PRODUCTION AND RADIOACTIVE-WASTE DISPOSAL
A MATHEMATICAL MODEL

G.Testoni(1),T.Bernardi(1),R.Zannoli(1),O.Tubertini(2)

(1) Servizio di Fisica Sanitaria . Università di Bologna.
(2) Centro di Radiochim.ambientale Unive-rsità di Bologna.

INTRODUCTION

Radioactive-waste materials production in Bologna commune is due almost esclusively to research activity (University, C.N.R., E.N.E.A.) or to hospital assistence activity (Nuclear Medicine). Radioactive-waste products - different for half-life, radiotoxicity, but also chemical and biological toxicity - , can follow different ways of disposal and they can finish incontrollably in the environment.

For estimating the radioecological impact resulting from abovementioned activities , a census of users and main used radioisotopes has been done.

Different methods of disposal has been analyzed and radioactive measures in different samples drawed from city sewer dynamic system - expecially at the entry and at the exit of water depurator. Since the greatest contribute to environmental radioactivity rises from Nuclear Medicine diagnostic protocols, a simple mathematical model that correlates the activity administered to patients with the activity at the entry and at the exit of depurator in different matrix (solid, liquid,and gas matrix) has been created and verified .

A good realiability of model for the most important radioisotopes , like Tc-99m, I-131 ang Ga-137 has been verified . Admissible Maximum Concentration (A.M.C.)has been compared with concentration derived by human activities in water and air.

It has been concluded that the risk for the population is now difficult to point out.

RESULTS

Results are reported in the following tables. Beta-emitter radioisotopes mainly used by laboratories of the University,as H-3, C-14, S-35, P-32, Ca-45 etc., were not foundet at the entry of depurator and not even in other "hot points" in the city sewer system, at least with regard to concentrations higher than 1 Bq/litre. This result is not surprising because radioactive waste products of research laboratories are picked up and treated by authorized firms.

Tab.I shows most important radioisotopes used in Nuclear Medicine, their gamma energy levels (keV),their T(1/2) and the annual amounts administered in Malpighi and Maggiore Hospitals in 1993 (MBq). We can see that more than 95% of activity is imputable to Tc-99m.

Radiois.	En.(keV)	T(1/2)	Malp(MBq/y)	% Malp.	Magg.(MBq/y)	%Magg.
Tc-99m	140	6 h	3,7.10^6	95,5	2,8.10^6	95,4
I-131	364	8,04 d	6,7.10^4	1,75	7,4.10^4	2,5
I-123	159	13,3 h	1,6.10^3	0,04	-	-
Ga-67	91/185 300	78,1 h	4,5.10^4	1,1	7,4.10^3	0,25
Ta-201	81	3,1 g	6,3.10^4	1,6	3,3.10^3	1,14
Xe-133	809	5,3 g	-	-	1,9.10^3	0,64
In-111	171	67,4 h	5,5.10^2	0,02	1,9.10^3	0,06

Tab.II enumerates the really used activities during 1993 in Malpighi Hospital because of exams on day hospital's patiens and hospitalized patiens. The real activities are compared with the activities calculated by us starting from measures results(MBq).

Radiois.	Day hos.p.	hospit.p.	%	Tot.Admin.	Tot. Calcul.
Tc-99m	2,32.10^6	1,65.10^6	95,7	3,96.10^6	3,7.10^6
I-131	5,99.10^4	0,48.10^4	1,5	6,48.10^4	6,7.10^4
I-123	1,67.10^3	6,66.10^3	0,2	8,33.10^3	1,6.10^3
Ga-67	2,46.10^4	2,79.10^4	1,3	5,25.10^4	4,5.10^4
Tl-201	3,11.10^4	1,67.10^4	1,2	4,77.10^4	6,3.10^4
In-111	1,85.10^3	1,85.10^3	0,1	3,70.10^3	5,5.10^2

Tab.III schows the activities Weekly administered to patiens (Adm.) and the activities measured on the entry of depurator (Entr.) during each measurement week (MBq).

Radio-act.	Tc-99m	I-131	Ga-67	Tl-201
Adm . '90	163400	2400	1400	2500
Entr. '90	16800	500	200	tracce
Adm . '91	171000	5600	1800	3200
Entr. '91	22400	1200	300	tracce
Adm . '92	142000	3700	1500	1900
Entr. '92	17900	tracce	tracce	tracce
Adm . '93	161000	1700	1500	2400
Entr. '93	19500	500	60	tracce
Adm . '95	168200	3890	962	1010
Entr. '95	15700	900	200	tracce

MATHEMATICAL MODEL

To formulate a mathematical model to value the environment impact starting from the activities administered to patiens we considered: 1) The activities administered to patiens; 2) the half-time T(1/2); 3) the activity distribution in the body; 4) the activity excreted by the patient after three hours since administration; 5) transit time in the sewer city system; 6) activities that,even if escreted, don't reach the depurator (sedimentation, decay, volatilisation).Transit time between the 2 Nuclear Medicine divisions and the depurator was evalued as 3 hours. The treatment of waste waters lasts about 49 hours.

According to the proposed mathematical model, 12% of Tc-99m administered to the patients reaches the depurator and 0,04% leaves the depurator in several ways (ashes,waters,gases).

The final formulation of this mathematical model is :

$$AR = \frac{AS\left(\frac{1}{2^{(TM/T(1/2))}} - K1\right)\left(\frac{1}{2^{(TT/T(1/2))}} - K2\right)}{2^{(TD/T(1/2))}}$$

AR = Activity really released in environment
AS = Activity administered to patients.
K1 = (%) not excreted the first time.
K2 =(%) not reaching the depurator.
TM = Average time between administration and 1° excretion (3 h).
TT = Transit time in the sewer city system (3 hours).
TD = Total time required for depuration treatment (49 hours).

Tab.IV reports the good agreement between activities measured each year and values calculated with mathematical model.

Year	Fraction at the entry (%)		
	Tc-99m	I-131	Ga-167
1990	11	21	15
1991	13	22	15
1992	13	22	17
1993	12	72	5
1995	10	23	20
Val.Calculated (Mathem.Model)	12	23	17