COMMISSION OF THE EUROPEAN COMMUNITIES

RADIOACTIVE EFFLUENTS FROM NUCLEAR POWER STATIONS IN THE COMMUNITY

Discharge Data

Radiological Aspects

NOVEMBER 1972

DIRECTORATE GENERAL OF SOCIAL AFFAIRS

DIRECTORATE OF HEALTH PROTECTION

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A B S T R A C T

This report assembles literature data for 1969, 1970, 1971 on radioactive waste discharges from the nuclear power stations in the European Community. In the case of gaseous effluents a distinction is drawn between noble gases, aerosols and iodine-131, and in the case of liquid effluents between the total activity (excluding tritium) and tritium alone. The discharge data are compared with the discharge limits for the various power stations. In addition, for the liquid effluents the average yearly concentrations reached in the receiving waterbodies are shown, expressed as a percentage of the maximum permissible concentration in drinking water.

Based on the actual waste releases, an evaluation is made of the maximum exposure around each plant site and this exposure is compared with the radiological protection standards in force and with the natural radiation background. Finally, for each power station the ratio of activity discharged to energy produced is given.

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C O N T E N T S

TABLES

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INTRODUCTION

Only in recent years have data been published on radioactive waste discharges from nuclear plants and, in particular, from nuclear power stations. The Commission of the European Communities has initiated an analysis of information available on the subject on a community scale, by drawing up a data-sheet of the waste releases from nuclear power stations within the Community and hereby submits an assessment of their possible radiological consequences. This study is supplementary to the regular publications by the Commission on environmental radioactivity measurements, in accordance with the provisions of Article 36 of the Euratom Treaty.

This report will be issued annually in the hope of extending it and improving its presentation and scope, with the collaboration of the competent authorities and nuclear power station operators.

This document assembles for the Community countries data taken from literature and is limited to gaseous and liquid effluents from nuclear power stations, the increasing number of which will probably represent the major source of radioactive waste discharges in the future. An attempt has also been made to quantify and give a better picture of the risk which the population could face through exposure to radioactive effluents. This is why attention is being focussed on individual doses, expressed in dose equivalent *) (rem), which could have been received in the most unfavourable conditions near a nuclear power station (see section III). Thus,

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*) See /2/, section 10 et seq. on this subject.
For the sake of brevity, the term "dose" is used throughout this report to designate "dose equivalent".

by referring to the maximum permissible doses fixed by the Euratom Basic Standards on radiological protection /1/ or to reference values proposed by the International Commission on Radiological Protection (ICRP) /2/, as well as to the dose rates man receives from natural radiation, a relatively simple assessment can be made on the significance of the doses received.

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I. RADIOACTIVE WASTE DISCHARGES

1. General

Before considering the waste discharges, some preliminary remarks will show the difficulties encountered during the drafting of this report and which limited the utilization and interpretation of the data. The diversity of the publications used, already mentioned above, is due to various causes, i.e. both to the authors and their aims. There is a difference between a brief reference to data on radioactive waste discharges in a power station's operating report, the fact that a control body or authority wishes to show in an annual report that the limits have been complied with, or, again, the fact that such a collection of data should result in interpretation on a radiological basis.

The following omissions, however, made presentation of the data analysed more difficult:

- The activity discharges quoted do not always relate to the same units of time (hour, month or year); sometimes they are only based on an operational period of some months.
- Often the values published do not show if the discharge or discharge fluctuations can be considered as normal or if they must be attributed to operational difficulties, tests, etc.

- Discharges are mostly not reported by individual radionuclide, although the nuclide composition of the activity discharged can vary considerably, mainly depending on prior treatment.

- The publications do not generally provide technical details on the measurement techniques of the activity being discharged.

It is precisely the latter points which sometimes make it difficult to assess the waste discharges from the radiological point of view.

Finally, the following observations will provide a better insight into the tables accompanying this report:

- Each table is briefly annotated; bibliographical references are also quoted.

- Classification of power stations by countries was maintained throughout the tables. When several power stations are on the same site (Chinon, Saint-Laurent-des-Eaux), their discharges have been treated as only having one release point.

- The blanks in the tables indicate that information is lacking.

- The figure "0" is used for negligible values.

- The abbreviation MPCP, occurring several times, means "maximum permissible concentration for individual members of the public". The MPCP corresponds to a tenth of the MPC for continuous occupational exposure.

The data relating to waste discharges, dealt with in this report, relates to nuclear power stations in operation in the Community and on which, to our knowledge, such information is available. The main characteristics of these power stations /3/ for the purpose of this report are given in table I.

Radioactive effluents from these power stations are grouped as follows:

- gaseous effluents
  a) noble gases
  b) aerosols and iodine
- liquid effluents.

The data used in the tables were taken mainly from the following references:

for German power stations	/4/ /5/ /6/
for French power stations	/7/ /8/ /9/ /10/
for Italian power stations	/11/ /12/
and for the Dutch power station	/13/ /14/

When other sources were used, this is mentioned in the text.

Gaseous radioactive effluents

a) Noble gases

Gaseous effluents from gas-cooled reactors (see GG type of reactor in table I) are principally composed of argon-41, formed by the activation of argon-40 present in the CO_2 cooling gas. Argon-41 is also preponderant in the effluents from the EL-4 reactor of the

Monts d'Arrée (France) power station, formed principally by activation of the argon contained in the reactor vessel cooling air. The gaseous effluents from water-cooled reactors mainly contain the noble fission gases xenon and krypton. Table II indicates the annual discharges of noble gases.

Since the nuclear power stations for which effluent data is available come under different stages of technical development, the plants for treating gaseous waste are very varied (delayed discharge, storage before discharge). This means that the isotopic compositions of the effluents are not identical from one station to another, which complicates assessment of their health effects.

It will be noted that the discharge limits (table III), have been expressed in Ci/year for the purposes of this report, although sometimes, for example in German power stations, the competent authorities have fixed these limits in Ci/hour and waste discharges are generally subject to supplementary restrictions: daily, weekly limits, etc.

In determining the discharge limits the competent authorities usually took different criteria and hypotheses as their starting point. It follows that a comparison of the waste discharges from the various power stations, expressed as a percentage of the limits, is not very significant. It should, however, be emphasized that one criteria served as a common base for all limits: namely, the dose limits fixed by the Basic Radiological Standards /1/. The figures in table III show that, not only are these dose limits complied with, but that the exposure of the surrounding population generally only reaches a small fraction of these limits.

b) Aerosols and iodine

In all nuclear power stations, air which may become contaminated passes through absolute filters before discharge, and, therefore, the quantities of radioactive aerosols (comprising activation and, possibly, fission products) liberated in the atmosphere are minute, as shown in table IV. The release of radioactive aerosols remains in fact well below 1 Ci/year. Moreover, the activities indicated in this table are mostly excessive values, since the activity concentration in air before discharge is, in most cases, close to the detection limit of the detectors.

The figures indicated for the iodine releases from German power stations in 1969 and 1970 include besides iodine-131, the other iodine isotopes of short half-life. The quantities of iodine-131 discharged by these power stations are, therefore, in reality smaller than the table shows. At any rate, in all cases the release of iodine-131, the most significant nuclide from the health aspect, was lower than 1 Ci/year.

The comments made in table III with regard to the discharge limits for noble gases also apply to the aerosol and iodine discharge limits given in table V. This table shows that the quantities of aerosols released are generally below 1 °/oo of the limits and, for iodine-131, around 1 °/o. VAK in 1970 is an exception caused by operating with a defective fuel element in a test loop /4/; it can be seen however, that even under such exceptional conditions the release limit for iodine-131 was not exceeded (taking into account the presence of other iodine isotopes in the discharge figure).

3. Liquid radioactive effluents

The comment made above on gases and aerosols applies also to liquid radioactive effluents: both the waste treatment practices before discharge and the detection methods of the activity in the effluents change from one power station to another. Because of this, an assessment of the data relating to waste discharges proves difficult, especially as the activities are expressed sometimes in beta-gamma activity, in beta activity or in gamma activity. Whatever the case, table VI shows that, in most power stations, the liquid waste discharge amounts only to a few curies per year (excluding tritium). Furthermore, the discharge limits for liquid effluents, shown in table VII, have been fixed (as was noted with regard to gaseous effluents) on the basis of different criteria, whether the reference taken is the activity concentration in the body of water receiving the liquid waste, derived from the maximum permissible concentration in drinking water, whether the limit is based on a study of the radio-ecological capacity of the receiving body of water or whether the principle "as low as practicable" release is being used. This explains the differences in discharge limits for comparable power stations.

It should be pointed out that, for the French station, SENA (Chooz), the maximum allowed release under the Franco-Belgian convention established for this purpose is 100 Ci of an equivalent activity, weighted by a discharge formula for the radio-toxicity of the nuclides /7/. Italian stations are (Trino Vercellese) or will be applying similar discharge formulae /12/.

Tritium was neglected for a long time among the radionuclides discharged by nuclear power stations, with the exception of heavy water reactors. Some developments in the operational technique of light water reactors (notably PWR reactors): anti-corrosion additives or additives for chemical shimming have, by the increased production of tritium which they cause, aroused renewed interest concerning the presence of this nuclide in the effluents from nuclear power stations. Table VIII assembles the data relating to tritium releases, as found in the literature.

It can be concluded from examination of tables VII and VIII that even, in the case of the strictest limits, the discharge limits for liquid waste were always complied with during the operational periods in question.

II. RADIOLOGICAL ASPECTS

Despite the difficulties mentioned above which prevent a more precise assessment of the health effects of radioactive waste discharges, an attempt is made below to give an idea of man's exposure in the vicinity of nuclear power stations in the Community.

Considering the generally low level of activity discharged, the general impression is that nowhere around a nuclear power station within the Community an individual runs the risk of exposure approaching the limits fixed by the Euratom Basic Standards /1/, which have been adopted in the laws of all the member countries. This first impression needs to be verified for the various nuclear power station sites. To do this, an evaluation, based on actual waste releases, is made below of the exposure from effluents both gaseous and liquid, for each site. The figure obtained in this way is only indicative of the maximum exposure around a site. Such a purely theoretical procedure for assessing exposure is the only feasible one since, in reality, the level of environmental radiation due to waste discharges from nuclear power stations is so low that it is hardly ever possible to detect its presence.

1. Gaseous effluents and aerosols

The principal ways in which man is exposed to ionizing radiation emitted by gaseous effluents are by:

- External irradiation by the radioactive cloud (submersion).

- Internal irradiation by inhalation of radioactive aerosols and iodine.

- Internal irradiation by consumption of contaminated foods: for example, milk contaminated with iodine-131 (through the pathway grass-cow-milk).

Whatever the way of exposure, the air acts as the carrier of the effluent. It is clear, therefore, as emphasized with regard to waste discharge limits, that local conditions (notably the effective height of discharge and the meteorological conditions) play a determining role. However, even in the absence of precise information in this respect, valid results can be obtained for the surroundings of most power stations in the Community by using the model worked out by Bresser et al. /16/. In this model the various meteorological conditions are taken into account by referring to a frequency distribution of the atmospheric diffusion categories (according to Pasquill), typical for several countries in Western Europe.

By using this model exposures from external irradiation and inhalation were calculated for each site at two points situated in the prevailing wind direction, at 0,5 km and 5 km respectively from the point of discharge. The first of these points substantially corresponds to the point of average annual highest concentration, that is generally near the site boundary and, therefore, in a place where individuals hardly ever reside. The second point, situated at 5 km, corresponds to the approximate distance at which the closest group of dwellings to the point of discharge of a nuclear power station is often situated.

The calculations were based on the following hypotheses:

- an individual stays permanently at the two points considered,
- for water-cooled reactors, the noble gas effluents consist only of Xe-133, and for gas-cooled reactors only of A-41,
- the effective height of discharge is equal to the physical height of the stacks,
- the frequency distribution of the different atmospheric diffusion categories and the frequency distribution of the wind directions are the same for all sites.

The results of the calculations of the exposure from noble gases are given in table IX for the three years in question.

With regard to exposures from inhalation of aerosols as well as iodine since the discharge of these substances is very low, assessments have been limited to the maximum releases recorded during the reference period.

To calculate the exposure from inhalation of aerosols it was assumed that a concentration of 10^{-9} Ci/m^3 *) in air results in an annual dose of 5 rem.

It is found that, for VAK in 1970, the maximum exposure at 0,5 km from the release point from inhalation of aerosols was 0,02 mrem and that from inhalation of iodine 0,2 mrem. At 5 km the corresponding figures fell respectively to 0,004 and 0,04 mrem.

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*) that is, the MPC, for continuous occupational exposure, of any mixture of beta-gamma emitters from which Sr-90, I-129, Pb-210, Ac-227, Ra-228, Pa-230, Pu-241, Am-242m, Bk-249, Cf-253, Cf-254, Es-255 and Fm-256 can be excluded /1/.

No very accurate assessment can be made of the incorporation of iodine-131 through the grass-cow-milk pathway and the resultant exposure to the thyroid. However, the results of milk monitoring around nuclear power stations show that the iodine-131 concentration is below the detection limit, which is approximately 10 pCi/litre for the analytical technique generally used in environmental surveillance programs /17/ *). A concentration of I-131 in milk of 400 pCi/litre corresponding to a dose of 1,5 rem/year in the thyroid of a six month old child, a concentration equal to the detection limit therefore results in a yearly dose of approximately 40 mrem.

It can be seen from the preceding that typical exposure values due to radioactive effluent discharges into the atmosphere from nuclear power stations within the Community are as follows:

Type of effluent	Annual exposures /mrem/year/ in the prevailing wind direction	
	at 0,5 km	at 5 km
Noble gases (submersion)		
Pressurized water reactors	< 1	< 0,1
Boiling water reactors **)	< 10	< 1
Gas-cooled reactors	< 5	< 0,5
Aerosols and iodines (inhalation)	< 0,5	< 0,05
Iodine-131 (milk consumption)	..... < 40	

*) At some power stations a more sophisticated analytical method is employed with a detection limit of about 1 pCi/litre. Even with this method no I-131 has been detected in milk samples collected around these sites.

**) In modern power stations, equipped with a noble gas retention system with activated charcoal, the annual exposure is generally less than 1 mrem at 0,5 km and less than 0,1 mrem at 5 km.

It should be repeated that these figures are theoretical and are based on the hypotheses presented above; their sole aim is to give an idea of the maximum exposure around nuclear power stations in the Community.

2. Liquid effluents

As in the case of gaseous effluents, there are several ways in which man can be exposed to liquid effluents, viz. by internal irradiation following consumption of contaminated water or food, or by external irradiation. Exposure by internal irradiation usually preponderates and for this reason is principally dealt with below.

In view of the justifiable interest given to preserving the quality and reserves of drinking water, the question arises as to what extent these are affected by liquid radioactive waste discharges from nuclear power stations. For this purpose tables X and XI show the increase in activity concentration (total activity without tritium and for tritium alone respectively) resulting from these discharges in the receiving waterbodies. In order to get an idea of what these concentration increases mean on a health basis, reference is made to the MPCP's for drinking water, not forgetting that the drinking of water is only one of the possible ways in which man can be exposed. In table X the reference value taken is the MPCP of any mixture of radionuclides (exclusive of Ra-226 and Ra-228) in drinking water. It can be seen that the added concentration is generally less than 1 % of the MPCP. In 1971 the SENA plant discharges exceptionally gave rise to a concentration of 9,5 % of the MPCP and even 20 % if the presence of the gamma emitters Mn-54 and Co-58 in the effluents is taken

into account. However, if the radionuclide composition of the effluents is considered /10/, it can be seen that the sum of the ratios of the average concentration C_i of nuclide i in the river to the $MPCP_i$, $\sum_i \frac{C_i}{MPCP_i}$, is less than 0,01.

Table XI concerning tritium effluents, shows that the added activity concentration in the receiving waterbodies is less than 10^{-4} MPCP of tritium.

It can thus be inferred from the above what would be the exposure to a hypothetical person drinking only contaminated water at a concentration level determined by the liquid effluent discharges from a nuclear power station, that is on the assumption that this hypothetical person drinks the water direct from the receiving waterbody, without any filtration or purification. At the highest concentration obtained in a river (SENA/Meuse) during the period examined (9,5 pCi/l) and taking account of the nuclide composition of the effluent, the annual dose would be less than 1 % of the dose limits for individuals of the population, that is less than 5 mrem to the whole body.

With regard to other possible ways of exposure, according to an assessment made on the Garigliano river /11/, the total dose which individual members of the population, in this case the critical group of the population, would receive by consuming drinking water and fish from the river, would, for the year in question, 1970, be 0,5 mrem for an added concentration in the river of 2,8 pCi/l. In the same way, it was estimated for the Danube that, by all the possible ways of exposure, for an added concentration of 1 pCi/l of a mixture of fission and activation products from a water-cooled power station, individuals would not be exposed to a dose of more than 1 mrem/year.

If we take the latter figure as reference value, it can be seen that the annual doses due to liquid effluents discharges from nuclear power stations for the years 1969, 1970, and 1971 are generally around 1 mrem.

3. Evaluation of exposures resulting from effluent releases and conclusions

In order to assess the relative importance of the exposure of the population from effluents released by nuclear power stations it is necessary to compare it with appropriate criteria. To this end reference is hereafter made to both the radiological protection standards in force and the natural radiation background.

The radiological protection standards of Euratom /1/ fix the dose limits for individual members of the population at:

- 0,5 rem/year to the whole body,
- 3 rem/year to the bone and skin,
- 1,5 rem/year to other organs.

The genetic dose limit to the population is fixed at 5 rem in 30 years, i.e. 170 mrem/year.

Exposure to gaseous effluents is restricted to a limited group of the population around the nuclear power station; therefore the dose limits for individual members of the population can be applied to this group. It is noted that:

- the dose to the whole body due to noble gases is generally less than 1 % but can, in exceptions, reach a few per cent of the dose limit;
- the dose due to inhalation of aerosols and iodines is less than 0,1 % of the dose limits;
- the dose to the thyroid of a baby by milk consumption can be assessed with only slight accuracy. However, the iodine-131 concentration in milk was always below the detection limit, which corresponds to a few per cent of the dose limit.

In the case of exposure to liquid effluents, the consumption of water and foods contaminated by liquid effluents is not necessarily limited to a small fraction of the population; it is therefore better to refer to the dose limit for the population as a whole, namely 170 mrem/year. It can be seen that most exposure values remain below 1 % of this limit.

The natural radiation background to which man has always been exposed is of a double origin: extraterrestrial and terrestrial. Irradiation of terrestrial origin is both internal and external. According to UNSCEAR /19/ the average genetic dose rate to which man is exposed because of the natural radiation level is 93 mrad/year which corresponds to a dose equivalent of about 100 mrem/year. This dose rate is made up as follows:

	[mrad/y]
- Cosmic rays, ionizing component	28
- Cosmic rays, neutron component	0,35
- Terrestrial radiation (including air)	44
- Internal irradiation due to potassium-40	19
" carbon-14	0,7
polonium-210	0,6
other nuclides	0,45
	$\sum \sim 93$

It can be seen that, among the sources of natural radiation, the most important at ground level is that of terrestrial origin, which, however, varies considerably according to the geological nature of the sub-soil. It can be estimated that in the countries of the European Community the dose received in this way varies between 50 and 500 mrem/year. It should be added that man's natural exposure level depends also on the construction materials used in buildings.

Comparison of the exposures due to radioactive effluents from nuclear power stations with the above-mentioned figures shows that the former generally represent less than 5 % of man's average exposure from natural radiation, that is an exposure falling within the regional fluctuations of the natural radiation background.

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Enlarging the scope of this report, table XII shows the ratio of activity discharged to energy produced for each power station. An index can be established in this way, useful for studying the environmental implications of increased

energy production. This index could also be of some use in assessing the "cost-benefit" ratio of electrical power stations. An evaluation of this kind is, in fact, increasingly in demand by the competent authorities in order to estimate to what point the construction of a power station is justified. The term "cost" used here includes all the additional burdens placed on the environment.

For the gaseous effluents, only noble gas effluents have been considered here. These constitute in fact the largest part of the effluents. Table XII shows that:

- the noble gas activity discharged per unit of energy produced is generally less than 10 Ci/GWh. The stations equipped with a boiling water reactor (KWL, VAK, Garigliano) are exceptions, as well as the EL-4 plant equipped with a pressure tube reactor;

- the scatter in release values reflects a disparity in the plants due to their type and different levels of technical development.

With regard to liquid effluents, to enable some comparison between power stations, tritium release has been excluded from the following considerations taken from table XII:

- the activity discharged per unit of energy produced is generally below 10 mCi/GWh;

- the scatter in release figures, which reach different orders of magnitude, is not due to the type of reactor but mainly to the treatment practices of the effluents before discharge. Technical progress in this field will allow a substantial reduction in actual discharges in the future.

Although waste discharges are low at present, from the considerations on table XII it may be concluded that they will be reduced even further in the future. The installation of a range of new nuclear power plants in the next few years will, by providing a more accurate definition of an average value of the ratio of discharged activity to energy produced, give a reference value of "as low as practicable" waste discharge which could be specially useful in connection with forecasts of developments in energy production.

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Table I

GENERAL CHARACTERISTICS OF NUCLEAR POWER STATIONS

Facility/Location	Type of reactor (a)	Power level [MWth]	Power level [MWe]	Date of criticality	Height of discharge point for gaseous effluents [m]	Body of water receiving liquid effluents
GERMANY						
KRB Gundremmingen (Bav.)	B	801	250	Aug.1966	109	Danube
KWL Lingen (Lower Saxony)	B	520	180(b)	Jan.1968	150	Ems
KWO Obrigheim (B. Wurt.)	P	1050	345	Sep.1968	60	Neckar
VAK Kahl (Bav.)	B	60	16	Nov.1960	50	Main
FRANCE						
EDF1 Chinon (Indre-et-L.)	GG	300	82	Sep.1962	49	Loire
EDF2 "	GG	800	225	Aug.1964	67.5	Loire
EDF3 "	GG	1560	493	Mar.1966	52	Loire
SL 1 St-Laurent-des-Eaux (Loir-et-Cher)	GG	1660	500	Jan.1969	78	Loire
SL 2 "	GG	1700	530	Aug.1971	78	Loire
SENA Chooz (Ardennes)	P	905	282	Oct.1966	18(c)	Meuse
EL 4 Monts-d'Arree (Finistere)	D	242	77	Dec.1966	70	Ellez
ITALY						
Latina Latina (Latina)	GG	575	160	Dec.1962	52	Thyrrhenian Sea
Garigliano, Sessa (Caserta)	B	506	160	Jun.1963	92	Garigliano
Trino Vercellese (Vercelli)	P	825	257	Jun.1964	100	Po
NETHERLANDS						
Dodewaard Dodewaard (Gelderland)	B	173	55	Jun.1968	100	Waal

(a) B: boiling water reactor
P: pressurized water reactor
GG: graphite-gas reactor
D: heavy water reactor

(b) plus 74.5 MWe by conventional superheating

(c) stack sited on a plateau approximately 200 m above the Meuse valley.

Table II

ANNUAL GASEOUS RADIOACTIVE WASTE DISCHARGES (NOBLE GASES)

Country	Facility	Activity discharged [Ci/year] 1969	1970	1971
GERMANY				
	KRB	11 400	7 350	6 650
	KWL	200 000	132 000	
	KWO	5 560	7 700	1 456
	VAK	1 750	3 340	2 500
FRANCE				
	CHINON	12 300	8 085	4 225
	St-LAURENT-DES-EAUX	1 900	305	3 425
	SENA	0	3	4 500
	EL 4	46	72	53 810
ITALY				
	LATINA	1 500	2 500	2 470
	GARIGLIANO	140 000	275 000	640 000
	TRINO VERCELLESE	0	19	585
NETHERLANDS				
	DODEWAARD		~ 3 000	~ 3 000

Table III

ANNUAL GASEOUS RADIOACTIVE WASTE DISCHARGES (NOBLE GASES) AS A PERCENTAGE OF DISCHARGE LIMITS

Country	Facility	Discharge limits [Ci/year]	Discharge as a % of limits 1969	1970	1971
GERMANY					
	KRB	1.9×10^6	0.6	0.4	0.3
	KWL	3.1×10^6	6.5	4.3	
	KWO	8×10^4	7.0	9.6	1.8
	VAK	8.8×10^4	2.0	3.8	2.8
FRANCE					
	CHINON	4×10^5 (a)	3.1	2	1.1
	St-LAURENT-DES-EAUX	4×10^5 (a)	0.5	0.08	0.9
	SENA	2.5×10^6 (a)	0	0	0.2
	EL 4	4×10^5 (a)	0.01	0.02	13.5
ITALY					
	LATINA	5×10^5 (b)	0.3	0.5	0.5
	GARIGLIANO	3×10^6 (b)	4.7	9.2	21.3
	TRINO VERC.	5×10^4	0	0.04	1.2
NETHERLANDS	DODEWAARD	3×10^5		1	1

(a) At this discharge rate, assuming an atmospheric dilution factor of 1.5×10^{-5} sec/m^3 and a 20% probability of the wind being in one direction, the maximum concentration in the air at ground level is equal to the MPCP in air.

(b) The actual discharge limits for the Latina and Garigliano stations are based on the MPCP in air at ground level. These limits are being at present replaced by discharge formulae based on analyses of the critical groups of the population and on actual waste discharge needs of the power stations.

ANNUAL DISCHARGES OF RADIOACTIVE AEROSOLS AND IODINE-131

Country	Facility	Activity discharged [Ci/year] 1969		1970		1971	
		aerosols	iodine-131	aerosols	iodine-131	aerosols	iodine-131
GERMANY (a)	KRB	7.6×10^{-3}	0.36	7.5×10^{-2}	0.2	5.1×10^{-2}	0.32
	KWL	0.25		0.67	0.26		
	KWO	$<1.8 \times 10^{-2}$	6.3×10^{-2}	$<1.7 \times 10^{-2}$	4.4×10^{-2}		
	VAK	8.8×10^{-2}	7×10^{-3}	0.13	0.67	7×10^{-2}	2.9×10^{-3}
FRANCE	CHINON	$<1 \times 10^{-2}$		$<1 \times 10^{-2}$		18×10^{-3}	
	St-LAURENT-D.-EAUX	<1		$<1 \times 10^{-2}$		47×10^{-3}	
	SENA	0		0		0	
	EL 4	$<2 \times 10^{-3}$				73×10^{-3}	
ITALY	LATINA	0	0	0	0	0	0
	GARIGLIANO	6.3×10^{-2} (b)	0	6.3×10^{-2} (b)	6×10^{-2} (b)	6.3×10^{-2} (b)	0.13
	TRINO VERCELLESE	0	0	$<1.2 \times 10^{-4}$	$<5.9 \times 10^{-4}$	$<1.4 \times 10^{-4}$	1×10^{-3}
NETHERLANDS	DODEWAARD			2×10^{-2}	6.3×10^{-3}	4×10^{-2}	6.3×10^{-3}

(a) Iodine release from German power stations during 1969 and 1970 includes not only iodine-131 but also the other isotopes with shorter half-live.

(b) Average values for the three years in question /12/

ANNUAL DISCHARGES OF RADIOACTIVE AEROSOLS AND IODINE-131 AS A PERCENTAGE OF DISCHARGE LIMITS

Country	Facility	Discharge limits /Ci/year/		Activity discharged as a percentage of discharge limits					
				1969		1970		1971	
		aerosols	iodine-131	aerosols	iodine-131	aerosols	iodine-131	aerosols	iodine-131
GERMANY	KRB	2 850	22	2.7×10^{-4}	1.6	2.6×10^{-3}	0.9	1.8×10^{-3}	1.5
	KWL	15 800	16	$1,6 \times 10^{-3}$		4.3×10^{-3}	1.6		
	KWO		15 (a)		0.42		0.32		
	VAK	88	0.61	0.1	1.1	0.15	110	0.08	0.48
FRANCE	CHINON	1×10^{3}(b)		$< 10^{-3}$		$< 10^{-3}$		1.8×10^{-3}	
	St-LAURENT-DES-EAUX	1×10^{3}(b)		< 0.1		$< 10^{-3}$		4.7×10^{-3}	
	SENA	1×10^{3}(b)		0		0		0	
	EL 4	1×10^{3}(b)		$< 2 \times 10^{-4}$				7.3×10^{-3}	
ITALY	LATINA	5×10^{2}(c)	3×10^{3}(c)	0	0	0	0	0	0
	GARIGLIANO	3×10^{3}(c)	1×10^{4}(c)	2.2×10^{-3}	0	2.2×10^{-3}	6×10^{-4}	2.2×10^{-3}	1.3×10^{-3}
	TRINO VERCELL.	0.2 (d)	5×10^{-2}(d)	0	0	< 0.06	1.2	0.07	2
NETHERLANDS	DODEWAARD								

(a) Limit calculated from the hourly limit of 1.7×10^{-3} Ci/h. However, during the grazing period the limit is reduced to 1.4×10^{-5} Ci/h.

(b) At this rate, assuming an atmospheric dilution factor of 1.5×10^{-5} sec/m^3 and a 20% probability that the wind is in one direction, the concentration at ground level is equal to the MPCP in air (10^{-9} Ci/m^3).

(c) For Latina and Garigliano the actual limits correspond to the MPCP in air at ground level. These limits are being at present replaced by discharge formulae based on analyses of the critical groups of the population and on actual waste discharge needs of the power stations /12/.

(d) In 1969 the limits were still 15 Ci/year of aerosols and 300 Ci/year of iodine-131. /12/.

Table VI

ANNUAL LIQUID RADIOACTIVE WASTE DISCHARGES

(exclusive of tritium)

Country	Facility	Activity discharged [Ci/year] 1969	1970	1971
GERMANY				
	KRB	1.65	1.52	1.89
	KWL	0.64	0.6	0.3
	KWO	10.5	3	4.4
	VAK (b)	0.006	0.064	0.060
FRANCE				
(a)	CHINON	7.44	2.25	2
	St-LAURENT-DES-EAUX	2.71	0.77	2.25
	SENA	3.8	6.4	34.4
	EL 4	0.027	0.006	0.1
ITALY				
	LATINA	29.6	10.2	1.5
	GARIGLIANO	9	11.9	19.1
	TRINO VERCELLESE	3.09	2.96	19.07
NETHERLANDS				
	DODEWAARD	0.5	2.33	1.6

(a) For the French facilities only the gross beta activity is given (standard Sr-90 + Y-90).

(b) Including effluents from the experimental power station HDR-Grosswelzheim /4/.

Table VII

ANNUAL LIQUID RADIOACTIVE WASTE DISCHARGES

AS A PERCENTAGE OF DISCHARGE LIMITS

(exclusive of tritium)

Country	Facility	Discharge limits [Ci/year]		Activity discharged as a percentage of discharge limits 1969	1970	1971
GERMANY	KRB	14.4		11.5	10.6	13
	KWL	5.4		11.8	11	5.6
	KWO	18		59	17	25
	VAK	0.6		1	10.7	10
FRANCE			(a)			
	CHINON	900		0.82	0.25	0.22
	St-LAURENT-DES-EAUX	800		0.34	0.1	0.28
	SENA	100		3.8	6.4	34
	EL 4	4		0.67	0.15	2.5
ITALY						
	LATINA	1.6×10^3	(b)	1.8	0.6	0.1
	GARIGLIANO	5×10^3	(b)	0.2	0.2	0.4
	TRINO VERCELLESE	21	(c)	0.06 (c)	14	90
NETHERLANDS	DODEWAARD	2.6		19	90	62

(a) Limits derived from the MPCP in drinking water of 10^{-7} Ci/m^3 (any mixture of alpha, beta, gamma emitters, from which Ra-226 and Ra-228 can be excluded), and from the volume of water carried annually by the river /10/. A waste discharge formula is applied at SENA /7/.

(b) The actual discharge limits for the Latina and Garigliano power stations correspond respectively to 1/3 and to the MPCP in drinking water measured in the cooling water discharge canals. These limits are actually being replaced by discharge formulae based on analyses of the critical groups of the population and on the actual waste discharge needs of the power stations.

(c) In 1969 the limit was still 5×10^3 Ci/year.

Table VIII

ANNUAL LIQUID TRITIUM DISCHARGES

Country	Facility	Activity discharged [Ci/year] 1969	1970	1971	Discharge limit [Ci/year]	
GERMANY	KRB	17.8			432	(a)
	KWL	26	31.7			
	KWO	328				
	VAK				480	(a)
FRANCE	CHINON					
	St-LAURENT-DES-EAUX					
	SENA		340	706	7×10^6	(d)
	EL 4					
ITALY	LATINA	25.2	16.7	13	2.5×10^5	(b)
	GARIGLIANO	7	5	5	5×10^5	(b)
	TRINO VERCELLESE	0	135	1 117	5×10^3	(c)
NETHERLANDS	DODEWAARD		2.37			

(a) Figure derived from monthly limit.

(b) The actual discharge limits for the Latina and Garigliano power stations correspond respectively to 1/3 and to the MPCP in drinking water, measured in the cooling water discharge canals. These limits are actually being replaced by discharge formulae based on analyses of the critical groups of the population and on the actual waste discharge needs of the power stations.

(c) In 1969 the limit was still 5×10^5 Ci/year.

(d) Discharge limit derived from the MPC in drinking water /10/.

Table IX

MAXIMUM EXPOSURE FROM NOBLE GAS DISCHARGES

AT 0.5 KM AND AT 5 KM FROM THE POWER STATIONS

Country	Facility	Discharge height [m]	Atmospheric dilution factor [sec/m³]		Dose at 0.5 km [mrem]			Dose at 5 km [mrem]		
			at 0.5 km	at 5 km	1969	1970	1971	1969	1970	1971
GERMANY	KRB	109	2×10^{-7}	5×10^{-8}	0.12	0.08	0.07	0.03	0.02	0.02
	KWL	150	9.5×10^{-8}	2.6×10^{-8}	1.1	0.6		0.3	0.18	
	KWO	60	7×10^{-7}	1.3×10^{-7}	0.2	0.3	0.05	0.04	0.05	0.01
	VAK	50	1×10^{-6}	2×10^{-7}	0.1	0.18	0.13	0.02	0.04	0.03
FRANCE	CHINON	50 (a)	1×10^{-6}	2×10^{-7}	5	3.3	1.6	0.15	0.65	0.35
	St-LAURENT-DES-EAUX	78 (b)	4×10^{-7}	9×10^{-8}	0.31	0.05	0.6	0.07	0.01	0.13
	SENA	18	6×10^{-6}	4×10^{-7}	0	0	1.5	0	0	0.09
	EL 4	70	5×10^{-7}	1×10^{-7}	0	0	11	0	0	2.2
ITALY	LATINA	52	1×10^{-6}	2×10^{-7}	0.61	1	1	0.12	0.20	0.20
	GARIGLIANO	92	3×10^{-7}	7×10^{-8}	2.3	4.5	10.2	0.53	1	2.5
	TRINO VERCELLESE	100	2.3×10^{-7}	6×10^{-8}	0	0	0.008	0	0	0.002
NETHERLANDS	DODEWAARD	100	2.3×10^{-7}	6×10^{-8}	0	0.04	0.04	0	0.01	0.01

(a) The three Chinon power stations have different discharge heights (49, 67.5, 52 m). Calculation of exposure was based on the conservative hypothesis of a single discharge point at a height of 50 m.

(b) Calculation of exposure was based on the conservative hypothesis of a single discharge point for the two power stations.

Table X

AVERAGE CONCENTRATION (EXCLUSIVE OF TRITIUM) ADDED TO THE RECEIVING BODY OF WATER

Country	Facility	Receiv. waterbody; average flow rate [m³/sec]	Added concentration (a) 1969 [Ci/m³]	1969 [%] MPCP	1970 [Ci/m³]	1970 [%] MPCP	1971 [Ci/m³]	1971 [%] MPCP
GERMANY	KRB	Danube 147	3.6×10^{-10}	0.36	3.3×10^{-10}	0.33	4.1×10^{-10}	0.41
	KWL	Ems 38	5.4×10^{-10}	0.54	5×10^{-10}	0.5	2.5×10^{-10}	0.25
	KWO	Neckar 124	2.7×10^{-9}	2.7	8×10^{-10}	0.8	1.2×10^{-9}	1.2
	VAK	Main 150	1.3×10^{-12}	1.3×10^{-3}	1.5×10^{-11}	0.015	1.3×10^{-11}	0.013
FRANCE	CHINON	Loire 500	5.7×10^{-10}	0.57	1.4×10^{-10}	0.14	1.3×10^{-10}	0.13
	St-LAURENT-DES-EAUX	Loire 357	2.4×10^{-10}	0.24	7×10^{-11}	0.07	2×10^{-10}	0.2
	SENA	Meuse 116	1×10^{-9}	1	1.8×10^{-9}	1.8	9.5×10^{-9}	9.5
	EL 4	Ellez 2	4.3×10^{-10}	0.43	9.6×10^{-11}	0.096	1.6×10^{-9}	1.6
ITALY	LATINA	Thyrenian Sea						
	GARIGLIANO	Garigliano (b)	2.4×10^{-9}	2.4	2.8×10^{-9}	2.8	5.5×10^{-9}	5.5
	TRINO VERCELLESE	Po (c)	4.7×10^{-10}	0.47	8.4×10^{-10}	0.84	3.4×10^{-9}	3.4
NETHERLANDS	DODEWAARD	Waal 1300	1.4×10^{-11}	0.014	5.7×10^{-11}	0.057	3.9×10^{-11}	0.039

(a) Average concentration due to liquid radioactive waste discharges from the power station, at the place of discharge, after homogeneous dilution in the river, expressed in [Ci/m³] and in [%] of the MPCP in drinking water of 10^{-7} Ci/m³ (any mixture of alpha, beta, gamma emitters, from which Ra-226 and Ra-228 can be excluded).

(b) Average flow rate: in 1969: 120 m³/sec, in 1970: 134 m³/sec, in 1971: 110 m³/sec

(c) Average flow rate: in 1969: 20 m³/sec, in 1970: 112 m³/sec, in 1971: 175 m³/sec.

Table XI

AVERAGE CONCENTRATION OF TRITIUM, ADDED TO THE RECEIVING BODY OF WATER

Country	Facility	Receiving waterbody/ average flow rate [m³/sec]	Added concentration (a) 1969 [Ci/m³]	1969 [%] MPCP	1970 [Ci/m³]	1970 [%] MPCP	1971 [Ci/m³]	1971 [%] MPCP
GERMANY	KRB	Danube 147	3.8×10^{-9}	1.3×10^{-4}				
	KWL	Ems 38	2.2×10^{-8}	7.4×10^{-4}	2.7×10^{-8}	9×10^{-4}		
	KWO	Neckar 124	8.4×10^{-8}	2.8×10^{-3}				
	VAK	Main 150						
FRANCE	CHINON	Loire 500						
	St-LAURENT-DES-EAUX	Loire 357						
	SENA	Meuse 116			9.3×10^{-8}	3.1×10^{-3}	2.1×10^{-7}	7×10^{-3}
	EL 4	Ellez 2						
ITALY	LATINA	Tyrrhenian Sea						
	GARIGLIANO	Garigliano (b)	1.9×10^{-9}	6.3×10^{-4}	1.2×10^{-9}	4×10^{-4}	1.5×10^{-9}	5×10^{-4}
	TRINO VERCELLESE	Po (c)	0	0	3.8×10^{-8}	1.3×10^{-3}	2×10^{-7}	7×10^{-3}
NETHERLANDS	DODEWAARD	Waal 1300			5.8×10^{-11}	1.9×10^{-6}		

(a) Average concentration due to liquid tritium discharges from the power station, at the place of discharge, after homogeneous dilution in the river, expressed in [Ci/m³] and in [%] of the MPCP in drinking water of 3×10^{-3} Ci/m³.

(b) Average flow rate in 1969: 120 m³/sec, in 1970: 134 m³/sec, in 1971: 110 m³/sec

(c) Average flow rate in 1969: 203 m³/sec, in 1970: 112 m³/sec, in 1971: 175 m³/sec.

Table XII

RADIOACTIVE WASTE DISCHARGES
AND ELECTRICAL ENERGY PRODUCED

Country	Facility	Gross electricity production		Ratio of activity discharged to energy produced	
		Year	/GWh/	Gaseous effl. (noble gases) /Ci/GWh/	Liquid effluents (excl.tritium) /Ci/GWh/
GERMANY					
	KRB	1969	1 260	9.0	1.3×10^{-3}
		1970	1 844	4	0.8×10^{-3}
		1971	1 991	3.3	0.95×10^{-3}
	KWL	1969	1 351	147	0.5×10^{-3}
		1970	1 008	130	0.6×10^{-3}
		1971	1 011		0.3×10^{-3}
	KWO	1969	1 990	2.8	5.3×10^{-3}
		1970	2 533	3	1.2×10^{-3}
		1971	2 257	0.7	2.0×10^{-3}
	VAK	1969	90	20	0.07×10^{-3}
		1970	116	29	0.55×10^{-3}
		1971	115	22	0.52×10^{-3}
FRANCE					
	CHINON	1969	3 164	4.0	2.3×10^{-3}
		1970	3 611	2.2	0.62×10^{-3}
		1971	3 408	I.2	0.59×10^{-3}
	St-LAURENT-DES-EAUX	1969	1 120	1.7	2.4×10^{-3}
		1970	138	1.8	4.5×10^{-3}
		1971	3 156	1.1	0.71×10^{-3}
	SENA	1969	-		
		1970	1 313	2.3×10^{-3}	4.9×10^{-3}
		1971	1 930	2.3	18×10^{-3}
	EL 4	1969	-		
		1970	-		
		1971	176	300	0.57×10^{-3}
ITALY					
	LATINA	1969	497	3	60×10^{-3}
		1970	1 191	2.1	8.5×10^{-3}
		1971	1 845	1.3	0.8×10^{-3}
	GARIGLIANO	1969	1 182	119	7.6×10^{-3}
		1970	742	370	16×10^{-3}
		1971	1 164	550	16×10^{-3}
	TRINO VERCELLESE	1969	-		
		1970	1 243	1.5×10^{-2}	2.4×10^{-3}
		1971	1 356	0.4	14×10^{-3}
NETHERLANDS	DODEWAARD	1969	315		1.6×10^{-3}
		1970	368	8.1	6.4×10^{-3}
		1971	405	7.4	4.0×10^{-3}