PRE-DECOMMISSIONING ENVIRONMENTAL INVESTIGATIONS AT THE GARIGLIANO NUCLEAR POWER PLANT

M. Cambiaghi*, A. Garofalo**, G. Queirazza***
* CISE S.p.A., C.P. 12081 - 20134 Milano (Italy)
** ENEL, Garigliano Power Plant, C.P.6, Scauri (Italy)
*** ENEL - CRTN, Via Rubattino 54 - 20134 Milano (Italy)

INTRODUCTION

Garigliano power plant is a 160 MWe Boiling Water Reactor with dual cycle. It was operated from 1964 to 1978 generating 12.5 10^9 KWh with a capacity factor of 68%. In August 1978 it was shut-down due to damage to one of the two secondary steam generators. In March 1982 the Italian Electricity Generating Board (ENEL) declared it definitively out-of-service. In December 1982 ENEL approved an "Action Plan" to put the Garigliano plant in safe storage conditions (Stage 1) for at least 30 years. Specific studies (1-3) were started as well to select the best decommissioning alternatives. A feasibility study on dismantling and on the decontamination of all the building components was carried out to start up the decommissioning procedure of the turbine building. The aim of present investigations is to evaluate the radiological status of the environment before any decommissioning programs. Since most decommissioning projects can yield a large volume of low levels of radioactive liquid of effluents, a previsional aquatic model (4) was developed to simulate the radionuclide transport and distribution in the aquatic ecosystem.

RADIOECOLOGICAL INVESTIGATIONS

Two field investigations were carried out in 1985 and 1986. However the present paper reports only the data of the campaign carried out before the Chernobyl nuclear accident.

RADIOACTIVITY DISTRIBUTION IN TERRESTRIAL ENVIRONMENT

The investigated area is located within 15 km from the Nuclear Plant. The following environmental matrices were considered: agricultural and undisturbed soils, well water, and foodstuffs (both vegetable and animal). Only ^{137}Cs was detected in the examined matrices, except for drinking water from wells (Fig. 1). No ^{60}Co was measured above the detection limit (foodstuffs, 0.02 $Bq/Kg_{w.w.}$ and soil, 0.35 $Bq/Kg_{w.d.}$) in the direct gamma ray spectrometry. The activity of ^{137}Cs, mostly due to deposition from nuclear tests in the atmosphere, and gross alpha and beta activity, as obtained from radiochemical separation, decrease according to the following series: soil > vegetables > eggs > milk > meat. By using the derived working limits (DWL_a) it is possible to assign a radiological meaning to the measured activities. An individual exposition of 5 10^{-2} mSv/y was considered and accordingly the following DWL_a were derived: for foodstuffs DWL_α ^{239}Pu = 11 $Bq/Kg_{w.w}$ and DWL_β ^{90}Sr = 55 $Bq/Kg_{w.w.}$; for soil DWL_α ^{239}Pu = 444 $Bq/Kg_{w.d.}$ and DWL_β ^{90}Sr = 185 $Bq/Kg_{w.d.}$.

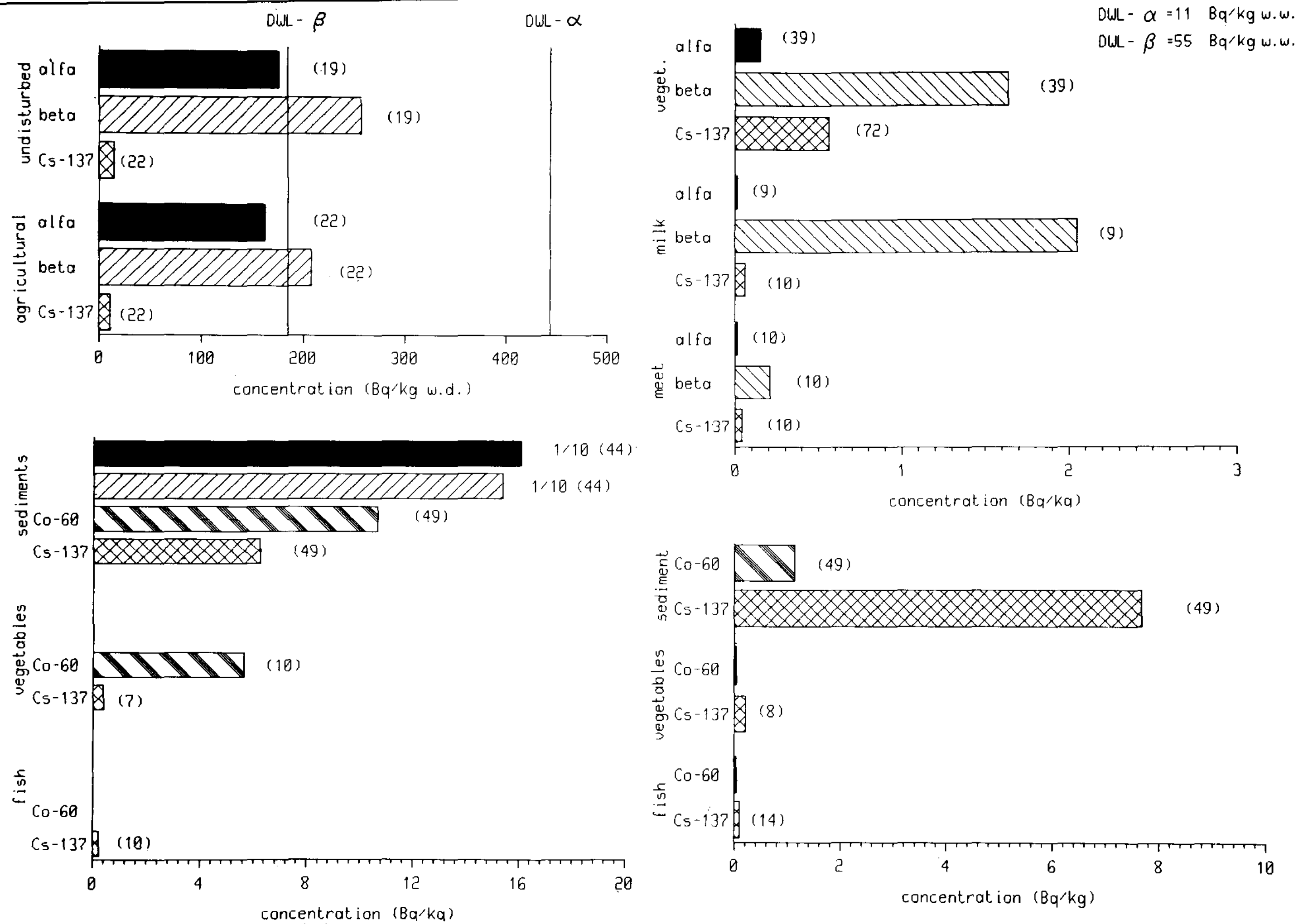

Fig. 1 Radioactivity in soil (A), terrestrial foodstuffs (B), sediment, aquatic vegetable and fish both for riverine (C) and marine ecosystems (D). () number of analyzed samples.

The measured gross alpha and beta activities, however, are 1 to 3 orders of magnitude lower than DWL_{β} for foodstuffs, whereas in soils the measured beta activity is similar to the DWL_{β} and the alpha activity is lower by a factor of two with respect to the DWL_{α} . In addition it is worthwhile to underline that the measured gross alpha and beta activities include a large contribution from natural radioactivity as the used radiochemical separation techniques (5) only partially discriminate between natural and artificial radioactivity.

RADIOACTIVITY DISTRIBUTION IN RIVER AND MARINE ENVIRONMENTS

A reach of the Garigliano river of 12 km from power plant to the mouth was considered, while the investigated marine environment is shown in Fig. 2. In both environments the following matrices were considered: water, suspended matter, sediment, vegetables and fish (edible portion). Artificial radioactivity, due to ^{60}Co and ^{137}Cs, was measured in the following decreasing order: sediment > vegetables > fish (only ^{137}Cs) > water (only ^{137}Cs).
The ^{137}Cs activity in river and marine fish and vegetables is similar. Conversely ^{60}Co activity in vegetables is higher in river ecosystem (6 $Bq/kg_{w.w.}$) than in marine macrophytes (less than 0.09 $Bq/Kg_{w.w.}$). A different distribution of ^{60}Co and ^{137}Cs is shown also in sediments; the $^{137}Cs/^{60}Co$ activity ratio is 0.59 in river environment and 6.7 in marine environment. It must be pointed out, however, that the ^{137}Cs levels are just of the same order of magnitude upstream and downstream the power plant and in the marine ecosystem. The spatial distribution of ^{137}Cs and ^{60}Co are shown in Fig. 2. ^{137}Cs activity appears to be evenly distributed, whereas it is possible to locate points of ac cumulation of ^{60}Co. A deeper reading at the above reported results indicates that: - ^{137}Cs activity is mostly due fallout depositions with respect to the one released from the plant, whereas the contrary happens for ^{60}Co activity; - the different spatial distribution of ^{137}Cs and ^{60}Co may be ascribed either to the different origin and to their different mobility in the environment; - it is necessary to describe, as accurately as possible, the complex transfer processes of radionuclides in the environment in order to identify the final fate of artificial radioactivity releases over large areas.

AQUATIC MODELLING

A mathematical model for Distribution of Radioactivity Material in Marine environment (DRAM) was developed to predict transport and distribution of most relevant fission and activation nuclides. DRAM is a box model which divides the coastal area into three-dimensional zones of uniform physical characteristics. Interzonal, external meteoric and evaporative water fluxes are associated to each zone. Fluxes between compartments (water, particulate, pore water and sediment) in the same zone are calculated assuming that: a) dissolved radionuclides are in equilibrium with suspended particulate radionuclide; b) suspended particulate settles out continuosly causing the bottom of each zone to rise with constant velocity. The process is associated with movements of radionuclides from the water column to the sediment; c) radionuclides flux across the water column sediment interface, is modelled through a catch-all parameter: the "diffusional transfer rate", to be experimentally determined. The model has been applied to the investigated site. The released radionuclides, initially associated with the liquid effluents, are incorporated into the Garigliano river and transported to sea. In order to obtain the source term, the necessary input for the DRAM model, a model of radionuclide river transportation was developed. The model is monodimensional and takes care of both dissolved and suspended radionuclides and of the tide cycle.

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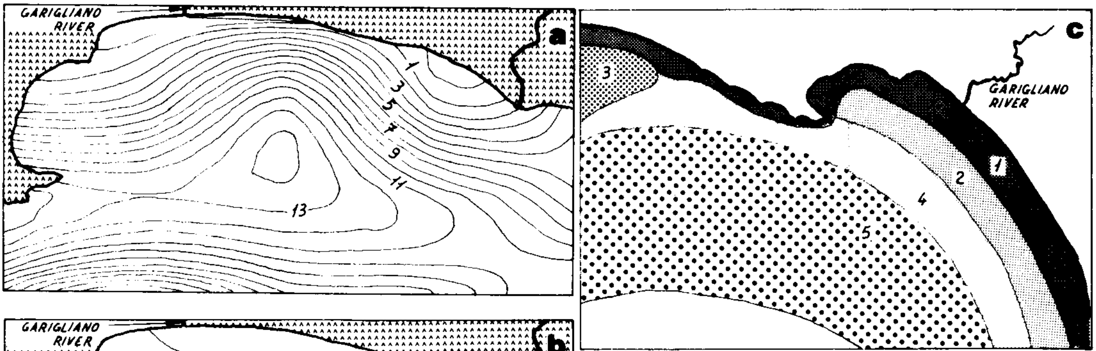

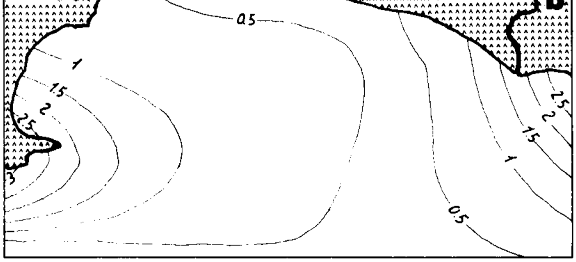

Fig. 2 Isoconcentration (Bq/Kg_{dw}) distribution pattern of Cs-137 (a) and of Co-60 (b) in sediment; (c) zones classification, 1...5, relative to bottom characteristics (porosity, in order: 0.43,0.61,0.53,0.74,0.81).