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HEALTH PHYSICS DIVISION

QUARTERLY PROGRESS REPORT

FOR PERIOD ENDING APRIL 20, 1951

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HEALTH PHYSICS DIVISION

K. Z. Morgan, Director
F. Western, Associate Director

QUARTERLY PROGRESS REPORT
for Period Ending April 20, 1951

Date Issued: MAY 31 1951

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ORNL-596	Period Ending January 15, 1950
ORNL-695	Period Ending April 15, 1950
ORNL-786	Period Ending July 15, 1950
ORNL-877	Period Ending October 20, 1950
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1. INSTRUMENT DEVELOPMENT

Constant Water Monitor. A production design of a constant water monitor has been completed and reduced to drawings, Nos. D-9029 through D-9035, which are on file in the Engineering and Maintenance Division. The drawings describe a continuous-flow water cell of 4 liters/min capacity, a 40-Kev beta-sensitive Geiger-Mueller counter, lead shielding, and control panel. The normal background count rate is about 7 c/m, and water of about 2×10^{-6} μc/ml of Sr^{90} activity is detectable by an approximately 50% increase of the background counting rate.

An operating model has been constructed and assembled. It is now monitoring the drinking water supply in room 100, and is under observation for possible faults. The present method of recording the count rate uses a scale of 2 and a traffic counter to print 15-min count integrations, totalizing and recycling every hour.

The production design is being considered (by Chemical Technology Division) for application to some waste-water monitoring problems on and off the area.

We have been informed by the Patent Office that a patent search discloses no similar art; an application will be made for a U. S. patent covering the features embodied in the water cell and counter assembly.

A preliminary report is to be written, for purposes of record and discussion, as to feasibility of continued effort.

2. RADIOACTIVE-WASTE-DISPOSAL RESEARCH

Further progress has been made toward expansion of the cooperative program of research on water and liquid-waste decontamination, particularly through increased participation by the Public Health Service. One additional sanitary engineer has been assigned on loan for an indefinite period for work in the waste research program. A detailed plan and budget for further increases of Public Health Service personnel assigned to this project during the next fiscal year have been prepared and are being considered for approval and authorization.

Construction of the Health Physics Waste Research Building, mentioned in the previous quarterly report (ORNL-968), is proceeding on schedule, and procurement of laboratory and experimental equipment for this building has begun. Facilities necessary to meet immediate needs for additional work space and equipment are being provided on a site near White Oak Creek east of the settling basin. These include a prefabricated building, a raw-water intake on White Oak Creek, re-erection of a 35,000-gal wooden tank salvaged from the former X-10 water plant building, pipes and connections for disposal of test materials, and arrangements for access to this site from the exclusion area.

Various members of the Waste Disposal Research Group have continued to spend considerable time and effort in assisting in education and training activities and in making available information regarding methods of water decontamination and liquid-waste control. For example, a group of seven municipal and state water works and public health officials from Missouri, Indiana, and the City of Detroit visited the Laboratory for two days to discuss specific questions pertaining to potential radioactive contamination and methods of emergency protection of large water supply systems. Under present plans it is expected that two professors of sanitary engineering and two graduate students will join the group early this summer for extended periods of work and training experience. Other activities in this category have included four lectures as part of water and sewage works short courses, a lecture to a student engineering society, participation in a two-day conference on sanitary engineering training, including qualifications for work in the atomic energy field, and preparation of replies to numerous inquiries concerning the results of the ORNL studies on radioactive-waste-disposal problems and techniques.

Water and Liquid-Waste Decontamination Processes. Active work has been continued in studies of the removal of radioactive materials by water treatment procedures. An extensive series of jar-test coagulation experiments designed to show the factorial interaction of four variable conditions has been completed. The radioactive test material was a mixture of radioisotopes which might be found in a water supply soon after an atomic explosion. The variables tested were: *p*H, turbidity (clay), coagulant dosage (alum), and level of radioactivity. In the experiments three values of each of the above variables were represented. Removals of radioactivity were in the range of 50 to 60%.

A series of studies on adsorption has been begun and is still in progress. In water contaminated with a storage-tank waste (evaporator concentrate) at least ten adsorbents are being tested, including montmorillonitic clays, tannins, and lignins. These experiments on a jar-test scale indicate removals of 10 to 50% of the radioactive contaminants.

A series of jar-test coagulation experiments to determine removals of yttrium, cerium, and iodine, singly and in combination, with variations of *p*H and turbidity has been completed. Under the best conditions, the removals of yttrium and cerium in a mixture and also individually ranged up to 98% while removals of iodine were about 77%.

Pursuant to an inquiry and request from the Engineering and Maintenance Division, sanitary engineers of the Waste Disposal Research Group are cooperating in a study to evaluate the efficiency of operation of the new ORNL sewage treatment plant, particularly in the removal of suspended solids. Changes in the routine of pump operation are being made to obtain better equalization of the flow of raw sewage to the treatment plant, after which a program of sampling and analytical determinations will be carried out.

Further studies have been made on the methods for emergency decontamination of drinking water. Experimental work has been completed for the evaluation of the small water-decontamination unit, mentioned in a previous report (ORNL-968), and a descriptive report of this unit and of the results obtained with it has been completed for publication in May. Also, some work has been done on the evaluation of a small commercial mixed-resin ion-exchange water-treatment unit of the type recommended for deionization of small quantities of water for laboratory use. The purpose is to appraise the operating characteristics of such a unit as well as performance of the materials it contains.

Survey Studies and Ecological Study of White Oak Creek Drainage System. The following studies have been made during the past quarter:

1. A determination of the time of water travel through White Oak Creek and Lake, using fluorescein dye, was made at the time that the rate of flow in the creek was about 7 cfs and the lake level was approximately 3 ft below the elevation of the spillway. It was found that under these conditions dye applied to the head of the lake first reached the dam in 29 hr and that the first peak moved through the lake and arrived at the dam in about 36 hr after dosage. A second peak somewhat higher than the first arrived on the fourth day and it was estimated that the mean time of travel or period of retention in the lake was approximately six days. Arrival at the dam of the fastest moving water particle in 29 hr indicates a minimum displacement of only 13% of the six million cubic feet of water contained in the lake at this water level. No stratification of flow in the lake was observed.

   A second determination of the time of water travel through the creek and lake has been made at a higher rate of flow in the stream and at a higher elevation of the lake, again without stratification. The results of the determination have not been reported.

2. The fish population study for the spring of 1951 is due to be completed on April 25. Preliminary estimates of the fish population indicate a decrease in numbers of about 25% from the estimate of last fall. This is considered within the natural range of winter mortalities in fish populations.

3. The botanist has completed the collection of several hundred sheets of plant specimens for definition of flora during the early spring period, and identification of specimens collected last fall has been practically completed subject only to checking and verification. Some absences of species of flora expected in this region have been noted but have not been explained.

4. In the limnological study increased time has been devoted to the collection of bottom organisms. These and other aquatic specimens showed normal changes during the winter season.

5. Physical and chemical studies have included completion of the silt survey of White Oak Lake, continued biweekly sampling of water at various points in the lake, and collection of a monthly sample for mineral analysis at the upper and lower end of the lake.

An analysis of the data on the discharge of radioactivity from White Oak Lake and diluting flows in the Clinch River during the past several years was prepared and presented at the meeting of the AEC Waste Processing Committee

at ORNL on February 5 and 6. Available data from past surveys of the Clinch River are being collected to aid in the preparation by the Tennessee Valley Authority of a comprehensive report on conditions in the entire Tennessee River Basin. This report deals principally with domestic sewage and other water pollutants, but any available information concerning radioactive contaminants was requested.

Preliminary laboratory experiments to determine the various factors that affect the uptake of radioactivity in small fish were carried out in tap water to which was added Cs^{137}. An extensive factorial series of further experiments to aid in evaluating the significance of five variable factors at three levels of radioactivity has been designed with assistance from the ORNL Mathematics Panel.

Well-logging measurements to determine and record the levels of gross radioactivity in the test wells installed in connection with the Geological Survey of the Laboratory area have been continued. To date a total of 80 records on 40 wells have been completed. An improved design of the cable reel apparatus is being used and two new reel outfits are being constructed. A summary report of well-logging data obtained up to March was prepared and furnished to the geologists together with tables, interpretations, and suggestions for further work. It was suggested that to aid in defining the subsurface background of radioactivity and in interpreting the well-logging data, two additional test wells should be drilled in an uncontaminated area of approximately the same geological formation that prevails where the 51 test wells have been installed for study of the X-10 site.

Instrumentation and Techniques. For use by the Health Physics Division and particularly in the development of instruments for waste-disposal research, a dry box has been completed for grinding and polishing sodium iodide crystals for scintillation-counter construction. An electric power grinder for grinding small crystals has been designed and is to be constructed.

Preliminary work has been done to explore the feasibility of measuring the concentration of fluoroescein dye as used in time-of-water-travel studies by means of photoelectric methods.

A detection and recording assembly has been completed and is being used in connection with continuous-flow ion-exchange experiments. The purpose is to detect residual contamination if present in the ion-exchange resins as received and also to measure radioactivity in the effluent during the experiments.

In response to requests for information from water works officials and sanitary engineers, two Landsverk analysis units have been repaired and tested. Further experiments will be made to determine the sensitivity and suitability of these units for the measurement of radioactivity in water supplies in the event of accidental or emergency contamination.

In preparation for the equipment and use of the Waste Research Building when completed, considerable time has been spent in the selection and preparation of procurement data for control instruments and equipment which will be needed in laboratory and pilot plant experimental studies.

Publications. The following is a list of reports which have been published during the past quarter:

1. *Studies on the Removal of Radioisotopes from Liquid Wastes by Coagulation,* R. A. Lauderdale, Jr., ORNL-932 (Jan. 23, 1951).
2. "Observation on the Removal of Radioactive Materials from Waste Solutions," Conrad P. Straub, *Sewage and Industrial Wastes* **23**, No. 2, pp. 188-193 (February, 1951).
3. "Problems in Disposal of Radioactive Wastes," Conrad P. Straub, *Wastes Engineering* **22**, No. 2, pp. 70-71 (February, 1951).

3. THEORETICAL PHYSICS

Fast-Neutron Tolerance Calculations. Collision densities and energy losses from a 10-Mev beam of neutrons normally incident on a 30-cm slab of tissue have been obtained by a Monte Carlo procedure. A preliminary report summarizing the data, together with the resulting tolerance determination, is being prepared. The neutron histories obtained for the 10-Mev beam are now being analyzed to obtain the energy losses of beams of lower initial energies.

Empirical Evaluation of an Effective Atomic Number. A report on the determination and use of an effective atomic number for compounds is being written. It is found that while the gamma-ray mass absorption coefficient can, in general, be determined to within 10% by the use of such formulas for the range $6 \leq Z \leq 20$ and for 0.01 Mev $\leq E \leq 0.25$ Mev, the error in some few cases may be as much as 20%.

Radiation Damage Due to Electronic and Nuclear Collisions in Tissue. The problem consists in evaluating energy losses due to fast-neutron radiation. The electronic and nuclear stopping powers of recoil ions of H, C, N, and O have been evaluated, using Bohr's formula [*Phys. Rev.* **59**, 271 (1941)]. The electronic stopping power as calculated does not agree with some experimental values, and therefore a semiempirical approach is used as suggested by Knipp and Teller [*Phys. Rev.* **59**, 658 (1941)].

Stopping Power of Protons, Alpha Particles, and Ions of Carbon and Oxygen in Tissue. In the projects discussed above we are concerned with the relative damage due to electronic vs. nuclear collisions for slow ions released by a fast-neutron stream. In this project we calculate the losses due to electronic collisions only, over an extended range of energies including those for which the nuclear collision losses are negligible. The method used is based on results of Hirschfelder and Magee [*Phys. Rev.* **73**, 207 (1948)] and Knipp and Teller [*Phys. Rev.* **59**, 658 (1941)].

4. PHYSICS OF NUCLEAR RADIATIONS

Measurements of Neutron Dosage. Work this quarter consisted mainly of further investigation of the practicability of monitoring exposure to fast neutrons against a gamma background by means of the difference in the responses of pocket chambers with walls of hydrogenous and nonhydrogenous materials. The responses of pocket chambers of various materials and dimensions were studied, using polonium-beryllium and polonium-boron neutron sources. The polonium-beryllium source has an energy spectrum averaging approximately 4.5 Mev with a maximum of about 11 Mev, while the polonium-boron source has an average of approximately 2.5 Mev with a maximum of about 6 Mev.

Materials used included polyethylene, carbon, and aluminum. The inside diameters of the chambers varied from 0.68 to 1.76 cm. Electrodes used in the smaller chambers were of aluminum, 0.16 cm (1/16 in.) in diameter, while electrodes used in the larger chambers were of various materials and ranged upward to 1.12 cm in diameter. The purpose of these variations in size was to change the surface-to-volume ratio; other consequences were changes in collecting volume and in capacitance.

In order to have a basis of comparison, the response of each chamber to a neutron source is expressed by giving the number of milliroentgens of radium gamma radiation required to give a response equivalent to that observed from an exposure of 10^7 neutrons/cm^2 from the source.

The best neutron responses occurred with polyethylene walls and electrodes and were approximately 55 mr equivalents per 10^7 Po-Be neutrons/cm^2 and approximately 43 mr equivalents per 10^7 Po-B neutrons/cm^2. This ratio of approximately 1.3 for the two energy spectra appeared in all chambers with organic walls. Aluminum walls and electrodes showed neutron responses of 17 to 20 mr equivalents per 10^7 Po-Be neutrons/cm^2 and approximately 11 mr equivalents per 10^7 Po-B neutrons/cm^2. The ratio of responses ranged between 1.58 and 1.77. Graphite wall and electrode gave 22.7 mr equivalents per 10^7 Po-Be neutrons/cm^2 and a ratio of 1.83.

It is thought that the responses of the hydrogen-free meters under the conditions of these experiments are not entirely due to gamma radiation. The fraction of the response which may be ascribed to neutron irradiation of the meters is under investigation.

The pocket meters described above are read by observing the position of an electrometer filament. Another construction underway uses the capacitance change of a leaf electrometer when discharged by radiation. This meter is inserted in a high-frequency circuit where the capacitance variation produces a frequency variation measured against a crystal-controlled frequency standard. This method may become very sensitive, since small fractions of 1 $\mu\mu$f can cause a frequency change of several kilocycles. This construction is still in the initial stage.

Beta Particles. Absorption measurements were completed with collimation for P^{32}, Sr^{90}, and S^{35}, using absorbers of varying thicknesses and atom numbers from 4 to 82. Organic substances and wet tissues were investigated particularly. The extrapolation chamber and Geiger counter were used for these measurements to obtain the attenuation by energy absorption (chamber) as well as the reduction of number of particles (counter).

In addition, the attenuation by air was investigated with the counter up to 500 cm (P^{32}, S^{90}) distance between source and detector.

Particle Problems. Facilities for radioactive particles technology are under construction in Building 2001. Their completion is anticipated during the next quarter. The laboratory will be under positive pressure with incoming and outgoing air carefully filtered to make it as dustproof as possible. Micromanipulators, a microforge, and thermal precipitators have been acquired, and a Leitz "Panphot" photomicrographic apparatus with necessary accessories is on order.

During this quarter a technique for the measurement of particles down to 0.006 μ (60 A) in diameter has been investigated with good preliminary results. Measurements in the range of 0.003 to 0.006 μ are somewhat questionable, and measurements below 0.003 μ do not seem feasible with the equipment presently available. A size analysis of particles penetrating CWS No. 6 filter paper shows that the greatest penetration does not occur with particles of 0.3 μ. Using a group of influent particles ranging from 0.01 to 2.8 μ with a medium size of 0.13 μ, it was observed that the size giving maximum penetration lies below 0.02 μ. Below 0.01 μ the discrimination between particles and background becomes difficult.

Publications. The following are reports which have been published by this section during the past quarter:

1. *Construction and Operation of a Variable Pressure Extrapolation Chamber,* T. E. Bortner, ORNL-905 (Mar. 19, 1951).

2. *Dose Rates of Radiation from Thorium and from Enriched Uranium,* T. E. Bortner and H. K. Richards, ORNL-761 (Apr. 9, 1951).

5. RADIOCHEMICAL ANALYSIS

Analytical Procedure for Analysis of Urine for Uranium. Preliminary work has been done on the development of a better procedure for the analysis of urine for uranium. For the determination of uranium isotopes with short half-lives at levels of urinary excretion which are considered safe, it is necessary to measure the alpha activity of the sample rather than depending upon fluorometric analysis.

The *Health Physics Division Quarterly Report for Period Ending February 28, 1949* (ORNL-346) described a method for isotopic determination of uranium in urine. However, the procedure is long and time-consuming. The primary objective in seeking a new analytical procedure is for efficiency of time and ease of routine operations.

The details of the procedure now under investigation will be reported upon completion of the work. In 12 experimental runs, made thus far, an average of 88% of tracer uranium has been recovered from 100-ml urine samples. The reproducibility of results is favorable in that the maximum deviation from the average was 4%.

6. PHYSICS OF RADIATION DOSIMETRY

Pulse-Integration Fast-Neutron Dosimeter. Recently reported neutron cross-sections [R. K. Adair, *Revs. Mod. Phys.* **22**, 249 (1950)] have been used to compare the energy absorbed per gram of tissue to the energy absorbed per gram of ethylene due to fast-neutron irradiation. It was found that the ratio of tissue dose to ethylene dose is very nearly independent of the neutron energy in the region of 100 Kev to 20 Mev. Thus ethylene is tissue-equivalent insofar as fast-neutron dosimetry is concerned. Since paraffin has almost the same atomic composition it may be used as a wall liner for chambers containing ethylene.

More careful investigation of the problem of measuring the fast-neutron tissue dose with the proportional counter, mentioned in *Health Physics Division Quarterly Progress Report for Period Ending January 20, 1951*, ORNL-968, reveals that the proportional-counter method is completely analogous to the ionization-chamber method, provided special consideration is given to the following:

1. The gas amplification of the counter must be known at all times. This may be achieved by permanently installing an alpha source in the counter. The problem is now being investigated.

2. A correction must be made for energy of those protons which recoil with an energy less than that which will be rejected by the bias which is used to discriminate against gamma-ray pulses. A preliminary calculation has been made and the results are as follows in the case of 0.2 Mev bias energy:

NEUTRON ENERGY (Mev)	PERCENT OF TOTAL ENERGY LOST UNDER BIAS
0.2	100.0
0.4	26.0
1.0	5.0
2.0	2.0
4.0	1.0

3. The linear amplifier which is used to observe the pulses produced in the proportional counter must have a rise time and a decay time such that the maximum height of the output pulse is not appreciably affected by the rise time of the counter pulse. The distribution in rise times is being measured and the necessary amplifier characteristics are being determined.

Arrangements have been made for the use of the Cockcroft-Walton machine in the High Voltage Laboratory for the purpose of using the counter to measure the dose from well-defined beams of monoergic neutrons. A target and counter assembly has been designed and constructed for the D-D and the D#T thick-target reactions.

Uniform-Response Neutron Proportional Counter. The uniform-response neutron counter, mentioned in *Health Physics Division Quarterly Progress Report for Period Ending April 15, 1950,* ORNL-695, has been calibrated with the polonium-beryllium and the polonium-boron neutron sources. The counter has an equal sensitivity of $(1.75 \pm 0.10) \times 10^{-2}$ counts/neutron/cm^2 for the two sources. The sensitive area is about 20 cm^2 and the background less than 10 counts per hour. In order to make these calibrations, it was necessary to correct for the neutrons scattered from the floor and walls of the laboratory. This correction was first made by suspending the source and counter about 15 ft from the ground. With this geometry a 15-in. cone of paraffin placed between the source and counter reduced the count rate to 3% of the rate when the cone was not used. If it is then assumed arbitrarily that half this reading is still due to scattered neutrons (from the suspension), then the cone is effective in reducing the direct neutrons to 1.5%. This assumption seems reasonable when it is considered that the scattering near a floor amounts to 13%. The cone is then used to make scattering corrections under the conditions of laboratory geometry.

The counters have the physical size of the count-rate dosimeters described in ORNL-930. It is calculated that their response is uniform from 0.5 to 10 Mev, while being insensitive to less than 2 r/hr of gamma radiation. Their response to monoergic neutrons of various energies will be determined when sources become available.

Shielding Calculations. Calculations have been made of the contribution of neutrons scattered in air to the total dose at different distances from a spherically symmetric shield assuming constant cross-sections, isotropic scattering, and no absorption in the air. The calculations were made by evaluating the exact solution of the Boltzmann equation for this case. The results do not agree with those (NEPA-997 and 1657) which treat only first and second collisions. It has been shown that[1] the diffusion type solution is approached rapidly as the distance from the source is increased so that the method of treating only the first two collisions seems to be in error and to give results which are too low.

(1) G. Placzek, *Notes on Diffusion of Neutrons Without Change in Energy,* Montreal Report MT-4 (April, 1943).

It may be shown that the dose received in air at a distance R from a spherically symmetric shield of radius r is $\frac{1}{2}(r/R)^2 D$ if $r \ll R$. D is the dose measured at the outerside of the shield. This result is independent of the angular distribution of the dose at the shield surface.

In determining thermal-neutron flux in water by the foil method, a correction must be made for the difference in flux perturbation in water and in the standard graphite pile. The theory proposed by Skyrme[2] was used to calculate this correction for a 1-mil foil. The activity found in water should be increased by 5%.

To obtain an idea of the error in Skyrme's theory, which is correct to second order only, a one-dimensional model of a delta source and a foil in an infinite capturing medium was considered. This model should be a good approximation for large foils in water. The flux at any point in the infinite medium may be described by an integral equation which involves the symmetric kernel $E(x - x')$ and which is integrated over all space. It may be converted to a much simpler integral equation by applying a Fourier transformation. The resulting equation is integrated over the foil only and has as a kernel the solution for the undisturbed density in an infinite medium. Numerical work with this equation is planned.

To determine a more accurate value of the diffusion length of thermal neutrons in graphite from experimental data, the solution for the thermal-neutron density in a rectangular parallelopiped containing a point nonthermal source has been given to the Mathematics Panel in a form suitable for computation. It will be iterated over the data to obtain an improved value for the diffusion length.

X-Rays. Further work on pocket ionization chambers has been delayed by the necessity of improving the shielding on the X-ray machine before it can be used. Extensive lead shielding has been added to the tube head, and modified controls are under construction to permit a wide range of dosage rates.

Cooperation with the School of Reactor Technology. One member of the section has been assisting the School of Reactor Technology Laboratory in the completion of an experiment on the space distribution of neutron flux in the X-10 pile.

(2) T. H. R. Skyrme, Montreal Report MS-91 (no date).

7. EDUCATION AND TRAINING

AEC Fellowship Program. The present group of 20 AEC Fellows in Radiological Physics are in their third quarter of work at Vanderbilt University. Since February 12, members of the Health Physics Division have been spending two days a week in Nashville teaching a four-semester-hour course in health physics.

Training Program for Military Personnel. On April 2 six medical officers were assigned to this Section for an eight-week training course in health physics. Training includes both lectures and field training, and follows a year's training in radiation biophysics at Duke University.

Training Program for AEC Contractors' Personnel. On March 23 an eight-hour health physics seminar was conducted for personnel from the American Cyanamid Company, E. I. du Pont de Nemours & Co., and the California Research and Development Corporation.

Beginning April 2, and extending for three weeks, a course in health physics was given one hour a day, five days a week, for the Phillips Petroleum employees currently assigned to ORNL for training.

A medical doctor from the American Cyanamid Company is participating in the health physics program for the present military group.

Physics Course for Division Personnel. A course in Atomic and Nuclear Physics at the college level, which was instituted for a group of Health Physics surveyors who expressed a desire for such a course, has continued throughout this period. It is given in the evening, three hours a week.

Miscellaneous Activities. Members of the staff continue to assist in other teaching activities in the Laboratory, particularly in the Apprentice Training School and in the Reactor School.