Public Radiation Exposures from a CANDESAL® Co-generation Facility

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ABSTRACT

As part of an evaluation of the practical and economic viability of using the CANDESAL® (CANDU DESALINATION) approach to desalinate water in an Indonesian environment, radiation doses to members of the public were conservatively calculated. The calculations show there is a negligible radiological impact on the public.

Conservative radiation doses to members of the critical group (an adult male and a 1-year-old infant) were calculated, according to the CAN/CSA N288.1-M87 compartmental pathways analysis methodology, and show that use of the desalinated water supply would increase the dose to a member of the critical group (adult or infant) by less than 20 $\mu Sv \cdot a^{-1}$.

About 99% of the dose from the CANDESAL® [1] facility is from tritiated heavy water (DTO or HTO) and the rest is from trace concentrations of beta and gamma emitters.

The doses to a member of the critical group from a combined CANDU 6 and CANDESAL® Co-generation Facility will be less than 4% of the ICRP-60 recommended effective dose limit of 1000 $\mu Sv \cdot a^{-1}$ to a member of the public. These doses are not only a small fraction of the regulatory dose limits, but are also within the normal variations of natural background radiation levels.

[1] CANDESAL® is a registered trademark of Candesal Enterprises Limited.

INTRODUCTION:

In a CANDU nuclear power station, about two-thirds of the heat transferred to the steam generators is rejected by the turbines and taken away by the condenser cooling water. Candesal Enterprises Limited has proposed that a reverse-osmosis desalination facility, coupled with a CANDU power generating facility, can utilize some of the waste heat to preheat the water in the desalination facility or, as analysed in this study, the condenser outflow water can be used directly as desalination feedwater. Using condenser outflow water directly as desalination feedwater is more energy efficient than the preheat option because it does not require an intermediate heat exchanger.

Generally, provided the temperature at which the ion-exchange membranes is compromised is not exceeded, the higher the feedwater temperature, the higher is the solute (brine) extraction efficiency in the desalination process. Additional details of the technical and economic evaluations of reverse osmosis nuclear desalination are given in Reference 1.

The use of condenser outflow water as desalination feedwater introduces some of the waterborne CANDU 6 emissions into the desalination water supply. Most of the gross beta-gamma waterborne emissions would be removed during desalination but traces of radioactivity may persist in the desalinated water. These trace quantities can be transferred through the associated pathways and could result in public radiation exposures.

This paper discusses the methodology and calculations used to conservatively estimate the radiation dose to a member of the critical group from use of desalinated water. The sensitivities of the calculated dose to diet, and dose-conversion factors are also investigated. The total dose from a combined CANDU 6-Desalination Facility is presented in the context of regulatory limits and variations in background radiation.

RADIOACTIVE SOURCE TERM

The condenser cooling water (CCW) system of a CANDU reactor is a non-radioactive system. However, low-level radioactive liquid waste is discharged to the condenser outflow water making the resulting CCW outfall slightly radioactive.

Most of the radioactivity contained in the outflow water is tritium in the form of tritiated water. Small quantities of other beta and gamma emitters are also present in the outflow.

Radioactive liquid discharges (excluding tritium) averaged over the years 1985 to 1994 for 2 typical CANDU 6 stations, Point Lepreau and Gentilly-2 (Reference 2), are given in Table 1. Tritium releases in waterborne effluents from Point Lepreau, Gentilly-2, Embalse, and Wolsong-1 over the period 1985 to 1994 averaged 1.83E14 $Bq \cdot a^{-1}$ (extracted from Reference 2). The corresponding Point Lepreau and Gentilly-2 annual waterborne tritium release averaged 2.54E14 $Bq \cdot a^{-1}$ and 1.6E14 $Bq \cdot a^{-1}$ over the same period (Reference 3).

One may propose that the low-level active liquid waste discharge should be routed to a discharge location downstream of the condenser cooling water inlet. This approach would mean that radiation exposures to the public would be reduced because the waterborne radioactive discharges would be drawn into the condenser cooling water inlet and transferred to the cooling water discharge only after having been diluted to trace concentrations in the bulk ocean. This is a design option that may be invoked, if required. However, for the present study, to maintain as much design flexibility as possible, and to be conservative, it is assumed that the condenser outfall waterborne releases of tritium from the low-level active liquid waste discharge are 3.4E14 $Bq \cdot a^{-1}$. This release is roughly 45% higher than the CANDU 6 1988 to 1994 water-borne tritium release average of 1.83E14 $Bq \cdot a^{-1}$. This higher value is used to allow an additional margin in the predictions of consequences from water-borne releases.

The beta and gamma particulate releases used in the calculations are taken from Point Lepreau and Gentilly-2 data given in Table 1. The activity concentration of the condenser cooling water discharge is assumed to be the same as the inflow of the desalination feedwater.

The proposed desalination filtration system is composed of a pre-filter, an ultra-filtration unit and a bank of reverse osmosis (RO) membranes, all in series. These systems would remove most of the particulate and dissolved activity contained in the condenser-outfall/desalination-feedwater. The RO membranes alone are designed to remove the elements listed in Table 1 with an efficiency of 97% to 99% or better. However, in the calculations presented here, for conservatism, the combined pre-filter, ultrafiltration unit and RO membranes are credited with a total removal efficiency of only 95% for the elements listed in Table 1. That is, 5% of the radioactivity shown in Table 1 is assumed to be transferred to the potable water supply.

Note that neither the RO membranes nor the ultra-filtration units are designed to remove any of the tritium from the potable stream. Therefore, 3.4E14 $Bq \cdot a^{-1}$ of tritium are assumed to be transferred, unattenuated, to the public potable water supply.

The condenser cooling water discharge rate is typically 27 $m^3 \cdot s^{-1}$; it is dependent on ocean temperatures. This value corresponds to 8.5E11 L of cooling water discharged per annum. Therefore, the average concentration of tritium in the condenser cooling water discharge is (3.4E14/8.5E11) = 400 $Bq \cdot L^{-1}$. It is assumed that the tritium concentration in the condenser cooling water is constant. In reality, the instantaneous concentration can exceed 400 $Bq \cdot L^{-1}$, but under normal operations, the annual average will always be less than 400 $Bq \cdot L^{-1}$. Since annual doses are being evaluated, the annual average concentration and not the instantaneous concentration is the important value. Similar average concentrations of the gross beta and gamma concentrations for the radionuclides listed in Table 1 have also been made.

CALCULATIONAL METHODOLOGY

The pathways analysis methodology recommended in CAN/CSA N288.1-M87 (Reference 4) has been used to calculate doses to the public. For design flexibility purposes, limiting doses were calculated. This approach means that doses from the desalinated potable water were calculated for the most-exposed member of the public. The most-exposed member of the public was taken to be an adult male or a 1-year-old infant (whichever produces higher doses), and it is assumed that all the individual's intake of water is derived directly, or indirectly, from the desalination facility.

The following pathways were considered in the assessment:

a. intake of drinking water. All the drinking water is assumed to originate from the desalination plant (tritium and other beta and gamma emitters). This analysis also assumes that commercial drinks such as sodas, beer, etc. are made with desalinated water.

b. immersion/swimming in a pool containing desalinated water (tritium and beta and gamma emitters)

c. all bathing and daily hygiene uses (tritium and beta and gamma emitters)

d. evaporation of water and inhalation of the airborne activity by humans (tritium). It is conservatively assumed that the air has a relative humidity of 80% and a temperature of 30^0C. It is also conservatively assumed that the relative humidity is entirely due to evaporation of desalinated water with a concentration of 400 $Bq \cdot L^{-1}$.

e. evaporation of water and inhalation of airborne tritiated water by animals (e.g., livestock), which are then consumed by humans (tritium).

f. irrigation of crops with water from the desalination facility. These crops are consumed directly by humans and by animals that are subsequently consumed by humans (tritium and beta and gamma emitters). All food intake by animals is assumed to be from crops irrigated by desalinated water.

g. consumption of fish inhabiting waters with activity concentrations corresponding to the average tritium and average particulate activity concentrations (tritium and beta and gamma emitters).

h. exposure from ground-deposited activity on the shoreline or elsewhere (beta and gamma emitters).

Figure 1 shows a block diagram of the pathways for beta and gamma emitters, other than tritium. Figure 2 gives the pathways block diagram for tritium.

RADIATION DOSES FROM GROSS BETA AND GAMMA EMITTERS AND TRITIUM

Specific transfer parameters applicable to an Indonesian environment were not available for this study. Therefore, transfer parameters applicable to a Canadian population, for each of the radionuclides listed in Table 1 (obtained from Reference 4), are used for this preliminary calculation. When Reference 4 did not provide transfer factors, for example, for ^{153}Gd, data from References 5, 6 and 7 were used. Definitions and values of the P_{26}, P_{24}, P_{25}, P_{28}, P_{45}, P_{14}, P_{15}, P_{49} and P_{59}, transfer parameters, and dose-conversion factors are given in CAN/CSA N288.1-M87.

The analysis considers the summation of radiological exposures from a variety of pathways. For any given pathway, the dose is evaluated by tracking the activity transferred through the given chain. For example, the doses resulting from direct consumption of forage and crops, which are irrigated with water from the desalination facility, can be evaluated by the following expression (see Figures 1 and 2).

$$Dose_{(crops)} = X_0 * P_{24} * P_{49}.$$

Similar expressions were derived for all the pathways given in Figures 1 and 2 and were used to compute the total dose.

The specific transfer parameters are calculated with the following conservative assumptions.

1. It is assumed that the most-exposed individual is either a 1-year-old child or an adult male who consumes fish that has resided in water that has a concentration corresponding to the annual emissions given in Table 1.
2. The individual consumes only grains and vegetables that are grown locally and irrigated with water only from the desalination facility.
3. Milk, poultry, beef, pork and eggs are assumed to be obtained from animals that are raised on forage and crops that are irrigated with water from the desalination facility.
4. It is assumed that the individual's liquid intake (water, coffee, tea, soft drinks etc.) has the same activity concentration as the potable water discharge of the desalination facility.
5. The individual is also assumed to swim for 100 hours per year in water with the same concentration of the desalinated potable water.
6. The individual is assumed to be completely immersed in desalinated water during the course of daily hygienic activities (bathing, etc.) for about 200 h per year.
7. The shoreline in the vicinity of the desalination facility is assumed to have a contaminated layer 0.025 m thick, with radioactivity uniformly deposited from the potable water facility. The individual is assumed to spend 100 h per year on the shoreline.

RESULTS

The doses to adults and infants from beta and gamma emitters (other than tritium) for releases from Point Lepreau using the CAN/CSA N288.1-M87 transfer parameters and dose-conversion factors are given in Table 2. The corresponding doses to infants and adults for beta and gamma releases (other than tritium) from Gentilly-2 are given in Table 3.

The dose from tritium is given in Table 4 and includes all the pathways identified in Figure 2. The total dose from the beta and gamma waterborne emissions and tritium emissions is 1.39E-05 $Sv \cdot a^{-1}$ for adults and 1.89E-05 $Sv \cdot a^{-1}$ for 1-year-old infants with more than 99% of the dose resulting from tritium.

About 41% of the dose comes from direct consumption of desalinated water. Twenty-six percent of the dose is from inhalation of air at 30^0C with a relative humidity of 80% that has a tritium concentration of ~ 11 $Bq \cdot m^{-3}$. About 17% of the dose is from consumption of animal produce that have ingested desalinated water and consumed crops that have been solely irrigated with desalinated water. About 14% of the total dose is from ingestion of crops that have been irrigated with desalinated water. The rest of the projected dose attributed to the desalination facility comes from use of the desalinated water for other activities such as swimming and bathing.

It is evident that the doses from the radionuclides listed in Table 1 are insignificant compared with the waterborne tritium releases.

It should be noted that the dose to infants is roughly 35% higher than the dose to adults, making infants the limiting group.

SENSITIVITY STUDIES

DIET

The dose calculation results given in Tables 2, 3 and 4 apply for transfer and consumption parameters obtained from CAN/CSA N288.1-M87. These parameters are typical for a Canadian population. Because tritium contributes the largest proportion to the effective dose, the sensitivity of the calculated tritium dose to Indonesian consumption data is investigated. Transfer parameters specific to the Indonesian environment were unavailable; consequently only the effect of different consumption data on doses was investigated.

Data for typical food consumption for Indonesia from the Food and Agriculture Organisation (FAO) for 1969 and 1993 through 1995 were available (References 8 and 9). A comparison of tritium doses calculated using these data with CAN/CSA N288.1-M87 consumption data is given in Table 5. It is assumed that all the other pathways– i.e., drinking water consumption, bathing, swimming etc. are the same and only the effect of food consumption is investigated. It is also assumed that the FAO data are fairly representative of adult males.

The tritium dose from consumption of grains, fish, meat and animal products using CAN/CSA N288.1-M87 consumption parameters is about 40% higher than the corresponding dose using the FAO Indonesian food consumption data. This difference is partly because the total food consumption data for Indonesia is averaged over the whole population whereas the Canadian data are partitioned by age. The Indonesian per capita total annual food consumption is also less than the equivalent Canadian average.

Also, in Indonesia, most of the food consumed consists of grains and cereals, with a very small component from meat and animal products. This choice of diet translates into larger tritium doses from milk consumption, beef, pork, eggs and poultry for a Canadian diet compared with an Indonesian diet.

The average fish consumption is roughly the same for both countries, so the tritium dose from the fish pathway is similar for N288.1 Canadian diet and the FAO Indonesian diet.

However, all these differences result in only a 15% larger tritium doses for a Canadian diet than for a corresponding Indonesian diet. When available, site-specific diet data should be used in assessments. However, use of Canadian diet data will result in a further degree of conservatism in dose predictions for an Indonesian environment.

The differences between the FAO 1969 Indonesian diet data and the 1993 to 1995 diet data are minor, and the projected doses agree within a few percent The sensitivity of doses to diet from the other trace beta and gamma activities in the desalinated potable water was not investigated but any differences will be insignificant.

DOSE CONVERSION FACTORS

The base calculation was done with dose conversion factors given in CAN/CSA N288.1-M87. Since ~99% of the total dose is from the ingestion–inhalation pathway, the sensitivity of the results to more up-to-date dose-conversion factors was investigated. Inhalation dose-conversion factors for tritiated water and ingestion dose-conversion factors for tritium and the radionuclides given in Table 1 were extracted from ICRP Publications 71 and 72 (References 10 and 11) and were used in the calculations. All other parameters were unchanged.

Results are summarized in Table 6. The results show that the adult doses (tritium) decrease by 10% and the infant doses (tritium) decrease by ~17% when the ICRP dose-conversion factors are used instead of the CAN/CSA N288.1-M87 values.

The doses from the gross beta and gamma radionuclides, given in Table 1 increase by about 5% for adults and 23% for infants for the mixture of radionuclides characteristic of Point Lepreau releases, with the ICRP dose-conversion factors (References 10 and 11) used instead of the CAN/CSA N288.1-M87 values. However, the doses with ICRP dose-conversion factors (References 10 and 11) were 2% less for adults and 2 % less for infants when the mixture of gross beta and gamma radionuclides characteristic of Gentilly-2 releases were used. This analysis implies that the composition of the releases is somewhat important when assessing the effect of different dose-conversion factors. Much of the increase in dose for the gross beta and gamma releases with the ICRP dose-conversion factors (References 10 and 11) for Point Lepreau compared with the decrease for Gentilly-2 can be attributed to the 'relatively' higher ^{131}I and ^{133}I releases at Point Lepreau. That is, more ^{131}I and ^{133}I are released on a percentage basis at Point Lepreau than at Gentilly-2 (see Table 1). Thus the higher dose-conversion factors for ^{131}I and ^{133}I given in ICRP Publications 71 and 72 compared with those in CAN/CSA N288.1-M87 make up for most of the difference.

Since most of the total dose is dominated by tritium, the net effect is for adult doses to decrease by about 10% and the infant doses to decrease by about 17% when the dose-conversion factors from ICRP publications 71 and 72 are used instead of the CAN/CSA N288.1-M87 values. Thus use of the CAN/CSA N288.1-M87 values for CANDU desalination assessments will result in higher, more conservative doses than will use of ICRP publications 71 and 72 values.

DOSE LIMITS

From the calculations, the 'bounding' doses to the most exposed member of the public (an infant) from use of desalinated water will be less than 19 $\mu Sv \cdot a^{-1}$ (1.9 E-05 $Sv \cdot a^{-1}$). However, the proposed CANDU-6 desalination facility will also have airborne emissions from the CANDU 6 facility contributing to public exposures. Current operating experience from a typical single unit CANDU 6 station, Point Lepreau, shows that a hypothetical individual located at the site boundary will receive annual exposures that are historically less than 3 $\mu Sv \cdot a^{-1}$ (0.3 E-05 $Sv \cdot a^{-1}$) (Reference 12).

Calculations have been done with very conservative assumptions which shows that the airborne dose to a most exposed member of the public will be less than 17 $\mu Sv \cdot a^{-1}$ (1.7 E-05 $Sv \cdot a^{-1}$) for all sites, provided the stations are operated as designed.

Therefore, the maximum combined doses from the operation of the CANDU 6 and Desalination facility will be less than{19 $\mu Sv \cdot a^{-1}$ + 17 $\mu Sv \cdot a^{-1}$ = 36 $\mu Sv \cdot a^{-1}$}. This dose corresponds to less than 3.6 % of the ICRP 60 recommended annual public dose limit of 1000 $\mu Sv \cdot a^{-1}$.

CONCLUSIONS

The public dose from normal operation of a combined CANDU 6 and Desalination Facility was conservatively calculated. Most of the public radiation exposures (99%) would be from tritium in the form of tritiated water. The radiological consequences are insignificant compared with background doses and are a small fraction of public dose limit (<3.6% of the 1000 $\mu Sv \cdot a^{-1}$ limit).

Measurements of background gamma dose rates throughout Canada, reported in Reference 13 indicate that the national average of gamma dose rates is 76 $nGy \cdot h^{-1}$ (equivalent to an effective dose of 670 $\mu Sv \cdot a^{-1}$). The standard deviation of gamma dose rates among sites across Canada is 10 $nGy \cdot h^{-1}$ (~100 $\mu Sv \cdot a^{-1}$). Although this data is for Canada similar variations exist for most countries in the world.

This finding means that the conservatively calculated dose to a member of the critical group (<36 $\mu Sv \cdot a^{-1}$) from a combined CANDU 6-Desalination facility is well within one standard deviation of the background gamma dose variations, and is consequently insignificant.

TABLES

Table 1: Average Annual Waterborne Releases for Point Lepreau and Gentilly-2(1985-1994) [excluding tritium]

Radionuclide	Average Radioactivity from 1985 to 1994 ($Bq \cdot a^{-1}$) Point Lepreau	Average Radioactivity from 1985 to 1994 ($Bq \cdot a^{-1}$) Gentilly-2
^{24}Na	1.3E08	6.7E08
^{24}Cr	4.0E08	2.8E08
^{54}Mn	3.1E08	2.1E07
^{58}Co	3.0E05	1.3E07
^{59}Fe	1.1E07	2.4E07
^{60}Co	9.0E07	1.7E09
^{65}Zn	1.5E08	9.5E07
^{90}Sr	7.4E05	-
^{95}Nb	3.5E08	9.5E10
^{95}Zr	1.7E08	7.3E09
^{103}Ru	7.9E07	2.6E06
^{106}Ru	8.5E07	-
^{110m}Ag	5.3E06	-
^{124}Sb	1.3E08	3.0E09
^{131}I	1.1E09	1.5E07
^{133}I	1.6E08	7.2E07
^{134}Cs	8.5E06	2.8E07
^{137}Cs	4.0E07	1.6E08
^{141}Ce	2.3E06	1.4E09
^{144}Ce	2.1E06	-
^{153}Gd	9.8E08	6.8E07
Other	1.4E09	2.8E09
Total beta and gamma measured	3.2E09	1.0E11

Table 2: Beta and Gamma doses for Point Lepreau releases

Radionuclide	Dose ($Sv \cdot a^{-1}$)	
	Adult	Infant
^{24}Na	1.4E-11	3.1E-11
^{51}Cr	1.8E-10	1.8E-10
^{24}Mn	1.8E-09	1.7E-09
^{58}Co	1.9E-12	2.2E-12
^{59}Fe	1.4E-10	1.1E-10
^{60}Co	1.6E-09	1.5E-09
^{65}Zn	1.7E-09	1.3E-09
^{90}Sr	1.7E-12	5.1E-12
^{95}Nb	1.7E-09	1.8E-09
^{95}Zr	8.2E-09	8.1E-09
^{103}Ru	6.8E-12	4.9E-12
^{106}Ru	5.0E-10	4.9E-10
^{110m}Ag	1.0E-10	9.4E-11
^{124}Sb	1.5E-09	1.5E-09
^{131}I	1.3E-09	4.3E-09
^{133}I	4.1E-11	1.3E-10
^{134}Cs	2.6E-10	1.2E-10
^{137}Cs	7.9E-10	2.8E-11
^{141}Ce	1.4E-12	1.3E-12
^{144}Ce	1.5E-12	1.1E-12
^{153}Gd	2.4E-09	2.4E-09
Total beta and gamma	**2.1E-08**	**2.4E-08**

Table 3: Beta and Gamma Doses for Gentilly-2 releases

Radionuclide	Dose ($Sv \cdot a^{-1}$)	
	Adult	Infant
^{24}Na	7.1E-11	1.6E-10
^{51}Cr	1.2E-10	1.2E-10
^{24}Mn	1.2E-10	1.2E-10
^{58}Co	8.7E-11	9.8E-11
^{59}Fe	2.9E-10	2.5E-10
^{60}Co	2.9E-08	2.8E-08
^{65}Zn	1.1E-09	8.2E-10
^{95}Nb	4.8E-07	5.0E-07
^{95}Zr	3.5E-08	3.5E-08
^{103}Ru	2.3E-13	1.6E-13
^{124}Sb	3.5E-08	3.4E-08
^{131}I	1.8E-11	5.8E-11
^{133}I	1.8E-11	5.9E-11
^{134}Cs	8.6E-11	3.8E-11
^{137}Cs	3.2E-10	1.1E-10
^{141}Ce	8.5E-10	8.2E-10
^{153}Gd	1.7E-10	1.7E-10
Total beta and gamma	**5.9E-07**	**6.0E-07**

Table 4: Tritium Doses from Pathways Identified in Figure 2 and Using CAN/CSA N288.1-M87 Models, Transfer Parameters and Dose-Conversion Factors

	Effective Dose (Whole Body) Infant	*Effective Dose (Whole Body) Adult*
	Sv/a	*Sv/a*
Ingestion of Fish	**9.28E-08**	**1.28E-07**
Ingestion of Produce and crops		
Leafy Vegetables	2.09E-07	1.01E-07
Above ground vegetables and fruits	1.04E-06	7.92E-07
Root Vegetables	5.01E-07	5.69E-07
Cereal	2.51E-07	5.33E-07
Subtotal	**2.0E-06**	**1.99E-06**
Ingestion - Animals Produce		
Milk	6.79E-06	1.28E-06
Beef	3.06E-07	3.69E-07
Pork	2.16E-07	3.85E-07
Eggs	1.10E-07	1.56E-07
Poultry	3.7E-07	2.04E-07
Subtotal	**7.79E-06**	**2.39E-06**
Inhalation from Evaporation Humans	**1.74E-06**	**3.60E-06**
Drinking	**7.19E-06**	**5.68E-06**
Bathing	**7.81E-09**	**1.68E-08**
Swimming	**2.93E-08**	**8.42E-08**
Total Dose ($Sv \cdot a^{-1}$)	**1.89E-05**	**1.39E-05**

Table 5: Comparison of Annual Adult Tritium Doses Using Different Food Consumption Data

	Annual Effective Dose ($\mu Sv \cdot a^{-1}$) to an Adult using different food consumption data		
Radionuclide	CAN/CSA N288.1-M87 (Canadian)	FAO (Indonesia) 1969	FAO Food Balance Sheet (Indonesia) 1993-1995
Tritium Dose from grains, vegetables, fish, meat and meat products	4.5	2.61	2.8
Total Tritium Dose	13.9	12.0	12.1

Table 6: Comparison of Doses using CAN/CSA N288.1-M87 Dose Conversion Factors and ICRP Publications 71 and 72 Dose Conversion Factors with Waterborne Releases from Point Lepreau and Gentilly-2

Dose Conversion Factor	Doses from Point Lepreau Releases		Doses from Gentilly-2 Releases	
	Adult ($\mu Sv \cdot a^{-1}$)	Infant ($\mu Sv \cdot a^{-1}$)	Adult ($\mu Sv \cdot a^{-1}$)	Infant ($\mu Sv \cdot a^{-1}$)
CAN/CSA N288.1				
Beta and Gamma	2.1E-02	2.4E-02	5.9E-01	6.0E-01
Tritium*	13.9	18.9	13.9	18.9
ICRP 71 and 72				
Beta and Gamma	2.3E-02	2.9E-02	5.7E-01	5.9E-01
Tritium*	12.5	15.6	12.5	15.6
* Assumes concentration of 400 $Bq.L^{-1}$				

FIGURES

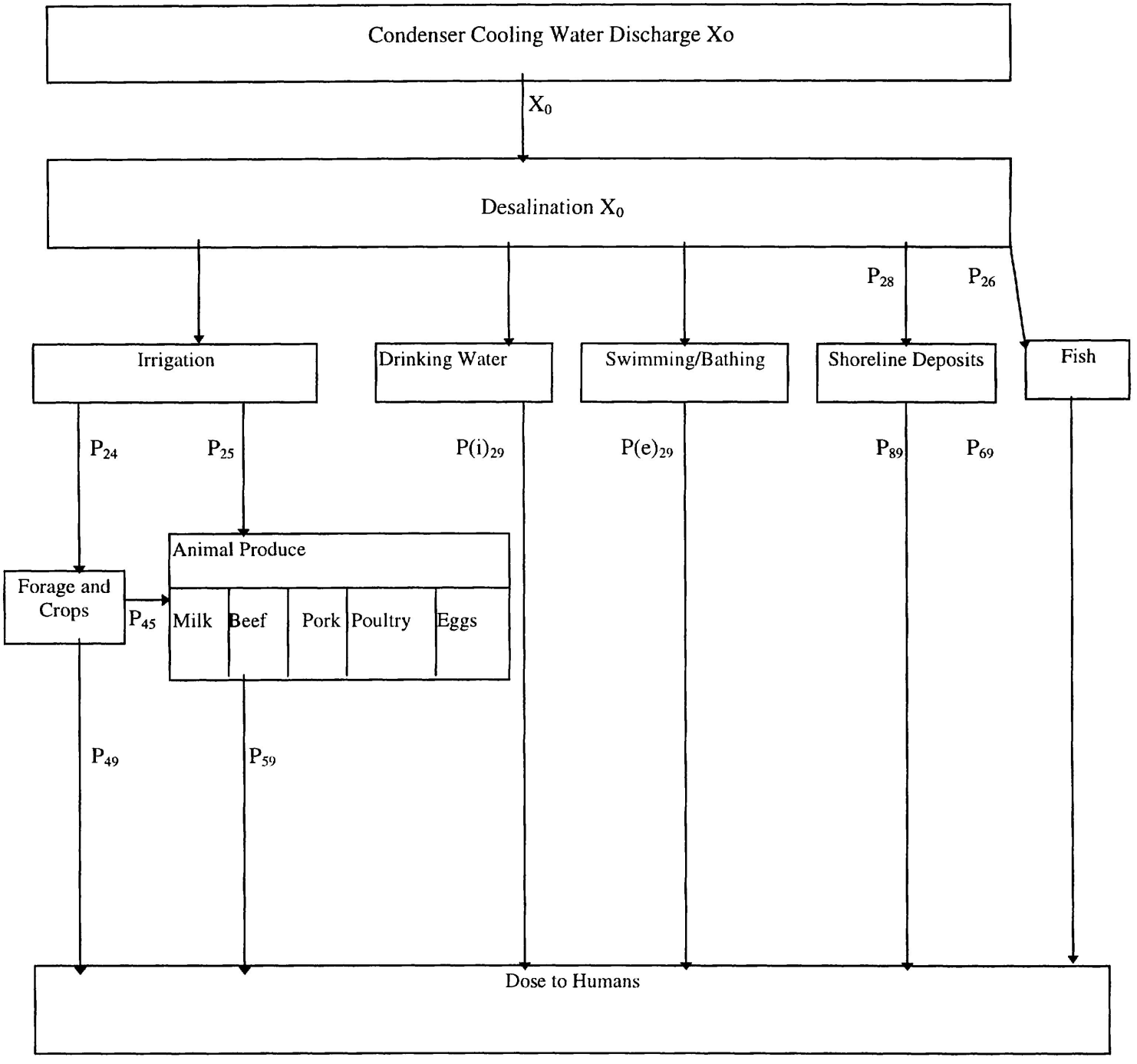

Figure 1: Pathways Model for Beta and Gamma Emitters from Desalinated Potable Water

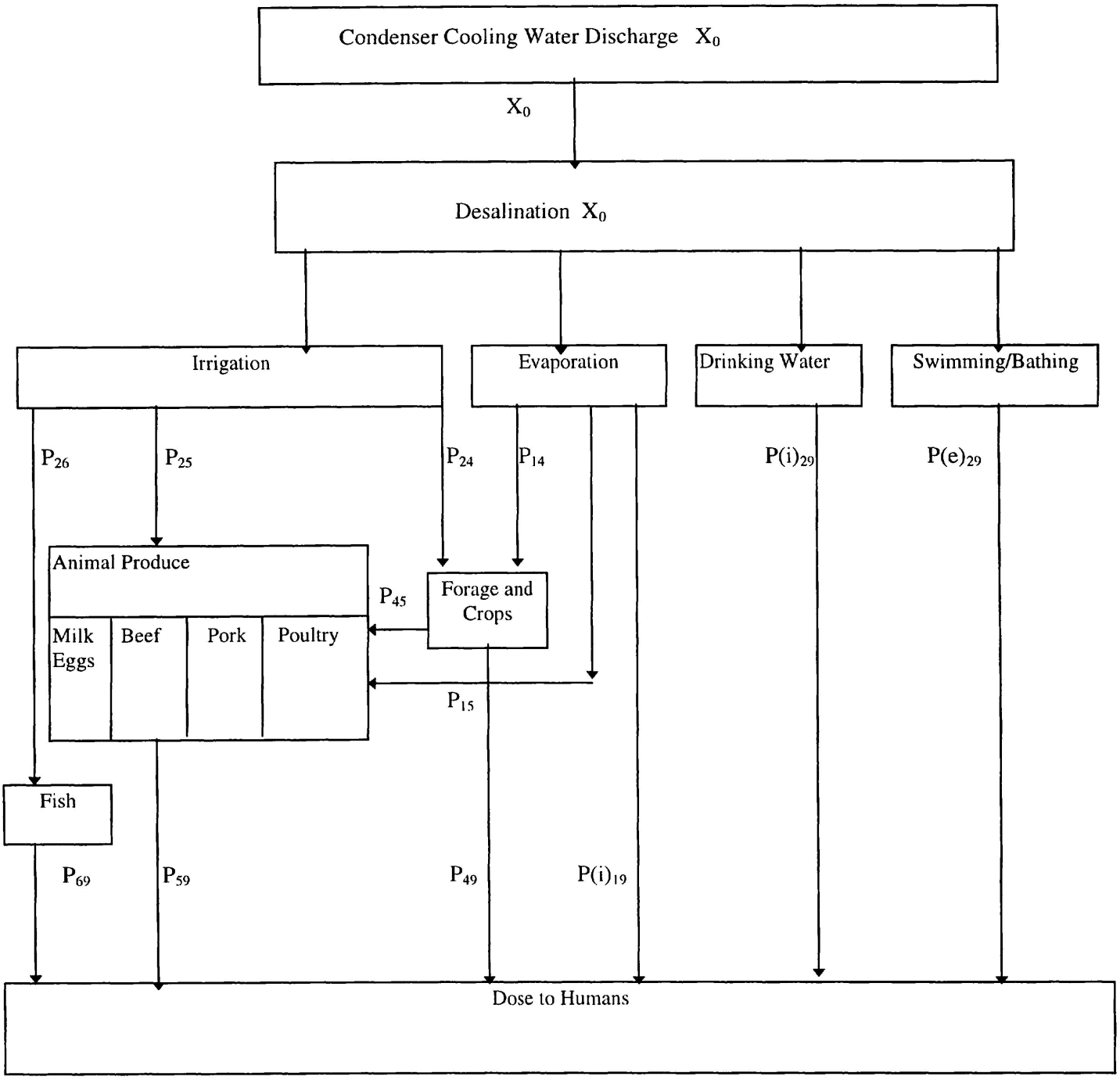

Figure 2: Pathways Model for Tritium from Desalinated Potable Water

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