Why the presumption of guilt? Perhaps because almost all those pioneers who led the way during the War left shortly thereafter, and there was simply less attention directed at waste disposal challenges, many of which were perceived to have been addressed. Attrition of staff and new directions of programs quickly took their toll, and no written history was left behind. In the absence of a record, recent revelations related to cleaning up the "sins" of the past—revelations by individuals with no first-hand knowledge of what transpired 50 years ago—automatically spawn the thinking that waste disposal must have been done incorrectly if it is such a problem today. Obviously, this leads one to ponder what we may be doing "correctly" today that will provide a costly or dangerous legacy for our descendants.

Weinberg[7] addresses this historic issue of waste disposal, reflecting that standards have changed and pointing out that there should have been more scientific attention given to waste disposal challenges in the early years. In principle and in hindsight, it is difficult to disagree; however, it is even harder to envision exactly how a more structured waste disposal research effort might have been mounted during the War years in light of the urgency of the time and recalling the simple fact that the detrimental environmental impact of radionuclides was poorly understood. After the War, certain staff at ORNL (and elsewhere) did, indeed, strive to develop a more formal research program to address this issue, but exactly what level of active support and leadership was received from the AEC is unclear.

THE FACTS SPEAK: A CONCLUDING STATEMENT

Certainly the perception that liquid wastes were handled in a haphazard or careless fashion during the earliest years of existence of Clinton Laboratories cannot be substantiated on the basis of material presented in this analysis. In fact, the evidence is irrefutable that the highest level of professional concern was devoted to proper disposal of wastes on the basis of knowledge at the time and considering the wartime environment in which all had to operate. These facts should speak for themselves.

Essentially all aspects of the waste disposal challenges faced today were effectively handled during the War. Problem areas were identified, and research was proposed to address the problems; waste minimization and treatment, establishment of release limits, and monitoring were all evident. Establishment of authority, policing, and castigation were demonstrated in a highly responsive way.

The individuals responsible for management of the wastes were not lightweights. Many had been recruited because of their expertise to work at the University of Chicago Met Lab and to later transfer to Clinton Laboratories. Here they were in positions of authority and responsibility, as were others who arrived via alternate routes. After the War ended, most left, and many took prestigious positions elsewhere, whereas a few continued their professional careers at Oak Ridge to make contributions to the nuclear sciences. In retrospect, it can be said that Clinton Laboratories—and today ORNL—immeasurably benefited from the professional integrity that had been instilled in these leaders; if they had had a mentality oriented toward pure production, the environmental insults could have been much greater, and we could today be facing an ever greater restoration challenge.

The nexus between intent and action has been shown for any number of incidents, although many still deserve more investigation. The realization of this waste disposal effort can be appreciated only by viewing the entirety of the evidence, including the day-to-day actions, rather than considering individual pieces of documentation. No single document has been found that serves as the "Rosetta Stone," alone unlocking the thoughts and actions of the times. A full and complete review of the ORNL Central Files archives plus interviews with individuals personally knowledgeable of the practices at the time would be desirable to complete the history. Perhaps this can be accomplished in the future.

Regardless, the attitudes and achievements of those scientists, engineers, and medical professionals mentioned in this study are deserving of high recognition and acknowledgment. Their integrity and foresight, although perhaps not as visible as that of their counterparts who actually pioneered, designed, and produced the nuclear weapons to end the War, can be viewed to be of equal importance as we look back five decades.

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