First Domestic Waste Stabilization Pond in Pennsylvania

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PENNSYLVANIA'S first waste stabilization pond for treatment of residential sewage was pioneered by the Allegheny County Health Department. The lagoon method of aerobic treatment, established in the western part of the United States, was not used in Pennsylvania until the State sanitary water board in 1958 approved a permit for an experimental project in Hampton Township, a suburban municipality near Pittsburgh.

Since that time the county-supervised pond has established a good record of efficiency, and after reviewing its operation for 1 year, the State board established standards (*1*) for the construction and use of waste stabilization ponds.

Lagoons, oxidation ponds, and oxidation evaporation ponds are names given to the waste stabilization pond. But whatever the name, the method or process is essentially the same, although there are modifications caused by holding periods and climatic conditions. Successful use of such ponds has prompted many studies by the Public Health Service, State health departments, and local agencies. Information accumulated on the suitability of the ponds as a method of disposal in all temperature zones encountered in the United States indicates that properly designed and operated ponds provide a degree of treatment equal to that of the trickling filter or activated sludge type of sewage treatment.

During the 1950's the literature became voluminous as interest increased in the use of the waste stabilization pond for treatment of many different wastes, even those from hog farms (*2*).

The first States to adopt standards for disposal of domestic wastes by this process were located in semiarid regions, and rates of evaporation were important in establishing permissible loading. Consequently, many of the units were designed and constructed as true ponds with no effluent, since evaporation was capable of dissipating the entire liquid influent. The evaporation pond, used where impervious soils and very dry atmosphere exist, is a truly complete treatment process, since there is no post-treatment discharge or percolation into subsurface waters. In such areas, the potential uses of the process are not limited to treatment of domestic or organic wastes but extend to the treatment of toxic materials which must not be discharged to surface or subsurface waters.

In eastern United States, because of the more humid atmosphere, an evaporation pond cannot be used. However, the lagoon may be particularly suitable for sewage disposal in smaller residential communities or developments.

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Advantages of the Lagoon

The treatment processes that take place in a waste stabilization pond are as old as mother nature, and have been known for many years. These processes occur continuously in streams and other natural bodies of water. The lagoon is merely a facility for treatment of wastes by

natural processes to avoid excessive loading of receiving waters. The three requirements for adequate treatment by these processes are dilution, oxygen, and time. The raw waste is diluted by the volume of the pond itself. The algae that develop and grow in the pond generate oxygen. The waste may be retained in the pond for a period of months.

Important to the operation of the facility are chemical, biological, and physical processes. Organic matter is stabilized as the result of a cycle established between bacteria and algae. The bacteria break down the organic matter to carbon dioxide and other products. The algae utilize these bacterial byproducts in the presence of light to produce quantities of oxygen through photosynthesis (see chart).

Since the presence of dissolved oxygen in the water is dependent largely on photosynthetic activity of the algae, the size and nature of the algal community present has significance. Furthermore, sufficient oxygen must be produced during daylight hours to permit aerobic processes within the pond to continue during periods of darkness. Under moderate temperatures and normal light intensity and with controlled loading of the pond, this condition is easily maintained.

The lower temperatures and shorter daylight periods of winter will result in decreased biological activity. Thick ice, particularly when it is covered by heavy snow, will reduce the amount of light available for photosynthesis, the oxygen content of the water may drop to zero, and the pond become anaerobic.

The lagoon may be a permanent installation or an interim expedient. In either case many factors must be considered since the adequacy of a stabilization pond depends on an accurate and thorough analysis of all specific circumstances of the particular situation. Important features to consider are availability of sufficient land, distance of the proposed pond from the source of the waste, local topography, nearness of the site to inhabited areas, nature of the soil, anticipated future usefulness of the land, and nature of waste to be treated. These features account for the principal cost of installation, the primary concern.

If the plans for a growing suburban area include a complete system of sewer lines, the pond may be considered as an interim measure and located on land that can be developed later for other purposes. Or the pond may be considered as a permanent installation, and the availability of a complete sewer system is of minimum significance, if a portion of the land in a subdivision is suitable only for use as a pond site.

Once it has been decided that a waste stabilization pond is feasible and acceptable for a locality, it can be expanded as the subdivision grows. Thus the cost of the sewage disposal facility becomes directly related to the rate of development, a strong point in favor of the ponds when the cost of installing treatment facilities is considered.

Planning and Design

In 1957 the Allegheny County Health Department became interested in making practical use of the method in the State. The department, a newly organized agency, recognized that one of its foremost problems was sewage disposal in outlying areas where sewers or plans to provide sewers were lacking.

The department's first step was to withhold approval for installing additional individual disposal systems in subdivisions wherever feasible. As a result, it was necessary for developers to install central collection and treatment facilities in accordance with the needs of the particular area. In most cases, secondary treatment would be necessary in order to comply with the requirements of Pennsylvania. The requirements stipulate that (*a*) sewage discharged directly into major rivers of Allegheny County must receive intermediate treatment resulting in at least 50 percent reduction in biochemical oxygen demand (BOD); (*b*) any discharge entering streams, other than major rivers, must have a minimum of 85 percent BOD reduction; and (*c*) additional treatment may be required where continuous flow does not exist in streams receiving discharge. In any instance disinfection is ordinarily required.

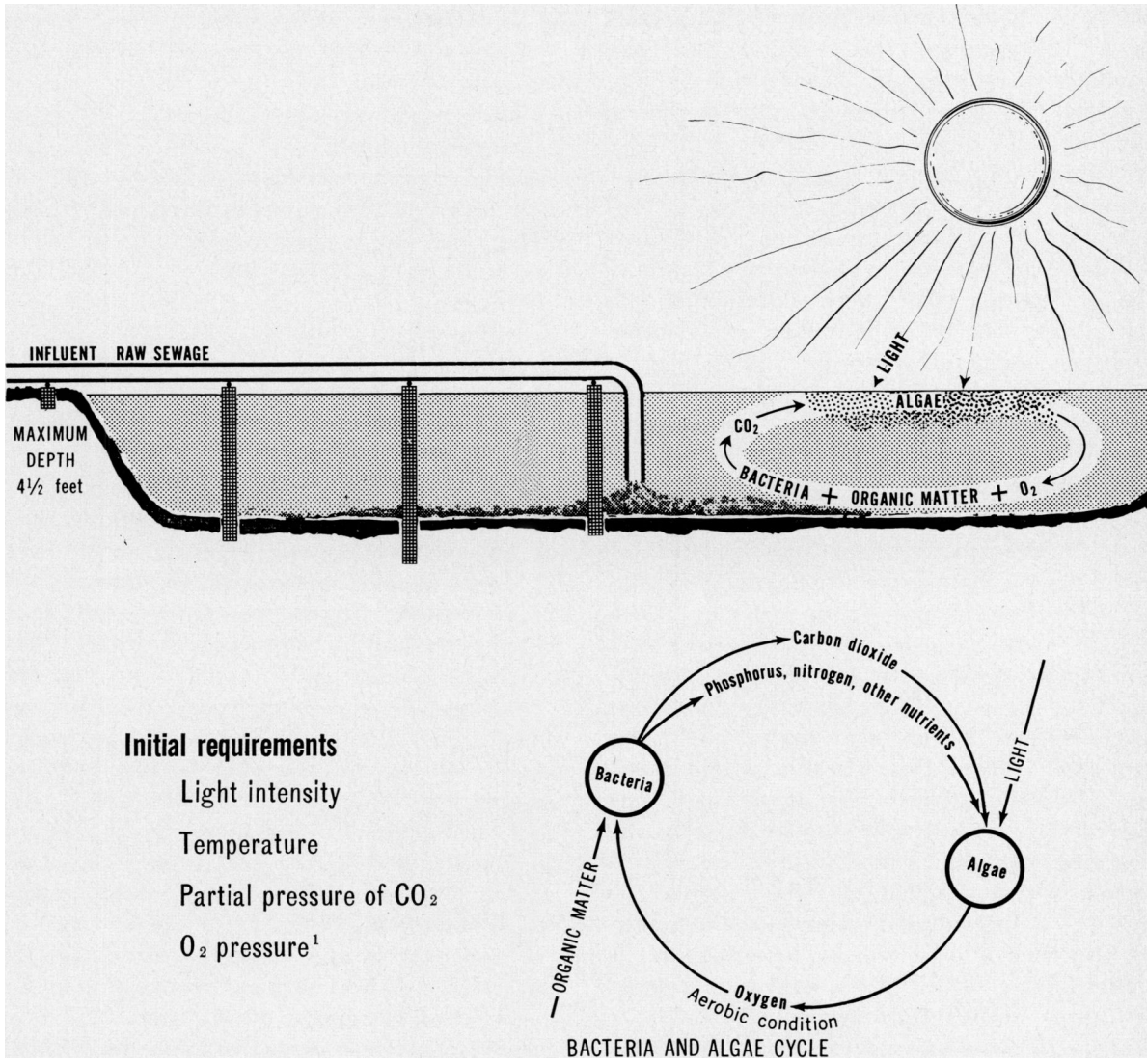
To assure adequate sewage disposal for the subdivisions, the department needed the cooperation of municipal officials, developers, builders, engineers, the planning commission, and the general public. When approached in

regard to the potentialities of waste stabilization ponds, the developers and builders of Allegheny County became interested in the method, particularly since it is less expensive than conventional facilities. The total cost of the pond installation is one-half to two-thirds the cost of conventional treatment facilities, depending on which method of treatment is selected. However, because of extreme fluctuations in the cost of constructing these ponds, the difference may vary widely.

In July 1957, a favorable site was found in Allegheny County for an experimental waste stabilization pond. The site was a swamp with railroad tracks on one side and a cliff, 125 feet below the development area, on the other side. The nearest house in the development was to be approximately 400 feet distant horizontally. The nearest home outside the proposed development was approximately 1,000 yards away.

Northwood Acres, the development selected for the initial installation, is located in Hamp-

Sewage disposal by the waste stabilization pond method



[1] Presence of O_2 in the decomposition of organic matter (carbon compounds) prevents formation of obnoxious and offensive gases associated with anaerobic digestion.

ton Township in the north central part of the county. The site was considered especially suited since the homes were to be constructed over a period of several years, permitting study of the efficiency of the pond as the load was increased. The ultimate plans were for 143 homes, 37 to be built in the first group.

The developer, Nelson Beggs, and his consulting engineers, North Hills Engineering Co., were receptive to the proposal for installing the facility in consultation with the Allegheny County Health Department. Next, it was necessary to convince the township officials that the method was feasible and that adequate safeguards would be taken to protect against hazards. To reassure the municipality, the developer agreed to provide conventional treatment facilities if the lagoon failed to operate as required.

The township officials were cooperative and submitted the application for the permit required by the Pennsylvania Sanitary Water Board for the installation of sewerage facilities. The preliminary plans were submitted to the State in October 1957. However, considerable clarification and additional detailed supporting data were necessary before a permit was issued at the August 1958 meeting of the sanitary water board. Construction of the pond was started immediately.

The facility has two cells, each with approximately 0.88 acre of surface area, or a total of 1.76 acres (77,000 square feet), joined so they can be operated in parallel or in series. Each cell has a discharge control device to permit maintaining the depth at any level between 2½ and 4½ feet, as well as permitting drawoff at depths of 0 to 2 feet below the surface. The cells discharge to Pine Creek, a tributary of the Allegheny River. The creek flows just beyond the railroad tracks approximately 150 feet from the cells. The influent lines, supported on piers, discharge at the center of the cells. A division box distributes the raw sewage to either or both cells. The entire area is enclosed by a 6-foot chain link fence topped with three strands of barbed wire.

The cliff, although an excellent barrier between the homes and the stabilization pond, created difficulties in constructing sewer lines to the site. In the side of the steep grade bulldozers scraped out a ledge wide enough to permit the trenching equipment to operate and to serve later as an access road to the pond.

The heavy equipment was hampered by poor drainage from the swampy area and considerable precipitation during the construction period. As a result, the cost of construction was considerably more than anticipated. Nevertheless, the first cell was placed in operation on October 15, 1958, receiving wastes from 26 homes.

Plans to pump stream water into the cell to provide dilution to the initial flows were found unnecessary. Two weeks after the introduction of waste into the unit, an excellent algal growth had developed. By the end of November, an ice cover formed over the entire cell except around the influent line, and later reached a maximum thickness of 11½ inches. Although the ice cover remained until the middle of February 1959, no nuisance developed during the critical thaw period. No discharge occurred during the winter of 1958–59.

The second cell, completed in July 1959, was immediately placed in operation in series with the first cell. No discharge to the stream occurred until October 1959.

Experimental Studies

The Allegheny County Health Department had agreed to have experimental studies conducted on the operation. The National Home Builders Association, through the Metropolitan Home Builders Association of Pittsburgh, provided a research grant to pay for part of the cost of the studies.

Because of the possibility that an obnoxious odor might develop, a mechanical hydrogen sulfide detector was placed at the proposed site during May 1957, before starting construction, to determine baseline concentrations of the gas. This instrument is capable of detecting H_2S gas at about one-half part per billion (ppb), which is well below the threshold of 100 ppb, the lowest point at which a person can detect its presence. The instrument was operated for a period of 430 hours during May 1957. Of the 215 samples collected, 67 percent had between 0 and 1 ppb of H_2S, with the highest reading between 7 and 8 ppb. The method of measurement was in accordance with recom-

mended procedures of the American Iron and Steel Institute (*3*).

Since November 25, 1958, the instrument has been in continuous operation. Through December 31, 1959, 5,601 2-hour samples were collected. Fifty-seven percent of the samples remained below the 1 ppb concentration. Though the increase is significant, it has remained below the odor threshold except for two occasions.

Other studies have been conducted to determine the type and quantity of oxygen-producing algae present and the reduction of intestinal organisms through the two cells. Chemical analyses have been done to ascertain the BOD, indicating the degree of stabilization accomplished by each cell, the dissolved oxygen concentration in each cell, and the pH or hydrogen ion concentration.

Some published reports indicate the presence of a wide variety of algal species in waste stabilization ponds. However, in this pond the algal community was composed of very few species. During most of our study the algal community was dominated by *Chlamydomonas*, with a smaller number of *Euglena*, both single-celled motile algae. Following the thaw period in February 1959 the total algal population decreased. *Euglena* increased in relative numbers during April and all but disappeared in May. A few pennate diatoms were present during May.

During the first winter of operation, when only the first cell was being used, *Chlamydomonas* was present in high concentrations even under the 11½ inches of ice. At no time during the first year of operation did the pond become anaerobic. With continued low temperatures and a heavy ice cover (but little snow cover) sufficient light penetrated the ice to permit photosynthesis. In contrast, during the second winter of operations heavy snow lay on the ice for nearly 2 months, and the first cell became anaerobic during the latter part of December 1959.

Results of weekly determinations of suspended organic matter by centrifugation and gravimetric procedures indicated that suspended substances, including the algae, were not evenly distributed within the pond. Differences in vertical distribution of the algae result in part from the positive responses of the motile cells to light; also, daytime surface concentrations are easily moved about by the wind and tend to become concentrated on the leeward side of the pond. Variation in the algal population at specific sampling points was evident from one week to another from both cell counts and measurements of extractable chlorophyll. This reflects to some extent the unequal distribution of organisms as well as differences in growth rates resulting from daily variations in temperature and light intensity.

Because of the relatively constant supply of nutrient elements available from breakdown of the organic wastes by bacteria, the extreme fluctuations in algal populations characteristic of many natural ponds and lakes were not observed. Concentrations of algal cells in this pond reached 1 million cells per milliliter. This compares with 700,000 cells per milliliter developed during the summer blooms in highly productive lakes and reservoirs (*4*) and with concentrations of nearly 100 million cells per milliliter produced in large-scale experimental cultures (*5*).

The data obtained from the chemical and bacteriological studies are shown in the table. Although the number of coliform organisms contained in the influent is reduced more than 99 percent, the discharge still contains appreciable numbers. In the event enteric pathogens are being emptied into the lagoon, possibly they would also be carried over with the discharge. In order to determine if this could occur, the survival of enteric pathogens in the lagoon content was studied in the laboratory. Numerous tests were carried out to study this point.

The tests were conducted essentially as follows. Portions of influent and effluent as received in the laboratory for other testing were transferred to sterile tubes and to each was added a heavy suspension of *Salmonella* organisms. The tubes were kept at room temperature, and their contents were cultured at intervals of 1 or 2 days to detect the presence of the salmonellae among the coliform organisms. The numbers of *Salmonella* organisms rapidly decreased and the maximum survival time in either of the fluids was 12 days. The Coliform organisms, however, showed very little reduction in numbers in this time.

These tests indicate that if a carrier of *Salmonella* organisms lived in the development and was discharging wastes into the lagoon, these pathogenic organisms would die off before being discharged to the stream. Months are required before influent becomes discharge. It can be concluded that even though some coliform organisms are discharged to the stream, there is little chance that these enteric pathogens will be discharged.

Loading Capacity

The first cell of the facility has been loaded at the rate of 350 persons per acre (311 people on 0.88 acre) since November 1959. This amounts to a loading of 175 people per acre on the two combined cells, which is approximately double the designed loading rate. In February 1960, a 72-hour continuous sampling program was conducted by the Pennsylvania State Health Department and the Allegheny County Health Department to determine efficiencies at that level. During this period, both cells were covered by 2 inches of ice, and the air temperature ranged from 10° F. to about 32° F. Samples were collected at 30-minute intervals and included the raw sewage entering the first cell, the discharge from the first cell (this being the influent to the second cell), and the discharge from the second cell to the stream. Flow measurements were taken from the influent to the first cell. Samples for 24-hour periods were composited, and aliquots were taken to laboratories of the State and the county health departments. The results obtained by both laboratories were comparable and varied within a range of only 2 percent.

During the 72-hour sampling period the first cell continued to operate under the anaerobic

Monthly [1] summary laboratory analysis, waste stabilization pond, Hampton Township, Allegheny County, Pa.

Month	Dissolved oxygen (ppm)		Biochemical oxygen demand (ppm)					Coliform bacteria (number per ml. × 10^3)				
			Influent	Effluent		Percent reduction		Influent	Effluent		Percent reduction	
	Cell 1 [2]	Cell 2 [2]		Cell 1 [2]	Cell 2 [2]	Cell 1	Cell 2		Cell 1 [2]	Cell 2 [2]	Cell 1	Cell 2
1958												
December	7. 22	-------	361	27. 5	------	92. 4	------	345	3. 08	------	99. 1	-------
1959												
January	9. 40	-------	221	20. 4	------	94. 6	------	258	2. 38	------	99. 1	-------
February	12. 2	-------	186	22. 7	------	87. 6	------	527	3. 38	------	99. 3	-------
March	12. 9	-------	369	21. 5	------	94. 1	------	490	1. 47	------	99. 7	-------
April	8. 36	-------	272	20. 0	------	92. 6	------	1, 004	31. 10	------	96. 9	-------
May	6. 07	-------	261	12. 0	------	95. 5	------	286	1. 06	------	99. 6	-------
June	. 767	-------	275	27. 0	------	90. 3	------	1, 895	1. 58	------	99. 92	-------
July	4. 17	5. 13	209	17. 4	17. 4	86. 9	86. 9	1, 633	. 37	0. 09	99. 98	99. 994
August	3. 94	5. 05	327	20. 3	22. 7	93. 6	93. 0	1, 874	3. 90	. 39	99. 79	99. 979
September	5. 55	5. 93	332	19. 3	17. 5	94. 2	94. 8	2, 111	12. 63	. 38	99. 40	99. 982
October	6. 90	6. 55	390	36. 5	21. 3	90. 6	94. 5	1, 390	3. 80	. 19	99. 73	99. 987
November	5. 10	4. 77	250	26. 3	28. 5	89. 4	88. 5	1, 390	24. 0	2. 40	98. 27	99. 829
December	4. 10	2. 50	200	39. 8	12. 1	80. 1	93. 9	295	24. 0	2. 40	92. 20	99. 187
1960												
January	. 22	6. 35	315	53. 3	23. 0	83. 0	92. 7	1, 390	24. 0	2. 40	98. 27	99. 829
February	. 38	10. 20	205	71. 0	27. 4	65. 4	86. 6	1, 333	19. 0	2. 40	98. 57	99. 819
Average	5. 82	5. 81	279	29. 0	21. 2	88. 7	91. 4	1, 082	10. 4	1. 33	98. 65	99. 826

[1] Monthly results are based on average results of two samples per week.
[2] Samples taken from established points of discharge from the cell.

conditions which had developed during the latter part of December 1959, and the BOD reduction was 73 percent. The cold weather continued through February and the average reduction through the first cell was about 66 percent (see table). Although the second cell was also covered by 2 inches of ice during the study, the BOD reduction of the discharge of the second cell to the stream was 89 percent, and the sampling for February indicates an average reduction of 87 percent through the combined cells.

The measurements during the 72-hour sampling period indicated an average flow of approximately 12,190 gallons per day for 311 people, or 39 gallons per person per day. The 2-foot storage available between the 2½- and 4½-foot (minimum and maximum) operating depths permits the storage of approximately 1,155,000 gallons. This provides storage, at the present rate of flow, for 90 to 100 days. With this storage capacity available and the continued high BOD reduction through the combined cells, it is conceivable that the loading can be increased and the desired efficiencies maintained at all times during discharge to the watercourse.

The results obtained in operations and tests have been quite satisfactory and the degree of treatment has continued to be good. However, detailed tabulations show that cold weather, particularly ice and snow cover, affects the efficiency of the pond. The rate of recovery during spring weather to aerobic conditions will be significant in determining eventual loading capacities. At the present loading rate of 350 people per acre, the first cell is capable of providing greater than 85 percent BOD reduction except for periods of snow and ice cover. The maximum capacities of the two cells combined have not yet been determined, but at no time has the BOD reduction through the combined units been below the 85 percent minimum required by the State.

The efficiency of operation during the winter and spring months of 1959–60 will have considerable significance since the first cell became anaerobic during the latter part of December. A slight odor developed in the immediate vicinity of the pond although it could be detected only at very close range, and it did not attain the magnitude of a nuisance. During one period when the ice cover melted, oxygen returned to the first cell in significant quantity after only 3 days of relatively warm sunny weather.

Summary

An experimental project in Allegheny County, Pa., a stabilization pond for treatment of domestic wastes, illustrates that the semiarid conditions of some western States are not necessary for the efficient operation of a lagoon. However, high evaporation rates undoubtedly increase the potential uses of this method of waste disposal.

Based on the temporarily established load levels of 175 persons per acre of lagoon surface area the following observations were recorded. The minimum biochemical oxygen demand reduction was 87 percent. Algal growth rapidly reached a maximum level of 1 million cells per milliliter. Hydrogen sulfide gas levels have remained at an acceptable level except on two occasions, when odors could be detected in the immediate vicinity of the pond. The reduction of coliform organisms was more than 99 percent. Preliminary studies indicates a complete removal of the *Salmonella* enteric pathogens.

Although maximum loading capacities have not been reached, the lagoon method has proved feasible in this area. It is especially suited where no regular sewer systems are available and where topographic and climatic conditions are appropriate. However, further experiments must be conducted to determine the maximum loading capacities of lagoons in this climate. Preliminary studies indicate enteric pathogens cannot survive in the full sequence of lagoon operation, but further detailed studies are needed to establish this conclusively.

REFERENCES

(*1*) Pennsylvania Department of Health, Sanitary Water Board: Sewerage manual. A guide for the preparation of applications, reports and plans. Ed. 2. Division of Sanitary Engineering Pub. No. 1. Harrisburg, Pa., sec. 90, pp. 73–79.

(2) Bay, O.: Lagoons: Easiest way yet to clean a hog floor. Farm Journal (eastern edition) 83: 46, November 1959.
(3) Sensenbaugh, J. D., and Hemeon, W. C. L.: A low-cost sampler for measurement of low concentration of hydrogen sulfide. Air Repair 4: 5, May 1954.
(4) Hartman, R. T., and Graffius, J. H.: Quantitative seasonal changes in the phytoplankton communities of Pymatuning Reservoir. Ecology 41: 333–340, April 1960.
(5) Gummert, F., Meffert, M.-E., and Stratmann, H.: Nonsterile large-scale culture of *Chlorella* in greenhouse and open air. *In* Algal culture from laboratory in pilot plant, edited by John S. Burlew. Pub. No. 600. Washington, D.C., Carnegie Institution of Washington, 1953.

Surgeon General Terry

Dr. Luther L. Terry, assistant director of the National Heart Institute since August 1958, has been designated as the new Surgeon General of the Public Health Service. He succeeds Dr. Leroy E. Burney, Surgeon General since 1956.

One of the pioneers in research into the body's enzyme system, Dr. Terry has been a key man of a team of doctors who for 3 years have been developing enzyme-inhibiting drugs to fight high blood pressure.

Dr. Terry entered the Public Health Service in September 1942, assigned to the U.S. Marine Hospital (now U.S. Public Health Service Hospital), Baltimore, Md. He was chief of medical service from 1943 to 1953, when he became chief of the General Medicine and Experimental Therapeutics Branch of the National Heart Institute. Since 1944 he has also been on the staff of the Johns Hopkins University School of Medicine, becoming assistant professor of medicine in 1953.

Born in Red Level, Ala., September 5, 1911, Dr. Terry received his bachelor of science degree in 1931 from Birmingham-Southern College and his doctorate in medicine in 1935 from Tulane University of Louisiana School of Medicine.

From 1937 to 1942 he served successively as resident in medicine and intern in pathology at City Hospital, Cleveland; instructor in medicine and research fellow in pneumonia at Washington University, St. Louis, Mo.; instructor and associate professor of medicine and of preventive medicine and public health at the University of Texas, Galveston.

Dr. Terry was a member from 1945 to 1946 of the Medical Division of the Strategic Bombing Survey to Japan and was staff member of the Subcommittee Investigating Malmedy Atrocities, Senate Committee on Military Affairs, in 1949. He is past chairman of the Medical Board, Clinical Center, National Institutes of Health, and of the Cardiovascular Research Training Committee, National Heart Institute, and is a member of various organizations in the medical and public health fields.