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G. KHOE

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ABSTRACT

A technical description is given of the facilities and operation of the waste water and liquid waste management system at the Australian Atomic Energy Commission Research Establishment at Lucas Heights. Also described are practices and principles involved in the control and recording of radioactivity in the effluents.

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The following descriptors have been selected from the INIS Thesaurus to describe the subject content of this report for information retrieval purposes. For further details please refer to IAEA-INIS-12 (INIS: Manual for Indexing) and IAEA-INIS-13 (INIS: Thesaurus) published in Vienna by the International Atomic Energy Agency.

AAEC; WASTE MANAGEMENT; RADIOACTIVE WASTE DISPOSAL; LIQUID WASTES; RADIOACTIVE WASTE PROCESSING: RADIOACTIVE EFFLUENTS; ENVIRONMENT; RADIATION MONITORING; RADIOACTIVE WASTE STORAGE

GLOSSARY OF TERMS

Biochemical Oxygen Demand (BOD) : the quantity of dissolved oxygen, expressed in mg ℓ^{-1}, utilised in the biochemical oxidation of organic matter for five days at a temperature of 20°C.

Clarifier : a round tank, with a slowly rotating stirrer, in which the effluent is gently mixed with coagulant to induce coagulation, flocculation and agglomeration. The raw effluent enters at the bottom, passes through a suspended sludge blanket and the purified stream overflows at the top. In this report, it is also referred to as the low level treatment plant (LLTP).

Coagulant : a material that, when added to water or industrial waste, will combine with certain substances ordinarily present and form a precipitate comprising floc particles which are more or less gelatinous in character and have the capacity to remove colloids from water or wastes.

Curie (Ci) : that quantity of radioactive material in which the number of disintegrations per second is 3.7×10^{10}. The terms millicurie (mCi) and microcurie (µCi) are also used in this report. 1 curie = 3.7×10^{10} becquerel (Bq).

Delay tank : a tank used for holding a batch of effluent until the radioactivity content has been measured or the method of treatment decided.

Dispersion : the mixing of polluted materials with a large volume of waste in a stream or other body of water; it may also take place with other constituents of the environment, such as the atmosphere.

Effluent : a liquid which flows out of a containing space; sometimes used to indicate the liquid waste flow from a laboratory or nuclear centre. Effluent, raw: untreated effluent.

Filter, pressure : a closed vessel in which pressure is used to force a liquor or slurry through a porous medium to separate liquids from solids.

Filter, sludge : a device in which wet sludge is partly dewatered by means of vacuum or pressure.

Fissile materials : nuclides capable of undergoing fission by any process. In British usage, fissile is equivalent to fissionable but in US usage, fissile is restricted to interaction with slow neutrons.

Fission product : a radionuclide which has resulted from nuclear fission.

Floc : a light, gelatinous precipitate similar to precipitated aluminium hydroxide.

Gross α : total undifferentiated α-emitting nuclides.

Gross β : total undifferentiated β-emitting nuclides.

Ionising radiation : radiation, either corpuscular α- or β-rays, neutrons, or electromagnetic (γ-rays), which is capable of producing ions in the matter through which it passes.

Isotopes : nuclides having the same number of protons in their nuclei and hence having the same atomic number, but differing in the number of neutrons and therefore in the mass number.

Maximum permissible concentration : the concentration of a radioisotope in air, water, milk, etc., which will deliver not more than a given maximum permissible dose to a critical organ when breathed or consumed at a normal rate.

Maximum permissible dose : maximum dose of radiation that may be received by a person within a specified period with expectation of no harmful result to himself.

Neutron : a fundamental uncharged particle with a mass essentially the same as that of a hydrogen atom; its mass is 1.008982 mass units.

Nucleus : the central core of the atom composed of protons and neutrons.

Nuclide : a species of atom characterised by the constitution of its nucleus.

rad : the unit of absorbed dose, which is 100 erg/g in any medium. 1 rad = 0.01 gray (Gy).

Radioactive contamination : deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful.

Shielding : the interposition of an absorbing material between the source of radiation and, for example, an occupied space to reduce the intensity of radiation in that space.

Sludge : the accumulated settled solids deposited from industrial wastes, raw or treated, in tanks or basins, and containing more or less water to form a semi-liquid mass.

Sludge cake : the residue left on the filter after filtration of a sludge.

Solids, suspended : solids which either float on the surface of, or are in suspension in, water, industrial wastes, or other liquids and which are largely removable by laboratory filtering.

Specific activity : the radioactivity of a source, generally in curies per unit weight (gram) or per unit volume.

Stoking : dislodging of the settled sludge or solids from the walls of the sewage treatment plants settling chamber by means of a long-handled spatula.

Supernatant : floating on surface, like oil on water, or the liquid above a settled residue.

Vermiculite : a magnesium or calcium alteration product of mica.

Waste water : contaminated body or stream of water. It is also referred to as effluent.

CONTENTS

1. INTRODUCTION

The purpose of waste management in atomic energy operations is to control and minimise the radiation and contamination hazards that might be produced by the wastes. Strict control and surveillance are carried out during transfer, treatment, storage and/or discharge of the wastes. In addition, environmental surveys and studies are carried out to demonstrate that the behaviour and fate of the released waste products in the environment are as predicted.

Radioactive wastes have widely different levels of radioactivity and toxicity, and chemical and physical forms which dictate the different methods of treatment to be used. In general, three basic methods of waste management have been developed and safely applied:

(a) **Dilute and disperse** This method is used when the radioactivity in the effluent can be reduced to levels acceptable for discharge into the environment. Environmental surveys and studies are carried out to confirm that this approach can be used without compromising health and safety standards.

(b) **Concentrate and contain** This is used for liquid waste with a high level of radioactivity and/or toxic materials. The radioactivity or toxic materials are concentrated by volume reduction and the waste stored in special tanks. The concentrates can also be immobilised in vermiculite and concrete or in glass before storage.

(c) **Delay and decay** This method is used on wastes of short half-life. These are held in a suitable container over a certain period until the radioactivity is reduced to a level acceptable for discharge or further treatment.

This report provides a comprehensive technical description of the liquid waste management practices and facilities at the AAEC Research Establishment, Lucas Heights. Also included are treatment methods for non-radioactive waste waters such as sewage and trade effluents.

Effluents arising on the site are segregated at the source as follows:

(a) Waste waters are collected and transferred through the effluent drainage systems. These are described in Section 2.

(b) Liquid wastes (generally of small volume) that may not be compatible with the operation of the effluent treatment plant are segregated into approved containers and transported to the storage facility for storage and/or treatment. They are commonly referred to as type A liquid wastes. They may be one or more of the following:

- high, medium or low in radioactivity,
- toxic and non-radioactive

  or

- toxic and radioactive,
- aqueous

  or

- non-aqueous.

The classification of effluents is carried out at the source by the area supervisors.

2. WASTE WATERS

To facilitate treatment, waste waters on the site are further segregated into three categories:

- the B effluent which has a low level of radioactivity,
- the C effluent which is a probably non-radioactive, non-toxic trade waste,
- the non-radioactive sewage effluent.

They are collected and transferred through three different effluent drainage systems as shown in Figure 1.

2.1 Facilities and Operation

2.1.1 Low level B effluent

Strict control and surveillance of B effluent are effected by a series of holding tanks. As shown in Figure 1, the effluent flows through four different tanks before being discharged into the river, *i.e.* it passes through the delay tank and mixing tank before being processed in the effluent treatment plant, and then into the holding tank and discharge pond. In each of the first three tanks the effluent is sampled and analysed. These analyses enable a decision to be made whether the effluent should be released into the successive tank downstream, further analyses should be carried out, or the effluent should be further treated *in situ*.

The technical features and operation of the facilities for handling and treatment of the B effluent are described below:

The Delay Tank

Every building in which radioactive materials are handled is provided with one or more delay tanks. They are installed above ground on

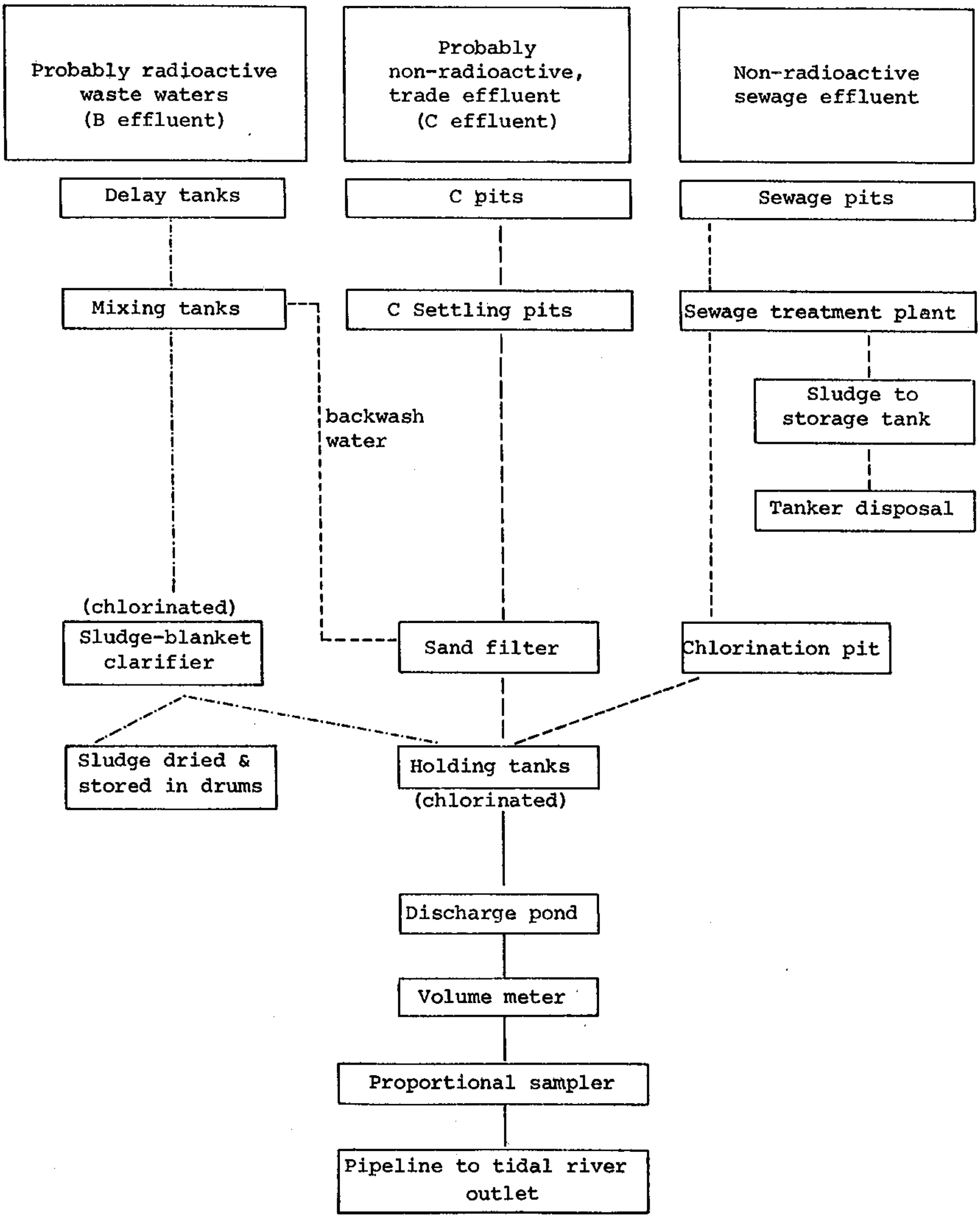


FIGURE 1. WASTE WATER SYSTEMS FLOW DIAGRAM

concrete catch trays. Effluent from the building drains into a pit tank from which it is automatically pumped into the delay tank. Effluent containing short-lived radioactivity may be held in a delay tank for decay.

In normal operation, one delay tank is filled at a time. Its volume is measured and it is sampled, analysed and discharged into a mixing tank according to the instructions of the plant supervisor. The volume, origin, destination and analyses of the effluent are recorded on a card (delay tank card). Continuous monitoring is not desirable because of the continually changing and widely varying characteristics of the effluent. The delay tanks, each of 13 to 45 m^3 capacity, are mild steel tanks coated on the inside with epoxy paint or rubber lining. Each is fitted with a high level alarm system. Stainless steel centrifugal pumps are used in the pit tanks and single rotor screw pumps (Mono) are used for moving effluent out of, between, or within the delay tanks.

The Mixing Tank

The five mixing tanks, each of 150 m^3 capacity, are of mild steel with an internal coating of epoxy paint. Like the delay tanks and the holding tanks, mixing tanks are installed above ground on concrete catch trays. Sliding lids are fitted to prevent undesirable aerosols being carried away by winds. Effluent in the mixing tank is circulated, sampled and analysed before being pumped to the clarifier for treatment.

Effluent containing short-lived radioactivity may be held in a mixing tank for decay. pH adjustment or other chemical treatments, if necessary, may also be carried out in the tank.

Five centrifugal pumps are installed in the mixing tank complex to move effluent between, within, or out of the tanks. Sand filter backwash and holding tank rinse are pumped back to the mixing tanks.

Clarifier

Effluent is pumped from the mixing tank to the clarifier for chemical flocculation treatment. Two Dorr-Oliver sludge blanket clarifiers of 4 m diameter and 24 m^3 capacity are installed; normally one is on standby, but they can be operated in series or in parallel.

Feed flow rates are at present set at 5-6 $m^3\ h^{-1}$. They are estimated from hourly mixing tank dip volumes. pH of the feed is adjusted to 5.7-6.3 by adding acid or alkali to the mixing tank.

Decontamination of the effluent in this unit, can be depicted as a two-step process involving chemical and physical processes; chemical coagulants are added to de-stabilise and flocculate colloidal materials in the water (and to precipitate some dissolved impurities), followed by settling and separation of the floc particles (sludge).

The effluent treatment plant operator controls the chemical process by adding alum and coagulant aid at predetermined rates to give an optimum set of concentrations in the clarifier. The quantity of soda ash added is varied to keep a pH in the overflow between 6-6.4 (the optimum range for effective flocculation). The settling and separation process, *i.e.* the height and thickness of the sludge blanket are controlled by increasing or decreasing the stirrer speed, feed rate and the rate of sludge withdrawal.

To achieve these controls, the operator is required to check hourly the following:

(a) pH of samples taken from the overflow, at bottom and at a blanket height of 50 cm;

(b) blanket height (normal height is 150-200 cm); and

(c) the residual chlorine level of the sample taken from the clarifier at a height of 50 cm. (Chlorine is added to eliminate the possibility of clarifier content becoming septic or obnoxious.)

In addition, the operator is required to collect at midday, samples of the overflow, sludge blanket and withdrawn sludge for analysis by the effluent laboratory.

Chemical reagents added for a feed rate of 5-6 m^3 h^{-1} are:

(a) Alum - a stock solution of 4.2% $Al_2(SO_4)_3$ $13H_2O$ is injected to the feed at the rate of 300 mℓ min^{-1}, producing an aluminium ion concentration of about 14 mg ℓ^{-1}.

(b) Soda ash - a stock solution of 5% Na_2CO_3 is injected at a rate of 100-214 mℓ min^{-1} depending on the pH of the overflow.

(c) Calgon coagulant aid - a stock solution of 0.05% is injected to the blanket at a rate of 200 mℓ min^{-1}.

(d) Chlorine - chlorine gas is injected to the feed at a rate of 2.3 kg day^{-1} (typical). Residual chlorine level in the clarifier is about 0.5 mg ℓ^{-1}.

Sludge Withdrawal

When indicated by the laboratory test results of the total solids content in the blanket and the blanket height, the plant supervisor notifies the treatment plant operator to withdraw a specified quantity of sludge from the clarifier. It is pumped into one of the two 4 m^3 cylindrical concrete settling tanks.

The settled sludge is discharged from the settling tanks into the solar evaporation ponds for drying. After about ten weeks, depending on the weather, its water content is reduced to about 30 per cent. The dry sludge cakes are transferred into 200 ℓ epoxy-coated steel drums which are lined with polythene bags. It has been shown by surveys that sludge drying in the solar evaporation ponds does not result in airborne contamination [AAEC internal memorandum].

Eight solar evaporation ponds have been constructed on site. One of the ponds is used to evaporate waste solvents. The solar pond is essentially a concrete storage area of 23 m^2, surrounded by a kerb 30 cm high and fitted with sliding metal roofs. About 3.6 m^3 of settled sludge is charged into the pond at each loading.

A filter press, normally on standby, is used only when the ponds are overloaded. In this case, sludge withdrawn from the clarifier is pumped direct to the filter press. The filter cakes and bags are discharged to the evaporation ponds. This reduces the time required for drying the sludge in the pond from ten to three weeks.

2.1.2 Trade C effluent

In general, all laboratories, workshops, *etc.* in which radioactive and toxic materials are not handled are connected to the C system. Effluent from these buildings drains into C pits. From the pit tanks, the effluent is automatically pumped into the C settling pit and from there to the sand filters.

The Sand Filter

Filter size: twin Permutit vertical pressure sand filter 1.65 m diameter x 1.52 m height (on straight).

Filtering flow: 11 m^3 h^{-1} maximum for each filter. However, the recommended maximum pressure drop across the filter bed limits the operating capacity to a smaller rate.

Backwash flow: 80 m^3 h^{-1} 10 minute backwash with tap water is carried out every morning. The backwash water is discharged into the mixing tank.

Monitoring: Spot check monitoring of activity and suspended solids in the sand filter's outflow is carried out twice a week.

2.1.3 Non-radioactive sewage effluent

The average dry weather flow of the sewage effluent consists of effluent from toilet facilities, the animal house and the canteen. (Showers, hand basins, *etc.* in active buildings are connected to the B system.) Effluent from buildings in the northern areas drains into a collection pit tank and is then automatically pumped into the Epco sewage plant. Effluent from other buildings drains through the sewage lines direct to the plant.

The Epco plant is a packaged activated sludge plant which consists of a rectangular 137 m^3 capacity aeration chamber and a 20 m^3 settling chamber. The raw sewage flows into the aeration chamber through a comminutor. In the chamber, organic matter in the effluent is converted into cellular materials and metabolic products such as carbon dioxide, water and nitrates. The treated liquor passes through the control float and transfer pipe into the settling chamber and the sludge, which is the cellular materials and other solids, settles into the hopper bottom. It is returned to the aeration chamber or removed to the sludge storage tank to maintain the mixed liquor suspended solids concentration in the aeration chamber at 4-5000 mg ℓ^{-1}. In summer, when biological oxidation of the organic matter is more complete, less sludge is produced. The stored sludge is removed by the Sutherland Shire Council's tanker service.

Compressed air for aeration and air-lifting of the sludge for return and removal is supplied by two Roots-Connersville rotary blowers (one on standby). An intermittent mode of aeration reduces power consumption and avoids excessive aeration.

Control of the plant includes

- maintaining a set range of pH, dissolved oxygen and mixed-liquor-suspended solids concentration in the aeration chamber;
- daily stoking and cleaning of the settling chamber (or more often as required); and
- maintaining the residual chlorine concentration of the treated effluent leaving the chlorinator at 6-8 mg ℓ^{-1}.

The Epco plant is designed to treat a maximum flow of 135 m^3 day^{-1}. During rainy periods when the 'sewage' flow is greater than 135 m^3 day^{-1}, part of the flow which contains less sewage solids is diverted through the normally unused trickling filter plant. The two flows join in the chlorinator on the way to the holding tank. However, when this flow is excessively high, both flows must be discharged into the storm water channel instead of the holding tank. In storm periods, sewage effluent is chlorinated to give, if possible, a residual chlorine level of 0.5 mg ℓ^{-1}.

Bacteriological Examinations

To demonstrate the effectiveness of the chlorination process, different effluents have been sampled for bacteriological examinations. The samples, whose extraction was observed by an inspector from the Health Commission of NSW, were sent to the Health Commission Laboratory for plating and counting. The following results were obtained.

Effluents Sampled	No. of Samples (over 2 weeks)	Bacterial Counts/100 mℓ		
		Total Colony (Range)	Total Coliform	Faecal Coliform
Pipeline discharge	6	30-9000	0	0
Holding tank discharge	6	1-16	0	0
Sewage plant discharge	6	0-24	0	0
Clarifier overflow	4	0-1	0	0
Sand filter overflow	4	0-4	0	0

For comparison, microbiological standards for drinking water in different countries are given in the following table [AWRC 1974].

COMPARISON OF DRINKING WATER STANDARDS

Criteria	Australia, Capital Cities [NH&MRC 1973]	USA [EPA 1972]	WHO, European [WHO 1970]	WHO, International [WHO 1971]
Microbiological				
Total coliforms	(a) none in 95% of samples in year	1/100 mℓ (membrane filter) arithmetic monthly mean	(a) none in 95% of samples in year	(a) none in 95% of samples in year
	(b) no sample with > 10/100 mℓ		(b) no two consecutive samples with coliforms	(b) no two consecutive samples with coliforms
	(c) no two consecutive samples with coliforms			
Faecal Coliforms	0/100 mℓ			0/100 mℓ

EPA, 1972 - Drinking Water Standards, US Environmental Protection Agency, Washington (Preliminary Draft)

NH&MRC, 1973 - Desirable Standards for Public Water Supplies in Australian Capital Cities, Seventy-fifth Session of the National Health and Medical Research Council, Canberra, November 1972.

WHO, 1970 - European Standards for Drinking Water, 2nd Edition, World Health Organisation, Geneva.

WHO, 1971 - International Standards for Drinking Water, 3rd Edition, World Health Organisation, Geneva.

2.1.4 Discharge facilities

Holding Tank

The overflow from the clarifier, together with the treated sewage and filtered C effluent, flows into the holding tanks. The six holding tanks, each of 220 m^3 capacity, are made of mild steel and are internally coated with epoxy paint.

Effluents may be held in the holding tanks for hours or days until it is confirmed by analysis that they are satisfactory for discharge. While held in the tanks, they are chlorinated to give a residual chlorine concentration of 1-2 mg ℓ^{-1}.

Final pH adjustments or other chemical treatments, if necessary, may be carried out in the holding tanks.

Discharge Pond

Usually, two holding tanks of effluent (440 m^3) are discharged simultaneously into the discharge pond for 5-7 hours. Discharge from the pond into the river *via* the pipeline is commenced halfway through the pond filling period. Discharge of the 440 m^3 of effluent through the pipeline takes up to 15 hours.

The discharge pond is a 700 m^3 concrete tank, internally coated with epoxy paint. About 200 m^3 of effluent is kept in the pond all the time to prevent the settled solids at the bottom from being disturbed and entrained into the discharged effluent. The flow into the pond is deflected upward to further reduce the chance of the settled solids being disturbed.

The pond is scrubbed and cleaned twice a year. The solids removed from the pond which consist mainly of algae are pumped into the solar evaporation ponds where they are dried and treated in the same manner as sludge from the clarifier (about 1 drum per year). To avoid excessive algal growth in the pond in summer, the effluent movement supervisor arranges effluent transfer into and out of the pond at a time such that a minimum amount of effluent is exposed to the sun in the pond. Excessive algal growth in the pond leads to the depletion of dissolved carbon dioxide in the effluent which, in turn, gives rise to high pH values of up to 10.

Effluent is discharged from the pond to the Woronora River through a pipeline strainer, flow meter and proportional sampler. The discharge pond provides a final stage of effluent treatment which helps keep the BOD level below 15 mg ℓ^{-1}.

2.2 Controls and Records of Radioactivity in the Effluents

2.2.1. B effluents in delay tanks

The plant operator samples each tank, after proper mixing, and submits the identified sample with the delay tank card to the laboratory. Depending on the laboratory analyses, the plant supervisor directs the delay tanks to:

- a filling mixing tank,

  or

- an empty mixing tank,

  or

- a holding tank *via* the C line and the sand filter.

The criteria for C line transfer of delay tanks are:

(i) Analysis of delay tank confirms only trace levels of radioactivity, *i.e.* the total for undifferentiated β-emitters (gross β) is less than 100 μCi and the pH range 4.5-8.0.

(ii) Previous records of this delay tank area confirm the absence of significant radioactivity or other contaminants.

(iii) Need to maintain a working reserve capacity at delay tanks or mixing tanks.

Additional analyses on delay tanks are requested on the following basis:

If gross $\beta > 1$ mCi, then total undifferentiated α-emitters (gross α) are counted. If gross $\beta > 2$ mCi and the nature of the radioactivity has not been indicated previously by the area supervisor, identification by γ-spectrometry is requested by the plant supervisor. Pending results of gross α- and γ-spectrometry, the contents of the suspect delay tank volume are transferred to an empty mixing tank.

2.2.2 Decay storage and radioactivity distribution in mixing tanks

To enable the radioactivity received to be distributed through the mixing tanks without overloading the capacity of the clarifier to decontaminate, upper limits for a single mixing tank are defined as follows:

Maximum gross $\alpha \sim 0.5$ mCi
Maximum gross $\beta \sim 4.0$ mCi

In practice average contents are well below these levels. Effluent from delay tanks with high radioactivity is held in a mixing tank for decay of short-lived emitters. It is checked before other delay tanks are added, either by an analysis for gross β or by estimation of decay during the storage period. Radioactivity which is longer-lived is divided between several mixing tanks for processing, within the limit of total clarifier feed radioactivity.

2.2.3 C effluent transfers and controls

C effluents are pumped automatically from collection pits, *via* the C line, settling tank and sand filters, to a filling holding tank. Twice a week random samples from C pits, settling tank and sand filter effluent are taken and checked for gross β and suspended solids.

2.2.4 Sewage plant effluents

Treated and chlorinated effluents from the Epco plant flow to the filling holding tank. For most samples gross β is near the minimum detectable level of 4×10^{-8} Ci m^{-3}. Levels in excess of 10^{-7} Ci m^{-3} for two consecutive samples are subject to inquiry by the plant supervisor.

Excess sludge, withdrawn and stored for tanker removal, is monitored for total solids and gross β, levels in excess of 10^{-6} Ci m^{-3} in consecutive tanker volumes being subject to inquiry. The sample is taken from the sludge after it has been transferred to the tanker.

2.2.5 Effluent discharge

The current discharge authorisation is of the form [Fry 1966]

$$\Sigma \frac{Xi}{\text{m.p.m.d.}_i} = \frac{V}{3 \times 10^6}$$

where Xi = the quantity of the i^{th} nuclide discharged during the month (Ci); m.p.m.d.$_i$ = maximum permissible monthly discharge of the i^{th} nuclide (in Ci). (The m.p.m.d.$_i$ of 173 individual nuclides were set out by Fry [1966]); and V = volume of effluent discharged over the month (imp. gallons) or 3×10^6 gallons, whichever is the smaller.

This discharge formula has been easy to work with, since operational analyses can be minimal. In the absence of specific analyses, undifferentiated radioactivity, *e.g.* gross α and β, must be assumed to be that of the most hazardous nuclide. Compliance with the formula can be demonstrated with a minimum of analytical effort, by identifying and quantifying the most likely components, for which γ-spectrometry is frequently sufficient.

In general, the measured values for gross α and β are used as a tank-to-tank guide, considering the history of the original delay tanks and mixing tank, together with any identification of major nuclides before treatment.

Gross β in a holding tank, above the level of 1 mCi, requires γ-spectrometry to identify the major emitters, so that permitted discharge levels may not be exceeded. Where no positive identification of nuclides is available, the holding tank radioactivity concentration is reduced by concurrent discharge with tanks of negligible radioactivity, so that the pipeline discharge sample resulting from the discharges is less than 3 mCi for gross β.

The working discharge criteria from holding tanks to the discharge pond are:

gross β	less than 1 mCi/tank
pH	6.5-8.5
residual Cl_2	0.5-1.5
suspended solids	10 mg ℓ^{-1} (maximum)
beryllium	0.1 mg ℓ^{-1} (maximum)
colour	None at 5000 dilution.

Processing of Records

Delay tank cards, grouped with the relevant mixing tank card, are retained by the plant supervisor until processing, sampling and analysis of the relevant holding tank is completed. When the analyses demonstrate compliance with the primary discharge requirements, the holding tank is discharged to the pond concurrently with one or two other analysed holding tanks.

Discharges to the River:
Quality controls and sampling

Proportional pipeline samples are collected automatically. Volumes discharged are obtained by differential meter readings. Correlation of holding tanks discharged and discharge pond stocks with the metered volume of discharge is performed by the plant supervisor. When volumes cannot be correlated to within ± 2 per cent (meter nominal accuracy), the meter is examined and cleaned to avoid systematic and cumulative errors.

Pipeline discharge samples

Each bulk sample from the pipeline discharge is subsampled; one is for an AAEC audit officer who makes independent checks that discharges comply with the current discharge formula. The second sample is given to the Effluent Control Laboratory, which analyses for radioactivities and for other contaminants as specified by the NSW Clean Waters Regulation. Two random samples of pipeline discharges per month, in addition to the monthly composite sample, are analysed for non-radioactive contaminants.

When an individual discharge indicates a relatively high radioactivity, it is subjected to γ-spectrometry.

Monthly pipeline composite samples

The individual pipeline discharge samples are used to prepare monthly composite samples. Composites are prepared by the Effluent Control Laboratory, so that three different monthly composites are also available:

(i) unacidified, for gross α, gross β, ^{3}H and non-radioactivity analyses;

(ii) acidified (20% HCl), for ^{210}Po and spectrographic metal analyses (^{210}Po is the α-emitting nuclide with the smallest maximum permissible monthly discharge. If this nuclide is shown to be absent, the monthly sum of gross α can be expressed as ^{226}Ra, the next most restrictive α-emitter); and

(iii) acidified (4.8% HNO_3), for γ-spectrometry.

Effluent discharge report

A monthly effluent discharge report is prepared by the plant supervisor from the results of analyses of all pipeline discharge samples and the various monthly composite samples. The minimum number of specific analyses required to satisfy the requirements of the discharge formula are used in compiling the report. ^{210}Po, ^{3}H and β-γ emitters are determined quantitatively on composites, and gross α and gross β are derived from the totals of all individual pipeline discharges, or the analysis of the monthly pipeline composite, whichever is the greater.

If a pure γ-emitter is detected in the monthly composite analyses, its value would be included as an additional component of the discharge formula, assuming that it has not been counted towards the sum of gross β for the month. Normally, the significance of the summation term

$$\Sigma \frac{Xi}{\text{m.p.m.d.}_i}$$

is inflated by assuming that the major radioactivity term gross β is all $^{114m-114}$In. ($^{114m-114}$In is a β-emitting nuclide with the smallest maximum permissible monthly discharge. If this nuclide is shown to be absent, the monthly sum of gross β can then be assumed to be ^{32}P, the next most restrictive β-emitter.) If necessary, further analyses can reduce the value of the summation term to well below the permissible discharge value $\frac{V}{3 \times 10^6}$.

3. LIQUID WASTES IN CONTAINERS

Waste disposal request cards accompany the containers and carry information about the wastes' characteristics and volume and the content of any accountable nuclear materials in the containers. Papers relating to wastes containing accountable fissile materials are processed through the Nuclear Materials Officer.

Segregation of the wastes at the source facilitates handling and treatment because

- the main fraction of the waste radioactivity remains concentrated within relatively small volumes which can be further concentrated and stored or disposed of by other special measures;
- wastes not compatible with the operation of the low level effluent treatment plant can be excluded from the system; and
- toxic and non-aqueous wastes can be treated and disposed of individually.

3.1 Facilities

The medium and high level liquid waste storage facility is used for

(a) long-term storage of safeguarded liquid wastes containing fissile and fertile materials, and

(b) temporary storage and treatment of aqueous and non-aqueous liquid wastes before disposal.

The building has a concrete storage basement divided into five bays, four of which contain eleven shielded stainless steel and glass lined storage tanks. Two of these tanks are used for storage of liquid wastes containing fissile materials. The basement roof forms the floor of the operating bay. Access for wastes and equipment is through an airlock and roller shutters and doors which are normally closed. A filtered air ventilation system operates continuously, with balanced supply and exhaust ducts serving the operating bay, the storage basement and the other areas. The operating bay is certified to hold 100 g of fissile materials. Containers of radioactive wastes with surface dose rates exceeding 200 mrad h^{-1} cannot be stored in the bay.

Facilities and equipment in the operating bay include:

(a) An overhead crane of 10 tonne capacity.

(b) An arrangement of valves, transfer couplings and a manifold for liquid waste transfer into the basement storage tanks. Liquid is transferred by creating a vacuum in the selected storage tank. A rotary vacuum pump capable of giving a pressure of 3.4 kPa absolute (29 in. Hg vac) is installed.

(c) Pressure differential equipment to gauge the volume of liquid in the basement tanks. Tanks are gauged after each liquid waste transfer, to check the nominal volume of waste transferred and the correct selection of storage tanks. As a routine precaution, catch-tanks under the basement storage tanks are pneumatically checked for signs of leakage once a week. A device to sample high level waste from the basement storage tanks is available.

(d) Three stainless steel process tanks of 700 ℓ capacity each, a transportable stirrer for the process tanks, and a centrifuge for dewatering process sludge or precipitates.

(e) Stainless steel drums (200 ℓ) to hold degraded heavy water from drainage and flushing of the heavy water circuit ion exchange column in the reactor HIFAR. Every two years, when 800 ℓ of degraded heavy water has accumulated, contaminants are removed by an ion exchange process. The purified heavy water is then stored for future upgrading.

(f) Various armoured glass and plastic containers for interim storage of medium level, toxic and non-aqueous liquid wastes.

3.2 High Level Liquid Waste

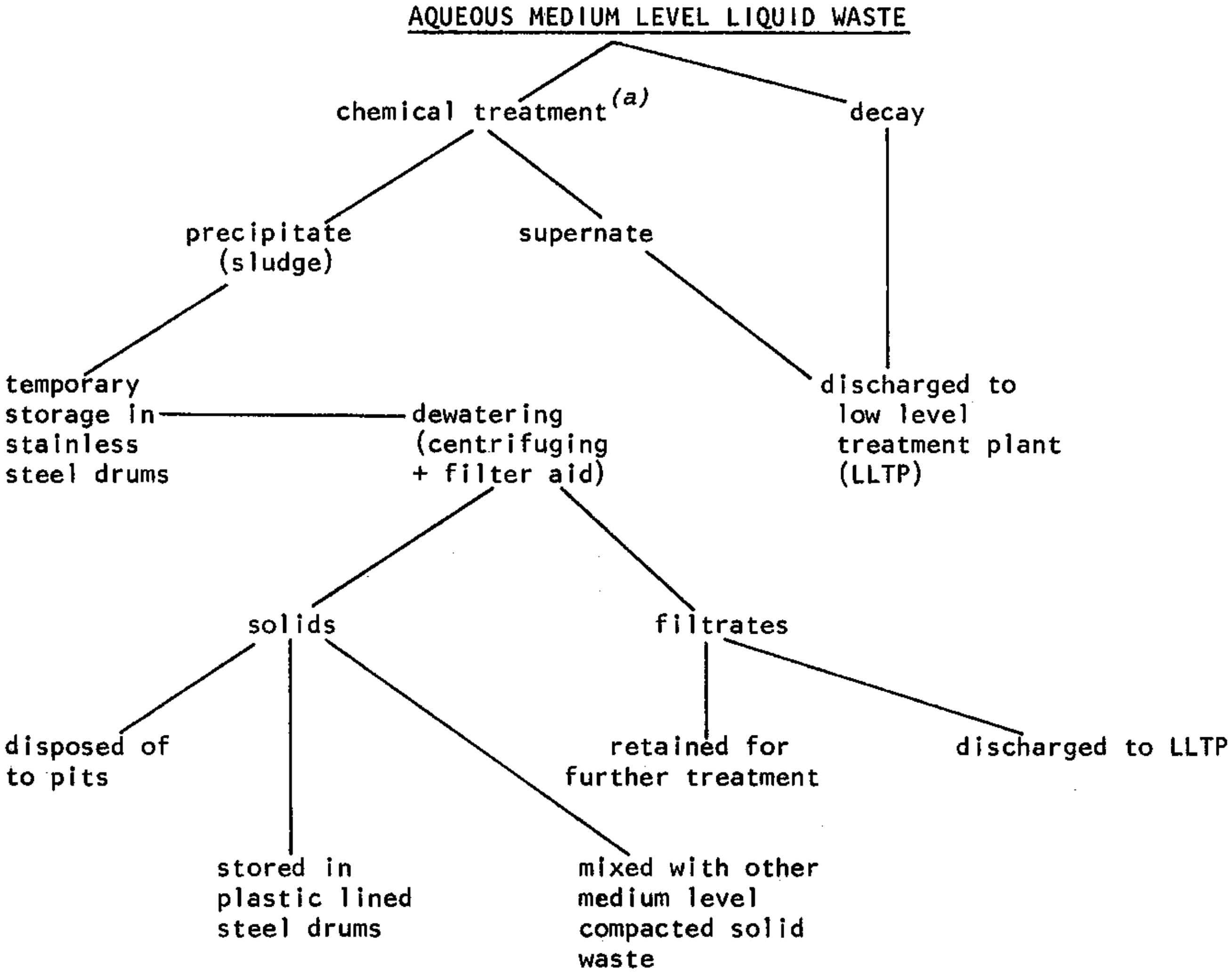
High level liquid wastes are collected in appropriate containers and transported on a trailer. The vehicles, shielded flasks and staff required for the transportation of the wastes are provided by the AAEC personnel responsible for solid waste handling.

High level wastes with surface dose rates exceeding 200 mrad h^{-1} are temporarily stored in the building where high level solid wastes are stored. After sufficient decay period, when the surface dose rates have decreased to a level below 200 mrad h^{-1}, they are transferred for treatment. However, the high level waste uranyl nitrate solutions from the elution of irradiated UO_2 for the production of ^{99}Mo (dose rate greater than 200 mrad h^{-1}) are transported direct for storage in basement tanks.

High level liquid wastes have so far been received in aqueous form. Treatment of the cooled (decayed) wastes usually involves chemical precipitation and/or coagulation of the radioactivity bearing elements and other contaminants. The precipitates or sludges are dewatered and stored. Occasionally, the precipitates have been immobilised in vermiculite and concrete before disposal to concrete pits at the Research Establishment. The supernates are discharged to the low level effluent treatment plant or retained for subsequent treatment, depending on the residual level of radioactivity or contaminant.

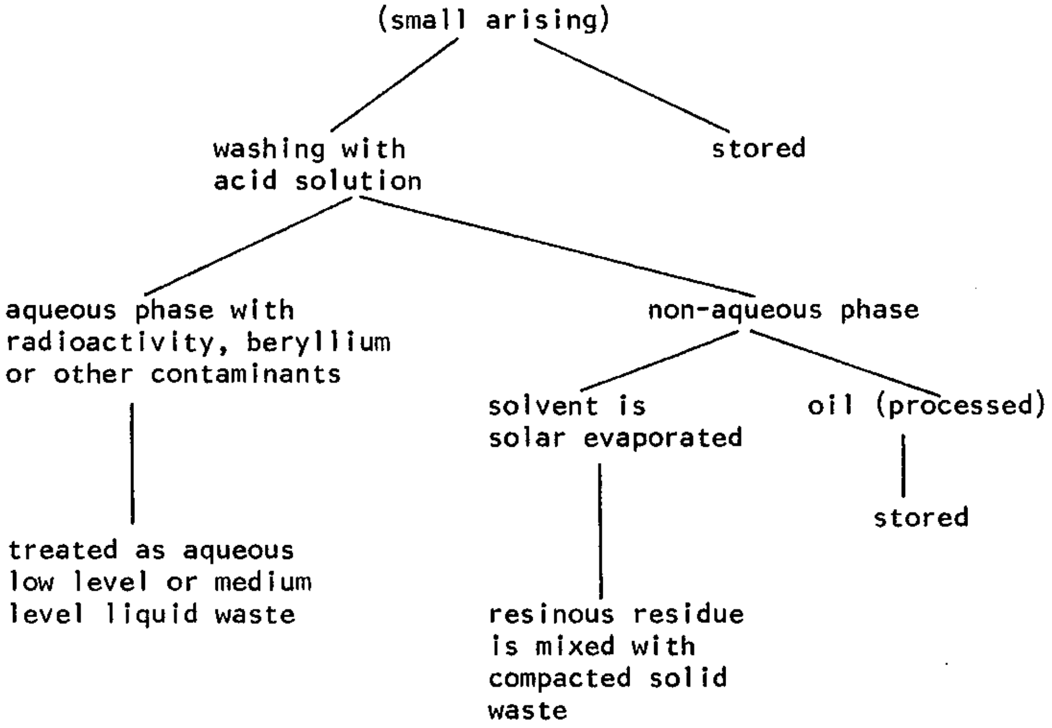
3.3 Medium Level Liquid Waste

The treatment and disposal of medium level liquid wastes are summarised in the following diagrams:



(a) *Chemical treatment may be carried out in the container in which the waste is received or in the process tank in which the waste is mixed with other wastes requiring similar treatment.*

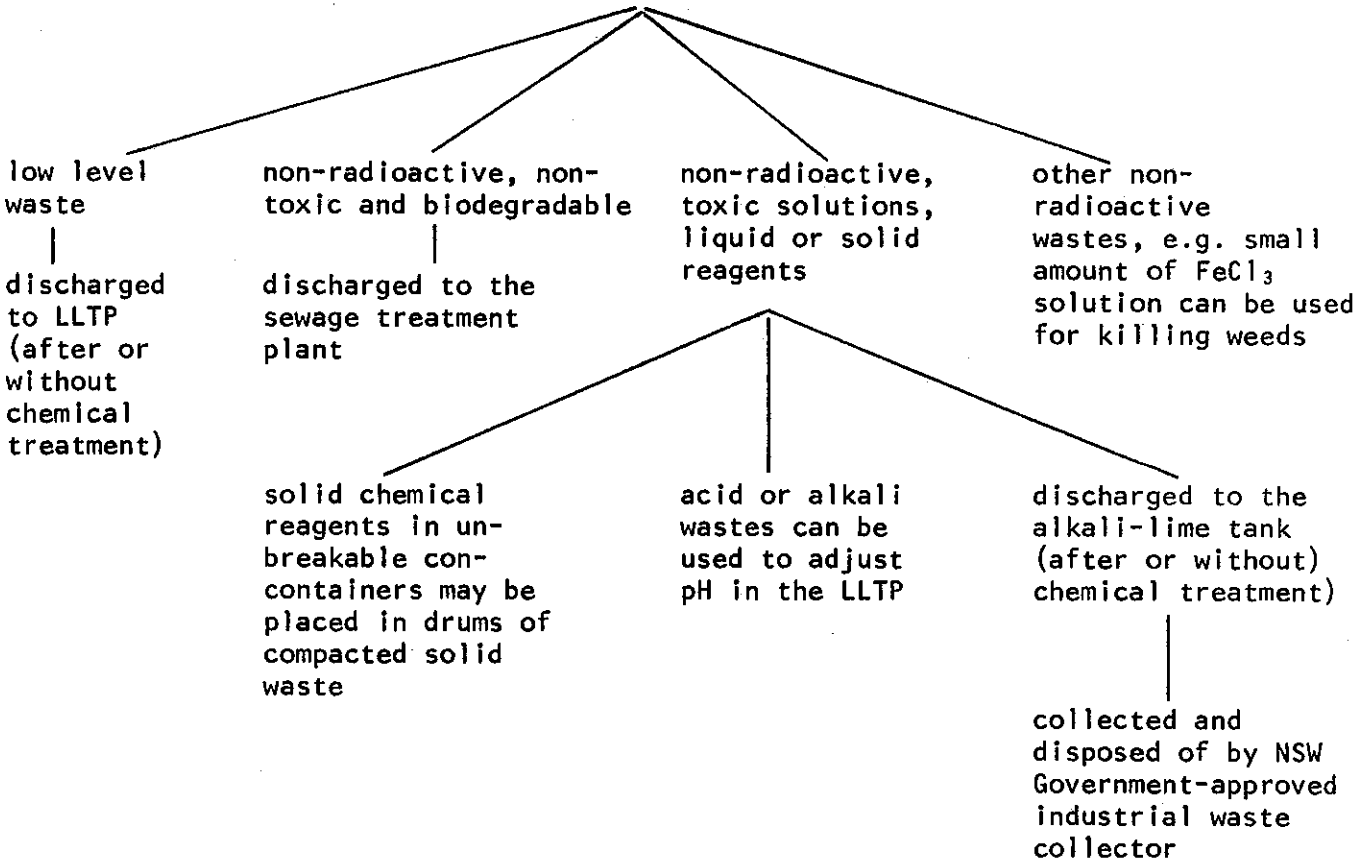
NON-AQUEOUS MEDIUM LEVEL LIQUID WASTE



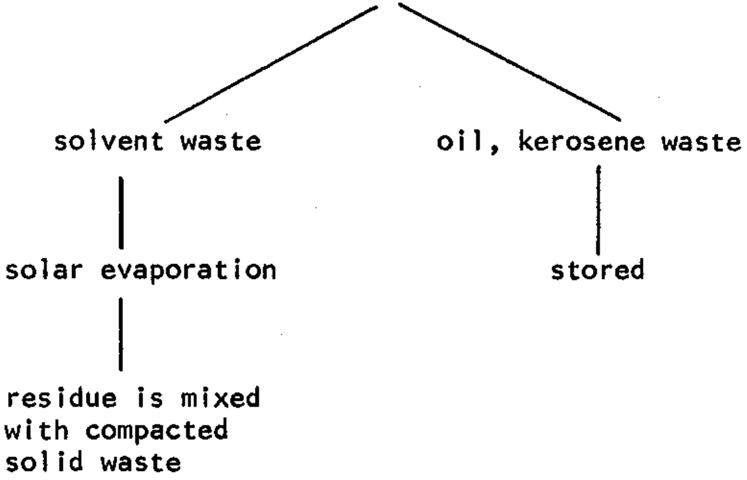
3.4 Low Level and Non-radioactive Liquid Wastes

The treatment and disposal routes for these wastes are shown in the following diagrams:

AQUEOUS LOW LEVEL AND NON-RADIOACTIVE LIQUID WASTES



NON-AQUEOUS LOW LEVEL AND NON-RADIOACTIVE WASTES



4. ENVIRONMENTAL SURVEY

The environmental sampling program of the Research Establishment, comprising the site, its surrounding area and the Woronora River estuary, was initiated before controlled discharges into the river commenced in 1961. This program was designed to verify the effectiveness of the imposed effluent discharge controls, and to enable comparisons to be made with the background radioactivity readings taken before discharge began.

The Woronora River environmental survey includes the sampling of fish, oyster, vegetation, sands, residues and river water. Samplings to date show that the maximum possible effect due to the presence of some radioisotopes which could not be attributed to natural background or weapon test fall-out is below three orders of magnitude less than maximum permissible dose limits recommended by the International Commission on Radiological Protection for members of the public [ICRP 1966].

Published reports of the environmental survey results can be obtained from the Australian Atomic Energy Commission [Davy & Dudaitis 1961-1976]

5. ACKNOWLEDGEMENT

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