LIQUID RADIOACTIVE WASTE DISPOSAL AT THE PRETORIA GENERAL HOSPITAL

D. J. SAVAGE, M.SC.;* J. KRABBENDAM;† P. N. SWANEPOEL, M.B., CH.B., D.P.H.‡ and T. FICHARDT, M.D., D.SC., M.MED. (RAD.T.), F.F.R. (R.C.S.I.)¶

Pretoria General Hospital

While the new Department of Radiotherapy, with its own surgical theatre, radioactive laboratories, and 32-bed ward consisting of 4-bed and 2-bed wardlets each with its own bathroom, WC and sluice, was under construction at the Pretoria General Hospital in 1957, attention had to be given to the safe disposal of radioactive sewage and other liquid radioactive waste products. In this article we describe our solution of the problem 6 years ago, and review the recent literature.

Consultation

An initial meeting was called of representatives (see addendum) from the Superintendent's office and the departments of Radiotherapy, Medical Physics, and Engineering, of the Pretoria General Hospital; the Pretoria City Engineers' department; the Council for Scientific and Industrial Research; the Transvaal Provincial Administration's Building Branch; the Commissioned Architects; and the Commissioned Mechanical, Electrical and Structural Engineers; for the purpose of devising a plan for the safe disposal of about 500 millicuries (mc) of liquid radioactive waste per day. It was not anticipated that such a large quantity would be disposed of every day, but possibly on 10 occasions during the month; i.e. about 5 curies per month.

In their planning the meeting had to bear in mind the stringent recommendations (1954) of the International Commission on Radiological Protection (I.C.R.P.)[1] and to realize that the maximum permissible concentration of radioactivity in the body was very small compared with that used in radiotherapy.

This emphasized our responsibility towards the nursing staff of the 32-bed radiotherapy ward, most of whom would be relatively uneducated in nuclear medicine and radiation protection. It was felt that the nursing staff should not be required to undertake the collection, storage or disposal of any radioactive urine or other radioactive wastes, since they would not fully understand the nature of the hazard involved or the degree of protection that would be adequate. For this reason it was decided that all the effluents from the bathrooms, WCs and sluice rooms in the radiotherapy wardlets should be connected to a radioactive waste-disposal system. This would reduce to a minimum the use of bedpans by patients excreting radioactive matter. If a bedpan should be required, it would be regarded as an emergency procedure requiring the supervision of the ward sister, who would be trained

*Chief Medical Physicist, Department of Medical Physics.
†Consulting Engineer, at present in association with S. E. K. Everitt, Consultant Mechanical and Electrical Engineers, 611, S.A. Permanent Building, Pretoria.
‡Superintendent.
¶Professor and Head of the Department of Radiotherapy.

in radioprotection. This would limit the storage of radioactive bedpans. Any other problems of radioactive waste disposal that might arise would be handled by the radiotherapy or medical-physics staff.

At that time no regulations for the disposal of radioactive waste in the sewerage system from a general hospital had been promulgated, but it was realized that because of the small flow of the Apies River, into which the processed sewage was eventually discharged, it was important to impose more stringent limitations on such disposal than those adopted by most other countries that had considered the problem.

Deliberation

The radio-isotopes likely to be used in large quantities for therapeutic purposes were radio-iodine (^{131}I), radiophosphorus (^{32}P), and colloidal radiogold (^{198}Au). Of these, (^{131}I) is regarded as the most toxic.*

Taking into account the recommendations of these authorities and the particular aspects of our own problem, it was decided that the concentration of radioactive waste entering the municipal sewerage system should not exceed 10^{-5} μc./ml. This concentration of radioactivity when further diluted by other sewage would be well below the recommended levels. It would allow for the possibility of biological or chemical concentration of the radioactivity and would not exclude other institutions from disposing of radioactive waste in the same system.

In order to arrange that the concentration of radioactivity in the waste water from the radiotherapy ward and surgical theatre and the radioactive laboratories did not exceed the value decided upon, it was agreed that the waste should be accumulated for one month, by which time its volume would be about 25,000 gallons, and then stored for one month (decay factor about 0·075). It was decided that this should be effected automatically.

Recommendation

The following general specifications were recommended: The plant should consist of three 25,000 gallon tanks, one filling, one standing, and one emptying. If possible they should be placed underground for purposes of protection. There should be means of agitating full or partly full tanks to prevent the formation of scum. The outflow rate should be controlled to avoid exceeding the capacity of the sewers lower down. This should be done by allowing a tank to discharge one-tenth of its volume per day at a constant rate; that is to say, an outflow for $\frac{1}{2}$-1 hour per day for 10 days. There should be a system of recording the contents of the tanks and the concentration of the radioactivity in each tank at any particular moment. There should be a system of alarms in the physicist's office to indicate immediately any malfunction of the radio-waste disposal system. The tanks should be automatically flushed after emptying.

*The maximum permissible concentration of ^{131}I in drinking water for continuous exposure of occupationally exposed persons was laid down by the I.C.R.P.[1] in 1954 as 6×10^{-5} microcuries per ml. (6×10^{-5} μc./ml.). (This was reduced in 1959 to 2×10^{-5} μc./ml.[4, 5]). In the USA National Bureau of Standards Handbook no. 52 of 1953[2] a figure of 3×10^{-5} μc./ml. is given for drinking water.

Implementation

The construction of the radio-waste retention plant as envisaged was carried out by building, electrical and sanitary contractors to the designs of the commissioned architects and consultant engineers. The completed installation (Figs. 1 and 2) includes a building of 3 rooms, viz. (A) the monitor room, (B) a room containing the inlet pipes, valves and pumps, and the clean-water storage tank used for flushing the tanks when empty, and (C) an electrical control room. Behind this building and on a lower level are the three underground tanks to hold 25,000 gallons each. On a sloping level below the tanks is a one-room building containing the outlet pipes, valves, and constant-flow mechanism.

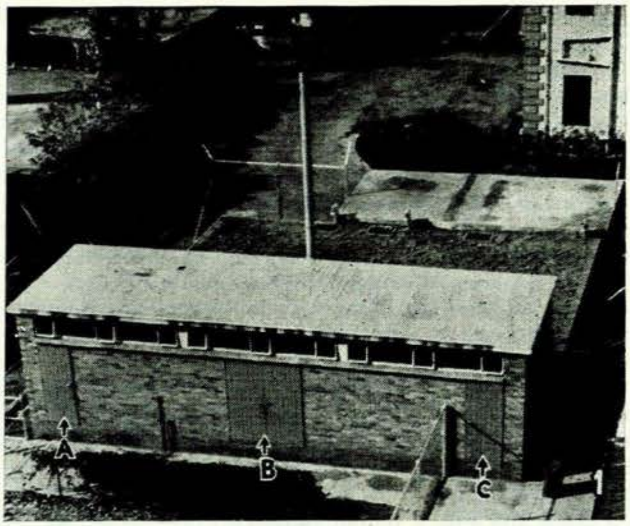

Fig. 1. View of the underground radioactive-sewage retention tanks, with the three-room building in front and the entrance doors to the 3 rooms, viz. room A housing the monitor, room B the inlet pipes, gate valves and pumps, and clean-water tank for flushing, and room C, the electrical control panel. The single low-level room, of which only the concrete roof is visible, houses the outlet pipes, gate valves, and constant-flow mechanism. The three 25,000 gallon underground tanks are situated between these two buildings (see Fig. 2). The whole area is enclosed by security fencing.

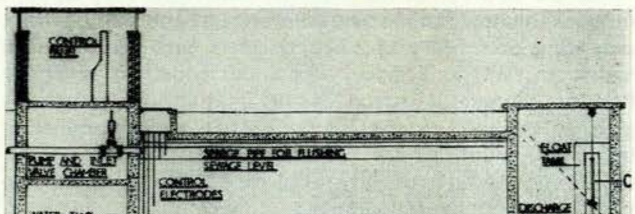

Fig. 2. Longitudinal section through the radioactive-sewage retention tanks. These are situated in the centre of the drawing. On the left is the three-room building housing the monitor, the inlet pipes, gate valves, pumps, and clean water tank, and the electrical control system. On the right is the low-level single room housing the outlet pipes, gate valves, and constant-flow mechanism (C).

Operation

The incoming radioactive sewage is led to one of the 3 tanks through hydraulically operated gate valves (Fig. 3). These valves are controlled by means of solenoid-operated taps connected to the municipal water supply. The automatic

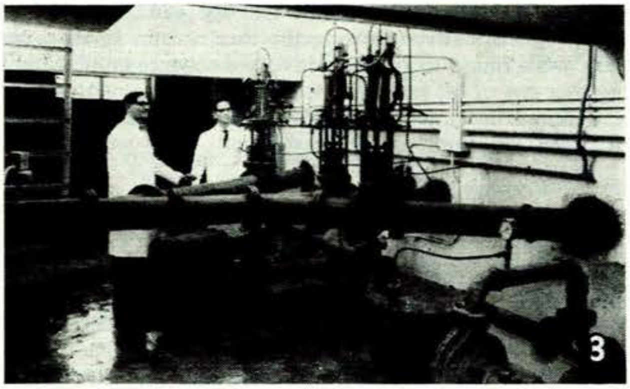

Fig. 3. Room B. Showing the inlet pipes, gate valves, and pumps for agitation and flushing, leading to the three retention tanks.

operation of the valves is governed by the level of the sewage in the tanks. Each tank contains electrodes at various levels which, by means of electronic circuits, operate relays to control the various functions taking place.

When a tank is one-tenth full an electrode-controlled relay will set the agitation mechanism in operation. The agitator consists of a centrifugal pump sucking from the bottom of the tank and discharging through two orifices. The high-velocity jet stream impinges on the surface of the contents and sets the whole contents in rotation. The agitation pump has been made to operate for 5 minutes in each hour that the tank is filled to 10% or more of its capacity.

When a tank is full, an electrode-controlled relay causes the inlet gate valve to close and the inlet gate valve of the next tank to open. If for any reason the inlet gate valve of the first tank should fail to close, the level will rise above the 'full' mark and make contact with another electrode, the so-called high-level electrode, which causes an alarm and warning light to flash in the physicist's office. If the inlet gate valve of the second tank should fail to open when the inlet gate valve of the first tank closes there will be no pathway for the sewage, which will build up pressure in the pipe leading to the retention plant. A pressure transducer mounted in the inlet pipe then causes an alarm and warning light to flash in the physicist's office.

When the tank has reached the full level it is required to stand for 30 days while the radioactivity of its contents decays. This has been arranged by means of a synchronous clock that gives an electrical impulse every 24 hours. This impulse is registered by a counter which, when it reaches 30, transfers further impulses to the motor drive of a set of cam-operated contacts (Fig. 4), which control the further

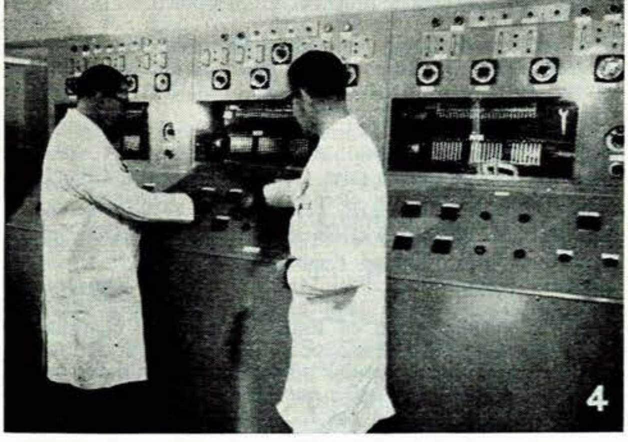

Fig. 4. Room C. Control panel showing various timers, manual controls, and in the centre the 3 sets of cam-operated contacts.

events of the tank's cycle. Firstly a light flashes in the physicist's office, indicating that the contents of the tank are ready to be discharged, but, before discharging, the radioactivity in the tank must first be checked. When the physicist has checked the activity level and is satisfied that it is within safe limits he sets the outlet cycle into operation by pressing a switch button.

There are 10 electrodes in each tank to control the outflow of sewage. Each daily impulse from the impulse timer causes the outlet gate valve (similar to the inlet gate valve) to open

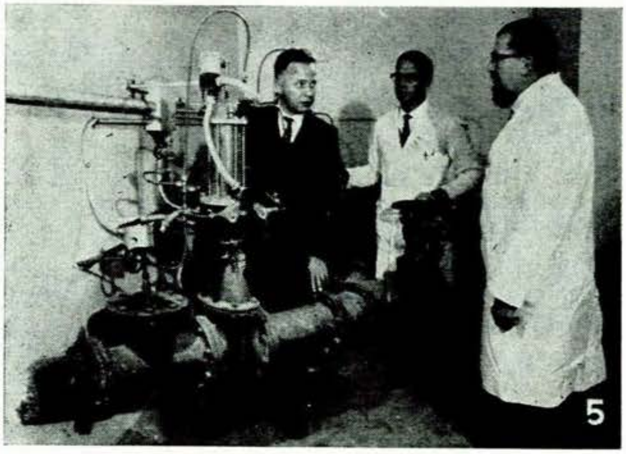

Fig. 5. The one-room low-level building housing the outlet pipes and the 3 hydraulically controlled outlet gate valves.

and remain open until the level in the tank has fallen from the one electrode to the next. The distance apart of these electrodes is such that 10% of the contents is released when the level drops from one electrode to the next. Each time an outlet gate valve opens the flow is controlled by a constant-flow mechanism (Fig. 5).

The constant-flow mechanism consists of an inverted U tube supported on two watertight hinges (Fig. 6). The arm is balanced with a loaded float in a float tank by means of a cable run over pulleys. The top position of the arm coincides with the level of the full tank. At the same time as the discharge gate valve opens, a constant flow of water enters the float tank and the inverted U tube is lowered at a constant rate. After 10 days the tank will be empty. The impulse timer in association with the cam-operated contacts then causes the flushing pump to start and the walls of the tank to be sprayed with clean water. There is only one flushing pump and the spray pipe of the tank to be flushed is connected to the pump by means of a hydraulically operated diaphragm valve.

After the flushing operation (which takes about 5 minutes) is completed the next impulse to the cam-timer causes contacts to be made which restore the position of the U tube by causing the float tank to empty.

The cam-operated contacts have now turned through a full circle and are back in the original position. The first tank whose filling, standing and emptying cycles have taken about 70 days waits in readiness until the third tank is full and the first tank's inlet gate valve is again caused to open.

Monitoring. The liquid levels are indicated by means of pressure transducers mounted near the outlet gate valves and recorded on a multichannel printing recorder situated in the monitor room (Fig. 7). The activity levels are measured by means of thin-walled Geiger-Müller tubes and a rate meter. The activity is also recorded on the multichannel recorder. The Geiger-Müller tubes are mounted (*via* inspection holes in the top of the tanks) near the bottom of the tanks by means of rods. A transistorized pre-amplifier is situated immediately behind the Geiger-Müller tube in a small watertight compartment. The Geiger-Müller probe can be withdrawn for decontamination.

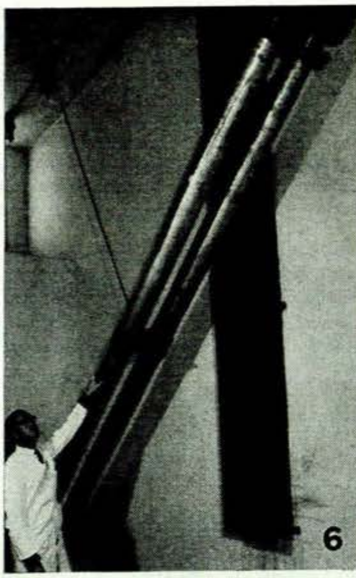

Fig. 6. The one-room low-level building housing also the constant-flow mechanism. The inverted U-tube is shown supported on two watertight hinges. The arm is balanced with a loaded float in the float tank by means of a cable run over pulleys.

Fig. 7. Room A. Housing the monitor and multichannel recorder.

Experience

Experience has indicated that the plant requires regular maintenance about once a month. The maintenance contract is made with a private firm. As a full cycle for each tank takes about 70 days, it is difficult to check each part of the operation. A system has therefore been built up simulating the entire operation in a short time. For example, external switches and resistors are attached to the tank electrodes to simulate a condition of immersion or non-immersion as required. In this way the operation of the plant can be rapidly checked each month and any faults corrected in advance. Not much experience has been gained as yet with the Geiger-Müller monitors. Originally the counters were mounted permanently under the roofs of the tanks but these soon went out of operation and, owing to their inaccessibility, have not been replaced. The system of immersed counters at present in operation, which we have described, seems better, because it enables the counters to be decontaminated or replaced if they became faulty. Moreover, it enables a more accurate assessment of the activity in the tank to be made.

We have had much trouble from an excessive flow of water into the tanks. This caused a tank to fill in 4 days. It was found that this excess of water came from sources that were not originally intended to flow into the tanks, such as darkroom wash-water, theatre condenser water, and water from laboratories not using radioactive matter. These sources were diverted, and the filling time is now nearer 30 days, as intended. It does not matter if a tank takes longer than 30 days to fill. If, however, it takes an appreciably shorter time, then the situation will arise when all three tanks are full and none ready for discharge. If this should happen in practice, then any of the tanks having a sufficiently low level of activity can be made to empty by manually operating the mechanism. If all three tanks were found to be too active to discharge immediately then the use of all radioactive fluids in the hospital would be temporarily stopped and the retention tanks bypassed. Provision has been made for this.

Recent Recommendations

It is interesting to note that the International Atomic Energy Agency's booklet (1958)[3] entitled *'Safe handling of radio-isotopes'* states as follows: 'The release of wastes into drains does not usually need to be considered as a direct release into the environment. Hence a restrictional safe limit will usually be provided if the concentrations of radioactive waste material, based on the total available flow of water in the system, averaged over a moderate period (daily or monthly), would not exceed the maximum permissible levels for drinking water recommended by the I.C.R.P. for individuals occupationally exposed.'

This booklet, which of course was not available at the time of our meeting, indicates that our limitation of 10^{-5} μc./ml. on the concentration of radioactivity in waste water leaving the hospital is very much on the safe side.

The latest recommendations of the I.C.R.P.[4] (1959) give a lower figure for the maximum permissible concentration of ^{131}I in drinking water, viz. 2×10^{-5} μc./ml. This concentration is still greater than that which we accepted 6 years ago for our liquid radioactive waste-disposal system, viz. 10^{-5} μc./ml.

SUMMARY

We have described an automatic system for the safe disposal of liquid radioactive waste from a radiotherapy institution that is entitled to discharge as much as 5 curies of radioactive waste per month. The system operates on the principle of dilution and storage, in three 25,000 gallon retention tanks operating in rotation, until the radioactivity has reached a concentration in the tank ready for discharge that is low enough for discharge into a municipal sewer.

ADDENDUM

The following is a list of the persons who attended the initial meeting on 6 December 1957, and whose interest afterwards made the building of the retention plant we have had the pleasure of describing a practical proposition:

Commissioned Consultants: Mr. I. Aronson, of Aronson and Hirsch, Associated Architects, Pretoria; Mr. S. F. K. Everitt and Mr. J. Krappendam, Associated Consultant Mechanical and Electrical Engineers, Pretoria; Mr. E. Anderson, Consultant Structural Engineer, Pretoria.

Transvaal Provincial Administration Building Branch: Mr. E. C. Northover, Hospital Architect; Mr. A. A. Phillips, Water and Drainage Engineer. (Mr. R. C. Abbot, Chief Hospital Architect, could not attend the initial meeting.)

Pretoria City Engineering Department: Mr. N. P. Nicol, Chief Chemist; the late Mr. C. H. Haddon, City Engineer; Mr. J. M. Coogan, Design Engineer.

Pretoria General Hospital: Mr. L. Farndell, Resident Engineer; Mr. D. J. Savage, Medical Physicist; Prof. T. Fichardt, Head of the Department of Radiotherapy, and chairman of the meeting. (Dr. P. N. Swanepoel, Superintendent of the Pretoria General Hospital, could not attend the initial meeting.)

The Council for Scientific and Industrial Research: Dr. J. K. Basson, Physicist; and Dr. I. McMurray, Physicist.

We wish to thank Dr. H. J. Hugo, the Director of Hospital Services, for his keen interest and cooperation in the project, and Dr. J. D. Verster, his successor, for continued interest and support of our endeavours. We also wish to thank Mr. Theo Marais, Chief Clinical Photographer, for the photographs.

REFERENCES

1. Recommendations of the International Commission on Radiological Protection (1955): Brit. J. Radiol., Suppl. 6.
2. National Bureau of Standards (1953): *Maximum Permissible Amounts of Radio-isotopes in the Human Body and Maximum Permissible Concentration in Air and Water*. National Bureau of Standards Handbook no. 52. Washington, D.C.: U.S. Government Printing Office.
3. International Atomic Energy Agency (1958): *Safe Handling of Radioisotopes*. Vienna: I.A.E.A.
4. I.C.R.P. (1959): *Recommendations of the International Commission on Radiological Protection*. London: Pergamon Press.
5. Radioactive Substances Standing Advisory Committee (1959): *The Control of Radioactive Wastes*. London: Her Majesty's Stationery Office.