SPANISH EXPERIENCE IN INTERVENTION AT AN ACCIDENTALLY CONTAMINATED SITE

J. Gutiérrez, C.E. Iranzo, A. Espinosa, E. Iranzo

CIEMAT. INSTITUTO DE MEDIO AMBIENTE. Madrid, (Spain)

(Presented at International Symposium on Remediation and Restoration of Radioactive-Contaminated Sites in Europe, Antwerp, Belgium, October 1993.)

ABSTRACT

As a consequence of an aircraft accident occurred on January 1966, over the town of Palomares (Spain), a plutonium contamination of about 2.3 km^2 of uncultivated, farmed and urban land occurred. In order to return the area to a normal situation intervention was decided and some remedial actions undertaken depending on the contamination levels. The resulting wastes were collected in drums and sent to the Savannah River Plant in USA.

After the intervention was completed a radiological surveillance program concerning population and the environment was established to control the achievement of the radiation protection objectives for the public in the area. A summary of the results obtained along the years is presented showing that the situation is acceptable from the radiological point of view.

1. THE ACCIDENT

An accident involving two US Air Force planes engaged in a refueling operation occurred at 0922 GMT on January 17, 1966 over the town of Palomares (1), within the province of Almería in Southeastern Spain, close to the mediterranean coast (Fig.1). The mid-air collision was followed by an explosion and pieces of the aircraft fell onto Palomares and neighboring Villaricos. Seven of the 11 crew members were killed and the four thermonuclear weapons transported by one of the planes fell with the aircraft wreckage. Three of the bombs, one intact, were found on land, in or near Palomares, within 24 hours of the accident. Following an extensive search, the fourth was removed intact from the Mediterranean Sea on April 7. The parachutes of two of the bombs did not deploy resulting in the detonation of their conventional explosives and release of fissile material upon impact. Partial burning of the fissile material formed an aerosol that contaminated approximately 226 hectares of uncultivated, farmed and urban land. At the time of the accident very few people were working in the fields because most villagers were in holiday to celebrate the patron saint of Palomares. No one was injured in Palomares neither in Villaricos, and the conventional explosion of one of the weapons threw four people to the ground near impact point number 3, (Fig.2), without any harm.

The first weapon, only slightly damaged, was recovered southeast of Palomares, near the dry Almanzora riverbed, about 300 meters from the shore. This was designated as impact point number 1.

The second landed about one mile to the west of Palomares, in a hilly and uncultivated area; this impact point was numbered 2, (Fig.2). The third fell on the east edge of the village, impact point 3 in figure 2.

At the time of the accident a 55 km per hour wind was blowing from the west. The plutonium-bearing dust cloud from impact point 2 travelled across uncultivated and irrigated fields and through the northern edge of the village as it is shown in figure 2. The cloud from impact point 3 traveled away from the ville but across prime irrigated area used for growing tomatoes, beans and alfalfa. The last tomato crop, the most important from the economical point of view of the season, was just ready for harvest.

2. THE SCENARIO

The town of Palomares is located close to the mediterranean coast in the province of Almería in the SE of Spain. It is a small town of about 1200 inhabitants with houses spread in an extense area not well grouped in a downtown. Landscape is desertic with a scarce number of trees; riverbeds between mountains or hills are totally dry. The wild vegetation is semitropical with palm trees, agaves, esparto grass, etc.; the main cultures in the area are tomatoes, watermelons, beans, maize, alfalfa, cereals and citrics.

Due to it special climate and the use of different systems of irrigation, a minimum of two crops are collected per year. The economy is therefore based on the agriculture although fishing is also a contributing factor.

3. ENVIRONMENTAL CONTAMINATION

An assesment of the situation aiming to determine the extension and quantification of the Pu contamination began inmediately after the bomb's and air crafts fragments were located (2). From the geographycal situation of the two crashed bombs impact points, the affected area was divided in 3 zones, two corresponding with the impacts points 2 and 3 and the third one corresponding to the urban area. These zones were denominated as zone 2, 3 and 5 respectively (fig. 2)

Due to the wind direction at the moment of the accident, the urban area (zone 5), located between zones 2 and 3, was the less contaminated.

From the impact points 2 and 3 and following radial axes separated 15° one from each other, superficial alpha contamination levels were measured with proportional counters,PAC-15 alpha detectors. Data were collected each 25 m up to exceed in 100 m the point with null contamination; so a called "zero" line was defined. In some limited areas further quantitative measurements were made over a 10 m grid. At the same time the measurements were realized, the visible bomb's fragments were recuperated. The results showed that the surface contamination by alpha emitters was greater than 1.2 MBq m^{-2} in 2.2 Ha, from 0.12 to 1.2 MBq m^{-2} in 17 Ha, between 0.012 and 0.12 MBq m^{-2} in 87 Ha and below 0.012 MBq m^{-2} in 120 Ha approximately. The higher values were obtained in an uncultivated area, close to the impact point 2 and located among hills at 1.5 km in the SW from the town of Palomares. The majority of houses in the urban area were not contaminated. Contaminated houses showed values lower than 1.2 KBq m^{-2} mainly located in roofs and external walls.

4. THE INTERVENTION

After determining the radiological characterization of the transuranic contamination, intervention was decided to avoid unacceptable risk for present and future generations living and working in the area.

The selection of remedial actions took into account the existing knowledge on Pu concerning to:

- movility in soils
- potential for resuspension in air
- transfer from soil to plants
- intake by people and animals due to inhalation and ingestion.

Based on it the following remedial actions were applied (3).

- removal of visible fragments of the bombs
- removal of uncultivated and wild vegetation having superficial contamination higher than 3.5×10^{2} Bq m^{-2}.
- removal of the 5-10 cm deep top layer of soils in areas where surface contamination was greater than 1.2 MBq m^{-2}. The soil removed was considered as radioactive soil and canned in 200 l. metallic drums.
- replacement of removed soil by well-fertilized earth from non-contaminated areas.
- wet down, plonghed to a 30 cm depth, harrowed and mixed all arable land with levels between 0.012 and 1.2 MBq m^{-2}.
- wet down of arable land with surface contamination lower than 0.012 MBq m^{-2}.
- pressure washing of contaminated bushes and trees. Removal of those with contamination levels higher than 3.7×10^{-2} Bq m^{-2}.
- pressure washing of roofs and external walls of contaminated houses, until complete decontamination. In the cases that it was not possible to decontaminate completely by washing, removal by mechanical procedures was carried out.

Soil removal was accomplished by the use of road graders, where possible, with it first being moved into windrows, and then into piles and finally loaded into trucks. Where graders could not be used, as in the isolated hilly area around zone 2, the work had to be done by hand.

When scraping left small hot spots, ploughing and /or hand removing was necessary. For low contamination, scarifying of the soil, with minimum turnover, dropped the contamination to acceptable limits. This minimum movement of surface area was primarily important in zone 2, where it was feared that major movement of top soil in the fragile area could create a dust bowl. Because of the extremely dry climate of Palomares, the deposits were at first fixed with mineral oil in and around the small creaters where the contamination was greatest, and by abundant watering in other places where contamination was lower.

The equipment used was (4):

- 11 dumper trucks
- 3 road graders
- 2 bulldozers
- 2 front end loaders (2 cubic yards buckets)
- 5 gang ploughs and
- 16 water distributor trucks to reduce and avoid the resuspension.

The final amount of wastes produced from removed soil of about 1000 m^3 were placed in 200 l barrels and send to Savannah River Plant in USA.

In devegetating, machetes were used to cut tomatoes and other crops, as well as sickles, scythes and hoes. As tomato crops required cane poles for their growth, three-limb shredders were requested. Cane poles were pulled from the ground, shredded, and the remains loaded into the trucks for delivery to the storage site.

A total of 11.500 m^3 vegetation wastes (alpha surface contamination > 370 Bq m^{-2}) from about 110 Ha was collected. Approximately 310 m^3 had contamination levels higher than 7 kBq m^{-2} and were buried in a disposal trench constructed in a hilly uncultivated area located in the zone 2. The rest of vegetation removed, with levels between 370 Bq m^{-2} and 7 kBq m^{-2} was burned and then mixed and placed in barrels with the highest contaminated soils.

5. SURVEILLANCE PROGRAM

When the remedial actions were finished, a set of experimental activities was planned aimed at studying the direct consequences of the accident on the population and the effects wich, in future, might derive from it and from the residual contamination in the area. Given the characteristics of the area's contaminating radionuclides all of wich are alpha emitters while some emit very low-energy photons, the risk of external irradiation for the inhabitants of the zone, derived from the residual contamination, is practically negligible.

Therefore the following main objectives (5) were set up:

- To determine the magnitude of the risk of internal contamination for the inhabitants of the zone during the period immediately following the accident and the subsequent emergency phase.

- To assess at short, medium and long-term the risk of internal contamination for those people living in and around Palomares, for those who cultivate the contaminated land and for those who consume vegetable products grown in this area, as well as products from animals which have been given as fodder cereals and other vegetables grown in the area.

In order to reach these objectives a wideranging Surveillance Programme has been in constant operation since June 1966

This Surveillance Programme (6) is based both on performing direct contamination measurements on people, and on keeping track of the evolution of the contamination in the soil and in the means and products that might give rise to the contaminating radionuclides being intaked by the human beings. A summary of the results obtained is exposed below.

5.1 SOIL

A gross estimate of the plutonium inventory (6) deposited in the zone on the basis of the specified contamination values and of the surface area affected made it possible to deduce that, excluding the two areas close where the two fractionated bombs had fallen and where the maximum contamination levels were to be found, a minimum of $2x10^{11}$Bq (≈5Ci) would remain in the zone as residual contamination once the countermeasures decided upon had been applied.

In order to determine how the concentrations of activity were spread in the soil as a result of the countermeasures undertaken, and how they have evolved with the passing of time (7), six plots were chosen as being representative of the situation in each of the three zones into wich the contaminated area was divided. The locations of the plots referred to as 2-1, 2-2, 5-1, 5-2, 3-1 and 3-2 are specified in figure 2.

The plots are quadrangular in shape with sides measuring 50 metres, and the soil samples taken from each of them correspond to nine points situated on the diagonals and equidistant from each other. The samples were cylindrical with a diameter of 31 mm. and a depth of 45 cm. Each sample was divided into five fractions representing depths of 0-5, 5-15, 15-25, 25-35 and 35-45 cm.

A total of about 5000 samples have been analyzed giving the average values of the plutonium and americium concentrations in the 45 cm soil layer that are summarized in tables 1 and 2.

In addition to it specific samplings have been performed to determine the spread of the contamination outside the original"zero" line and to improve the estimation of the residual contamination in the very close area to the impact point 2. This area, called 2-0, had been

considered as having a low level of residual contamination due to remedial action applied of removal the surface layer of soil. However the values obtained show contamination levels higher than anticipated in the order of 80 kBq k^{-1} for Pu-239+240 and 13.4 kBq kg^{-1} for Am-241, and distributed in a very heterogeneous manner. It should be borne in mind that zone 2-0, apart from being the most highly contaminated as a result of the accident, was chosen for the canning of all the heavily contaminated soil and vegetation as well as being the site where part of the highly contaminated vegetation was buried.

Particle size analysis of the soil indicates that less than 15 % of the residual plutonium and americium contamination is associated with particles less than 10 μm diameter. Maximum activity corresponds to size fractions ranging between 63 and 250 μm diameter (8).

4.2 AIR

The programme, aimed at determining the level of contamination in the area's atmosphere in order to establish the risk of inhalation for people living in and cultivating the area, has been carried out on a continous basis, ever since the remedial actions were concluded (9).

For this purpose sampling stations were put in place, as shown in figure 2, and were referred to as 2-1, 2-2, P and 3-2, according to where they were located in the three reference zones that had been established. All of them were started up in 1966. Stations 2-2 and P have been taking air samples continously since 1966. Stations 3-1 and 2-1 finished sampling in October 1969 due to problems regarding electricity supply. Sampling in station 2-1 began once more in 1984 on account of the interest prompted by its locations.

The air samples were collected until 1981 on cellulose filters with a diameter of 74 mm., placed at a height of 1.70 m. They were changed on a daily basis and corresponded to an average air volume of 90 m^3 every 24 hours.

In January 1981 (6) the sampling systems were replaced by others with a greater aspiration capacity wich have made it possible to collect aerosols corresponding to 10,000 m^3 per week on asbestos filters with a surface area of 500 cm^2.

All these air samples took in all existing aerosol particles, and their direct correlation with the risk of inhalation implied an overestimate of the risk. For this reason, in April 1987, stations P and 2-2 were provided with a sampling system which, since then, has made it possible to collect on the asbestos filter particles of a size of under 10 μm and which constitute the really inhalable fraction. The average concentration values for Pu-239 + Pu-240 corresponding to each of the sampling stations during each of the years included in the period between 1966 and 1990 are specified in table 3.

The highest values in station 2-1 for 1986 and 1987 were due to the big movement and removal of soil made at that time in area 2-1 to build an irrigation dawn and pool.

Calculation of the inhalation risk to people based in a cronic intake along the period 1966-1990 (6) for adults who live in the urban zone and the people in the cultivated zone with the greatest potential risk, station 2-2, and mean aerosol size (AMAD) of 1μm have been done. Dose conversion factors of ICRP 30 were used. Under these considerations, the potential committed dose equivalents for the five main organs (bone surface, lungs, liver, red bone marrow and gonads) are shown in table 4.

Taking in consideration the ICRP 26 weighting factors for these five organs, the total potential committed effective dose equivalent to people during the 24 years period 1966-1990 is 0.21 mSv in he urban zone and 1.97 mSv in the zone which corresponds to the critical group.

4.3 VEGETATION

The activities carried out under the Surveillance Programme with respect to vegetation have been aimed from the very beginning at ascertaining the level of plutonium contamination in both cultivated and wild plants growing in the area, specially as regards their edible parts (10). Since 1983 tests have also been carried out in order to determine the levels of americium contamination.

Until 1978 the plants were collected from the same plots chosen for studing soil contamination, in other words, the six study plots shown in figure 1 with the reference numbers 2-1,2-2, 5-1, 5-2, 3-1 and 3-2. Due to the fact that, for various reasons, these plots were not cultivated every year, it was decided in 1978 to extend the plant-sampling process to the areas close to these plots. In recent years some crop-growing in the area has taken place in greenhouses, specially for tomatoes, cucumbers and peppers, and so it was decided also to take samples of plants grown in greenhouses in order to ascertain the differences that might result from enclosed cultivation systems.

So as to give an idea of the size of the plant monitoring programme, about 2000 has been the number of samples taken between 1966 and 1991. In general, each sample corresponds to a wet weight of at least 3 kg.

Table 5 shows the concentration values of Pu-239 + Pu-240 in the various plants grown in the area for the period 1966-1986 and wich are typical Mediterranean products. The results obtained in the same crops for the period 1986-1991 does not modified in a significative way the average values.

Studying the results of the plutonium concentration in the plant samples, with most of the contamination affecting the parts with the greatest surface area or with a rough surface, and with a high degree of inhomogeneity among plants growing in the same area, led us to conclude that the contamination process is not due, in the vast majority of cases, to absortion through the roots. External contamination is predominant and, as a result, resuspension processes are an important factor (11).

The wild vegetation in plot 2-1, which is the nearest to point of impact 2 and which was decontaminated with manual tools on account of the nature of the soil, as well as the vegetation collected around this plot and in the so called 2-0 zone, has shown plutonium contamination in practically all the samples that have been taken. The highest concentrations have been found in esparto grass with average value of 0.6 kBq kg^{-1} but having large deviations.

Individual and collective effective committed doses by the direct ingestion way can be estimated from these values, choosing the tomato as the most representative food produced and consumed in the area.

The maximum individual dose (consumption of tomatoes with the maximum Pu concentration obtained of 1.05 Bq kg^{-1}) results in 7μSv per year. However a more realistic value would be 1μSv per year taking into account an averaged comsumption of 24 kg per person and year (10) and a Pu activity of 0.15 Bq kg^{-1} (mean value obtained considering only "positive" values).

Based on the data of productivity in the area of 80.000 kg of tomatoes per Ha and the above mentionned Pu-concentration value of 0.15 Bq kg^{-1} a collective dose of 3.4 x 10^{-3} man-Sv per Ha is obtained. These results are of negligible importance and demostrative of the adequacy of intervention.

Doses by indirect ingestion ways as the comsumption of meat and milk from animals feeding in the area are significantly lower.

4.4 PEOPLE

The surveillance programme on human beings (12) was set up for the purpose of providing a direct estimate of the level of internal plutonium contamination affecting the inhabitants of Palomares as a result of their subsequente remaining and carrying on their activities in the area.

This undertaking was planned for a long period of time, equivalent to the average life span of the people living in the area, and is aimed at monitoring all the inhabitants of Palomares. Internal contamination measurements and clinical/medical examinations are performed on those people who undergo annual testing.

Testing on people was begun in 1967 and, since 1975, has been peformed annually, without a break, on approximately 150 people per year.

Measuring internal contamination in human beings used to be done by means of direct plutonium contamination measurements on the lungs, using a specific lung counter, and by determining the excretion of plutonium in the urine. Owing to the fact that the lung counter failed to detect -in any person- an amount of plutonium higher than the detection limit of 814 Bq, these measurements have not been carried out on a routine basis since 1988, and are only performed on people being tested for the first time. The counting facility was included in a international calibration study several years ago. Between 1966 and 1990 a total of 1,190 measurements have been performed on 769 persons.
Since 1985 everyone has been tested for Am-241 excreted in the urine (6).

Table 6 gives the figures showing the size of the surveillance programme on human beings, both as regards the people as a whole and on an individual basis, for the period 1966-1989.

The results of the excretion of Pu-239 + Pu-240 in the urine, obtained by means of the radiochemical analyses performed for the period 1966-1991, are set out in table 7.

Determination of the activity of Plutonium intake through inhalation was done on the basis of the values of excretion in urine on the date of the sample (13), by means of the method developed by K.Eckerman in the Oak Ridge National Laboratory. This method is based upon the metabolic intake and pulmonary distribution model of the ICRP and on the urinary excretion model of Langham modified by W. Moss (14) in Los Alamos National Laboratory. In the case of those people who have had Pu measurements in urine higher than the MDA, it was considered that their MDA values were positive and with a value equal to the limit.

Calculation of the committed effective dose equivalent was done by means of the Sv/Bq conversion factors recommended by the ICRP publication 30 in order to calculate the weihted committed dose equivalent for the most important organs from the point fo view of their contribution to the committed effective dose equivalent.

The estimation of the committed effective dose equivalent was carried out on the 55 people who were considered really to have suffered internal contamination, by making a rigorous study, for each of them, of the Pu values in urine, the possibility of extrnal contamination of

the sample and its greater or lesser corrrelation with the model developed by K. Echerman on the basis of ICRP pulmonary model and W. Langham's excretion curve modified by W.Moss.

Following this procedure, calculations were made for the intake of Pu due to acute inhalation for the 45 people, 24 men and 21 women, who were in Palomares when the accident occurred. In the case of the 10 people, 5 men and 5 women were not in the area when the accident took place, it is difficult due to the shape of the curve for the excretion of plutonium in urine, to determine the date of intake on the basis of the factors indicated in the methodology. In fact, the doses were estimated in terms of the date of intake considered to be the most likely.

The values of the committed effective dose equivalent estimated for the people in question fall between 20 and 200 mSv (2-20 rem) (Table 8).

The study made on the doses calculated for these 55 people reveals a normal logarithmic correlation. Having calculated Henry's straight line, and with the established logarithmic types having been represented, it can be seen that all of them are within the 95% confidence determined by the calculation of Leveau's abacus (fig.3) This fact confirms that the criterion followed for calculating the possible intake by ussing the averages of the intakes calculated for each excretion is right enough.

REFERENCES

(1) E. Ramos, E. Iranzo. Experience of an accidental contamination by radioactive material. Proceedings of the "Second International Civil Defense Symposium on Nuclear Radiation Hazards". Mónaco 1996.

(2) E. Iranzo, C.R. Richmond. Plutonium contamination twenty years after the nuclear weapons accident in Spain. Proceedings of the "8th International Congress of Radiation Research". Edinburgh. 1987.

(3) Improvement of practical countermeasures: The agricultural environment. EUR 12554 EN. Luxembourg 1991.

(4) Palomares summary report, Field Command Defense Nuclear Agency, USA. 1975.

(5) E. Iranzo et al. Informe resumido sobre la vigilancia radiológica realizada en la zona de Palomares (Almería). Internal report JEN, Madrid, 1985.

(6) C.E. Iranzo et al. Summary report on the Palomares surveillance program. CIEMAT/IMA/UGIA/M5A01. Madrid, 1992.

(7) E. Iranzo et al. Geochemical distribution of Plutonium and Americium in Palomares soil. Proceeding of the symposium on "The cicling of long lived radionuclides in the biosphere. Observations and models". CEC, Madrid, 1986.

(8) E. Iranzo et al. Distribution and migration of Plutonium in soil of and accidentally contaminated environment. Radiochemical Acta, 52/53, 249-256, 1991.

(9) E. Iranzo et al. Air concentrations of Pu-239 and Pu-240 and potential radiation doses to persons living near Pu contaminated areas in Palomares (Spain). Health Physics. Vol. 52. nº4. pp. 453-461, 1987.

(10) E. Iranzo et al.Evaluation of remedial actions taken in an agricultural area contaminated by transuranides. Proceedings of the seminar on "The impact of nuclear origin accidents on environment". CEC, Cadarache, 1988.

(11) C.E. Iranzo et al. Factores de concentración suelo-planta para plutonio y su aplicación en la evaluación de la dosis. Proceedings of the "III Congreso Nacional de Protección Radiológica". Valencia, 1989.

(12) E. Iranzo et al. Dose estimation by bioassay for population involved in and accident with Plutonium release. Proceedings of the "Second Conference on Radiation Protection on Dosimetry". Orlando, 1988.

(13) R.W. Legget. A model of the retention, translocation and excretion of systemic Pu. Health Physics, 49 1115-1138.

(14) W.D. Moss et al. A review of the human Plutonium injection studies. Proceedings of the "29th Annual Conference on Bioassay, Analytical and Environmental Chemistry". 1983.

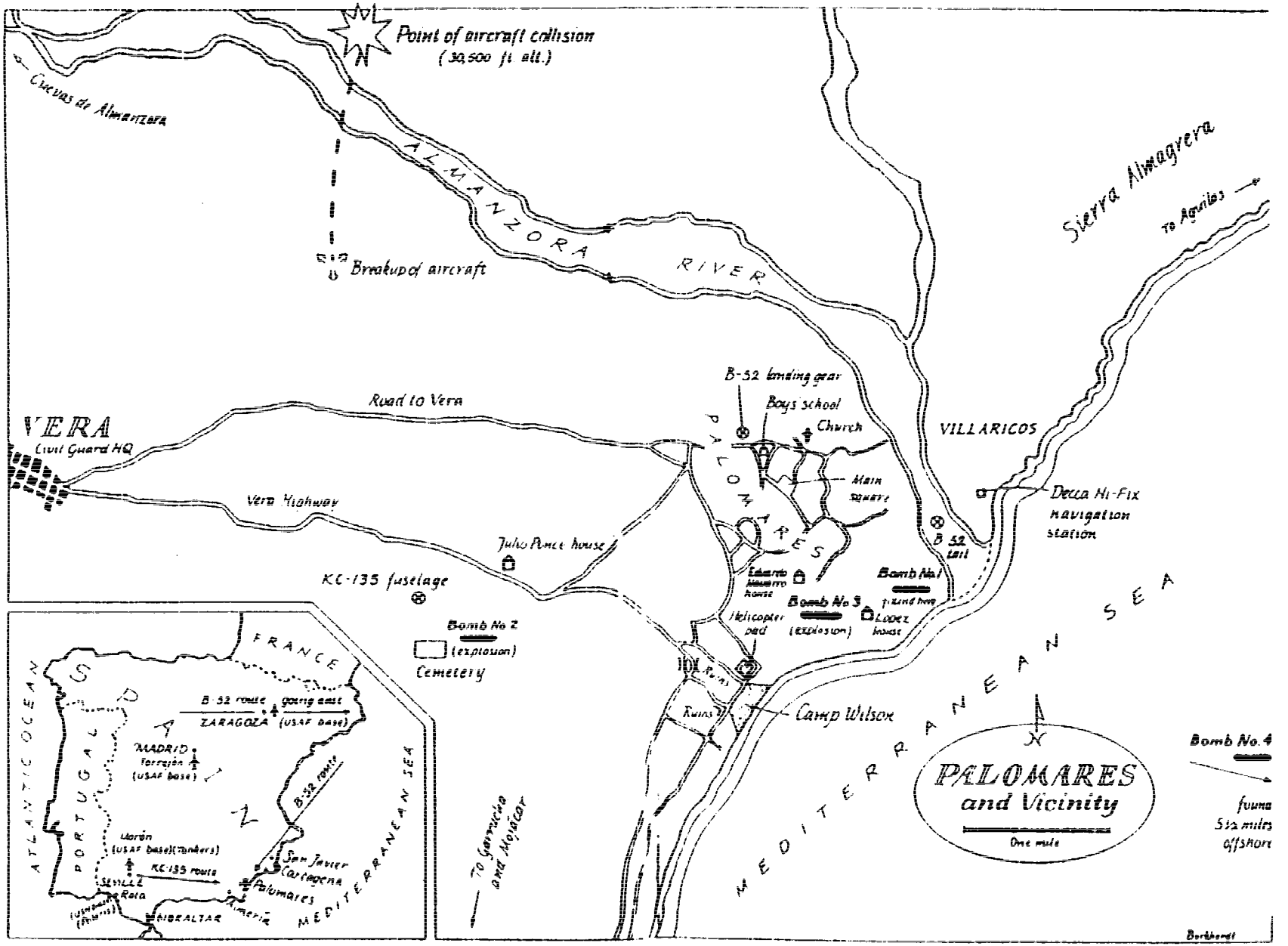
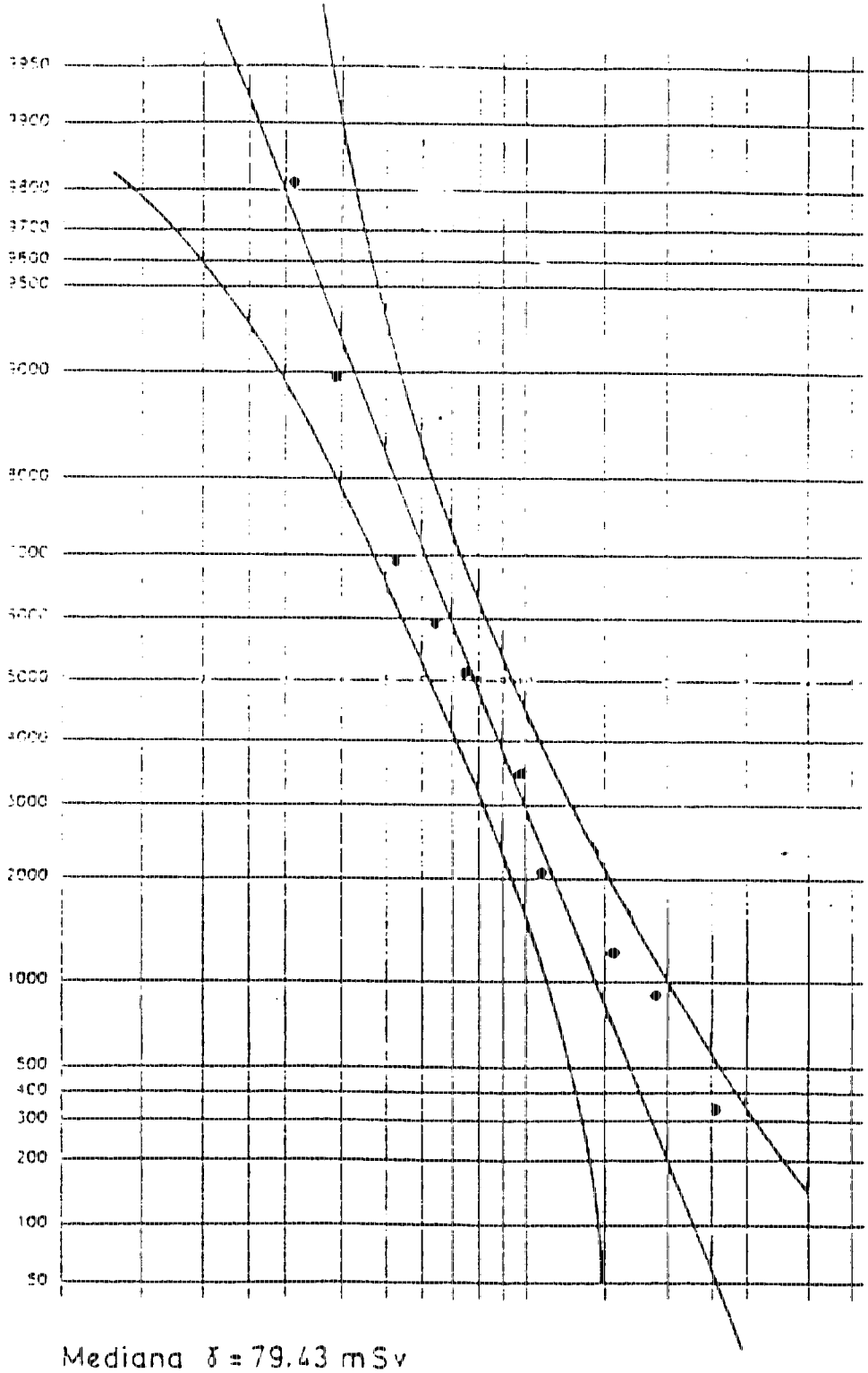


FIGURE 1. AREA OF PALOMARES WITH LOCATION OF THE THERMONUCLEAR WEAPONS IMPACT POINTS

Figure 3 DISTRIBUTION OF ESTIMATED $S_{\varepsilon,50}$ FOR PALOMARES PEOPLE

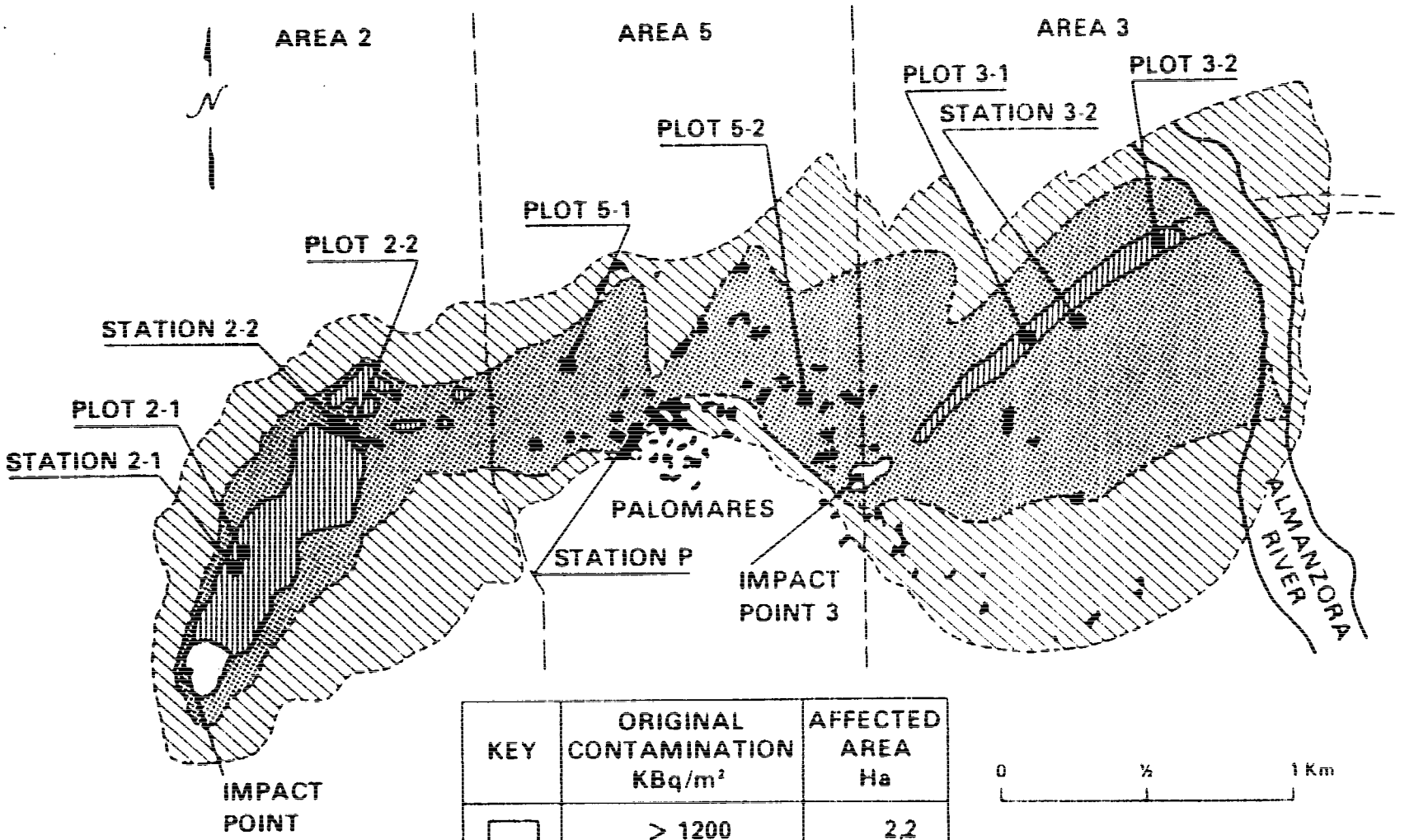


Mediana $\delta = 79.43$ mSv

Varianza $\sigma^2 = 0.31$

Media log. normal = 92.7 mSv

FIGURE 2. PALOMARES AREA: ORIGINAL CONTAMINATION LEVELS AND LOCATION OF SAMPLING STATIONS



KEY	ORIGINAL CONTAMINATION KBq/m²	AFFECTED AREA Ha
	> 1200	2,2
	120-1200	17
	12-120	87
	< 12	120

TABLE 1. PLUTONIUM CONCENTRATION IN SOILS OF THE SELECTED PLOTS

PLOT	Pu-239 + Pu-240 kBq/kg		
	AVERAGE	MAXIMUM	MINIMUM
2-1	0,44	1,60	0,03
2-2	2,06	3,31	0,80
3-1	1,10	2,00	0,05
3-2	1,79	5,70	0,23
5-1	0,13	0,30	0,02
5-2	0,29	0,99	0,01

TABLE 2. AMERICIUM CONCENTRATION IN SOILS OF THE SELECTED PLOTS

PLOT	Am-241 kBq/kg		
	AVERAGE	MAXIMUM	MINIMUM
2-1	0,07	0,21	0,01
2-2	0,55	0,64	0,40
3-1	0,24	0,53	0,14
3-2	0,49	0,87	0,16
5-1	0,04	0,09	0,01
5-2	0,09	0,13	0,06

TABLE 3. AVERAGE ANNUAL CONCENTRATIONS OF Pu-239+Pu-240 IN THE AIR DURING THE PERIOD 1966-1990

YEAR	CONCENTRATION AT THE STATION (uBq/m3)			
	2-1	2-2	P	3-2
1966	41,8	44,8	14,8	27,4
1967	15,2	441,8	4,1	13,0
1968	7,0	21,8	2,6	3,3
1969	161,0	142,0	2,6	14,1
1970		5,9	2,2	
1971		2,2	<1,8	
1972		10,4	<1,8	
1973		3,0	2,2	
1974		8,1	4,1	
1975		16,3	<1,8	
1976		4,4	<1,8	
1977		11,8	5,6	
1978		16,7	2,2	
1979		19,2	5,6	
1980		32,9	28,1	
1981		46,6	14,3	
1982		60,4	18,6	
1983		87,9	9,1	
1984	18,7	339	4,9	
1985	63,9	64,4	5,0	
1986	405	48,5	4,7	
1987	135,4	63,0	12,5	
1988	59,2	21,6	4,4	
1989	20,5	2,5	2,6	
1990	6,6	4,6	7,2	

TABLE 4. TOTAL POTENCIAL COMMITTED DOSE EQUIVALENT FOR ORGANS DURING THE PERIOD 1966-1990

ORGAN	TOTAL COMMITTED DOSE EQUIVALENT, mSv	
	URBAN ZONE (P)	STATION 2-2
BONE SURFACE	1,12	10,54
LUNG	0,40	3,55
LIVER	0,25	2,33
RED BONE MARROW	0,10	0,84
GONADS	0,01	0,13

TABLE 5. PLUTONIUM CONCENTRATION IN CROPS (PERIOD 1966-1986)

CROP		SAMPLES		Pu-239+Pu-240 Bq/kg		
SPECIES	PART	TOTAL	% POSITIVE	AVERAGE	MAXIMUM	MINIMUM
Tomato	fruit	236	10	0,03	1,15	D.L.
"	plant	118	38	3,17	27,08	D.L.
Barley	grain	395	22	0,85	10,91	D.L.
"	straw	403	34	2,61	30,82	D.L.
Maize	grain	16	0	D.L.	D.L.	D.L.
"	plant	48	19	0,97	10,47	D.L.
Bean	grain	26	0	D.L.	D.L.	D.L.
"	pod	26	8	0,005	0,13	D.L.
Alfalfa		78	42	0,60	4,33	D.L.
Melon	fruit	26	0	D.L.	D.L.	D.L.
"	plant	14	29	0,27	1,10	D.L.
Pig	fruit	24	8	0,03	10,61	D.L.
Prickly Pear	fruit	16	6	0,001	0,06	D.L.
Pepper	fruit	6	0	D.L.	D.L.	D.L.
Orange	fruit	6	0	D.L.	D.L.	D.L.
Lemon	fruit	6	0	D.L.	D.L.	D.L.
Carob	fruit	6	0	D.L.	D.L.	D.L.

D.L.: DETECTION LIMIT

TABLE 6. QUANTIFICATION OF THE PEOPLE SURVEILLANCE SURVEILLANCE PROGRAM PERIOD 1966-1989

EXAMINATIONS	EXAMINATED PEOPLE			EXAMINATION
PER PERSON	MALES	FEMALES	TOTAL	
1	112	93	205	205
2	163	160	323	646
3	37	42	79	237
4	20	32	52	208
5	14	13	27	135
6	14	9	23	138
7	7	5	12	84
8	5	6	11	88
9	9	4	13	117
10	5	4	9	90
11	2	6	8	88
12	2	2	4	48
13	1	0	1	13
14	1	1	2	28
TOTALS	392	377	769	2125

TABLE 7. PLUTONIUM EXCRETION IN URINE OF PEOPLE DURING THE PERIOD 1966-1991

EXCRETION IN URINE mBq/day	ANALYSES	PERCENTAGE	
		PARTIAL	ACCUMULATE
<0.37	1757	92,62	92,62
0,4-1,8	71	3,74	96,36
1,8-3,7	39	2,05	98,41
3,7-18,5	24	1,26	99,67
18,5-37,0	4	0,22	99,89
37,0-55,5	2	0,10	99,99

TABLE 8. ESTIMATED EFFECTIVE DOSE EQUIVALENT BASED ON URINARY EXCRETION DATA AND ASSUMED ACUTE INHALATION

ESTIMATED DOSE mSv (rem)		NUMBER OF PEOPLE
<20	(<2)	714
20-50	(2-5)	22
50-100	(5-10)	22
100-150	(10-15)	6
150-200	(15-20)	5
	total	769