WASTE DISPOSAL PROBLEMS AT THE INSTITUTO DE ENERGIA ATÔMICA

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CIDADE UNIVERSITÁRIA "ARMANDO DE SALLES OLIVEIRA"

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WASTE DISPOSAL PROBLEMS AT THE INSTITUTO DE ENERGIA ATÔMICA

por

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RESUMO

O Autor apresenta uma avaliação preliminar do problema dos resíduos radioativos líquidos, no Instituto de Energia Atômica.

Vários tipos de resíduos produzidos no presente ou esperados em futuro próximo são descritos ou tentativamente avaliados.

O sistema de drenagem natural, nesta área é brevemente descrito e as vazões anuais indicadas.

É examinada a dispersão dos resíduos líquidos nas correntes próximas e sugerida a construção de uma estação de tratamento.

SOMMAIRE

L'Auteur présente une évaluation preliminaire de problème des effluents radioactifs liquides de l'Instituto de Energia Atômica.

Différents types d'effluents produit actuellement du esperés dans un futur proche sont décrits et évalués approximative - ment.

Le système de drainage naturel est décrit brievement, on a aussi indiqué les debits annuels.

On a examiné la dispersion d'effluents liquids et on a suggeré la construction d'une station de traitement.

ABSTRACT

A preliminary evaluation of the radioactive liquid waste problem at the Instituto de Energia Atômica is hereby presented.

Several types of wastes produced at present, or expected in the near future, are herein described or tentatively evaluated.

The natural drainage system of this area is also briefly described and the annual flowrates indicated.

Dispersion of radioactive liquid wastes into the available near-by streams is examined and the construction of a treatment plant suggested.

A) INTRODUCTION

The aim of this paper is to present a first evaluation of the radioactive waste disposal problems at the Instituto de Energia Atômica in São Paulo. Several factors contribute to render this evaluation difficult.

This Institute started operating only a few years ago and is still in the process of development. Many fields of research in nuclear science remain open, practically untouched by the scientific organization of the said Institute.

There are plans for considerable expansion in the years to come, where a staff of 500 people, including scientists, technical and administrative personnel, is being considered.

Particularly in the fields of Nuclear Engineering, Nuclear Metallurgy, Chemical Engineering and Reactor Physics, a large amount of work will be required to support the implementation of the Brazilian Atomic Energy Program.

The utilization of radioisotopes in medical science, research and the profession as a whole, is spreading steadily, and

industry in general is beginning to get acquainted with and interested in the application of radioisotopes to its own uses.

Furthermore, atomic technology is a fast-changing one, rapidly and constantly improving as a result of the very considerable expenditures applied to research by the more developed countries.

It seems difficult to evaluate today what will be the characteristics and intensity in the development of scientific and technologic activities at the Institute five or ten years hence.

As a first step for a sanitary engineering evaluation, some sort of prediction must be made if it is wished to project our present waste disposal picture into the near future.

We hope that our assumptions and considerations will allow for at least some design criterion to be achieved for a future waste-disposal plant or procedure.

In the following considerations, only the radioactive contamination aspect will be considered, the chemical, organic, thermal or other pollution aspects being disregarded.

B) RADIOACTIVE LIQUID WASTES

Liquid wastes from the Radiochemistry Division

There are three main sources of contaminated wastes originating in the normal Radiochemistry Division operations, namely:

1. Radioisotopes production
2. Ion exchange uranium purification pilot plant
3. Research laboratories.

1) Radioisotopes production

In the radioisotopes production, the effluents from the

I^{131} preparation process constitute the major problem. This radionuclide has been produced at the Instituto de Energia Atômica by neutron activation of Te^{131}, irradiating Telluric Acid in the swimming pool reactor with a neutron flux of 2×10^{13} n/sec.cm^2 at an average energy level of 2 Mev.

This operation is performed at present eight hours a day for two consecutive days each week.

Fig. 1 shows the monthly quantities of irradiated acid; Fig. 2 and 3, typical gamma spectrograms of the residue, and Fig. 4 the theoretical total gamma activity decay pattern. It is a very concentrated waste and must be classified as "hot" or "high level waste" (over 1 mc/gal) until approximately 10^3 hours of cooling time.

The other radioisotopes produced by irradiation of liquid solutions, like P^{32}, do not present a problem of waste disposal due to the short half-lives of the activated nuclides and to the small amounts produced to date.

2) Ion exchange purification pilot plant

This is a small scale installation and the quantity of effluents produced is not large. The main residue from the process, with the radium and other alpha emitter daughters of Uranium is retained and stored. Only a very low level liquid effluent is discarded intermittently, its volume being so small that it could be considered as part of the radiochemistry research laboratories' wastes.

3) Research laboratories

There are almost 50 laboratory sinks connected to the contaminated waste drainage system at the IEA. The present flow is small; however, with the proposed increase in the number of research personnel, it could be estimated at 5 m^3/day. There is

no point in trying to assay the composition and activity of this waste now, because we know that very soon great modifications will occur. Table 1 (*) reproduces the more complete information we were able to find for this type of laboratory waste among published literature.

LIQUID WASTE FROM RADIOBIOLOGY DIVISION

At the moment the liquid waste flow is also very small. However, with the proposed expansion, new laboratory facilities will be installed and a flow rate similar to that of the Radiochemistry Division will be a reasonably expected figure. Table 1 also presents information regarding radioactive physical and chemical characteristics of this type of waste.

Liquid wastes from the Chemical Engineering Division

The Chemical Engineering Division is concerned with the technological problems related to the production of nuclear grade Uranium and Thorium from monazite sands. In the future, burnt fuel processing and Plutonium separation may also be objects of investigation and research.

Monazite is processed in a plant operated by CNEN, also located in São Paulo, but not at the IEA. Fig. 5 indicates schematically the flow sheet of this process. Final products, Torta II, a slurry containing Th and U, and the $U_2O_7Na_2$ solutions are the starting raw materials for the two pilot plants that will be constructed at IEA for the solvent extraction and purification of Th and U respectively.

Fig. 6 and 7 indicate the flow sheets of both processes, the

(*) K.A. Bolshakov - Conference for Peaceful Uses of Atomic Energy Genebra 1958 - vol. 18 - Pilot Plant for laboratory Liquid Wastes Decontamination

Table 1

Contaminant	Wastes of chemical laboratories	Wastes of biophysical laboratories	Wastes of laundries
	ppm		
Sodium, Na	92	62	359
Calcium, Ca	40	80	2
Magnesium, Mg	18	18	1.2
Ferric oxide	2.8	-	-
Ammonia	0.18	1.1	0.2
Potassium, K	-	33	11.2
Manganese, Mn	-	-	8.2
Bicarbonate	85	67	79.2
Nitrates	99	31	-
Chlorides	46	96	241.5
Chromates	0.6	-	-
Sulphates	14	48	91.2
Silica	106.5	106.5	106.5
Sulpho-naphtenic acides[a] ..	38.2	13.9	174
Oil and other organic substances	40	41.4	160
Total quantity of different salts	622	1040	1756
pH	7.8	8	5.5
Concentration of α-emitters, curie/liter ..	$1x10^{-7}$	$1x10^{-9}$	$1x10^{-7}$
Concentration of β and γ emmitters, curie/liter	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$
Biochemical oxygen demand (BOD) ppm	5-10	300-350	250-300

a) Sulpho-naphtenic acides are components of the petroleum-oil wetting agent used for washing surfaces contaminated with radioactive elements. The petroleum-oil wetting agents are obtained by treating high temperature oil-refinery products with sulphuric acid.

amounts and probable compositions of the wastes expected. Most of the Radium and other alpha emitter daughters of Thorium and Uranium will be co-precipitated with SO_4Ba and retained as filter cakes, which will be stored for further reprocessing.

The filtrates and wash waters from the Uranium pilot plant will amount to approximately 4.6 m^3/day with 40 ppm uranium, almost free of radium. It is expected that the specific activity of this residue will be of the order of 10^{-5} μc/ml. The filtrates and wash waters from the Thorium Pilot Plant will also amount to 4.6 m^3/day with 10 ppm of Th.

However, due to the relatively short-lives of the Th^{232} daughters, the purified element Th^{232} is brought rapidly to equilibrium with its descendants as indicated in Fig. 8. It is then expected that this waste will also have a specific activity of 10^{-5} μc/ml, considering the presence of the Thorium daughters.

Liquid wastes from the Nuclear Metallurgy Division.

Liquid waste processed at the Nuclear Metallurgy Division originates from cleaning, washing and decontamination routine operations, of equipment surface accessories, tools and personnel.

The processes at the Nuclear Metallurgy Division are related to the fabrication of UO_2, ThO_2 and BeO sintered pellets, and laminated fuel elements with Aluminium cladding. Figure 9 indicates the flow sheet for the fabrication of sintered UO_2 pellets. Similar processes are or will be used for ThO_2 and BeO.

It can be seen that only solid materials are processed. However, due to the fineness of UO_2 powder, the hazard of atmosphere contamination by dusts should be considered. Also gases such as radon and thoron will escape in several phases of the process and will reach the atmosphere during operations, like charges and discharges of the equipment. Alpha emitters daughters of radon and thoron will be deposited on the surface of dusts and

impurities in the atmosphere and eventually will settle on the floor or other surfaces. A decontamination routine operation is carried out by periodically washing the areas and facilities for these processes. The waste waters produced in these operations will carry insoluble oxides of U and Th that may be in colloidal suspension. However, the contamination by soluble compounds is very improbable. It is estimated that the wastes from the Nuclear Metallurgy Operations' flow rate will be near 10 m^3/day.

It is expected that the specific activity of this waste, after sedimentation, will be low ($\leqslant 10^{-6}$ μc/ml).

Other liquid wastes from IEA

The swimming pool reactor has a water purification system consisting of recirculation through beds of activated carbon and ion exchange resins. Corrosion products, activated by neutron flux, fission products that may eventually diffuse through the fuel elements cladding and radioisotopes that may escape from the inside of the recipients where they are irradiated, may continuously contaminate the demineralized water of the reactor swimming pool. These contaminants are continuously retained by the ion exchange resins. Periodically, these resins are regenerated and the spent regeneration solutions will carry the contaminants away and will constitute a radioactive waste.

Fig. 10 shows a gamma spectrogram of a sample of this type of waste after a cooling period of about 3 months, showing clearly the presence of I^{131}. However, the amount of this waste, which reaches 500 liters every 3 months, is insignificant.

Another contaminated waste is that originating in laundry operations. Table I also indicates typical characteristics of this waste.

It is estimated that the IEA uncontaminated wastes from washing and cleaning routine operations, equipment cooling water

and sanitary sewage, after the proposed expansion, will not exceed 200 m^3/day.

We can, for a preliminary study, use the figures indicated in Table 2.

Table 2

Type of waste	Specific Activity	Daily quantity
Hot	over 10^{-3} μc/ml	2 liters
Cold	$10^{-3} > A > 10^{-8}$ μc/ml	25 m^3
Uncontaminated	10^{-8}	100-200 m^3

Table 3 shows an estimation of the future daily amounts of radioactivity discharged, considering a cooling time of 10^4 hours for the Telluric Acid irradiated.

Table 3

	Q M^3/day	Spec. act. μ/ml	μc/m^3	Total act. μc/day
Chemical Engineering Division	5	10^{-5}	10	50
Radio Chemistry & Radio Biology Division	10	10^{-4}	100	1000
I^{131} processing	.002	10	10^7	20000
Nuclear Metallurgy Division	10	10^{-6}	1	10
				21060 μc/day

c) ENVIRONMENT

The IEA is located in the campus of the University of São Paulo, Butantã District, on the left bank of the Pinheiros River, as indicated in Fig. 11.

The campus covers an area of approximately 3.8 km^2 with a hilly topography and an altitude varying between 720 and 800 meters. It is limited on the northeast by the Jaguaré stream and on the southwest by the Pirajussara stream, both afluents of the Pinheiros River.

The sub-basin of the Pinheiros forms part of the socalled Upper Tietê basin, which is defined by its watersheds from the springs to Pirapora Dam, with nearly 5.0 km^2 of drainage area.

Average flow, based on 15 years of observation, is assumed to be 105 m^3/sec. The Pinheiros sub-basin contribution of about 30 m^3/sec. is regulated by the Billings and Guarapiranga Reservoirs and diverted to the Cubatão Power Plant. Also more than 95% of the balance from the Upper Tietê flow is pumped to the Billings Reservoir to be used in the same Power Plant. This is achieved by two pump stations located at Pinheiros, which was transformed into a channel and has had its course reversed.

From the Cubatão Power Plant, the waters from the Upper Tietê basin reach the Ocean through the Santos Estuary.

Considering that the maximum permissible concentrations in the water are based on the assumption of chronic exposition to radiation during a working life of 30 years, it is reasonable to take yearly average flows to calculate dillution capacities. With this criterion, we can adopt the following figures, indicated in Table 4.

The University Campus has a drainage system of a separate type. Rain water is collected and conveyed to Jaguaré or Pirajussa

ra streams. Sanitary sewage is collected and directed to the Pinheiros Sewage Treatment Plant (in construction), the effluent being discharged into the Pinheiros.

Digested sludges from this Treatment Plant will be pumped to sludge drying lagoons located at Vila dos Remédios, and the dry product may be used as fertilizer. Gases produced in the sludge digestion will possibly be used as fuel.

Table 4

	Average flow	
	M^3/sec.	M^3/day
Jaguaré Stream	0.2	1.7×10^4
Pinheiros Channel	70.0	6×10^6
Billings Reservoir	100.0	8.6×10^6
Santos Estuary	120.0	10^7

PRELIMINARY ANALYSIS OF THE DISPOSAL OF THE IEA RADIOACTIVE LIQUID WASTES INTO THE INLAND SURFACE WATERS

Legal Aspects. Water Pollution Control in our country is regulated by the following applicable legislations:

Federal Decree Nº 24643 of July 10th, 1934
Federal Decree Nº 50877 of July 29th, 1961
São Paulo State Law Nº 1561 - A of December 29th, 1951
São Paulo State Law Nº 2182 of July 23rd, 1953
São Paulo State Law Nº 3068 of July 14th, 1955
São Paulo State Decree Nº 24806 of July 27th, 1955

This legislation forbids the discharge of wastes into streams unless it can be demonstrated that the physical, chemical

and biological characteristics of the waters will not suffer alteration in such a way as to inconvenience its actual or potential utilization.

Water supervision is provided by Federal and State Public Health Authorities.

In the legislation there is no direct reference to radioactive pollution; however, it could be included in the general water pollution concept.

Activities in the Atomic Field in this country are regulated by Federal Law Nº 4118 of August 27th, 1962 and Federal Decree Nº 51726 of February 19th, 1963, that organized the CNEN - Comissão Nacional de Energia Nuclear.

In Tit. II - Chapter I "Objectives and Attributions", Art. 4 from the Federal Ordinance says: ..... it is of the incumbency of the CNEN .....

> "V - To establish safety rules and procedures, related to the use of ionizing radiations and nuclear materials, and the installation and operation of plants that produce nuclear materials or use nuclear energy, and to fiscalize the observation of the said rules and procedures directly or in collaboration with other government agencies".

Public health aspects

The International Committee of Radiation Protection has made recommendations for the following categories of exposure to ionizing radiation:

A. Occupational exposure.
B. Exposure of special groups.
C. Exposure of the population at large.

Table 5 indicates the maximum permissible concentration of

radionuclides in water, for continuous occupational exposures.

Table 5

Limitations	$\mu c/cm^3$ of water
If none of the radionuclides Sr^{90}, I^{126}, I^{129}, I^{131}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ra^{228}, Ac^{227}, Th^{232} and Th-nat. are present	3×10^{-5}
If none of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{223}, Ra^{226}, Ra^{228}, Pa^{231} and Th-nat. are present	2×10^{-5}
If none of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Ra^{226}, Ra^{228}, are present	7×10^{-6}
If neither Ra^{226} or Ra^{228} is present	10^{-6}
If no analysis of water is made	10^{-7}

Regarding the exposure of populations at large (Category C), the suggested limits are not considered definitive but are presented as a guide in planning nuclear energy programs.

If the radionuclides or mixtures of radionuclides in consideration have the body or the gonads as critical organs, its is suggested that a factor of .01 be applied to the values listed in table 5. In the other cases, a factor of .033 should be applied.

Taking into consideration the recommendations in this preliminary evaluation, we shall use as Maximum Permissible Concentrations the values 2.3×10^{-7} μc/ml for the Telluric Acid waste and 10^{-9} for the mixture of the other radioactive wastes.

The amount of water then required to dilute the activities indicated in Table 3 to the above concentrations will be:

$$\frac{2 \times 10^{4}}{2.3 \times 10^{-7}} = 8.7 \times 10^{10} \text{ ml/day} = 8.7 \times 10^{4} \text{ m}^3 \text{ day}$$

$$\frac{1.06 \times 10^{3}}{10^{-9}} = 1.06 \times 10^{12} \text{ ml/day} = \frac{1.06 \times 10^{6} \text{ m}^3/\text{day}}{\text{Total} \sim 1.15 \times 10^{6} \text{ m}^3/\text{day}}$$

Comparing this figure with those indicated in Table 4, it can be seen that the discharge of these waters into the Jaguaré stream will require a treatment with a decontamination factor of 10^2 order of magnitude, and the discharge into the Pinheiros River is feasible once the following relationship is observed:

$$\frac{C_{Te}}{MPC_{Te}} + \frac{CM}{MCP_m} \leq 1, \text{ where}$$

(C_{Te} = water concentration of Telluric Acid.

C_m = water concentration of mixed radio-nuclides

MPC_{Te}) = maximum permissible

MPC_m concentrations

Uncertainty and other aspects.

We have seeen that in a first evaluation of the radioactive wastes expected in the near future from IEA, the required amount

of water dillution is of the same order of magnitude as the average flow of the Pinheiros Channel. However, the following facts must be duly considered:

1) The absence of better elements to permit more precise forecasts on the problem.

2) The limited knowledge we possess at this time of the reconcentration mechanism of certain nuclides by the aquatic biota, and the associated hazard represented by increased internal exposition due to the possible contamination of food chains.

3) It is desirable to study problems related to radioactive waste treatment and to train personnel, since this type of specialists will be required at the future Atomic Power Plants and Fuel Processing Plants.

In consideration of the above-mentioned reasons, we believe that the following conclusions could be reached and used as criteria in the waste disposal problem:

a) Hot effluents should be kept in cooling storage for an adequate period.

b) Cold effluents should be collected in separate contaminated drainage systemsaand monitored.

c) Treatment facilities in pilot plant scale, as suggested in fig. 12, should be provided, as the development of the diverse activities might require.

d) Uncontaminated and sanitary sewage should be collected in separated uncontaminated drainage systems and monitored.

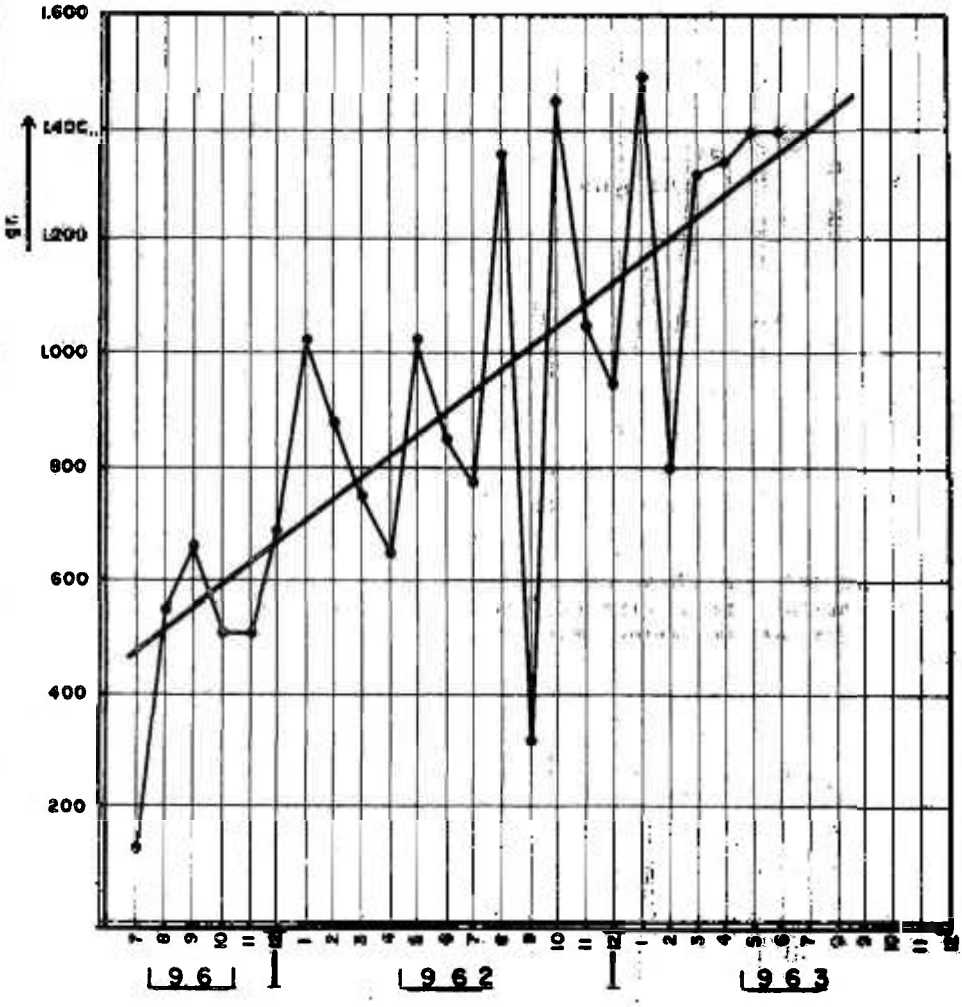
e) Both drainage systems should convey their wastes to the same area or point where, having only one installation, all the waste handling activities, like hot storage, treatment and monitoring, dispersion or permanent storage, could be centraliz

ed with resulting operational benefits.

f) Daily discharge should comply with the formula

$$0.7\ Te + 166.6\ M \leq 1$$

where Te and M are curies of Telluric acid wastes and other mixed radioactive wastes.



MONTHLY QUANTITIES OF TELLURIC ACID IRRADIATED AT I. E. A. FOR I^{131} PRODUCTION

Fig. 1

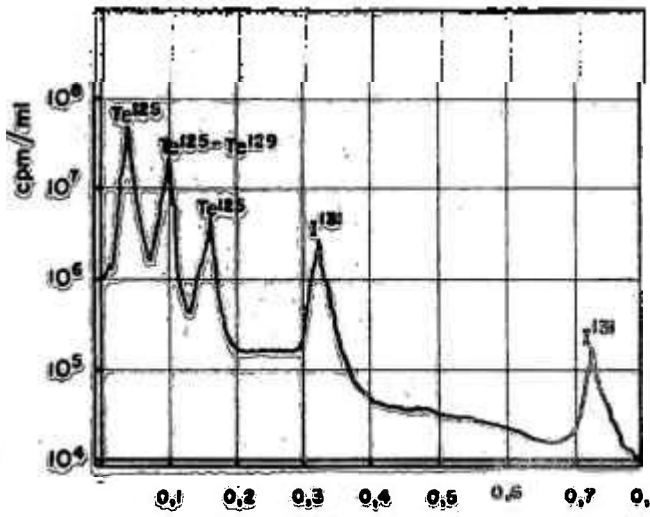


Fig. 2

SPECTROGRAM FROM IRRADIATED TELLURIC ACID EFFLUENT MIXED SAMPLE WITH COOLING TIMES FROM ONE TO SIX WEEKS, FROM MULTICHANNEL PULSE ANALYSER

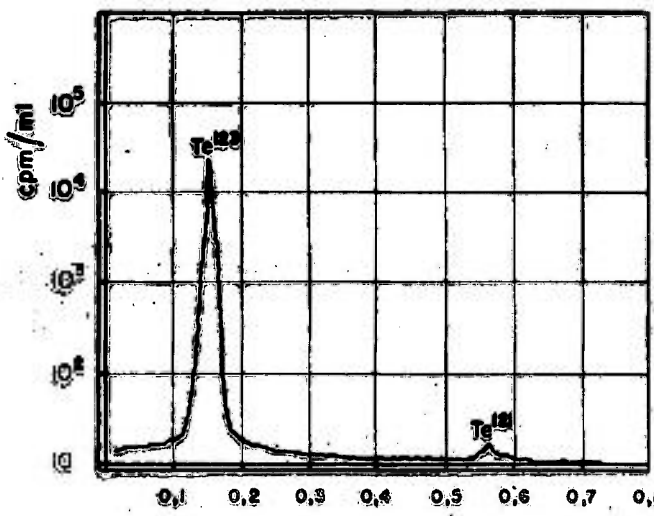
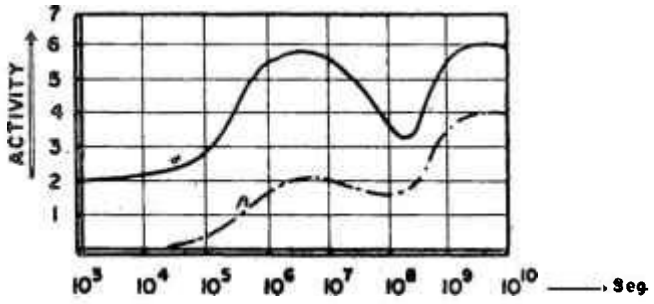
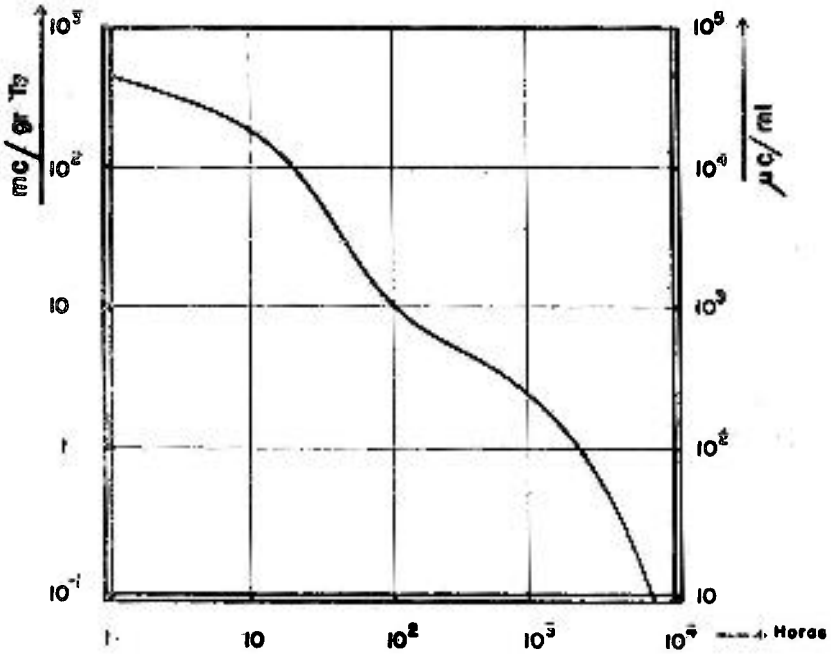


Fig. 3

SPECTROGRAM FROM IRRADIATED TELLURIC ACID SAMPLE WITH ONE YEAR COOLING TIME, FROM MULTICHANNEL PULSE ANALYSER



Th^{232} and Th^{228} ACTIVITY BUILD-UP Fig. 8

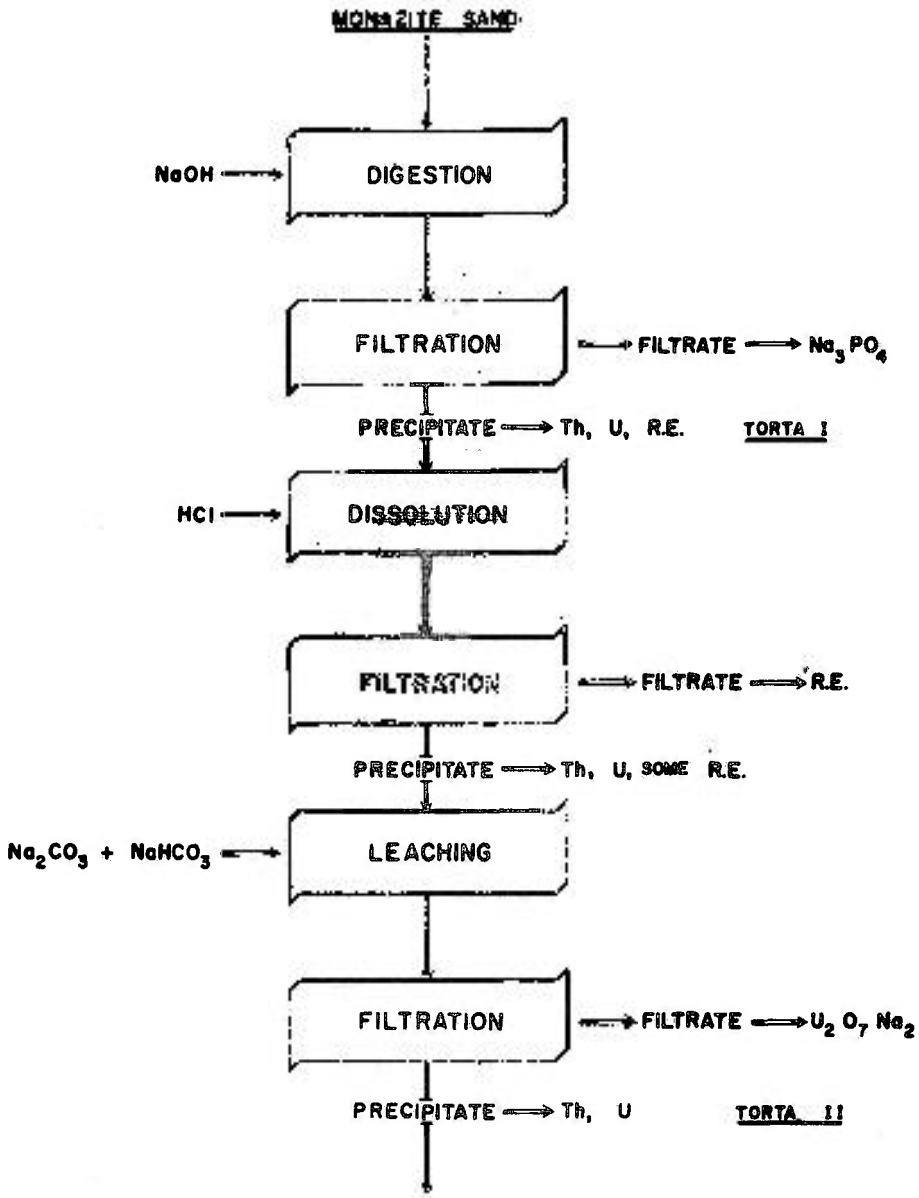


IRRADIATED TELLURIC ACID TOTAL ACTIVITY DECAY Fig. 4

MONAZITE SAND TREATMENT PROCESS

Fig. 5

SIMPLIFIED FLOW SHEET



URANIUM EXTRACTION AND PURIFICATION PROCESS
SIMPLIFIED FLOW SHEET

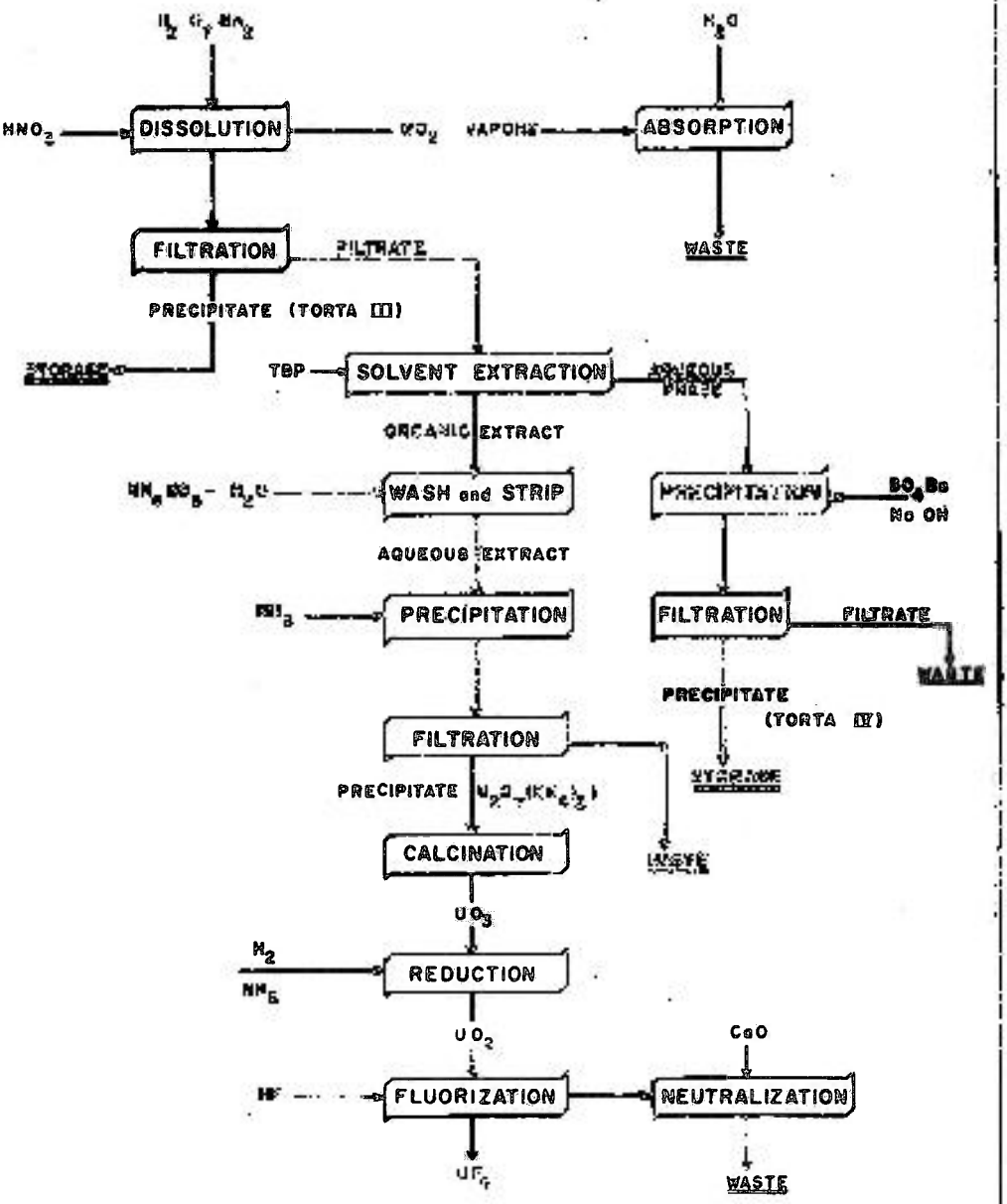


Fig. 6

THORIUM AND URANIUM EXTRACTION AND PURIFICATION PROCESS

SIMPLIFIED FLOW SHEET

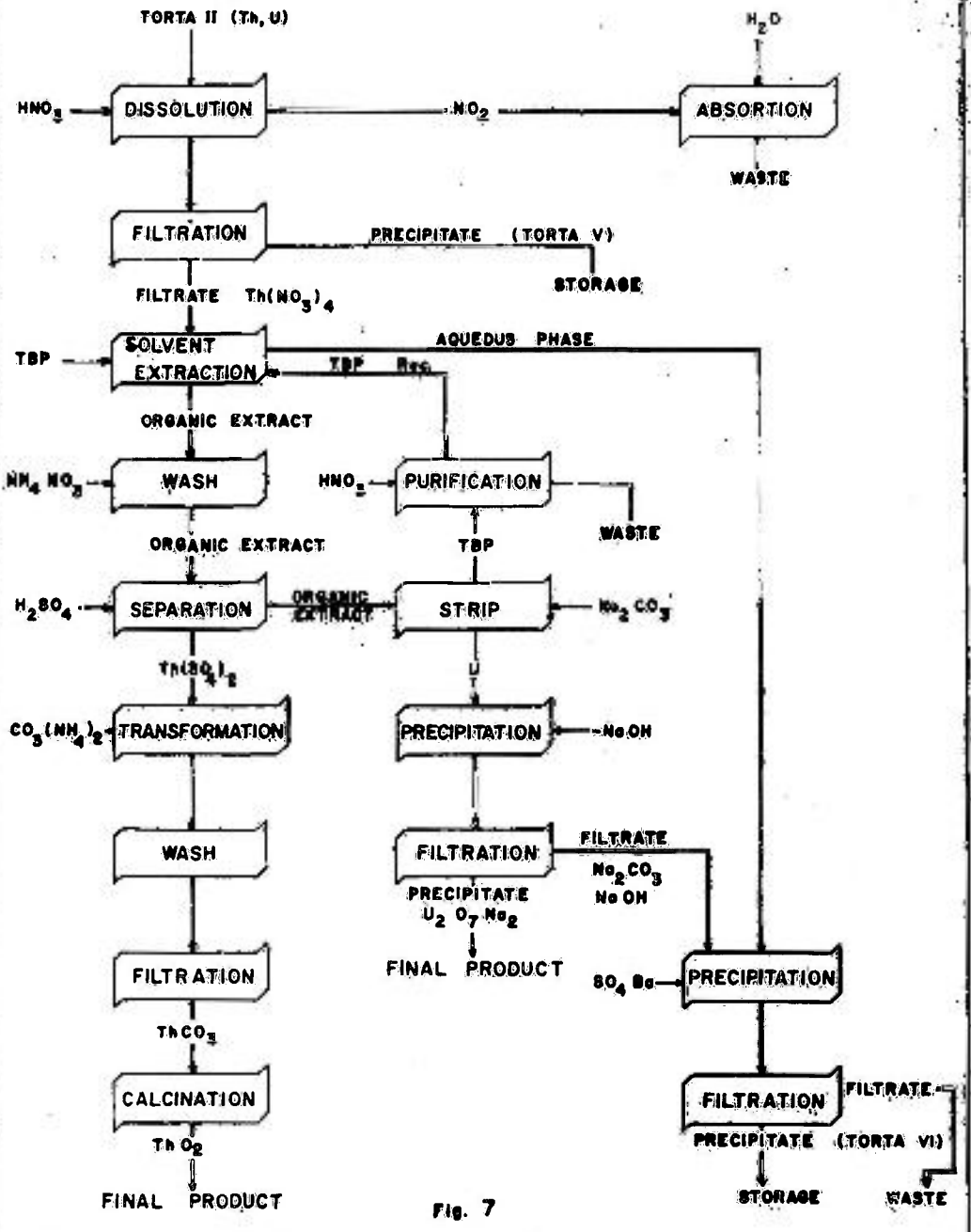


Fig. 7

UO_2 SINTERED PELLET PROCESS

SIMPLIFIED FLOW SHEET

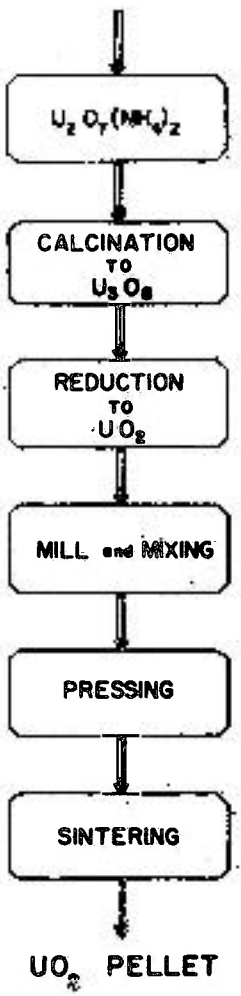
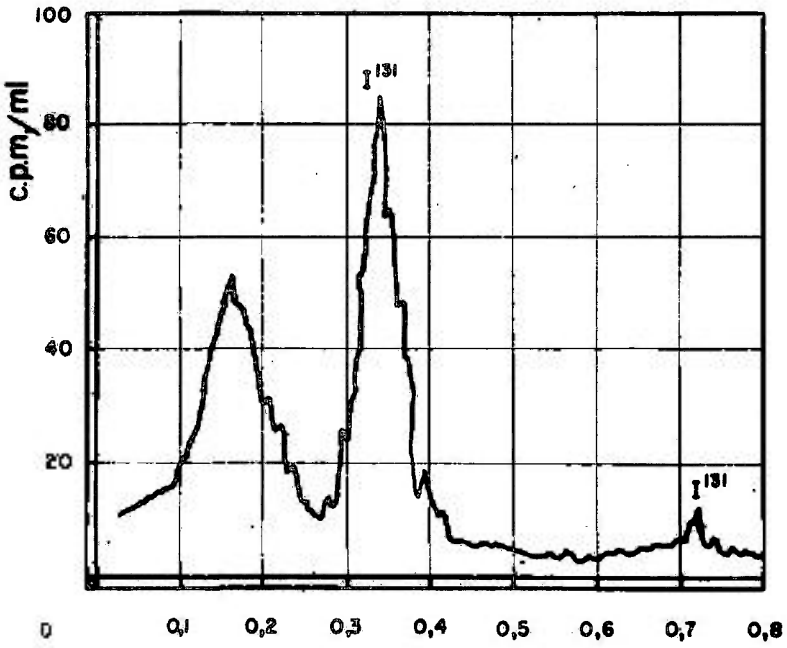
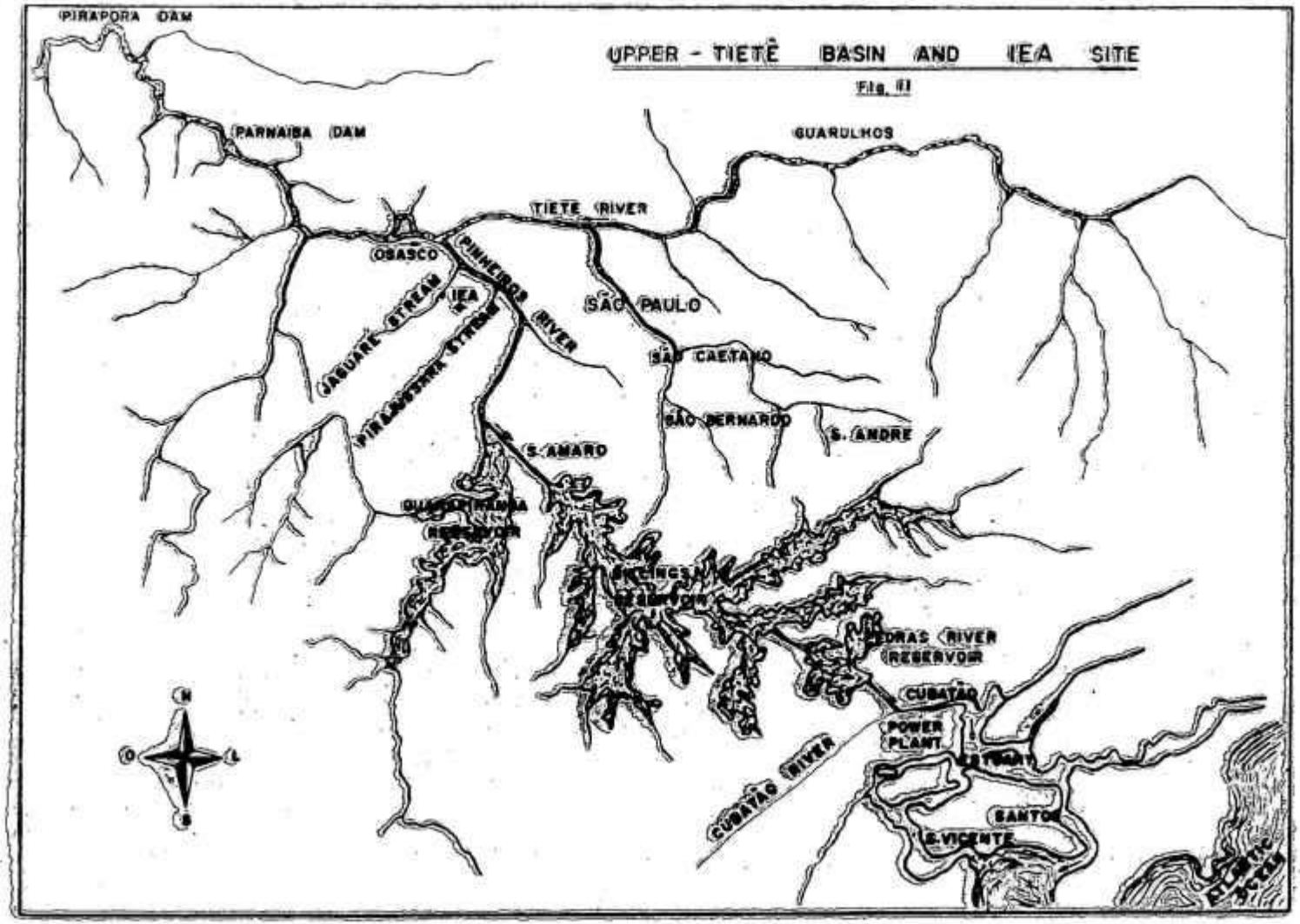


FIG. 9



SWINMING POOL REACTOR ION EXCHANGE PURIFICATION SYSTEM SPECTROGRAM FROM SPENT REGENERATION SOLUTION SAMPLE WITH 70 DAYS COOLING TIME

Fig. 10


UPPER - TIETÊ BASIN AND IEA SITE
Fig. 01
PIRAPORA DAM
PARNAIBA DAM
GUARULHOS
TIETE RIVER
OSASCO
PINHEIROS RIVER
IEA
JAGUARE STREAM
PIRAJUSSARA STREAM
SÃO PAULO
SÃO CAETANO
SÃO BERNARDO
S. ANDRE
S. AMARO
PEDRAS RIVER RESERVOIR
CUBATÃO
POWER PLANT
CUBATÃO RIVER
SANTOS
S. VICENTE
N
O
L
S

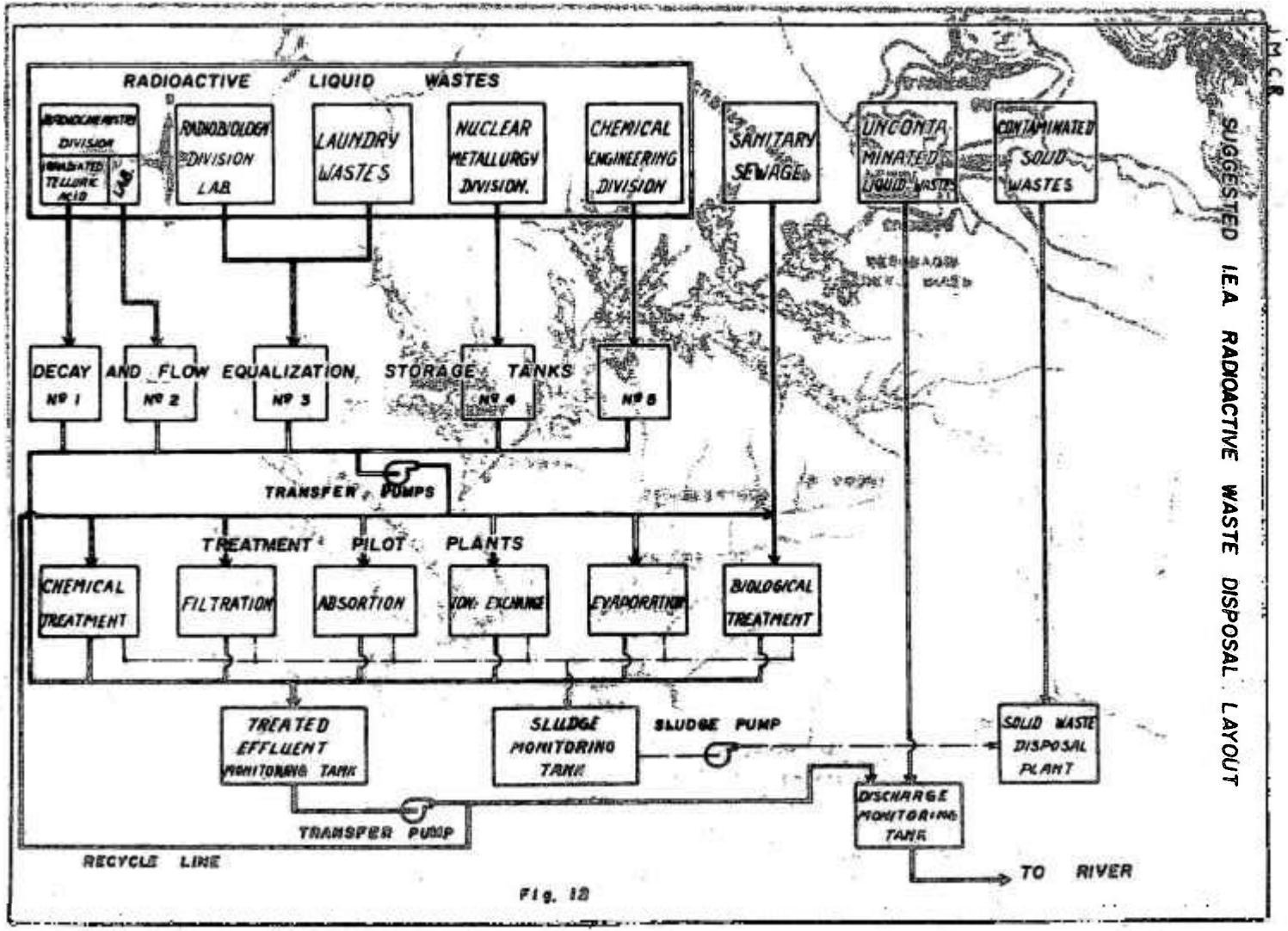


Fig. 12

M.C.R.

SUGGESTED I.E.A. RADIOACTIVE WASTE DISPOSAL LAYOUT