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**Ciemat
Environmental Institute
Active Radiological Protection Program**

INDALO PROJECT

**RADIOLOGICAL MONITORING OF THE AREA OF PALOMARES AND
RELATED EXPERIMENTAL RESEARCH ACTIVITIES
SUMMARY AND FRAMEWORK OF ACTIVITIES**

February 1996

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INDALO PROJECT: RADIOLOGICAL MONITORING IN THE AREA OF PALOMARES AND RELATED EXPERIMENTAL RESEARCH ACTIVITIES SUMMARY OF ACTIVITIES AND SCOPE OF ACTION

1. INTRODUCTION

This document summarizes the group of activities that are being carried out by the what is traditionally known as the Indalo Project, which was established following the 1966 accident that occurred in the area of Palomares (Almeria), and its scope of action. The purpose of the document is to serve as basic technical information in the process of reaching a scientific cooperation agreement with the DOE (USA) to continue and further development the monitoring and research activities relating to the radiological situation in Palomares. The scientific and technical conclusions reached during the implementation of the project from its inception are beyond the scope of this document.

2. SUMMARY

Stemming from the aviation accident that occurred over the area of Palomares (Almeria) in January 1996, measures were taken to radiologically protect the resident population in the area that suffered radiological contamination. In addition to the decontamination and corrective measures taken immediately after the accident, a Radiological Monitoring Program was set up that has functioned uninterrupted since then.

This Radiological Monitoring Program (Indalo Project) was established as a scientific cooperation project between the United States of America and Spain, under the framework of the "Agreement on Cooperation for Civilian Purposes" between the two countries in force at the time of the accident. The specific cooperation agreement goes by the name of the Otero-Hall Agreement. It is now deemed advisable to establish an updated frame of reference for the implementation of the scientific cooperation under the Indalo Project to replace the aforementioned Otero-Hall Agreement.

In Spain, CIEMAT, and formerly its precursor, JEN, have had the technical responsibility for designing and carrying out the work. In 1986, the newly-created CSN became responsible for evaluating the design of the Radiological Monitoring Plan and its conclusions. As of that date, therefore, the CIEMAT took on the responsibility for both continuing the Monitoring Program on the basis of what the CSN considered necessary and, due to its scientific and technical capabilities, periodically reporting to the Nuclear Safety Council on annual activities planned and their results.

The technical documentation relating to such reports, as well as other project-related scientific-technical production arising out of the information and R&D project, are held at the CIEMAT's Environmental Institute (IMA . Instituto de Medio Ambiente). The IMA also has the project management documentation.

3. THE ACCIDENT

At 10:20 a.m. on January 17, 1966 an air accident occurred at an altitude of approximately 9,500 meters over the area of Palomares (Almeria), involving the collision of a B-52 strategic bomber with a KC-135 refueler, both pertaining to the United States Air Force (USAF), during an in-flight refueling operation.

As a result of the accident the four thermonuclear bombs carried by the B-52 fell off the aircraft. Two of the bombs' parachutes did not open, causing, and upon their impact with the ground, the detonation of the conventional explosive, ignition of part of the basic core of the bombs and the subsequent formation of an aerosol made up of fissile material oxides, leading to the plutonium contamination of a 226 hectare area of scrub vegetation, farmlands and urban areas. The other two bombs were recovered intact, one in the dry riverbed of the Almanzora river and the other in the sea. The accident caused the death of 7 of the 11 members of the aircraft crews, but no victims or injuries were recorded among the population of Palomares or other nearby towns.

4. THE SCENARIO

The town of Palomares, near the Mediterranean coast in the province of Almeria, has some 1,200 inhabitants. The urban area is spread out over a relatively large area, with homes not closely grouped around a central core. The landscape is desert-like with few trees and the riverbeds running between mountains or hills are usually totally dry. The natural vegetation consists mainly of prickly pear, agave and esparto grass. The main crops cultivated in the area are tomatoes, watermelons, beans, corn, alfalfa, grains and some citrus fruit. Because of the specific climate in the area and the use of various irrigation systems, a minimum of two crops a year are obtained of some of the crops mentioned. The economy is based on agriculture, although fishing is also a contributing factor.

5. ENVIRONMENTAL CONTAMINATION

Taking the points of impact of the two fragmented bombs as starting points, measurements were taken of surface alpha contamination at specified space intervals along radial lines until nil contamination was reached, and line zero established. In carrying out the measurements were being carried out, all visible bomb fragments were picked up where encountered. The results showed that the alpha-emitting surface contamination was above 1.2 MBq/m² over 2.2 hectares, 0.12 - 1.2 MBq/m² over 17 hectares, 0.012 - 0.12 MBq/m² over 87 hectares and under 0.012 MBq/m² over approximately 120 hectares. The highest contamination values corresponded to an uncultivated, hilly area quite near the points of impact of the fragmented bombs, 1.5 km. SW of the town of Palomares. Most of the homes in the urban area were not contaminated, although in some cases values under 1.2kBq/m² were detected primarily on the roofs and the outside walls.

6. ACTION TAKEN

After radiologically characterizing the contamination, implementation of specific measures was decided on the basis of existing and available knowledge and experience regarding plutonium and its mobility in the environment, to avoid undue risk for the persons inhabiting and/or working in the area and future generations. The corrective measures that were decided were directed and carried out by U.S. expert personnel in collaboration with Spanish personnel. The measures taken were the following:

- a) Gathering of visible bomb fragments.
- b) Removal of a layer of soil approximately 10 cm. thick in areas with surface alpha contamination over 1200 kBq/m^2 , which was put into drums and taken to the Savannah River Plant (U.S.A.) for deposit as radioactive residue.
- c) Irrigation, plowing and mixture of cropland soil with contamination under 1200 kBq/m^2 .
- d) Manual removal of contamination over 120 kBq/m^2 in the rocky areas impossible to plow.
- e) Washing of contaminated trees and bushes with water, and pulling up and removal of those not satisfactorily decontaminated.
- f) The most contaminated portion of plants was dealt with in the same way as the soil in b), while the portion with low contamination was placed in a pit near the site of impact, with a contamination equivalent to that of the plants. The pit was covered with soil from the same area.
- g) Washing with pressurized water and detergents of the contaminated surfaces of the homes and mechanical separation of those not totally decontaminated.

The soil removed, around 1000 m^3 , was placed in 200-liter drums and sent to the Savannah River Plant in the U.S.

A total of $11,500\text{ m}^3$ plant material was removed, of which 310 m^3 whose level of contamination was over 7 kBq/m^3 , were buried in the above mentioned pit dug on a hill near one of the points of impact. The rest of the plant material removed was incinerated and then placed in the drums containing the most contaminated soil.

7. RADIOLOGICAL MONITORING PROGRAM

After the implementation of above mentioned corrective measures was concluded, a series of experimental activities was planned to constitute a Radiological Monitoring Program to achieve the following objectives:

- a) Obtain information on the incorporation and retention of plutonium by a representative group of the population potentially exposed to the inhalation of plutonium oxide aerosol

- b) Measure the temporary and seasonal fluctuations of the atmospheric plutonium concentration in the area subject to the agreed decontamination procedures.
- c) Measure the contamination levels of the agricultural products grown in the residual contamination area.
- d) Study the seasonal migration and redistribution of plutonium oxide in the soil of the residual contamination area.

The Radiological Monitoring Program has been in constant operation since June 1996 and involves both measuring contamination in persons and monitoring the contamination of the soil and other environmental factors which can affect human beings.

As an illustration of the experimental magnitude of the Program, the following summarizes some data regarding the number of samples taken and the tests carried out:

SOIL: 5500 to 6000 samples including surface level and samples at varying depths. Some 5000 tests for Pu-239-240 and 2500 for Am-241.

AIR: Continuous sampling of 3 points with some periods of interruption (\cong 1500 samples). 2500-3000 tests for Pu-239-240 and 500 for Am-241.

VEGETATION: Over 2000 samples of crops and natural vegetation. Around 3500 analyses of and 1800 of Am-241.

ANIMALS AND ANIMAL PRODUCTS: Around 150 samples and tests for Pu-239-240.

BIOELIMINATION: (Urinalysis as a measurement of internal contamination): A total of 2654 examinations of 849 persons. All were tested for Pu-239-240 and 1650 were tested for Am 241.

DIRECT MEASUREMENTS BY MEANS OF PULMONARY RADIOACTIVITY METER:- Around 1200 measurements of some 800 persons.

In addition to the above data it is important to point out the medical examinations that have been performed on the population of Palomares over the 30 years since the accident. The current rate of examinations is 150 persons per year. An approximate total of 2500 exams have been performed to date. It can be stated that practically all the inhabitants of Palomares have been subject at least once to a medical exam and a measurement of internal contamination. Since 1986 the technical information of the Radiological Monitoring Program has been semi-annually to the CSN, which has reported in turn to the Spanish Parliament.

8. OTHER EXPERIMENTAL ACTIVITIES

Along with the specific activities under the Radiological Monitoring Program summarized in the above section, other research activities have been carried out in the years since the accident to acquire greater knowledge of the behavior of transuranic elements Pu-239-240 and Am-241 in the environment and the processes and parameters governing such behavior. This related research is essential for improving needed dosimetry evaluations of the population and updating the Radiological Monitoring Program. Such activities have sometimes formed part of the R&D programs of entities such as the CICYT or the EU, and some have also been partially funded by ENRESA. Of these, the following are worthy of mention:

- Chemical and mineral composition of Palomares soils.
- Distribution of Pu concentrations on the basis of particle size
- Geochemical association of Pu and Am
- Study of the vertical migration of Pu and Am in soil
- Annual incorporation limits and specific dose factors for inhalable dust in Palomares
- Study of the resuspension phenomenon
- Meteorological study of the Palomares area
- Soil-level turbulence parameterization
- Soil-plant transfer
- Marine radioecological study of Pu and Am in the area

The experience acquired in carrying out the above mentioned research activities has provided the opportunity to participate in multinational projects focusing on the Chernobyl scenario.

The production of scientific journal articles, presentations at international and national conferences, technical reports and other scientific and technical documents is extensive and, of course, broadly and unrestrictedly distributed. A mere listing would be beyond the possibilities and scope of this document.

9. FRAMEWORK OF PROJECT MANAGEMENT ACTIVITIES

From its inception, CIEMAT and its precursor, JEN, have been responsible for the technical design and execution of project activities. The framework of activities is the scientific cooperation agreement between the United States of America and Spain, under the "Agreement on Cooperation for Civilian Purposes" signed by the two countries in 1957. The specific agreement for the so-called Otero-Hall Agreement was established in an exchange of letters dated 2/25/1966 between then Assistant Director General for International Activities of the USAEC and the President of the JEN.

In 1982 a new management process of the Otero-Hall Agreement was initiated by referencing it as "Contract DE-GI01-82EP12126 ". From 1989 on, annual modifications

made to said contract have been signed by the Director General of CIEMAT and the contract officer of USDOE. These modifications principally involve yearly extensions of the contract and the corresponding extension of the payment obligation, as the economic support of the project. The latest such modifications took place in 1993.

In January 1994 USDOE informed through the American Embassy in Madrid, of the expiration on 12/31/93 of the above mentioned contract of reference and their intention to establish a new international agreement for an additional five-year period starting with the 1994 fiscal year. In February of that year a new communication was received from USDOE requiring a certificate of the economic support received by CIEMAT in the 1983-1993 period, declaring its full utilization for said contract and a report on the initiation of drafting of a new contract. The required certification was sent by CIEMAT in May 1994. It should be stated here that CIEMAT has not interrupted the activities of the Palomares Radiological Monitoring Program and is, therefore, awaiting resolution of the economic support for 1994 and 1995.

In parallel to this process, meetings were held in Madrid (CIEMAT) and Washington (DOE) in 1992, to update the relationship between the two organizations in the context of the Indalo Project. As a result of the meetings the United States brought its economic support for the project up to date and a protocol was established under which CIEMAT would have to send a preliminary Project budget for each current year and the following three years, in accordance with the U.S. fiscal calendar, together with the accounting for the expenditures made under the previous year's project. In the technical area, agreements were reached on carrying out joint activities and information exchange.

In 1995, as a result of changes in the U.S. Administration affecting the persons responsible for the management of the Indalo Project, new contacts were held to update and clarify cooperation in this project. These contacts involved participation by Mrs. Helen B. Lane, Counselor for Scientific and Technical Affairs of the U.S. Embassy in Spain, and to date have resulted in the signature by the U.S. of a USDOE-Spanish Ministry of Industry and Energy Agreement on Radiological Evaluation Research under the general framework of the Agreement for Scientific and Technical Cooperation between the U.S. and Spanish governments, signed in Madrid on June 10, 1994. This document provides a technical information base for management of said Agreement.

Apart from the CIEMAT-USDOE management context, CIEMAT has been committed since 1986, the year in which the CSN took over the evaluation of the design and the conclusions of the Radiological Monitoring Program in the Area of Palomares, to regularly sending the CSN the information generated in the performance of project activities. The semi-annual reports sent by CIEMAT to CSN are the basis for the information on Palomares that the CSN submits to the Spanish Congress of Deputies and Senate. In addition to the information CIEMAT sends semi-annually to the CSN, clinical and radiological files are sent annually to the persons subject to medical and radiological examination in CIEMAT during the year. This information is confidential and therefore sent directly to the interested parties.