# RADIOACTIVE CONTAMINATION IN THE BOLOGNA SEWAGE SYSTEM DUE TO NUCLEAR MEDICINE EXAMINATIONS

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## 1 - INTRODUCTION

Liquid wastes produced by the city of Bologna and surrounding areas are collected by a sewage system, leading to a depuration plant. At present, the capacity of the sewage system is about 230.000 $m^3$ per day, half of which is treated by the depurator.

The incoming flow is fairly constant throughout the year, except for August when, owing to factory shut-down for holidays, there is a decrease of about 60.000 $m^3$ per day.

The treatment of liquid waste in the depurator is in four phases:

a) primary decantation;
b) active oxidation;
c) active decantation;
d) disinfection.

After a treatment lasting 12-13 hours, "clarified" liquids are discharged into the Navile canal. This leads to the Reno river and then to the Adriatic sea.

Muds produced during decantation are further treated and reduced to ashes (within 24-48 hours) that are then stored.

Since the sewage system also collects liquid waste from two Nuclear Medicine Departements (Malpighi and Maggiore Hospitals), we decided to measure radioactivity in the liquids both at entrance and at exit from the depurator, and in the muds and ashes produced by treatment.

## 2 - MATERIALS AND METHODS

We gathered samples of the liquids at entrance and at exit from the depurator and of the ashes and muds.

For gamma ray spectrometry, 2 $dm^3$ of untreated samples were counted in Marinelli's beaker by a high-purity germanium coaxial detector (2 keV resolution at 1330 keV, relative efficency 30%) or a 3" x 3" NaI (Tl) crystal (6.5 % resolution at 662 keV). Minimum detectable activity was about 0.5 $Bq/dm^3$.

We did not regularly check the activity of beta-emitter radionuclides, since they are used only for "in vitro" analysis and liquid waste is not released into the sewage system.

In order to plot the destiny of a radionuclide released into the sewers, we carried out a test using a known activity of $^{99m}$Tc and collected samples of the liquid at entrance to the depurator every 15 minutes. The test was done on a day when there was no waste release from the Nuclear Medicine Depts.

## 3 - RESULTS

The above-mentioned test, allows us to evaluate the transit time in the sewers. From the moment of release (e.g. at the hospital) and arrival at the depurator, a 3 hour delay was observed. Knowing the capacity of liquid coming into the depurator at measurement time, we observed that only a fraction $K_o = 0.30$ of the released activity ( $A_r$ ) reaches the depurator.

Thus, if $A_m$ is the activity measured at the depurator:

$$A_m = K_o \times A_r \quad .$$

In order to confirm these observations, we collected a series of samples over 24 hours.

The total weekly incoming activity, for each radionuclide, can be calculated as:

$$A_t = \sum_j \left( \sum_i A_i \times Q_i \right)_j$$

where $A_i$ are the observed active concentrations in $Bq \cdot h/dm^3$ (fig.1) and $Q_i$ are the capacities at the same time in $dm^3/h$ (fig 2).

The activities, for the radionuclides found in the incoming liquids, are reported in Tab. 1 where they are compared with weekly administered activities ($A_a$).

Since it appears reasonable to assume that a fraction (f) of about 0.5 of the injected activity is excreted by the patients in the first few hours after administration, we can evaluate the fraction $K_1$,

$$K_1 = 1/f \times (A_t/A_a)$$

for $^{99m}$Tc we obtained: $K_1 = 0.266$
and for 131 I: $K_1 = 0.302$

These values approximate satisfactorily with $K_o$ ($K_o = 0.30$).

A second drop in liquid radioactivity concentrations took place during waste treatment in the depurator. This decrease is basically due to transit time of the liquid in the depurator (12-13 hours) and to mud production processes. We then introduced a second factor $K_2$:

$$K_2 = A_e/A_t$$

where $A_e$ is the activity at exit to depurator released into environment. We obtained:

| | |
|---|---|
| $^{99m}$Tc | $K_2 = 0.002$ |
| 131 I | $K_2 = 0.065$ |

The physical half life of $^{99m}$Tc accounts for the difference in the two values.

Annual activities evaluated in muds and ashes are:

| | Muds | Ashes |
|---|---|---|
| $^{99m}$Tc | 1702 MBq | 7585 MBq |
| 131 I | 3330 MBq | 1665 MBq |

## 4 - CONCLUSIONS

The model we used is based on a few simple factors that can be easily measured. The activity released into the environment through the liquid waste after treatment can be expressed by:

$$A_e = A_a \times f \times K_1 \times K_2$$

in which $K_1$ and $K_2$ are the "transfer factors" for passage in the sewage and depurator system. These factors, also include decay correction that takes into account the time needed for the two steps.

By this method, the release of radioactive meterials into the environment by the two Nuclear Medicine Depts. in our city (see tab.2 and tab.3) can be predicted and risks for the population assessed.

FIG. 1 Tc-99m LIQUID AT ENTRANCE

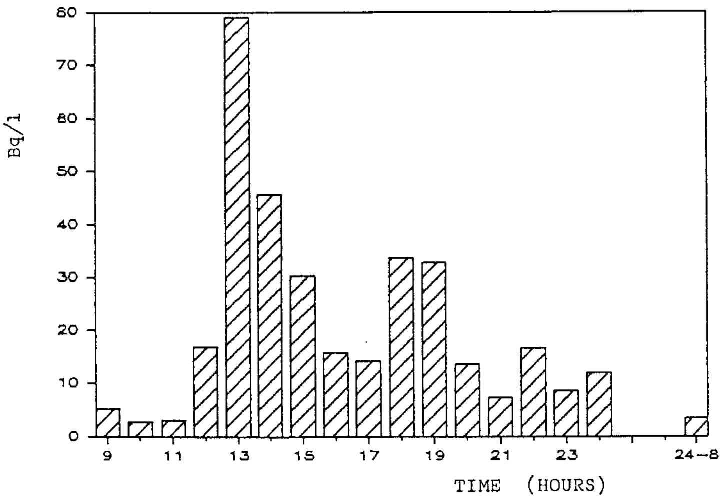
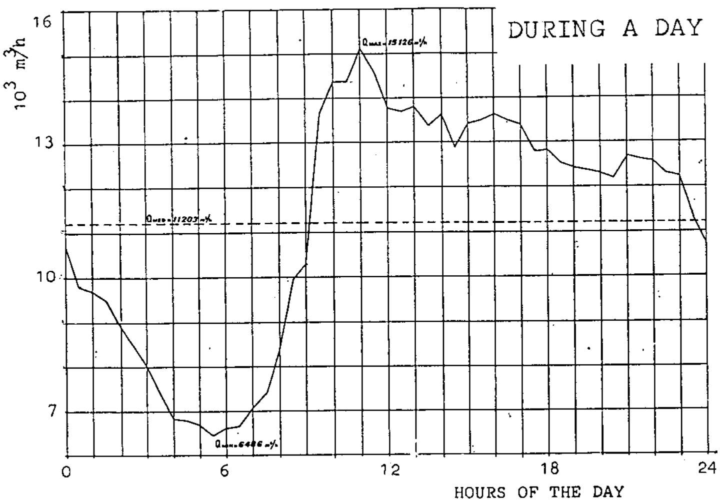



FIG.2 INPUT CAPACITY AT THE DEPURATOR DURING A DAY



TAB. 1 WEEKLY RADIOACTIVITY REPORT

| | | Tc-99m | I-131 | Ga-67 | Se-75 | Tl-201 | Xe-133 | I-125 |
|---|---|---|---|---|---|---|---|---|
| ADMINIS. ACTIVITY | MBq | 153439 | 3441 | 2812 | 11.84 | 2812 | 370 | 3.7 |
| | mCi | 4147 | 93 | 76 | 0.32 | 76 | 10 | 0.1 |
| LIQUID AT ENTRANCE | MBq | 20387 | 518 | 407 | 1.85 | 407 | 55.5 | 0.37 |
| | mCi | 551 | 14 | 11 | 0.05 | 11 | 1.5 | 0.01 |

TAB. 2 ACTIVITY PER YEAR

| | | Tc-99m | I-131 | Ga-67 | Se-75 | Tl-201 | Xe-133 | I-125 |
|---|---|---|---|---|---|---|---|---|
| ADMINIS. ACTIVITY | MBq | 7671950 | 173049 | 140600 | 555 | 140600 | 18500 | 185 |
| | mCi | 207350 | 4677 | 3800 | 15 | 3800 | 500 | 5 |
| LIQUID AT ENTRANCE | MBq | 1020349 | 25271 | 21090 | 88.8 | 21090 | 2775 | 25.9 |
| | mCi | 27577 | 683 | 570 | 2.4 | 570 | 75 | 0.7 |
| LIQUID AT EXIT | MBq | 2035 | 1628 | 1369 | 3.7 | 1369 | 1813 | 1.85 |
| | mCi | 55 | 44 | 37 | 0.1 | 37 | 49 | 0.05 |

TAB. 3 LIQUID RADIOACTIVITY LEVEL AT ENTRANCE

| | | Tc-99m | I-131 | Ga-67 | Se-75 | Tl-201 |
|---|---|---|---|---|---|---|
| MAX. MEASURED CONCENTRATION | Bq/l | 92.5 | 21.8 | 1.2 | 0.5 | 11.1 |
| | uCi/ml | 2.5E-06 | 5.9E-07 | 3.3E-08 | 1.3E-08 | 3.0E-07 |
| AVERAGE CONCENTRATION | Bq/l | 10.7 | 0.3 | 0.2 | .0 | 0.2 |
| | uCi/ml | 2.9E-07 | 7.4E-09 | 5.8E-09 | 2.6E-11 | 5.8E-09 |
| MAC (WATER) | Bq/l | 74000.0 | 12.2 | 1221.0 | 3700.0 | 3700.0 |
| | uCi/ml | 2.0E-03 | 3.3E-07 | 3.3E-05 | 1.0E-04 | 1.0E-04 |
| AVG.CONC./MAC | | 1E-04 | 2E-02 | 2E-04 | 3E-07 | 6E-05 |

TAB. 3a LIQUID RADIOACTIVITY LEVEL AT EXIT

| | | Tc-99m | I-131 | Ga-67 | Se-75 | Tl-201 |
|---|---|---|---|---|---|---|
| MAX. MEASURED CONCENTRATION | Bq/l | 1.6 | 1.1 | 0.9 | | |
| | uCi/ml | 4.2E-08 | 3.1E-08 | 2.3E-08 | | |
| AVEREGE CONCENTRATION | Bq/l | 2.1E-02 | 1.7E-02 | 1.4E-02 | | |
| | uCi/ml | 5.8E-10 | 4.7E-10 | 3.9E-10 | | |
| MAC IN WATER | Bq/l | 74000.0 | 12.2 | 1221.0 | 3700.0 | 3700.0 |
| | uCi/ml | 2.0E-03 | 3.3E-07 | 3.3E-05 | 1.0E-04 | 1.0E-04 |
| AVG.CONC./MAC | | 3E-07 | 1E-03 | 1E-05 | | |

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